The

Environmental Vulnerability Index

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The

Environmental Vulnerability Index

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1. Vulnerability index – environment

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Acronyms

AOSIS	Alliance of Small Island States
BINAS	Biosafety Information Network and Advisory Service
BGS	British Geological Survey
CIA	US Central Intelligence Agency Fact Book
CIESIN	Centre for International Earth Science Information Network
CRED	Centre for Research on Epidemiology of Disasters
EMDAT	Emergency Events Database (CRED, OFDA, OECD, WHO)
EVI	Environmental Vulnerability Index and Profiles
FAO	UN Food & Agricultural Organisation
GEO3	Global Environment Outlook 3
GMO	Genetically-Modified Organism
GROMS	Global Register of Migratory Species
HDR	Human Development Report
IPCC	Intergovernmental Panel on Climate Change
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
ITOPF	International Tanker-Owners Pollution Federation Ltd
IUCN	World Conservation Union
MEA	Multilateral Environmental Agreement
NOAA	US National Oceanic & Atmospheric Administration
NZAID	New Zealand Agency for International Development
OECD	Organisation for Economic Cooperation & Development
OFDA	Office of the US Foreign Disaster Assistance
PIC	Pacific Island Country
SEDAC	Social Economic Data Applications Centre
SIDS	Small Island Developing States
SIS	Small Island States
SOE	State of the Environment
SOPAC	South Pacific Applied Geoscience Commission
SPILLS	Worldwide Tanker Spill Database (etcentre.org)
SPREP	South Pacific Regional Environment Programme
SST	Sea-surface temperature
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USGS	US Geological Survey
WCMC	World Conservation Monitoring Centre
WDI	World Development Indicators
WHO	UN World Health Organisation
WRI	World Resources Institute
WTO	World Tourism Organisation

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EXECUTIVE SUMMARY

This report presents the results for the *Environmental Vulnerability Index (*EVI) for 2004 across 235 countries and territories.

Without exception, the environment is the life-support system for all human systems and is an integral part of the development success of countries. The Environmental Vulnerability Index is among the first tools now being developed to focus environmental management at the same scales that environmentally-significant decisions are made (countries), and focus them on outcomes. This is an appropriate scale because it is the one at which major decisions affecting the environment in terms of policies, economics and social and cultural behaviours are implemented.

The EVI uses 50 *smart indicators* for estimating the vulnerability of the environment of a country to future shocks. It is reported simultaneously as a single dimensionless index, several sub-indices, and as a profile showing the results for each indicator, allowing users to assess overall conditions and then drill-down to identify issues. This means that in addition to an overall signal of vulnerability, the EVI can be used to identify specific problems. It has been designed to reflect the status of a country's environmental vulnerability, which refers to the extent to which the natural environment is prone to damage and degradation. It does not address the vulnerability of the social, cultural or economic systems, and not the environment that has become dominated by human systems (e.g. cities, farms).

Indicators for the EVI were selected to characterise the risks to and resilience / vulnerability of the complex interactive and hierarchical natural systems that support countries. Data are collected for each indicator and located within an EVI scale which ranges between 1 – 7, where the value EVI = 1 indicates low vulnerability or high resilience, and EVI = 7 indicates extreme vulnerability for a country relating to an indicator.

The EVI results for 2004 categorise countries into 5 vulnerability groups ranging from Extremely vulnerable, Highly vulnerable, Vulnerable, At risk and Resilient. The EVI results are based on publicly available datasets as well as data compiled from 32 collaborating countries. The results include an overall listing of countries and their vulnerability status, as well as country reports that detail the results for a single country. The country reports, in addition to the overall EVI scores, provide information on 7 policy-relevant sub-indices, including aspects of vulnerability related to climate change; exposure to natural disasters; human health; agriculture and fisheries; water resources; and desertification and biodiversity. A detailed breakdown of the 50 indicators is also provided with a list of those issues contributing the most to a country's vulnerability, as well as those aspects of greatest resilience that could be preserved.

The EVI is now ready for application. In the pages that follow we present the first full evaluation of the EVI, and result sheets for selected countries, particularly SIDS.

1 INTRODUCTION

1.1 Background

Vulnerability has received growing international recognition as an issue of central concern to the sustainable development of all countries. The vulnerability of a country, or its converse resilience, is the result of an interplay of factors, which can result in damage to social, economic or environmental systems. The factors affecting the degree of vulnerability can include remoteness, transboundary issues, migrations, civil unrest, geographic dispersion, natural disasters, high degree of economic openness, small internal markets and limited or damaged natural resource base.

The issue of vulnerability was first raised in the context of the Global Summit on Small Island Developing States (SIDS) held in Barbados in 1994. Concern over the vulnerability of SIDS was expressed because it was perceived that these counties were at a disadvantage in relation to other countries because of their small size and susceptibility to disturbance. SIDS, with the support of the United Nations, expressed the desire in the Barbados Programme of Action (BPoA) that a vulnerability index integrating ecological fragility and economic vulnerability should be developed to reflect the status of their countries.

Although efforts to develop vulnerability indices for countries are not new, popular focus has been on economic and social vulnerabilities, giving only a limited understanding of the overall problem. The Environmental Vulnerability Index (EVI), a project undertaken in partnership by SOPAC, UNEP, SIDS, collaborating countries, institutions and experts looks specifically, and for the first time, into the issue of environmental vulnerability. That is, the risk of damage to the natural environment, which underpins all human activities.

The development of the EVI was carried out through a comprehensive consultative and collaborative process involving countries, experts and partners. Financial support from UNEP, Ireland, Italy, New Zealand and Norway facilitated the process. This initiative was lead by SOPAC through several phases of development summarised as follows:

- **Phase I** (Aug 1998 – Feb 1999) Developed a conceptual EVI model and carried out initial testing on three countries;
- **Phase II** (Mar 1999 – Feb 2000) Exposed the EVI to expert peer review, convened an Expert Think Tank, created an EVI database for Pacific SIDS, further developed the model and tested it on several Pacific Island countries;
- **Phase III** (Mar 2000 – Apr 2003) Globalised the EVI through the establishment of a global database, set levels for EVI indicators, calculated EVI values for a range of countries around the globe, convened a meeting of experts in Geneva to globalise EVI, presentation of the first Demonstration EVI
- **Finalisation of the EVI** (May 2003 – Dec 2004) Completed testing of all remaining EVI indicators, made several improvements to the overall EVI, exposed the EVI to expert peer review, convened Expert Think Tank II, developed an Excel EVI calculator, refined and finalised the EVI

In February 1999 SOPAC produced its Phase I results in a report entitled *'Environmental Vulnerability Index (EVI) to summarise national environmental vulnerability profiles'*. This report was extensively peer reviewed during Phase II of the project and critically discussed at an Expert Think Tank meeting held in Fiji in September 1999. SOPAC and the Foundation for International Studies (of the University of Malta's Islands and Small States Institute), with the support of the United Nations Environment Programme also organised a meeting of experts in Malta in late 1999 to further review the EVI. This process of development and refinement was accompanied by the accumulation of environmental vulnerability data profiles from several Pacific countries including Fiji, Samoa, Tuvalu and Vanuatu. This data provided the basis for preliminary testing of the model, which was completed in February 2000 and presented in the Phase II Report. Progress reports produced in March 2001 and 2002 detailed the first two years of work on Phase III of the project. These reports were concerned with the establishment of partnerships with 32 collaborating countries around the globe, creation of a global EVI database, collection of data from collaborators and public sources, and the establishment of mechanisms for controlling the quality and expediting collection of data from collaborating countries. To ensure the global applicability of the EVI a meeting of experts was convened in Geneva in August 2001 to expand the EVI. Phase III concluded with the presentation of the Demonstration EVI in 2003. This Demonstration EVI presented the first functional results for the EVI.

The final phase of the EVI development saw the EVI undergo comprehensive expert peer review and further testing. Expert feedback resulted in further improvements to the EVI. To ensure its readiness for application the EVI was exposed to another expert review at Think Tank II convened in Fiji in October 2004. The panel of experts made several recommendations for refinements to the EVI and stated that the EVI was now sufficiently well-developed to begin national implementation. The experts went on to highlight that the EVI captures the environmental vulnerability of SIDS and emphasises their ecological fragility thus meeting the BPoA requirements in the environment area but will need to be complemented by economic and social vulnerability indices for a complete measure of vulnerability.

In taking the EVI forward toward national application the EVI will be presented to the Mauritius International Meeting to be convened in January 2005 to review the BPoA.

Support for the EVI:

DONORS – New Zealand, Norway, Ireland, Italy and UNEP
ORGANISATIONS - UNEP, FIS (University of Malta), ISDR, WMO, CROP
SOPAC MEMBER COUNTRIES - Australia, Cook Is., Fiji, French Polynesia, FSM, Guam, Kiribati, Marshall Is., Nauru, New Caledonia, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Is., Tonga, Tuvalu, Vanuatu.
COLLABORATING COUNTRIES - Bangladesh, Barbados, Botswana, Costa Rica, Greece, Jamaica, Kenya, Kyrgyz Republic, Malta, Mauritius, Nepal, Palau, Philippines, St Lucia, Singapore, Thailand, Trinidad

This Report presents the results of the EVI for 2004, which is the first complete evaluation based on data for all 50 indicators in the index. We report on the status of the global EVI database, sources of data utilised, scoring for the EVI's indicators and results for 235 countries.

2 GENERAL DESCRIPTION OF VULNERABILITY, INDICES & THE EVI

2.1 Sustainability and purpose of the EVI

In *Our Common Future* (the Brundtland Report 1987) sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Where in the past, environmental management was separated from the concerns of economies; it must now become an integral part of the economic, social and cultural systems of each country. The relationship between the human world and the planet that sustains it underwent major, unintended changes during the last century. Resources and ecosystem services were - and still are - being rapidly being exhausted and/or damaged, and how *vulnerable* they are to damage is of central concern to us all. Damage and change have been seen in the world's atmosphere, soils, waters, plants and animals, and in the relationships among all of them. The rate of this change is outstripping the ability of our scientific disciplines and our current capabilities to assess and advise (Brundtland 1987). Attempts have been made over the past few years at developing criteria for ecologically sustainable development (Heinonen *et al.* 2001) and general conceptual frameworks for sustaining the Earth's life support systems (Daily 1999). These attempts have tended to be process rather than outcome focused, can be cumbersome to evaluate or implement, and may not easily allow for measuring the success of steps being taken. They are not focused on ensuring the future (Tonn 2000) in a way that facilitates the integration of all three pillars of sustainability: environment, economy and society.

2.2 Logic of the EVI

Vulnerability can be defined as the potential for attributes of any system, human or natural, to respond adversely to events. Hazardous events are those that can lead to loss of diversity, extent, quality and function of ecosystems. These changes are often described as damage to the biological integrity (Karr 1991) or health of ecosystems, and therefore their ability to keep supporting humans. These may include natural hazards as well as human pressures. Vulnerability to damage arises from a combination of the inherent characteristics of a country, the forces of nature and human use, including the special case of climate change.

Vulnerability can provide a valuable indication of how sustainably humans are living within their environment through a dual focus. The EVI simultaneously examines levels of risk and conditions now, predicting how the environment is likely to cope with future events. For example, environments that have been damaged in the past, particularly more recently, are likely to be more at risk of damage from events in the future. The EVI focuses on feedback and interactions, being more pro-active than measures of the state of the environment, though it includes them. A result indicating high vulnerability speaks of a high risk of damage from future conditions, some of which may be related to damage in the past, and may therefore be a more appropriate measure for adaptive management, particularly at the scale of countries.

The natural environment is unequivocally the life support for all human systems. Far from being a luxury available only to those that can afford it, successful environmental management will increasingly become the basis for the success or failure of the economies and social systems of entire countries.

The topic of environmental vulnerability is therefore concerned with the *risk* of damage to the natural environment of a country. For the natural environment, the entities at risk, termed *responders*, include ecosystems, habitats, populations and communities of organisms, physical and biological processes (e.g. beach building, reproduction), energy flows, diversity, genes, ecological resilience and ecological redundancy. Each of these responders (ecosystem goods, services and relationships) may be affected by natural and anthropogenic hazards, the risk of which may vary with time, place and human behaviour. The obvious complex nature of vulnerability has required the development of vulnerability theory to provide a framework for logical development and measurement.

The theory identifies three aspects[1], which can be identified wherever vulnerability is considered. These are: (i) the risk of hazards occurring, (ii) the inherent resistance to damage[2] and (iii) the acquired vulnerability resulting from past damage. The risk associated with hazards is dependent on the frequency and intensity of events that, by definition, may adversely affect the environment. The inherent resilience or resistance of the environment refers to the innate characteristics of a country that would tend to make it more or less able to cope with natural and anthropogenic hazards. For example, Nepal is inherently invulnerable to sea-level rise, regardless of the worldwide level of risk and any other damage that might be sustained to its environments. Acquired vulnerability arises from damage sustained in the past and is related to the ecological integrity or level of degradation of ecosystems. The underlying assumption is that the more degraded the ecosystems of a country (as a result of past natural and anthropogenic hazards), the more vulnerable they are likely to be to future hazards.

Risks to the natural environment include any events or processes that can cause damage. These include natural and human events and processes, such as the weather and pollution. It has been suggested that natural hazards should not be included in discussions of environmental vulnerability because unless we identify certain natural events as being altered by humans (e.g. human-induced sea-level rise), all natural events must be '*normal*' and are therefore not part of vulnerability. This view implies that nature cannot damage nature and/or that natural hazards operate more-or-less in isolation. Natural and human hazards affect the environment in interactive ways, therefore an integrated approach is required when analysing vulnerability issues. For example, the effects of cyclones on natural communities are worse where marine and shoreline ecosystems have been degraded by pollution and over-harvesting. High levels of natural disturbance can drive populations of organisms down to low levels or make their populations more variable. This in turn, makes the risk of local extinction from other hazards more likely. The frequency and intensity of natural disturbances cannot be separated from the effects of human disturbances and needs to be incorporated in the concept of environmental vulnerability.

Environmental vulnerability is a function of intensity, and any expressions of it need to reflect this. In any consideration of the effects of a hazard on the condition and function of the natural environment, it is necessary to take into consideration, the area over which the effects of the hazard are to be absorbed or attenuated. For example, in terms of damage to the environment, 10 litres of oil will do more damage as pollution on 1 square metre of land than it would if it were distributed over 1 square kilometre. On the smaller plot of land, local ecological communities of organisms are likely to be overwhelmed by the influx of such a relatively large amount of pollution, and shifts in ecosystem quality and function may be expected.

2.3 Review of environmental indicators and indices

We reviewed 30 environmental and vulnerability indicators to determine the types of indices and indicators being developed internationally and the context of the EVI. Globally, 4 major groups of indices and indicators have been developed. These are:

- State of the Environment (SOE);
- Sustainable Development (SD);
- Ecological Footprint (EF);
- Vulnerability. (also see Table 1 and Appendix 7.3).

[1] The three aspects (hazards, resistance and damage) apply to environmental, social and economic vulnerability.
[2] We define resilience as the converse of vulnerability, i.e. an entity is vulnerable to the extent that it is not resilient.

The number of indicators used in these studies ranges between 4 and 121, with a tendency for larger numbers of indicators for environmental indices and smaller numbers for economic indices (Table 1).

Almost all of these indicators report observed values for a country in relation to the world-wide range or are based on policy and do not attempt to set limits for indicator values that might show where state of the environment, or sustainable development are occurring within sustainable limits. With this approach, it is difficult to ensure the future because as conditions decline, countries would merely occupy a new position in the range and no mechanism is available to identify when a country has exceeded sustainable limits.

Very few of the indicators developed are expressed in relation to area, with most being expressed as changes through time or on a per capita basis. We would argue that for most environmental indicators, it is the density; per unit area over which effects can be attenuated that is the most important denominator (Table 1).

Table 1: Summary of some of the main environmental and vulnerability indices and indicators currently under development worldwide.

Title	Type	# Indicators
EUROSTAT	Vulnerability (as risk exposure)	60
Australian SOE	SOE	75
ANZECC	SOE	75
South Africa SOE	SOE	102
UK SOE	SOE	15 (indicators also used)
ENTRI System	SOE	20+
Leading Environmental Indicators	SOE	16
Living Planet	SOE, Ecological Footprint	8 indices (indicators also used)
Ecological Footprint	Ecological Footprint	Not fixed
Water Poverty Index	SOE (partial)	4
Pesticide Impact ranking Index	Vulnerability	3 indices (number of indicators not given)
Index of watershed indicators	SOE, some partial Vulnerability	15
Reefs at Risk	Partial Vulnerability	10+
OECD	SOE	121
Wellbeing of Nations	SOE, SD	51 (+socio-economic indicators)
World Bank Wealth of Nations	Economic SD index	Not given
CSD	SD	58
Environmental Sustainability Index	SD	66
Sustainable Development Index (Mexican)	SD	22
Sustainable Development Index (IISD Net)	SD	Variable, depends on user
Compass Index of Sustainability	SD	Variable, depends on user
Genuine Progress Indicator	SD	24
Human Development Index	SD	16
Index of Environmental Friendliness	Vulnerability (as risk exposure), SOE	23
Economic Vulnerability Index	Vulnerability	5
Coral Reef Vulnerability Index to Climate Change	Vulnerability	36
Vulnerability Assessment to Climate Change and Sealevel Rise	Vulnerability	20
Key indicators for Global Vulnerability Mapping	Vulnerability	Under development
Composite Human Vulnerability Index	Vulnerability	19
Island Indicators	Vulnerability	15

2.4 Uniqueness of the EVI approach

The EVI is unique among the studies reviewed above. It has been designed to be flexible to the range of conditions found around the globe and to provide a relatively rapid assessment of the overall vulnerability of the environment of countries, with a drill-down approach to allow users to identify major issues. It is focused on the potential for damage to the natural environment on the basis that it is the natural environment that is the foundation for economic and social structures of nations. As such the EVI is an essential aspect of understanding the environment and the influences of social and economic variables on sustainability, and is needed to complement state-of-the-environment and Ecological Footprint information. Further, the EVI uses a scoring system devised to instantly provide users with an assessment of how vulnerable countries are overall, and in terms of particular aspects of their risk to hazards; intrinsic characters; past damage and influences of meteorology, geological events, biodiversity and anthropogenic factors. Instead of focusing only on where a country sits on a scale from best to worst in terms of current world conditions, scoring is focused more on what is vulnerable or not.

It is possible that all countries could score a value of 7 (most vulnerable) for a single indicator, if it has been shown that the trigger point for environmental damage is outside of the currently-observed range across the globe. Trigger points are not known for many of the indicators, but the framework described here forces us to think in these terms and find the appropriate trigger values with further research. The EVI is a valuable new tool focused on ensuring the future by showing policymakers and managers how to adjust their actions to lower the environmental vulnerability of a country.

2.5 Summary of the Mechanics of the EVI

The EVI is based on 50 indicators for estimating the vulnerability of the environment of a country to future shocks. These indicators are combined by simple averaging and reported simultaneously as a single index, a range of policy-relevant thematic sub-indices and as a profile showing the results for each indicator. Simple averages across indicators are used because they can be easily understood and more complex models do not appear to offer any advantages to the expression or utility of the index. This overview with drill-down structure means that in addition to an overall signal of vulnerability, the EVI can be used to identify specific problems. The EVI has been designed to reflect the extent to which the natural environment of a country is prone to damage and degradation. It does not address the vulnerability of the social, cultural or economic systems, nor the environment that has become dominated by those same human systems (such as cities and farms) because these are included in the economic and social vulnerability indices which are needed separately to identify trade-offs. Therefore, the natural environment includes those biophysical systems that can be sustained without direct and/or continuing human support. The environment at risk includes ecosystems, habitats, populations and communities of organisms, physical and biological processes (such as beach building and reproduction), productivity and energy flows, diversity at all levels, and interactions among them all. Each of these ecosystem goods, services and relationships may be affected by natural and human hazards, the risk of which may vary with time, place and human choices and behaviour.

The indicators used are ‘smart’ or end-point indicators, selected because they signal a wide variety of conditions and processes that must be operating well if that measure is favourable in terms of environmental vulnerability. Smart indicators are a way of minimising data requirements while providing a good characterisation of environmental vulnerability. For example, the presence in a country of a high percentage of original forest cover automatically indicates that all the processes that lead to maintenance of good cover must be operating well for that end-point to be present, without the need to measure the many hundreds of indicators that could individually lead to losses. The conditions present may include good policies for preservation, low widespread degradation, sufficient renewable water recharge, and little problem with acid rain.

There are three distinct aspects of vulnerability recognisable for environmental, economic and social aspects of countries, all of which need to be evaluated to provide an overall sense of the issues at play. These are the risks associated with hazards, resistance and acquired vulnerability (damage). The first aspect relates to the likelihood of hazards coming into play, while the latter two aspects are related to the ability of the environment to withstand the effects of hazards. In the EVI, indicators were specifically selected to ensure that information on these three aspects is incorporated into the measure of the overall vulnerability of countries. There are 32 indicators of hazards, 8 of resistance and 10 that measure damage. The hazard indicators relate to the frequency and intensity of hazardous events. The resistance indicators refer to the inherent characteristics of a country that would tend to make it more or less able to cope with natural and anthropogenic hazards. This includes measures such as absolute size (there are fewer options for refuges in small countries) and number of shared borders (there are greater risks of transboundary effects). Damage indicators relate to the vulnerability that has been acquired through loss of ecological integrity or increasing levels of degradation of ecosystems. The underlying assumption is that the more degraded the ecosystems of a country (as a result of past natural and anthropogenic hazards), the more vulnerable it is likely to be to future hazards.

Indicators were also selected to ensure a good spread of information across the different elements that comprise and/or affect ecosystems. Indicators on weather & climate (6 indicators), geology (4), geography (6), ecosystem resources & services (28) and human populations (6) were chosen to ensure a good cross-section of the ecological processes, including human interactions occurring in countries.

> The anatomy of vulnerability. To illustrate the anatomy of vulnerability, let us look at an example we deal with every day concerning our vulnerability to catching a cold. In this case, our overall vulnerability would be influenced by: (1) the hazards, or the number of cold virus particles we would come in contact with during each day; (2) our inherent resistance in the form of the immune system with which we were born; and (3) our acquired vulnerability, which relates to the damage we might have sustained and how we look after ourselves (whether we drink, smoke, exercise etc). These same three aspects can be recognised in environmental, economic and social vulnerability.

For most indicators, signals are based on average levels observed over the past 5 years, but may include data for much longer periods for geological events. The indicators signal risk potentials based on the experience of the immediate past because these are the influences *most likely* to affect short-term trends in environmental vulnerability and how ecosystems may respond to hazards compared with the years preceding them. This does not imply that that there are no effects of older events, only that the EVI has been designed to focus on this time frame. With repeated evaluations, the EVI will demonstrate changes in otherwise longer-term processes. The outcome of this strategy will be an understanding that for a while after an event, vulnerability to future hazards is elevated. The short timeframe also allows improvements to be measured quickly for indicators that can be directly influenced by human action.

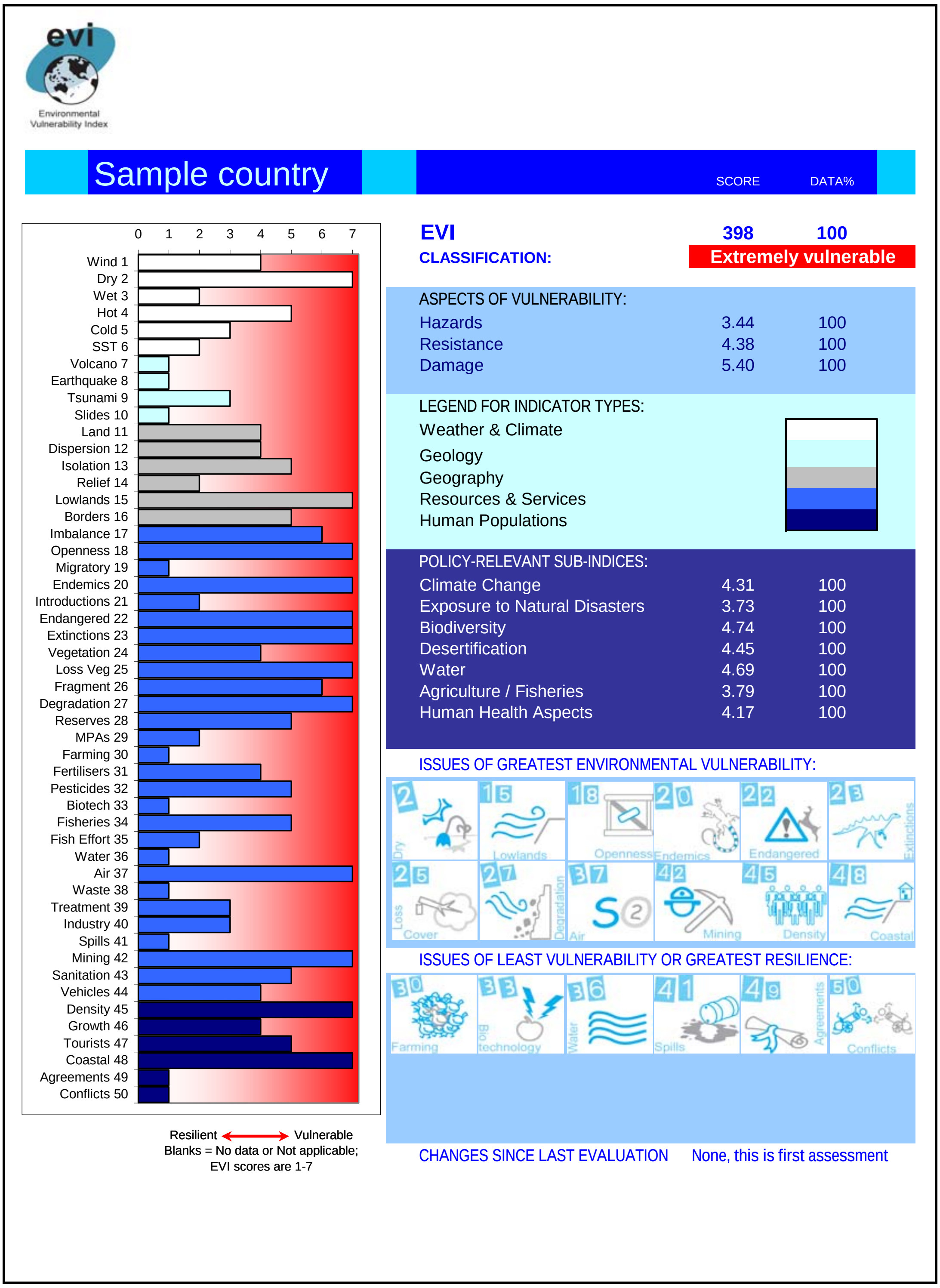
All of the EVI's indicators are transformed to a common scale so that they can be combined by averaging, and to facilitate the setting of thresholds of vulnerability. This new scale has been designed to reflect the environmental vulnerability associated with each indicator, regardless of any other scale on which an indicator could simultaneously exist. The EVI scale was defined as ranging between a value of 1 (indicating high resilience / low vulnerability) and 7 (indicating low resilience / high vulnerability). The EVI scale was determined separately for each indicator, is designed to be policy-relevant, and is based on the best available scientific information.

The EVI was developed on the basis of the logical requirements for assessing the environmental vulnerability of countries. There are still data gaps in the EVI, a problem found in all international reporting, but a tolerance has been built into the index which requires a minimum of 80% of data returns over the 50 indicators for a valid EVI evaluation. This strategy allows for some flexibility where data are not yet available, though it is expected that data for all of the EVI indicators will be available for most countries within a short time. There are currently sufficient data for valid evaluations of more than half of the world's countries, and it is intended that data gaps will be addressed on an on-going basis. In addition, there are 5 indicators that may not be applicable in land-locked countries because they do not have coasts (however, for some inland lakes are considered to have relevant coasts). Missing or not-applicable data do not contribute to the EVI calculation and do not increase or decrease the score, with the EVI being calculated only over indicators for which there are data.

EVI reports for countries are organised as a single-page, information-dense report card. The information available on the report includes an overall EVI score in points, with percent of data over which it was calculated and a classification of overall vulnerability. The classification, shown below, quickly identifies whether the environment of a country is highly vulnerable overall.

Extremely vulnerable	365+
Highly vulnerable	315+
Vulnerable	265+
At risk	215+
Resilient	<215

Below this, are presented the results for the three aspects of vulnerability, hazards, resistance and damage, and the percentage of indicators relevant to each for which data were available. These results are presented in relation to the EVI scale (1 – 7). The results for each of the policy-relevant sub-indices are given in the next section, followed by a brief identification in pictorial format of the main vulnerability issues the country is facing, and its areas of greatest resilience. Sub-indices have been calculated for climate change, exposure to natural disasters, biodiversity, desertification, water, agriculture and fisheries, and human environmental health (see Table 2 for details on the selection of policy-relevant indicators and how they were combined for specific uses). On the left side of each report, the results obtained for individual indicators, the profile, are given in a bar chart so that individual issues contributing to high vulnerability scores can be clearly identified. At the bottom of the report, space has been allocated for the future when the country's EVI is re-evaluated and changes since last evaluation can be assessed.



The EVI is unlike other environmental indices that describe the relative position of a country in relation to worldwide observed values. The EVI has been designed using thresholds which have been built in to the 1 – 7 EVI scale to create a link or anchor between what conditions are observed in countries and those that are environmentally sustainable. Using this approach, indicators are scaled independently of the observed values, providing an in-built mechanism by which countries can immediately assess *their* vulnerability, rather than identifying their position in relation to others. An additional advantage of this approach is that any individual indicator can be evaluated without information from any other, and any country can evaluate its EVI without information from other countries to provide a context.

Table 2: Summary of Indicators selected for the EVI and their allocation to policy-relevant sub-indices.

Indicator number and short name is shown with general types, aspects of vulnerability and sub-index to which each indicator is included. **General Types:** W&C=Weather & Climate; G=Geological; Gph=Geographical; R&S=Resources & ecosystem services; H=Human populations. **Aspects of vulnerability:** Hazards, Resistance and Damage. **Sub-indices:** CC=Climate Change; D=Exposure to natural disasters; HH=Human health aspects; AF=Agriculture & Fisheries; W=water; CCD=Desertification; CBD=Biodiversity.

INDICATORS	TYPES	ASPECTS	SUB-INDICES						
1 Wind	W&C	Hazards	CC	D				CCD	
2 Dry	W&C	Hazards	CC	D		AF	W	CCD	
3 Wet	W&C	Hazards	CC	D		AF	W	CCD	
4 Hot	W&C	Hazards	CC	D				CCD	
5 Cold	W&C	Hazards		D				CCD	
6 SST	W&C	Hazards	CC			AF			CBD
7 Volcano	G	Hazards		D					
8 Earthquake	G	Hazards		D					
9 Tsunami	G	Hazards		D					
10 Slides	G	Hazards		D					
11 Land	Gph	Resistance	CC						CBD
12 Dispersion	Gph	Resistance	CC						CBD
13 Isolation	Gph	Resistance							CBD
14 Relief	Gph	Resistance	CC					CCD	CBD
15 Lowlands	Gph	Resistance	CC					CCD	CBD
16 Borders	Gph	Resistance							CBD
17 Imbalance	R&S	Damage				AF			CBD
18 Openness	R&S	Hazards				AF			CBD
19 Migratory	R&S	Resistance				AF			CBD
20 Endemics	R&S	Resistance							CBD
21 Introductions	R&S	Damage				AF			CBD
22 Endangered	R&S	Damage							CBD
23 Extinctions	R&S	Damage							CBD
24 Vegetation	R&S	Damage	CC			AF	W	CCD	CBD
25 Loss Veg	R&S	Hazards				AF	W	CCD	CBD
26 Fragmentation	R&S	Damage				AF			CBD
27 Degradation	R&S	Damage				AF	W	CCD	
28 Reserves	R&S	Hazards					W		CBD
29 MPAs	R&S	Hazards				AF			CBD
30 Farming	R&S	Hazards				AF			
31 Fertilisers	R&S	Hazards			HH	AF	W		
32 Pesticides	R&S	Hazards			HH	AF	W		
33 Biotech	R&S	Hazards				AF			
34 Productivity overfishing	R&S	Hazards				AF			
35 Fishing Effort	R&S	Hazards				AF			
36 Water	R&S	Hazards	CC		HH	AF	W	CCD	
37 SO2	R&S	Hazards			HH				
38 Waste	R&S	Hazards							
39 Treatment	R&S	Hazards			HH		W		
40 Industry	R&S	Hazards							
41 Spills	R&S	Hazards							
42 Mining	R&S	Hazards							
43 Sanitation	R&S	Hazards			HH		W		
44 Vehicles	R&S	Hazards							
45 Density	H	Damage	CC	D			W		
46 Growth	H	Hazards					W		
47 Tourists	H	Hazards							
48 Coastal	H	Damage	CC	D					
49 Agreements	H	Hazards							
50 Conflicts	H	Damage							

2.5.1 Strengths & weaknesses

As for all methods of summarising and modelling data, the EVI is associated with conditions, strengths and weaknesses which must be understood for its proper application and use. The Think Tank participants and expert reviews identified a set of strengths and weaknesses that have been added to those compiled by the SOPAC team.

The strengths of the EVI have been identified as follows:

- It is the first comprehensive and convenient measurement of environmental vulnerability;
- Is based on a theoretical framework that prompted the EVI team and expert panel to find indicators for all identified aspects of vulnerability;
- Identifies issues and conditions that are contributing to vulnerability of a country, as well as the features that are currently in a strongly resilient state and which could be immediately preserved;
- Permits countries to examine their status and how it changes through time and in response to actions and policy changes;
- Stimulates debate at the science / policy interface at national and international levels and amongst disciplines;
- It is able to incorporate a range of data types on different response scales and non-linearities;
- Is globally applicable;
- Could be used for awareness-raising;
- Identifies areas of environmental concern which could provide a focus for new or improved data collection.

The weaknesses of the EVI were identified as follows:

- The scaling and thresholds for indicators are based on the best available information, but will need to be improved and refined as better information is collected globally and limits of sustainability become better understood;
- Some complex environmental factors have been represented by proxy indicators because they could not be measured directly;
- The EVI is affected by the specific indicators chosen and the results obtained may differ if different variables were chosen;
- The EVI is subject to problems with differences in quality of the data and the interpretation of users, although this could be minimised with training and the establishment of better data-collection mechanisms;
- Some of the data may be difficult to obtain.

In addition to the above strengths and weaknesses, users of the EVI will need to be aware of the following conditions:

1. The EVI emphasises short-term environmental change, rather than longer term trends, specifically so that it can in turn quickly detect improvements brought on by changes in policy and action;
2. Some local variations and other details are not incorporated into the model because it is focused on the national scale. If more localised information is required (e.g. a province), or broader information (a region or cluster of countries) the EVI can be separately calculated at the required scale as long as data can be found at that scale.

3 GENERAL APPROACH FOR DEVELOPMENT OF THE EVI

3.1 Establishing collaborators and the EVI database

A list of target countries established during Phase II of the project was used as the basis for inviting countries to become collaborators on the project. Invitations were extended through a combination of regional meetings, in-country visits, UNEP introductions and by inviting target countries to attend an EVI Globalisation Meeting in Geneva 27 – 29 August 2001.

Country data for the EVI were collected through direct collaboration with all SOPAC Member countries, other SIDS, and the target countries selected to globalise the context of the EVI. For all of these countries, the aim was to collect 100% of the required data using in-country sources to allow for the calculation of complete EVI profiles for each. Collecting data in-country would also allow us to compare sources of data and test the EVI model for sensitivities due to differing estimates of particular indicators, a measure of the robustness of the model. Each country was given a hard and / or electronic copy of the EVI indicator questionnaire which they were asked to fill out, citing sources of the data and person collecting them. The data collected using this method was stored in a Country EVI Database.

The EVI database also included data collected on individual indicators and which were available in the public domain. These data came from published papers, reports, web sites or the databases of other organisations and institutions collecting data for their own purposes on climate, weather, disasters, economic activity, imports and exports and aspects of human welfare.

3.2 Understanding characteristics of the data and setting the EVI scoring for indicators

All of the EVI indicators were tested and thresholds set for scoring on a 1 – 7 scale using a standardised protocol. The aim of these tests was to understand the underlying statistical distributions of the data, identify any transformations of the data that might be needed to make setting thresholds easier and to linearise scores so that the EVI model is additive and values for the EVI and its sub-indices could be more easily calculated without risk of excessive distortions. The results of these investigations were used to set levels on the EVI scale, with the aid of expert input and available information on how changes in the value of an indicator might affect the environmental vulnerability of a country. Four major aspects of indicators were considered before EVI scoring levels could be set. These were:

1. Whether an indicator was applicable to all countries;
2. Whether the indicator was correlated with country size;
3. Whether the scale of the indicator was better represented on a linear, logarithmic or other scale; and
4. What the trigger levels would be for an indicator. A trigger level would be defined as the level reached by an indicator beyond which environmental conditions would be considered unsustainable.

The following steps were taken to test each indicator, calculated using either Microsoft™ Excel or Statsoft™ Statistica. Full results are given in Appendix 7.4:

1. All data available for an indicator was plotted in the raw state as a frequency distribution of countries in 20 evenly-spaced value categories to examine any obvious underlying patterns for an indicator. For example, the distribution of raw values may be bimodal, with a group of countries having a small value, and another group having very large values, with few countries in between.

2. The observed data were fit to four possible distribution curves and subjected to statistical tests (in this case a Kolmogorov-Smirnov (K-S) test) to determine whether the fit was a good one and whether the underlying distribution for that indicator could be explained by one of the more commonly recognised statistical distributions. The distributions tested initially were: normal, rectangular, exponential and lognormal, which identified whether the data for an indicator were distributed linearly, evenly, as a power function, or as a logarithmic function, respectively. A significant K-S test indicated a poor fit to the proposed distribution, while a non-significant one meant that we could not reject a null-hypothesis of no difference between our observed values and those expected and that the underlying distribution is indeed in the form being tested (see also Appendix 7.4 for further information on distributions).
3. The raw data was examined to determine whether there was a correlation between the indicator and the size of country. This was done using a simple correlation coefficient test which ran the value of an indicator against the value for size of the country. In most cases, indicators are already articulated as a density function (i.e. a value divided by land area or sea area) to eliminate a signal on size of a country. The correlation test was run to determine whether this division by size was necessary, or whether it could be discarded.
4. The data was transformed if a non-linear function was found to be a good fit (e.g. exponential or logarithmic). This preserves the relationship among countries, but moves the raw data onto a linear scale, more suitable for the averaging technique used in the EVI.
5. The transformed data was then refitted (if necessary) onto a scale from 1 – 7 to begin the process of setting levels for EVI scoring for the indicator.
6. Proposal of an EVI scale for an indicator. This was partially based on the maximum and minimum observed values and the underlying distribution detected for the data. The most important component of the proposed scaling was concerned with information on how different values for an indicator might relate to environmental vulnerability. In some cases, values were mapped on a simple evenly-spaced scale that extends from the lowest to highest values because it was thought that vulnerability increases in direct proportion with the value of the indicator. In others, scoring may be discontinuous, folded back on themselves (i.e. a binomial distribution in which very high or very low values are considered risky, while intermediate values represent the lowest vulnerability), or be set with varying intervals.

Sustainable conditions tend to be found near one end of the world's range for any one indicator. For most indicators we do not know the true cut-off values of sustainability. Where information does exist to support a level that would be considered 'sustainable' (e.g. protected areas should be 20% of the land or sea area), these values were used in the vulnerability scoring. Where values are not known, values were scaled to spread them (logarithmically, see below) across global conditions, often clumping extremely low or high values. Most of the countries were forced into a clump at low values by the presence of just a few (sometimes only one or two countries) with extremely high values. Use of a logarithmic scale for many of the indicators helps us to distinguish between countries at the lower more resilient end where differences are smaller, shifts in values are likely to be relatively easy to achieve (improvements) and the level for sustainability is more likely to be located. Countries near the upper end of any indicator scale are not only very vulnerable, but also in a difficult position to effect improvements. They are often several orders of magnitude greater in value than most countries.

3.3 *Criteria for testing the EVI*

Recommendations made at the EVI Think Tank I in 1999 (Kaly *et al.* 1999b) included steps for the final testing of the EVI. Three criteria were suggested:

1. That there are no redundant indicators using data from at least 15 countries;
2. That EVI scores spread throughout the range of conditions found, and cluster countries according to known similarities for at least 15 countries around the globe; and
3. That the EVI is validated through independent assessments made in at least 5 countries.

These three criteria were developed to provide guidance to experts, funding agencies and the international community on when the EVI would be technically ready for use. The criteria were also developed to allow for the development of appropriate milestones and so that a completed EVI could be identified in relation to the funding required to complete the work. These criteria do not eliminate the need for additional testing on sensitivity, effects of errors in data and other aspects of the index and the data needed to evaluate it, but provide an independent 'finishing line' for the index.

Since Think Tank I, through later consultations (including Think Tank II), emphasis shifted from the value of the overall EVI score to country profiles and sub-indices because of their ability to identify issues. As a result of this shift, it was determined that Criterion 1 would no longer be of major importance. The second criterion was examined as part of Phase III of the project, with results given in this report. Funding for the third criterion has not yet been secured and will need to be examined in the future.

3.3.1 Criterion 1: Test for redundant indicators

This test is no longer being applied, as there was a shift in emphasis from calculation of the overall score, to a more pressing need to identify vulnerability issues and areas of resilience for preservation and improvement.

> **Test for Criterion 1:** When the correlation coefficient between two indicators for 15+ countries is non-significant in a standard statistical test.

3.3.2 Criterion 2: Scoring for indicators is global

The EVI scores needed to be evaluated for at least 15 countries across the globe with widely ranging characteristics to examine how well the model provides the spread required to distinguish them. The countries included in this test (same as for criterion 1) were to include small islands, large continental masses, highly-fragmented countries, land-locked countries, tropical, cold climate countries, deserts low-lying and high countries. It was considered that the EVI should be able to cluster similar countries together and provide spread among countries which are very different. The response scale for each of the indicators (i.e. the EVI score 1 – 7 is the mechanism in the EVI which provides the spread) would be finalised when data for these 15 test countries are available.

> **Test for Criterion 2:** When the spread in EVI values among the 15+ test countries occupies much of the 1 – 7 range expected and countries considered *a priori* to be 'similar' cluster closer together than 'dissimilar' countries.

3.3.3 Criterion 3: Validation

The purpose of constructing an EVI is to simplify the task of categorising countries according to their relative environmental vulnerabilities. If personnel, funding and time were unlimited, this could be done by sending several independent teams of evaluators to each country and commissioning them to carry out a vulnerability assessment for each. The replicate assessments for each country could then be used to classify countries in terms of their vulnerability and provide recommendations for each for corrective actions. This procedure would of course be extremely expensive. It is one of the aims of the EVI to simplify this process.

The only independent means of assessing the effectiveness of the EVI in carrying out this task in a simplified way is to compare the results of the EVI with a full assessment for a small number of, say 5, countries on a once-off basis. Several teams of experts would have to be mobilised in each of the test countries to provide a 'mean assessment' for each. The consultants involved should be unaware of the mechanics of the EVI to ensure that they do not unintentionally bring bias into the results. The assessments could then be compared with the EVI scores obtained.

> **Test for Criterion 3:** When the difference between the value obtained by the EVI and the mean of the assessments provided for a country by several experts (who are unaware of the workings of the EVI) is about the same, or less than, the spread found among the assessments of the experts. This test should be performed for about 5 countries.

4 RESULTS FOR EVI 2004

4.1 Collaborators and status of the Global EVI Database

A shortage of relevant and/or accessible environmental data was the single largest technical problem encountered whilst developing and testing the EVI. Although collaborators were cooperative and generally attempted to provide the data we requested, they were often unable to do so. Despite the great recent advances in global data collections for environmental treaties, most data are still oriented towards economic and human development needs, or where suitable environmental data may be found, they are focused on present state of the environment (SOE) rather than on measures of potential for future damage (vulnerability). Both of these types of data are required for planning for sustainability.

Despite some difficulties, data have now been obtained for all of the EVI’s indicators (Figure 1). The fewest data were obtained for Indicator 39 on waste treatment (41 countries), with data available for at least 100 countries for most indicators (47 of 50), allowing for good data characterisation and scaling based on a range of conditions worldwide. The issues with weakest data on vulnerability measures are concerned with freight movements, protected areas, pesticides, fishing effort, waste and sanitation.

On a country by country basis, there are now sufficient data in the EVI database for valid EVI evaluations for 142 countries, more than 60% of those examined (Figure 2). This contrasts with the sub-set of results obtained for SIDS, for which valid EVIs could only be calculated for 13 countries (or 28%).

Figure 1: Status of the global EVI database by indicator.

The bars indicate the number of countries for which data on each indicator are held. The indicator with the lowest number of countries of data is Indicator 39 on waste treatment.

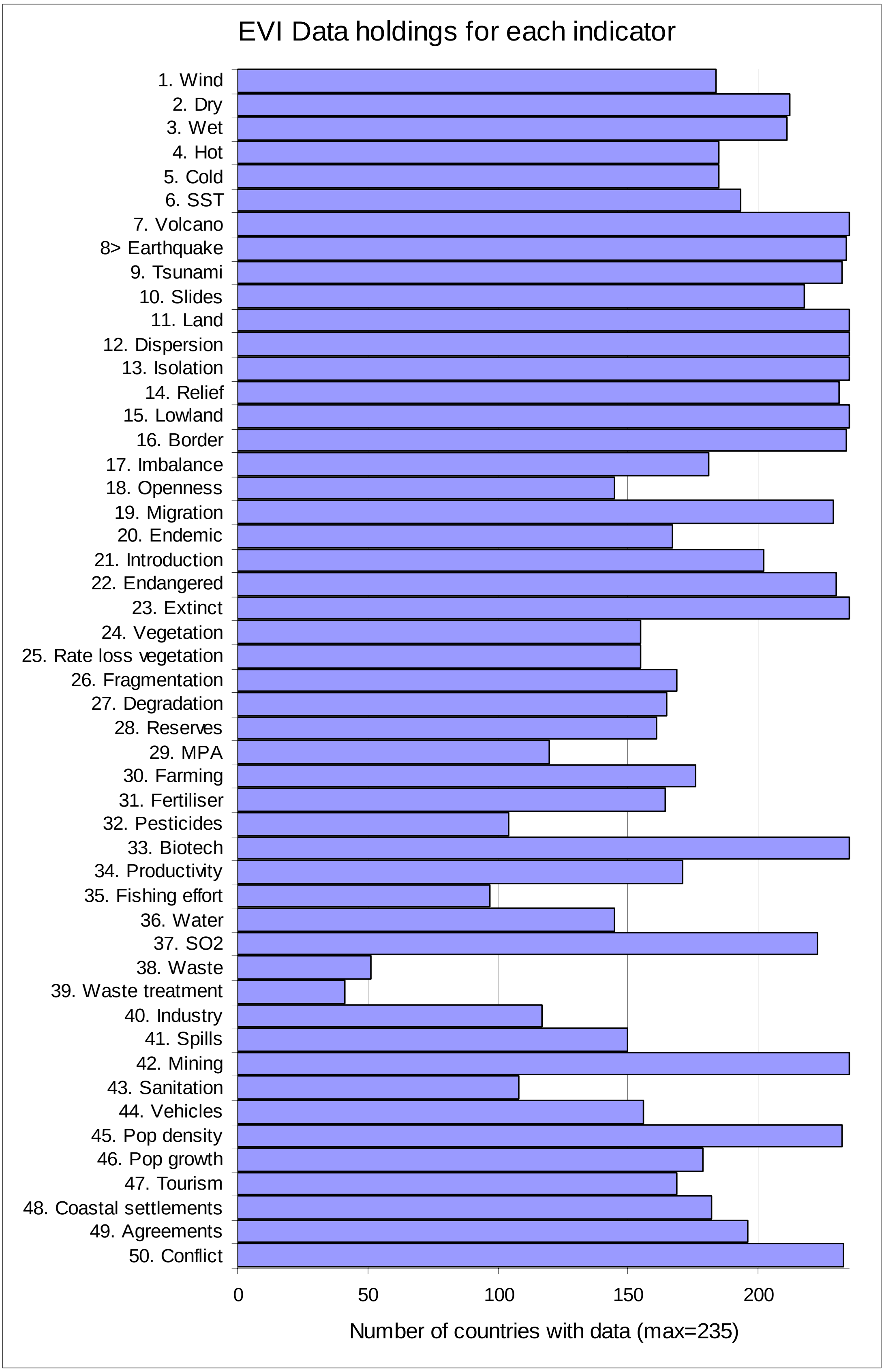
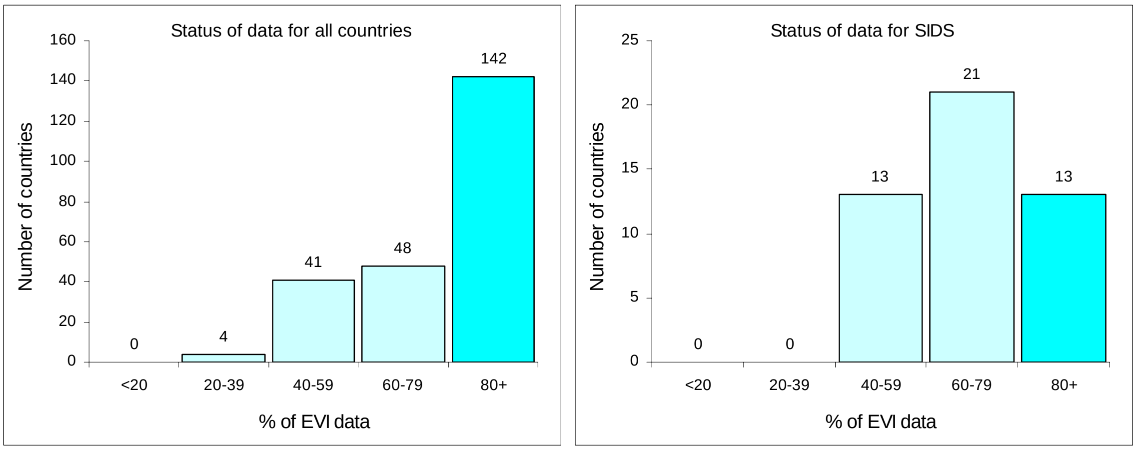


Figure 2: Status of the EVI database by country and EVI ranking.

(a) Shows the distribution of percent data held by country across the globe; (b) Shows the distribution of data holdings for SIDS. The dark bar represents countries with data for 80% or more of the indicators, resulting in valid EVI scores. Note that only 13 SIDS have sufficient data for valid EVI scores.

(a) (b)



Data for most countries of the 235 included in this evaluation of the EVI, were derived from a range of public data sources, including but not limited to World Resources Institute, CIA fact files, UN sources, Eurostat and the US and British Geological Surveys. Although it was originally intended that data from our 32 collaborating countries would ensure at least the 80% data minimum would be met for those countries, in practice sufficient data were not available within countries. In some cases, although our collaborators did provide data, we had to disregard them because either:

- there were errors in the units used;
- no data was held by the country;
- there was vast (sometimes several orders-of-magnitude) difference between values given by collaborators and in public datasets; or
- it was necessary to work with a proxy because data of the form requested were generally not available, making the data collected by the collaborators no longer compatible with the bulk of data available for an indicator.

Where datasets were compatible, collaborator data were used in conjunction with public data to provide maximum possible returns for each country. In cases where both public and in-country data were available for an indicator, we generally used the public source.

Globally, the average number of indicators evaluated per country across the entire database (235 countries) was 31 of 50, or around 60%. The maximum data return for any one country was 100% for Thailand (a collaborator) and the minimum 19% for Vatican City, with the world average of 78% of indicators per country. The regions with the best data returns were the Middle East & North Africa (88%), North America (80%), Sub-Saharan Africa (81%) and South America (87%), with the lowest data returns in Antarctica and the Antarctic Islands (<40%) (Table 3).

Table 3: Summary of data held by region.

Region	Number countries	Number Indicators evaluated			Percent Indicators evaluated		
		Mean	Min	Max	Mean	Min	Max
Antarctica	4	19.8	18	21	39.5	36	42
Asia	35	39.3	19	50	78.6	38	100
Central America & Caribbean	32	35.1	22	48	70.3	44	96
Europe	48	39.7	14	49	79.5	28	98
Middle East & Nth Africa	21	44.2	31	48	88.4	62	96
North America	3	40.0	24	49	80.0	48	98
Oceania	26	35.5	22	49	70.9	44	98
Sth America	14	43.6	30	48	87.3	60	96
Sub-Saharan Africa	52	40.5	23	48	81.0	46	96
All Countries	235	39.0	14	50	78.1	28	100

4.2 Global EVI and sub-index results

Countries were grouped into the 5 classifications set for the EVI from Extremely Vulnerable to Resilient to identify those with the most and least vulnerability issues in general (Figure 3, Figure 4, Table 4, Table 5). The world distribution of overall EVI scores was roughly normally distributed, with a total of 35 countries considered Extremely Vulnerable. Half of the world's Extremely Vulnerable countries are SIDS (Figure 3).

Figure 3: Distribution of world EVI classifications for all countries and the SIDS sub-set.

Note that these distributions include all countries regardless of whether the values are valid scores or only trends.

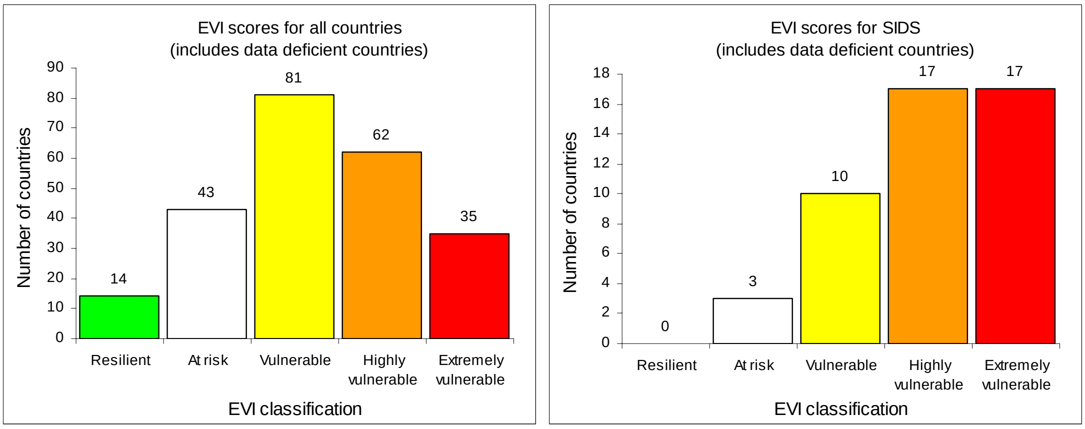


Table 4: EVI classification for countries with valid EVI scores.

Red countries are SIDS; the classifications are: Extremely Vulnerable (EVI of 365+); Highly Vulnerable (315-365); Vulnerable (265-315); At Risk (215-265) and Resilient (<215).

EVI CLASSIFICATION FOR COUNTRIES WITH VALID SCORES (>80% DATA)

- Austria
- Belgium
- Cook Islands
- India
- Israel
- Italy
- Jamaica
- Japan
- Kiribati
- Korea, Rep
- Lebanon
- Netherlands
- Pakistan
- Philippines
- Singapore
- Trinidad and Tobago
- United Kingdom

- Albania
- Bangladesh
- Bulgaria
- China
- Costa Rica
- Croatia
- Cuba
- Denmark
- Dominican Rep
- El Salvador
- Fiji
- France
- Germany
- Greece
- Guatemala
- Haiti
- Hungary
- Indonesia
- Iraq
- Ireland
- Korea, Dem People's Rep
- Kuwait
- Marshall Islands
- Nigeria
- Poland
- Portugal
- Romania
- Slovenia
- South Africa
- Spain
- Sri Lanka
- Switzerland
- Syrian Arab Rep
- Turkey
- Ukraine
- Viet Nam

- Algeria
- Argentina
- Benin
- Brazil
- Burundi
- Cambodia
- Chile
- Colombia
- Congo, Dem Rep
- Ecuador
- Egypt
- Estonia
- Finland
- Gambia
- Ghana
- Guinea-Bissau
- Honduras
- Iceland
- Iran, Islamic Rep
- Jordan
- Latvia
- Lesotho
- Liberia
- Lithuania
- Madagascar
- Malaysia
- Mexico
- Morocco
- Myanmar
- Nepal
- New Zealand
- Nicaragua
- Norway
- Peru
- Russian Federation
- Rwanda
- Saudi Arabia
- Senegal
- Sierra Leone
- Solomon Islands
- Somalia
- Sudan
- Sweden
- Thailand
- Togo
- Tunisia
- Uganda
- United Arab Emirates
- United States of America
- Vanuatu
- Venezuela
- Yemen

- Angola
- Australia
- Belize
- Bolivia
- Burkina Faso
- Cameroon
- Canada
- Chad
- Congo
- Cote d'Ivoire
- Equatorial Guinea
- Ethiopia
- Georgia
- Guinea
- Kazakhstan
- Kenya
- Lao People's Dem Rep
- Libyan Arab Jamahiriya
- Malawi
- Mauritania
- Mozambique
- Oman
- Panama
- Paraguay
- Papua Niugini
- Tanzania, United Rep
- Uruguay

- Botswana
- Central African Rep
- Gabon
- Guyana
- Mali
- Mongolia
- Namibia
- Niger
- Suriname
- Zambia

Extremely vulnerable | Highly vulnerable | Vulnerable | At risk | Resilient

Table 5: EVI trends for countries with insufficient data for valid EVI scores.

Red countries are SIDS; the classifications are: Extremely Vulnerable (EVI of 365+); Highly Vulnerable (315-365); Vulnerable (265-315); At Risk (215-265) and Resilient (<215).

EVI TRENDS FOR COUNTRIES THAT ARE DATA DEFICIENT

American Samoa
Barbados
Bermuda
UK Virgin Islands
French Polynesia
Fed. States Micronesia
Guadeloupe
Guam
Macau
Maldives
Malta
Nauru
Norfolk Island
Nothern Mariana Islands
Saint Lucia
Tonga
Tuvalu
US Virgin Islands

Azerbaijan
Bahrain
Cayman Islands
Christmas Islands
Czech Rep
Gibraltar
Grenada
Liechtenstein
Luxembourg
Macedonia, FYR
Martinique
Mauritius
Moldova, Rep
Monaco
Monserrat
Netherlands Antilles
Palau
Puerto Rico
Réunion
Samoa
Seychelles
St. Kitts and Nevis
St. Vincent & Grenadines
Taiwan
Tokelau
Yugoslavia

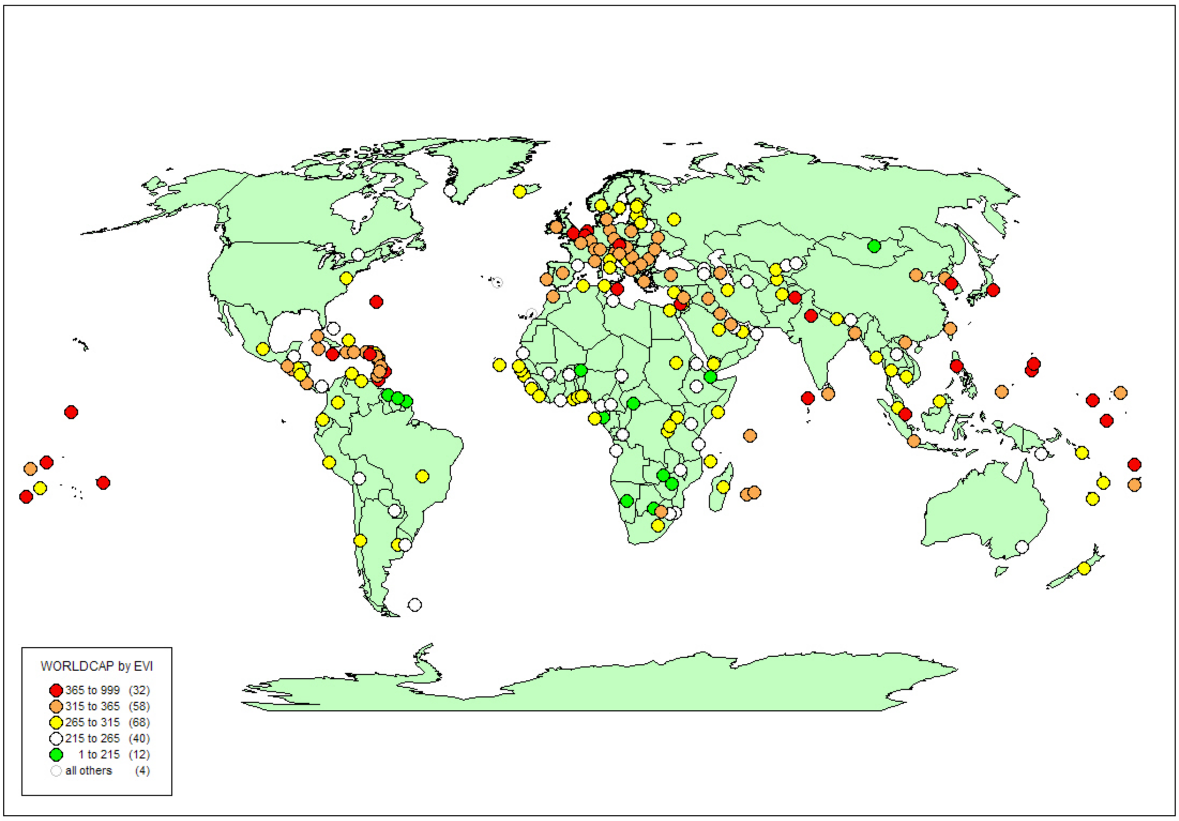
Afghanistan
Anguilla
Antigua & Barbuda
Aruba
Bouvet Island
Bosnia & Herzegovina
British Indian Ocean Territory
Brunei Darussalam
Cape Verde
Cocos (Keeling) Islands
Comoros
Cyprus
Faroe Islands
Heard & McDonald Is.
Hong Kong
Jan Mayen
Mayotte
New Caledonia
Niue
Pitcairn
San Marino
Slovakia
St. Helena
St. Pierre & Miquelon
Tajikistan
Turks & Caicos Islands
Uzbekistan
Vatican City State (Holy See)
Wallis & Futuna Islands

Andorra
Antarctica
Armenia
Bahama
Belarus
Bhutan
Eritrea
Falkland Islands
Greenland
Kyrgyzstan
Qatar
Sao Tome & Principe
Sth Georgia & Sth Sandwich Is.
Svalbard
Swaziland
Turkmenistan

Djibouti
French Guiana
Western Sahara
Zimbabwe

Extremely vulnerable | Highly vulnerable | Vulnerable | At risk | Resilient

Figure 4: World EVI scores in the 5 EVI classifications.



4.2.1 World patterns in aspects of vulnerability: Hazards, Resistance & Damage

The global results for the three main aspects of vulnerability, Hazards, Resistance and Damage were plotted using GIS software (Figure 5, Figure 6, Figure 7). Hazards appear to be a significant contributor to overall vulnerability in Europe, Asia and SIDS, with lower hazards signals observed in South America, Africa and Eurasia. The pattern observed for resistance differs, with the highest vulnerability / lowest resistance largely found smaller, scattered and isolated countries. Damage appears to be highest in Europe, the Caribbean, and parts of Asia and Africa. The differences in aspects contributing to the vulnerability of countries indicate that approaches to increasing resilience are likely to require different approaches across the globe (Kaly *et al.* 2002c).

Figure 5: World scores for the Hazards aspect of the EVI.

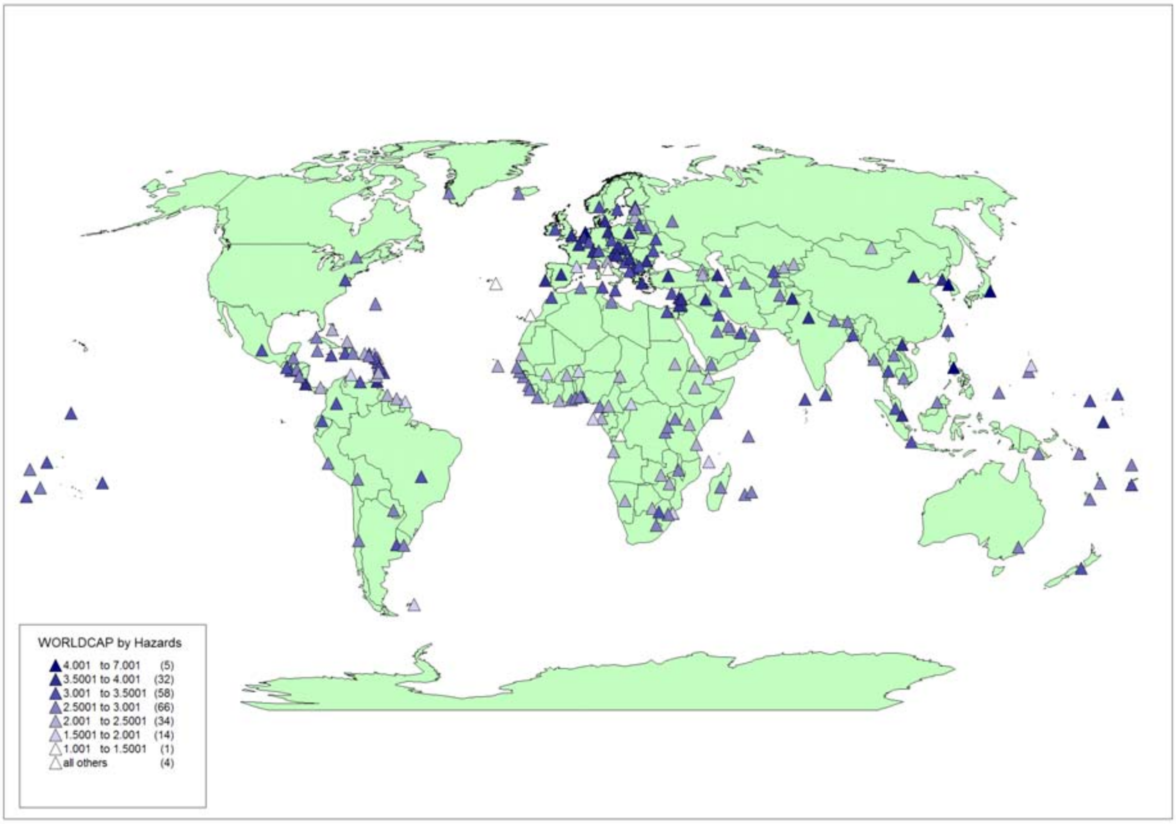


Figure 6: World scores for the Resistance aspect of the EVI.

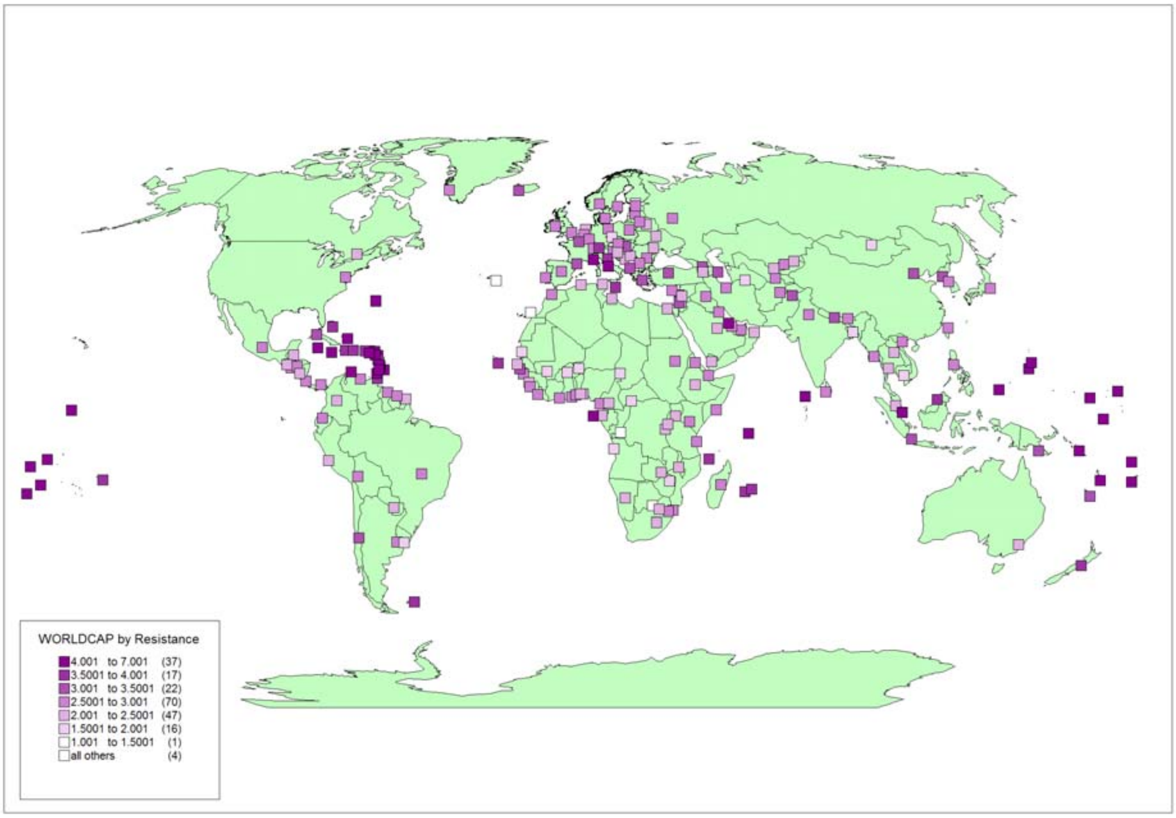
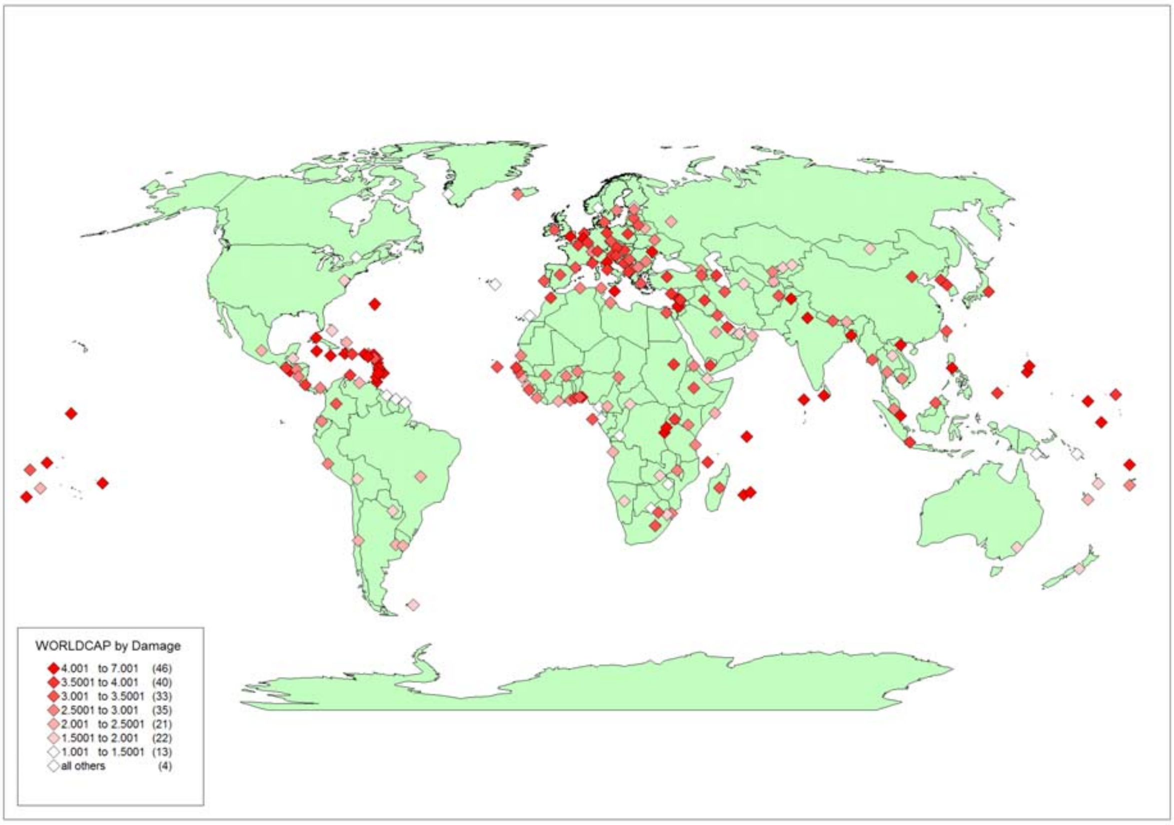


Figure 7: World scores for the Damage aspect of the EVI.



4.3 Natural characteristics, distributions and EVI scoring for individual indicators

Investigations of the underlying global distributions of the EVI data were made and scaling levels set for all of the EVI's indicators. Full details of the analyses and test sheets are provided in Appendix 7.4, and a summary of the main characteristics and scaling for each indicator is shown in Table 6.

4.3.1 Indicators not applicable to some countries

Up to 7 of the 50 indicators could be considered not applicable (NA) to all countries. This include indicators 6, 9, 29 and 38, concerned with coastal conditions; but could also extend to indicators 17, 34 and 35 that deal with fisheries / productivity. As an example, it was initially considered impossible that landlocked countries would demonstrate environmental vulnerabilities due to the characteristics of a coastline. Countries for which an indicator is considered NA attract no EVI score for that indicator. Many land-locked countries do however have inland seas and fisheries, for which coastal populations, fisheries production and other measures are available in relation to their coasts and waterways. It was therefore decided that non-applicability should be applied on a case-by-case basis, only for countries where an indicator is truly not applicable.

4.3.2 Indicators correlated with country size

The majority of tested indicators displayed a strong correlation with country size (60%, or 30 of 50 indicators). Many of these indicators were thus expressed as spatial densities to remove the signal of overall country size from the measure taken and provide a common denominator for comparison. That is, land area, and sometimes length of coastline were used to *remove* the signal of country size from indicators so that relative vulnerabilities could be compared in large and small countries by focusing on the amount of pressure per unit of area. For example, the number of endangered species in Indicator 20 was expressed as the number of species rated as ‘endangered’ per 1000 sq km. It is already expected that the total number of species present in countries is related to overall country size and the differentiation of large numbers of habitats. Comparing the number of endangered species in a very large country with those in a small country would be misleading because of the large difference in absolute number of species we would expect in each. By expressing the results as a spatial density a common basis for comparison was possible.

4.3.3 Indicators on a natural logarithm scale

Half of all indicators tested were transformed to a logarithmic scale after their global frequency distributions were examined. This was done because for most indicators not expressed as percentages, the usual form of the distribution was highly clustered at the low end of the scale, with a spread of very few countries forming a long distributional tail at high values (see Appendix 7.4). This distributional shape is common for bio-physical characteristics of the natural environment. When these data are transformed to their natural logarithms (either as LN(X) or LN(X+1) where zeros are present) data are spread more evenly along the horizontal scale, and allow for better differentiation among countries at the low end of the scale for that indicator and more clumping at the high end of the scale where conditions are usually not sustainable and need correction.

Table 6: Summary information on the scaling and critical thresholds set for EVI indicators.

For each indicator is given the category and aspect of vulnerability an indicator relates to, whether a proxy has been used (Proxy) because data were unavailable for the original form of the indicator and a summary of major sources of data. Specific information on the scaling is also given, including whether values are correlated with size of country, expressed as a spatial density function (%, by land area or length of coastline), whether data were on a linear scale, transformed to natural logarithms, and whether EVI scoring on the 1 – 7 scale was done evenly within the world range, unevenly or discontinuously. NA and ND show whether for that indicator entries could be either NA=not applicable; or ND=no data available. The values in the right side of the table are limits for each of the EVI scores on the indicated scale.

#	Category	Short name	Aspect	Proxy?	Data sources	Corr land size?	Spatial density?	Transform used	NA	ND	EVI=1	EVI=2	EVI=3	EVI=4	EVI=5
1	Weather & Climate	Wind	Hazards	No	NOAA DATSAV3 Surface SOD 1973-2003	N	No	LN(X)	×	✓	X<=5	5<X<=5.3	5.3<X<=5.6	5.6<X<=5.9	5.9<X<=6.1
2	Weather & Climate	Dry	Hazards	No	NOAA GHCN	N	No	Absolute valu	×	✓	X<=4	4<X<=4.5	4.5<X<=5	5<X<=5.5	5.5<X<=6
3	Weather & Climate	Wet	Hazards	No	NOAA GHCN	N	No	sqrt(X)	×	✓	X<=5	5<X<=7	7<X<=9	9<X<=11	11<X<=13
4	Weather & Climate	Hot	Hazards	No	NOAA DATSAV3 Surface SOD 1973-2006	Y	No	LN(X+1)	×	✓	X<=3.5	3.5<X<=4	4<X<=4.5	4.5<X<=5	5<X<=5.5
5	Weather & Climate	Cold	Hazards	No	NOAA DATSAV3 Surface SOD 1973-2007	Y	No	LN(X)	×	✓	X<=3.6	3.5<X<=5	4<X<=4.6	4.5<X<=6	5<X<=5.6
6	Weather & Climate	SST	Hazards	No	UBC	N	No	None	✓	✓	X<=0.5	0.5<X<=0.75	0.75<X<=1	1<X<=1.25	1.25<X<=1.5
7	Geology	Volcano	Hazards	No	NOAA, In-country	Y	No	LN(X+1)	×	✓	X<=2	2<X<=3	3<X<=4	4<X<=5	5<X<=6
8	Geology	Earthquake	Hazards	No	NOAA, In-country	Y	No	None	×	✓	X<=1	1<X<=2	2<X<=3	3<X<=4	4<X<=5
9	Geology	Tsunami	Hazards	No	NOAA, In-country	Y	Coastline	None	✓	✓	X<=0	0<X<=1	1<X<=2	2<X<=5	5<X<=10
10	Geology	Slides	Hazards	No	EMDAT, In-country	Y	Land area	LN(X+1)	×	✓	X<=0	0<X<=0.5	0.5<X<=1	1<X<=1.5	1.5<X<=2
11	Geography	Land	Resistance	No	WRI, CIA, In-country	-	No	LN(X)	×	✓	X<=4	4<X<=6	6<X<=8	8<X<=10	10<X<=12
12	Geography	Dispersion	Resistance	No	WRI, CIA, In-country	N	Land area	LN(X)	×	✓	X<=2	2<X<=3	3<X<=4	4<X<=5	5<X<=6
13	Geography	Isolation	Resistance	No	Times World Atlas, In-country	Y	No	LN(X+1)	×	✓	X<=0	0<X<=50	50<X<=100	100<X<=400	400<X<=800
14	Geography	Relief	Resistance	No	CIA, In-country	Y	No	None	×	✓	X<=1500	1500<X<=3000	3000<X<=4500	4500<X<=6000	6000<X<=7000
15	Geography	Lowlands	Resistance	Yes	Encarta 2004	Y	%	None	×	✓	X<=0	0<X<=15	15<X<=30	30<X<=45	45<X<=60
16	Geography	Borders	Resistance	No	CIA, Encarta, In-country	Y	No	None	×	✓	X<=0	0<X<=2	2<X<=4	4<X<=6	6<X<=8
17	Resources & services	Ecosystem imbalan	Damage	No	UBC	N	No	None	×	✓	X>=0	0>X>=-0.02	-0.02>X>=-0.04	-0.04>X>=-0.06	-0.06>X>=-0.08
18	Resources & services	Openness	Hazards	Yes	WRI, In-country	Y	Land area	LN(X)	×	✓	X<=1	1<X<=1.5	1.5<X<=2	2<X<=2.5	2.5<X<=3
19	Resources & services	Migratory	Resistance	No	GROMS, In-country	Y	Land area	LN(X+1)	×	✓	X<=1	1<X<=1.5	1.5<X<=2	2<X<=2.5	2.5<X<=3
20	Resources & services	Endemics	Resistance	No	WRI, In-country	Y	Land area	LN(X+1)	×	✓	X<=0	0<X<=2	2<X<=4	4<X<=6	6<X<=8
21	Resources & services	Introductions	Damage	No	In-country, FAO	Y	Land area	LN(X+1)	×	✓	X<=0	0<X<=1	1<X<=1.5	1.5<X<=2	2<X<=2.5
22	Resources & services	Endangered	Damage	No	IUCN, In-country	Y	Land area	None	×	✓	X<=0	0<X<=1	1<X<=2	2<X<=3	3<X<=4
23	Resources & services	Extinctions	Damage	No	IUCN, In-country	Y	Land area	None	×	✓	X<=0	0<X<=0.1	0.1<X<=0.2	0.2<X<=0.3	0.3<X<=0.4
24	Resources & services	Vegetation	Damage	Yes	WRI, FAO, In-country	Y	%	None	×	✓	80<X	60<X<=80	40<X<=60	20<X<=40	10<X<=20
25	Resources & services	Loss Veg	Hazards	Yes	WRI, FAO, In-country	N	%	None	×	✓	X>0			X=0	-1<X<0
26	Resources & services	Fragmentation	Damage	No	World Bank, In-country	Y	Land area	LN(X+1)	×	✓	X<=0.2	0.2<X<=0.4	0.4<X<=0.6	0.6<X<=0.8	0.8<X<=1
27	Resources & services	Degradation	Damage	No	FAO, In-country	N	%	None	×	✓	X<=5	5<X<=10	10<X<=15	15<X<=20	20<X<=25
28	Resources & services	Reserves	Hazards	No	WRI, In-country	N	%	None	×	✓	20<X	15<X<=20	10<X<=15	5<X<=10	0<X<=5
29	Resources & services	MPAs	Hazards	No	WCMC, WRI, In-country	N	%	None	✓	✓	20<X	15<X<=20	10<X<=15	5<X<=10	0<X<=5
30	Resources & services	Farming	Hazards	Yes	FAO, In-country	Y	Land area	LN(X+1)	×	✓	X<=2	2<X<=3	3<X<=4	4<X<=5	5<X<=6
31	Resources & services	Fertilisers	Hazards	No	WRI, OECD, In-country	Y	Land area	LN(X+1)	×	✓	X<=4	4<X<=6	6<X<=7	7<X<=8	8<X<=9
32	Resources & services	Pesticides	Hazards	No	WRI, OECD, In-country	Y	Land area	LN(X+1)	×	✓	X<=0	0<X<=0.5	0.5<X<=1	1<X<=2	2<X<=3
33	Resources & services	Biotechnology	Hazards	Yes	ISAAA, BINAS, OECD, In-country	Y	Land area	None	×	✓	X<=0	None	None	None	0<X<=20
34	Resources & services	Productivity overfisl	Hazards	Yes	FAO, In-country	Y	Coastline	LN(X)	×	✓	X<=10	10<X<=11	11<X<=12	12<X<=13	13<X<=14
35	Resources & services	Fishing Effort	Hazards	Yes	FAO, WRI, In-country	Y	Coastline	LN(X+1)	×	✓	X<=2	2<X<=2.5	2.5<X<=3	3<X<=3.5	3.5<X<=4
36	Resources & services	Water	Hazards	Yes	WRI, Worldwater, In-country	N	No	LN(X+1)	×	✓	X<=10	10<X<=20	20<X<=40	40<X<=60	60<X<=80
37	Resources & services	Air	Hazards	Yes	GEO3, WRI, WDI, OECD, HDR, In-country	Y	Land area	LN(X+1)	×	✓	X<=0.25	0.25<X<=0.5	0.5<X<=0.75	0.75<X<=1	1<X<=1.5
38	Resources & services	Waste	Hazards	No	Range of sources, In-country	Y	Land area	LN(X+1)	×	✓	X<=1	1<X<=2	2<X<=3	3<X<=4	4<X<=5
39	Resources & services	Waste treatment	Hazards	No	Data unavailable	N	%	None	×	✓	X=100	80<=X<100	60<=X<80	50<=X<60	40<=X<50
40	Resources & services	Industry	Hazards	Yes	WRI, World Nuclear Assoc, In-country	Y	Land area	None	×	✓	X<=5	5<X<=10	10<X<=20	20<X<=50	50<X<=100
41	Resources & services	Spills	Hazards	No	ITOPF, SPILLS, CRED, In-country	N	Land area	None	×	✓	X<=0	0<X<=50	50<X<=100	100<X<=150	150<X<=200
42	Resources & services	Mining	Hazards	Yes	USGS, other sources	N	Land area	LN(X+1)	×	✓	X<=1	1<X<=2	2<X<=3	3<X<=4	4<X<=5
43	Resources & services	Sanitation	Hazards	Yes	WRI, In-country	Y	Land area	LN(X+1)	×	✓	X<=1.5	1.5<X<=2	2<X<=2.5	2.5<X<=3	3<X<=3.5
44	Resources & services	Vehicles	Hazards	No	WRI, OECD, In-country	Y	Land area	LN(X+1)	×	✓	X<=1	1<X<=1.5	1.5<X<=2	2<X<=2.5	2.5<X<=3
45	Human populations	Density	Damage	No	WRI, CIA, In-country	N	Land area	LN(X+1)	×	✓	X<=3	3<X<=3.5	3.5<X<=4	4<X<=4.5	4.5<X<=5
46	Human populations	Growth	Hazards	No	WRI, US Bureau of Census, In-country	N	No	None	×	✓	X<0	X=0	0<X<=0.5	0.5<X<=1	1<X<=1.5
47	Human populations	Tourists	Hazards	Yes	WTO, In-country	Y	Land area	LN(X+1)	×	✓	X<=3	3<X<=3.5	3.5<X<=4	4<X<=4.5	4.5<X<=5
48	Human populations	Coastal	Damage	No	WRI, CIA, In-country	N	Land area	LN(X+1)	✓	✓	X<=3	3<X<=3.5	3.5<X<=4	4<X<=4.5	4.5<X<=5
49	Human populations	Agreements	Hazards	Yes	SEDAC / CIESIN, In-country	N	No	None	×	✓	60<X	50<X<=60	40<X<=50	30<X<=40	20<X<=30
50	Human populations	Conflicts	Damage	No	EMDAT, In-country	N	No	None	×	✓	X<=0	None	None	None	0<X<=2

5 CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions drawn from the first full evaluation of the EVI

The results of this evaluation of the EVI clearly show that collecting data, evaluating the index, sub-indices and profiles and interpreting the results of the EVI is possible and practical. Using a combination of the inputs of our collaborating countries (32 from around the globe) and publicly available datasets, we have been able to gather the required data, and to evaluate valid EVI scores for 142 countries (of 235 included in the EVI database). In addition, it has been possible to calculate the trends for countries with less than 80% of data requirements, though the results obtained for individual indicators and any of the sub-indices with greater than 80% of the data required could be considered valid.

Further improvements are required for on-going data collection and future evaluations of the EVI. There now remain several proxy indicators which could be improved in the future through formalised two-way data collection and storage processes, and several indicators for which data are still generally lacking (e.g. those on waste production and treatment). The main issues that need to be addressed in relation to data are:

- Some data for much-needed environmental monitoring and management are still lacking. There is a global need for better information on waste generation and treatment, and for water, information disaggregated to identify specifically the use of renewable resources (in contrast to fossil waters);
- In some cases, there is a lack of cooperation from agencies that hold the data;
- Some data (e.g. weather) are available largely as archived and/or disparate files that require processing to be in a useable form;
- There is a requirement of some agencies for cost recovery before releasing data and therefore the need to develop agreements or to access funding for that purpose;
- Quality of publicly-available data appears to be variable and there are few mechanisms for users to be able to assess the likely accuracy of data available; and
- Data collection mechanisms are inefficient so that data are often incomplete, discontinuous and not yet part of the normal requirements for managing countries.

The application of the Think Tank criteria for testing will be applied to these global EVI results (partial testing was carried out in Kaly *et al.* 2003). It is expected that at least some of the indicators will be correlated with each other (Criterion 1), an issue no longer considered of central importance to the index because the ability to identify vulnerability issues appears to be at least as important as the overall index (Pratt & Kaly 2004a). In any case, correlations could be expected to occur in large datasets with many observations and tests being applied, resulting in around 5% error in the testing. That is, statistically, it is expected that 5% of the correlation tests we used will have detected significant correlations among indicators where none exist (α=5%). This is not an error in technique or data, but a consequence of the use of statistics. If retained, we suggest that Criterion 1 could be applied as follows:

- Only to remove redundant indicators from the overall EVI and sub-indices where there is a possibility of redundancy (i.e. if indicators 26 and 44 correlate, they can still both be used separately in the Hazards and Damage aspect sub-indices; but one of two correlating indicators *within* a sub-index could be culled);
- Criterion 1 should only be applied to indicators correlated with many other indicators, and not to those with few correlations; and
- The EVI's profiles should retain all indicators to ensure that issues can be identified.

Correlations among indicators are expected because the EVI is being applied to a complex interactive system. This is its central purpose, and the reason for the approach used. Within such a system (the natural environment of a country) correlations and interactions among indicators are not only expected, but part of the reason for the need to develop an index to characterise conditions. Providing coverage for the wide range of ecosystems, species, hazards, diversity and energy flows in a country gives us the opportunity to pinpoint where problems are arising. If habitat fragmentation is leading to extinctions, the EVI would be most helpful if at least through the use of profiles it could assist in the identification of the nature of the problem. In this capacity, the EVI would not provide cause-and-effect information, but correlations between the two indicators that characterise these aspects of the environment would provide an efficient starting point. The first part of Criterion 2 (EVI representative of global conditions) has been fully met through this evaluation, and we were able to test indicators and set EVI scoring. The second part of Criterion 2 (clustering of countries considered *a priori* to be similar in characteristics) will be examined in the near future. The final test of the EVI (Criterion 3) of validating EVI scores against independent expert assessments could be undertaken in the future with additional funding.

5.2 Uses of the EVI

The EVI is essentially a synthesis framework for understanding the environmental vulnerability of countries. It is designed for use at the national scale, but could be evaluated at a range of geographic scales, including regions and provinces. The index and associated outputs can provide feedback to environmental managers on changes in environmental quality and vulnerability resulting from changes in policy and action. By using a common index, the characterisation can be comparative through time and space because there is a common basis for the measurements. If re-evaluated through time (suggested timeframe of every 5 years), the EVI can be used as a tool for adaptive management and ultimately for monitoring successes toward achieving sustainable development. It can also be used in developing countries for identifying issues that would benefit from external assistance, and can provide a performance indicator for the effectiveness of donor funding. The EVI contains within it much information on better practices and as such, can be used to raise awareness of environmental vulnerability and the actions that increase or decrease it. The box below shows some of the uses of the EVI suggested by participants to workshops held during the development of the index.

National uses of the EVI • National planning • Mechanism for identifying and prioritising issues requiring action, including those that cannot be directly influenced by human interventions (natural hazards and inherent characteristics) but for which vulnerabilities could be compensated for by increasing resilience in other areas • Develop policies to reverse trends that are increasing the risk of damage to the environment that supports development • Guide for legislation and resource management with a focus on trade-offs and achieving a sustainable balance for development goals • Mechanism for bringing together stakeholders, including government, civil society, non-government organisations, resource users and managers to coordinate their efforts and identify individual and joint responsibilities • Increasing national awareness • Transforms data that are currently not in widespread or efficient use to a form that greatly enhances the benefits to be derived from them • Promotes data collection and sharing between agencies for the benefit of the whole country • Basis for allocating budgets, including donor funding into priority areas • Regional and International reporting and conventions • Monitoring progress resulting from actions and policy changes.

International uses of the EVI • Mechanism for standardising and streamlining national reporting for multilateral agreements • Basis for funding assistance and dealing with transboundary issues • Improve awareness of vulnerability and sustainability issues • Mechanism for improving and updating international data resources.

5.3 Conclusions

The EVI is one of a new generation of tools designed specifically to help meet the challenges of assessment and advice to decision-makers and is intended to complement similar measures of economic and social vulnerability. It contains a wealth of information and a simplified format for identifying environmental vulnerabilities. The EVI is not 'perfect science', nor is it a one-stop solution to the complex problems we face today. In a perfect world we would use absolute measures of all the elements that make up our world and their interactions, a task that is clearly impossible. Using indicators, the EVI is intended to be a pragmatic tool that can be used right now to better inform our decisions.

The purpose of the EVI is to provide information on short-term trends to indicate vulnerability of the environment over the next few years. This approach is in keeping with the overall aim to provide information that will allow governments, funding agencies and others to adaptively respond to the vulnerabilities of countries as they stand at any point in time.

We need the information that tools such as the EVI can generate to recognise parts of our environmental systems that still have good resilience so we can maintain them. Clearly, preserving existing resilience would be the easiest, most pragmatic first step. We also need to be able to recognise areas of high vulnerability so that we can either manage them directly (for example, the loss of forests) or build resilience in other areas for issues that cannot be directly influenced by our actions (such as natural disasters). With tools like the EVI we can look forward to a future in which we could identify optimum development pathways and outcomes, without unwittingly compromising the environment that supports us.

Statement made by the EVI Review Think Tank Meeting 4 – 6 October 2004: The EVI is sufficiently well-developed to begin national implementation. Within the limitations of the available data, it successfully captures the nature and scope of environmental vulnerability, enabling countries to manage their vulnerability and protect and build their resilience. It is quantitatively robust and highly policy relevant at national and international levels. Countries could now be called upon to trial the index to test it under various national conditions and determine how well it defines their vulnerability and meets their national objectives.

With respect to the Barbados Programme of Action (BPoA), the EVI captures the environmental vulnerability of SIDS and emphasises their ecological fragility. It can also assist in national reporting for international processes, such as the Millennium Development Goals and priorities set at World Summit on Sustainable Development. It can generate outputs useful for reporting to international conventions such as the United Nations Framework Convention on Climate Change, Convention on Biological Diversity, Convention to Combat Desertification, etc, as well as many regional processes. At the national level it provides environmental profiles that can be used for priority setting and for identifying areas for urgent action. It is designed to capture short-term trends, changes and improvements (on a 5 year scale) and thus provide early warning of major risks and support for adaptive management. Indicators within the EVI may also be used for state of environment reporting.

The EVI will meet BPoA requirements for the environmental area, but needs to be complemented by economic and social vulnerability indices for a complete measure of vulnerability. The environmental and economic indices need to be piloted together at the national level, and the social index developed, leading to harmonisation of all three indices.

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7 APPENDICES

7.1 EVI Definitions

Damage: Refers to the loss of diversity, extent, quality and function of responders (environment, economic, social systems).

Damage sub-index: Acquired vulnerability arising from past damage to the environment.

External shock: Refers to economic or social vulnerability to hazards which originate outside of the country.

Hazard: A factor or process, which has the potential to cause damage to a responder. For example, thinness is a hazard to the economic system.

Index: Single number expression of a set of aggregated or weighted indicators.

Indicator: Any variable or measure which characterises the level of risk of hazards, resistance or damage in a country. A value which points to, provides information about, describes the state of a phenomenon / environment / area, with a significance extending beyond that directly associated with a variable's value. The term "indicator" originates from the Latin verb 'indicare' meaning to disclose or to point out. Indicators provide a means of communicating information about progress towards sustainable development in a significant and simplified manner. They focus and condense information about complex issues for management, monitoring and reporting, principally for decision-making. An indicator will provide a signal to an issue of greater importance or make more evident a trend or phenomenon that is not immediately detectable. In this regard an indicator's relevance extends beyond what is actually being measured to large issue of interest.

Indicators of sustainable development: Central to monitoring and report of progress towards sustainable development. They are also powerful tools which can help focus public attention on what sustainable development means and to give a broad overview of whether we are achieving "a better quality of life for everyone, now and for generations to come". They cover the three pillars of sustainable development – social progress, economic growth and environmental protection.

Internal shock: Refers to economic or social vulnerability to hazards which originate within the country.

Resistance: The natural or inherent sensitivity of a country to be damaged, or resist it due to the action of hazards. This concept relates to features of a country that are part of its initial conditions, e.g. size. Can be expressed as a sub-index, the resistance sub-Index

Likelihood: Probability that a specific hazard will occur within a given time frame.

Naming of a vulnerability index: This should be done on the basis of the responders and not the hazards. That is, an Economic Vulnerability Index is concerned with the vulnerability of the economic system in a country and looks at the risks of damage to that system by any hazards (natural, social, political, economic, etc.).

Natural Environment: Includes those biophysical systems that can be sustained without human support. Does not include the built environment (e.g. cities, farms).

Resilience: The converse of vulnerability. This is the extent to which the environment, economy or social system (the responder) is able to resist damage / degradation by hazards.

Responder: The system that is being impacted by hazards. For example, the environment, social system or economic system of a country.

Risk (level of): Likelihood of harmful consequences arising from the interaction of hazards, vulnerable elements and the responder

Risk Exposure: Expression or consideration of the amount of risk to a hazard or group of hazards. Can be expressed as a sub-index, the REI = Risk Exposure sub-Index

Shock: Similar to "Damage" though usually used by Economists and suggests a short time frame. Immediate change / response to the action of a hazard (may be positive or negative)

Smart indicator: An end-point indicator, which captures a large number of elements in a complex interactive system, while simultaneously showing how the value obtained compares to some ideal or agreed-upon condition.

Sub-index: Partial index that highlights a specified component of vulnerability

Vulnerability Index: Summarised, dimensionless measure of vulnerability to be used as a tool for monitoring and expressing the degree of vulnerability. This may be an aggregated measure of all indicators (or subsets of them arranged as sub-indices), to give a measure of the environmental, economic, social or composite vulnerability of a country

Vulnerability: The extent to which the environment, economy or social system (the responder) is prone to damage / degradation by hazards.

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7.3 Summary of environmental indicators and indices

7.3.1 State of Environment – Environmental Indicators

1. EUROSTAT – Environmental Pressure Indicators

Year(s) developed: 1997 -
Hazard(s): Human activities and indirect pressures (particularly in the following sectors: agriculture, energy, fisheries, households by consumers, industry, tourism, transport
Responder(s): State of Environment
Organisation(s): EUROSTAT - the Statistical Office of the European Communities
Number of Indicators: 60 pressure indicators

Purpose of the Indicators: Aims to describe human activities that are harmful to the environment in a comprehensive, systematic and comparable way using 60 – 100 pressure indicators. Through a process of experience with the use of "real" indicators in the policy process, the feasibility and usefulness of a detailed and systematic description of the pressures on the environment will be gained. Feedback through this process will ensure refinement and improvement in the selection of indicators.

Types of data required: Indicators are designed to monitor 10 policy areas: air pollution, biodiversity loss, climate change, marine environment & coastal zones, ozone layer depletion, resource depletion, dispersion of toxins, urban environmental problems, waste, water pollution & water resources

How are data processed in the indicator/index (organisation and mathematical approach)? Several core indicators have been developed in each policy area. Indicators are aggregated and weighted depending on their relevance and importance.

2. Environmental Indicators – National State of the Environment Reporting - Australia

Year(s) developed: 1996 – 2002 +
Hazard(s): Natural stressors and anthropogenic pressure
Responder(s): Natural resources and environmental quality
Organisation(s): Australian State of the Environment Committee, Environment Australia
Number of Indicators: 75 SoE indicators

Purpose of Indicators: To provide in depth reporting on the state of Australia's environment (SoE) to support decision making at all levels of society and provide reliable information that can foster a more integrated and longer-term perspective to environmental management.

Types of data required: Environmental indicators are physical, chemical, biological or socio-economic measures used to assess natural resources and environmental integrity. They are categorised into the following broad areas: atmosphere, coasts and oceans, land, inland waters, biodiversity, natural and cultural heritage, human settlements.

Several key indicators have been developed to reflect the anthropogenic pressure, current condition and human response for each process. Most indicators rely on being able to obtain data from government sources although several novel indicators have been suggested for consideration and potential monitoring.

How are data processed in the indicator/index (organisation and mathematical approach)? The approach to SoE reporting in Australia is based on a modified version of the OECD's 'pressure-state-response' model. The model is based on the concept of causality: human activities exert pressures on the environment; these change its state or condition; society responds by developing or implementing policies that influence those human activities, and so change the pressures. Australia has modified this model to include cultural aspects of the environment, to recognise the inherent variability and lack of knowledge about the Australian environment and to allow for an interactive rather than a linear model.

3. ANZECC - Core Environmental Indicators for Reporting State of the Environment

Year(s) developed: 1999 – 2000+
Hazard(s): Human activities
Responder(s): Environment – quality of environment and functioning of important environmental processes
Organisation(s): Australian and New Zealand Environment and Conservation Council (ANZECC)
Number of Indicators: 75 SoE indicators

Purpose of Indicators: Select set of environmental indicators aimed at improving the effectiveness and integration of environmental reporting.

Types of data required: Atmosphere – climate variability, enhanced greenhouse effect, stratospheric ozone, outdoor air quality. Biodiversity – threatening processes, loss of biodiversity, biodiversity conservation management. Land – land use and management, erosion, salinity, acidity, contamination. Inland waters – groundwater, surface water, aquatic habitats. Estuaries and the sea – marine habitat and biological resources, estuarine and marine water quality, global processes. Human settlements – energy, water, demographics, transport, waste, community attitudes and actions.

How are data processed in the indicator/index (organisation and mathematical approach)? The condition-pressure-response framework – is important for organising and presenting information and defining the range of issues to be considered. Indicators are chosen on the basis of best available scientific understanding and can be placed in a number of alternative frameworks to present and organise information.
Although the core indicators are linked the issue of relationships and causality between indicators is often complex.

4. South Africa - State of Environment Indicators

Year(s) developed: 1999 – 2001 –
Hazard(s): Human activities
Responder(s): Natural and human environment
Organisation(s): Department of Environmental Affairs and Tourism (DEAT)
Number of Indicators: 102 SoE indicators

Purpose of Indicators: To develop a core set of environmental indicators for State of Environment Reporting in South Africa in order to enhance existing tools for decision-making at all levels to facilitate management of progress towards sustainability. Indicators provide simple measures that will help in increasing awareness and understanding of environmental trends and conditions, their causes and consequences. It also aims to eliminate duplication with other national and international reporting obligations such as reporting on the progress of implementation of multilateral treaties and conventions.

Types of data required: For each theme area appropriate indicators have been selected to monitor and report on associated issues: atmosphere and climate, climate change, stratospheric ozone, air quality, biodiversity & natural heritage, species diversity, habitat change, resource value, natural heritage resources, environmental management, environmental management, human well-being, human settlements, vulnerability, land use, land use, land condition, coastal & estuarine, resource management, resource quality, waste management, waste generation, waste reduction, inland water, water quantity, water quality, freshwater ecosystem integrity.

How are data processed in the indicator/index (organisation and mathematical approach)? The 'Driving Force-Pressure-State-Impact-Response' (DPSIR) framework is utilised to structure indicators in a coherent way for use. The development of indicators involved a process of consultation and 8 key themes of sustainable development were prioritised - atmosphere and climate, biodiversity & natural heritage, environmental management, human well-being, land use, coastal & estuarine, waste management and inland water. Each theme forms a component of an Environmental Sustainability Index. Sub-indices for each theme include: marine, coastal and estuarine environment indicator, air quality index, inland water index, biodiversity index.

5. United Kingdom - State of Environment Indicators

Year(s) developed: 1999 –
Hazard(s): Human activities
Responder(s): Economic, social and environmental systems
Organisation(s): Department for Environment, Food and Rural Affairs
Number of Indicators: 15 headline indicators

Purpose of Indicators: In order 'to provide a high level overview of progress, and be a powerful tool for simplifying and communicating the main messages for the public' a set of 15 headline indicators have been developed – a quality of life barometer.

Types of data required: Economic output, investment, employment, poverty and social exclusion, education, health, housing, crime, climate change, air quality, road traffic, water quality, wildlife, land use, waste.

How are data processed in the indicator/index (organisation and mathematical approach)? Summary data are tabulated with progress and indication of trends. Progress is determined using the following criteria - Significant change, in direction of meeting objective, no significant change, significant change, in direction away from meeting objective and insufficient or no comparable data

6. Treaties (Stratospheric Ozone Depletion, Biological Diversity, Global Climate Change and Trade and Environment), Environmental Indicators and National Responses

Year(s) developed: 1997 – 2003
Hazard(s): Human activities
Responder(s): Human systems and natural environments
Organisation(s): CIESIN Columbia University
Number of Indicators: 20+

Purpose of Indicators: To provide access to an electronic database of information on a set of key issues related to the human dimensions of global change. Indicators presented provide measures of the problem, information on the environmental treaties developed to address the problem and resultant measures of the performance of national responses.

Types of data required: Data is collated in the following key areas: stratospheric ozone depletion, biological diversity, global climate change, trade and environment

How are data processed in the indicator/index (organisation and mathematical approach)? A modified Pressure-State-Response framework has been used to explain linkages between environmental treaties, key indicators (including those derived mostly from remotely sensed data) and national response strategies. Relevant indicators, data and data sources, international treaties and national level response strategies have been developed in 4 key areas - stratospheric ozone depletion, biological diversity, global climate change and trade and environment.

7. Index of Leading Environmental Indicators

Year(s) developed: 1994 – 2002 + (produced annually)
Hazard(s): Anthropogenic pressures
Responder(s): Natural resources and environmental quality
Organisation(s): Pacific Research Institute
Number of Indicators: variable ~16 indicators

Purpose of Index: To provide policymakers and interested citizens with an annual check-up on key environmental trends in the United States

Types of data required: Data ranges over a variety of themes: air quality, water quality, toxic chemicals, erosion, biodiversity. Data is compiled for both state and national levels.

How are data processed in the indicator/index (organisation and mathematical approach)? Several indicators are used to test a hypothesis (common perception). Discussion is then presented with graphs to illustrate whether the hypothesis is valid or refuted by the data presented.

8. Water Poverty Index (WPI)

Year(s) developed: 2001 +
Hazard(s): environmental degradation, impacts on water resources from human activities
Responder(s): community access to clean safe freshwater
Organisation(s): Centre for Ecology and Hydrology, Wallingford, UK
Number of Indicators: index calculated from 4 indicators

Purpose of Index: To produce an integrated assessment of water stress and scarcity, linking physical estimates of water availability with socio-economic variables that reflect poverty

Types of data required: Key elements of the composite WPI include: water availability, access to safe water, clean sanitation, time taken to collect domestic water.

How are data processed in the indicator/index (organisation and mathematical approach)? WPI is calculated by measuring: water availability through the assessment of ground and surface water availability related to ecological water requirements, plus all other domestic demands, as well as demands from agriculture and industry; adding population access to safe water and sanitation; combining it with the time and effort taken to collect water for the household (e.g., from proportion of population having access in or near the home and can be modified to take account of gender and child labour issues.

9. Pesticide Impact Ranking Index - PIRI

Year(s) developed: 2001
Hazard(s): Pesticides
Responder(s): Water resources
Organisation(s): Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Number of Indicators: index calculated from 3 variables each estimated from several indicators

Purpose of Index: To minimise the impact of agricultural pesticides on rivers, lakes (surface) and groundwater by assessing contamination potential of pesticides, providing a systematic means of improving the understanding of risk to surface and groundwater and a tool for (semi)quantitative basis for comparing risks

Types of data required: In-built into the database is pesticide fate data - KOC, half life, LC50 - actual, modelled or default; pesticide use - dosages, frequency, active ingredient, area, fraction farm used; soil data - slope, depth, fOC, cover, texture, loss; rainfall/irrigation, recharge rate; droplet size; buffer zone width

How are data processed in the indicator/index (organisation and mathematical approach)? PIRI is based on three components: the value of the asset (water resources threatened); the source(s) of threat to the asset (pesticide use); the pathway through which the threat is released to the asset. The detriment to the surface or groundwater in a catchment area is calculated as the product of these three components = VLT Detriment = Value x Toxic load x Transport where Value (=score) of water body (Human health, Ecological etc) Toxic load (amount applied x toxicity) Transport Groundwater Surface water (Erosion, Run off, Drift).

10. Index of Watershed Indicators - IWI

Year(s) developed: 1997 – 2002+
Hazard(s): Human activities including urban pollution, agricultural pollution, fish consumption, erosion, development modifications to watercourses, population change.
Responder(s): Water resources quality and watershed habitat condition
Organisation(s): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds.
Number of Indicators: 15 indicators

Purpose of Index: To provide a watershed-level assessment of the condition and vulnerability of the water resources in order to allow the EPA to better target programme resources to address watersheds at risk.

Types of data required: Data is required on several aspects of the state of watersheds and its vulnerability. Data includes information on: the condition of aquatic resources; the conditions or activities that may place stress on the resources.

How are data processed in the indicator/index (organisation and mathematical approach)? Index of Watershed Indicators – uses 15 indicators – referred to as data layers. These were selected on appropriateness to IWI and their availability across the nation as well as the ability to depict them on an eight-digit Hydrologic Unit Code (HUC) scale. 7 indicators – relate to the condition of aquatic resources – appropriate basis to describe the aquatic resources within the watershed as having good quality, fewer problems or more problems. 8 indicators – related to vulnerability – conditions or activities that may place stress on the resources through perhaps not to the point that its values or functions are currently impaired. Values that were considered to appropriately differentiate “lower” from “higher” vulnerability were selected. Additional indicators to provide a more complete picture on watershed health such as biological integrity, terrestrial condition, ground water and air deposition are being developed.

11. Reefs at Risk – Map-based Indicator of Threats to the World’s Coral Reefs

Year(s) developed: 1998
Hazard(s): Coastal development, marine-based pollution, pollution and sedimentation from inland sources, overexploitation of coral resources
Responder(s): Coral reefs
Organisation(s): World Resources Institute (WRI)
Number of Indicators: at least 10 indicators aggregated into 4 threat factors

Purpose of Index: To develop a series of globally consistent indicators of human pressure on coral reefs. These indicators evaluate pressure from coastal development, marine-based pollution, pollution and sedimentation from inland sources, and overexploitation of coral resources. The indicator draws on 14 data sets (including maps of land cover, ports, settlements and shipping lanes), information on 800 sites known to be degraded by people and scientific expertise in model areas where reef degradation is predicted to occur given existing human pressures on these areas. Results are an indicator of potential threat (risk), not a measure of actual condition. In some areas where there is good management is practiced, reefs may be at risk but remain relatively healthy while in others the indicator underestimates the degree to which reefs are threatened and degraded.

Types of data required: The Reefs at Risk analysis is driven by data sets reflecting population density, human population centres, airports and military bases, mines, tourist resorts, embayments, ports, oil-related threats, shipping related threats, overfishing, destructive fishing practices and derived estimates of threats from inland pollution and sedimentation.

How are data processed in the indicator/index (organisation and mathematical approach)? Reefs at risk is a global assessment of likely threats to coral reefs from several key human activities. Zones of high, medium and low threat were estimated for each threat factor and were combined through spatial overlay analysis with a data set reflecting the location of coral reefs. The resolution of data on coal reefs is a four-kilometre resolution (55,168 cells).

7.3.2 Ecological Footprint

12. Living Planet Report

Year(s) developed: 2000
Hazard(s): Human activities
Responder(s): Animal species
Organisation(s): World Wide Fund for Nature
Number of Indicators: 8 indexes with variable numbers of indicators

Purpose of Index: To quantify changes in the state of the Earth's natural ecosystems over time and to measure the human pressures on the natural environment arising from the consumption of renewable resources and pollution, and analyse the geographic patterns arising in those pressures.

Types of data required: Population data on forest, freshwater, marine species data from 1970 – 1999.

How are data processed in the indicator/index (organisation and mathematical approach)? The Living Planet Index (LPI) is a measure of the natural wealth of the Earth's forests, freshwater ecosystems and oceans and coasts. The LPI is the average of three indices which monitor the changes over time in populations of animal species in forest, freshwater and marine ecosystems respectively. Each separate index is set at 100 in 1970 and given equal weighting. Ecological Footprint is a conservative estimate of human pressure on global ecosystems. The analysis measures the amount of the globe's biological productivity an individual or a country occupies in a given year. It represents the biologically productive area required to produce the food and wood people consume, to give room for infrastructure and to absorb the CO2 emitted from burning fossil fuels, which is the primary cause of climate change. The Ecological Footprint is expressed in "area units" where each unit corresponds to one hectare of biologically productive space with "world average productivity".

13. Ecological Footprint – Revisiting Carrying Capacity: Area-Based Indicators of Sustainability

Year(s) developed: 1996
Hazard(s): Human economy – human activities
Responder(s): Environment – capital stocks, physical flows and corresponding ecosystem areas required to support the economy
Organisation(s): University of British Columbia

Number of Indicators: index calculated from variable number of indicators

Purpose of Index: To assess the capital stocks, physical flows and corresponding ecosystem areas required to support economy.

Types of data required: Population statistics, consumption figures for major items e.g. clothing, furniture

How are data processed in the indicator/index (organisation and mathematical approach)? Calculating the ecological footprint of a study population is to estimate the per capita land area appropriated (aa) for the production of each major consumption item 'i'. This is done by dividing the average annual consumption of that item ('c', in kg/capital) by its average annual productivity or yield ('p', in kg/ha) per hectare: aai = ci / pi. The total per capita ecological footprint ('ef') is then calculated by summing all the ecosystem areas appropriated by individual items in the annual shopping basket of consumption goods and services ef = ∑ aai. Thus the ecological footprint (efp) of a study population is the per capita footprint multiplied by the population size (N): EFp = N(ef)

7.3.3 Indicators of Sustainable Development

14. OECD State of Environment Indicators

Year(s) developed: 1991 – 1994 – 1998 – 2001+
Hazard(s): Human activities and indirect pressures
Responder(s): Environmental conditions ("State")
Organisation(s): Organisation for Economic Cooperation and Development (OECD)
Number of Indicators: 121 indicators

Purpose of Indicators: To provide a cost-effective and powerful tool for tracking and charting environmental progress and measuring environmental performance through the use of a selection of agreed environmental indicators.

Types of data required: Data for environmental indicators are collected on several major environmental issues: climate change, ozone layer depletion, eutrophication, acidification, toxic contamination, urban environmental quality, biodiversity, cultural landscapes, waste, water resources, forest resources, fish resources, soil degradation (desertification, erosion), socio-economic, sectoral and background indicators

How are data processed in the indicator/index (organisation and mathematical approach)? The Pressure – State – Response (PSR) Model – considers that human activities exert pressures on the environment and affect its quality and quantity of natural resources ("state"); society responds to these changes through environmental, general, economic and sectoral policies and through changes in awareness and behaviour ("societal response"). The PSR model has the advantage of highlighting these links and helping decision-makers and the public see environmental and other issues as interconnected (although this should not obscure the view of more complex relationships in ecosystems and in environment-economy and environmental-societal interactions).

A Core Set of Environmental Indicators has been selected to provide decision makers and the general public an overview of environmental issues as well as measure of performance and directions for future progress. Ten key environmental indicators focused on several important environmental issues have been compiled to address the need for timely information on important environmental issues. These indicators include: pollution issues, climate change, ozone layer, air quality, waste generation, freshwater quality, natural resources & assets, freshwater, forest, fish, energy, biodiversity.

15. Well-being of Nations / Barometer of Sustainability

Year(s) developed: 1997 – 1999
Hazard(s): Human activities
Responder(s): Human and natural systems.
Organisation(s): IUCN & Canada's International Development Research Centre (IDRC)
Number of Indicators: 36 socio-economic indicators, 51 state of the environment indicators

Purpose of Index: To provide a coherent way of measuring and communicating the well-being and progress toward sustainable development. It provides a systematic way of organising and combining indicators so that users can draw conclusions about the conditions of people and the ecosystem and the effects of people-ecosystem interactions. It presents those conclusions visually, providing anyone with an immediate picture of human and ecosystem well-being.

Types of data required: Key information on the ecosystem and people. Information for the measurement of the well-being of people and ecosystems are organised into two sub-systems with five components each: people – health and population, wealth, knowledge and culture, community and equity and ecosystem – land, water, air, species and genes, resource use.

How are data processed in the index/index (organisation and mathematical approach)? The Well-being of Nations – combines indicators into four indices and has equal treatment of people and the ecosystem – scale based on two axes, one for human well-being and the other for ecosystem well-being. This ensures that an improvement in human well-being does not mask a decline in ecosystem well-being or vice versa. The Human Well-being Index (HWI) – distils 36 socio-economic indicators which provide a more comprehensive approach than the Human Development Index and the narrow monetary indicators such as GDP. The Ecosystem Well-being Index (EWI) – synthesises 51 indicators of the state of the environment that encompasses systematically and fully national environmental conditions. The Well-being / Stress Index (ESI) – measures how much harm each country does to the environment for the level of development it achieves. The WSD and WI below break new ground in measuring people and the ecosystem together to compare their status and show the impact on one another and highlight the improvements in both. The Well-being Index (WI) combines the HWI and EWI on the Barometer of Sustainability – a graphic scale that shows how far each country is from the goal of high levels of human and ecosystem well-being.

16. World Bank – Measuring the Wealth of Nations

Year(s) developed: 1995 – 1996
Hazard(s): Human activities – including ranging from the use of resources, industrial development to institutional
Responder(s): Natural resources, produced assets and human resources
Organisation(s): World Bank
Number of Indicators: several economic indicators are utilised to provide measures of produced assets, natural capital and human resources in order to give an overall index of a country's wealth.

Purpose of Index: To measure sustainable development through assessment of the wealth of nations

Types of data required: Measuring the wealth of nations is a structured approach with aggregated monetary values made on natural capital, man-made capital and human capital

How are data processed in the indicator/index (organisation and mathematical approach)? The World Bank has determined the dollar value of natural capital, produced assets and human resources. The method is based on the concept of genuine saving as an indicator to explore the dynamics of creating and maintaining wealth. Genuine saving is “the true rate of saving of a nation after accounting for the depreciation of produced assets, depletion of natural resources, investments in human capital and value of global damages from carbon emissions. Negative rates of genuine saving must lead eventually to declining well-being” (World Bank 1997). It is actually the evolution of gross saving and net saving to include natural and social parameters in order to keep in touch with the sustainability concept aiming to an aggregate measure for progress report.

17. CSD – Indicators of Sustainable Development

Year(s) developed: 1995 – 2000
Hazard(s): Human activities
Responder(s): Economic, social and environmental systems
Organisation(s): Commission on Sustainable Development
Number of Indicators: 58 indicators

Purpose of Indicators: To assist decision makers at all levels focus on sustainable development. Indicators will by provide decision makers with information on where they are at the moment, developing trends and pressure points and where interventions or policies could be useful. Feedback on the effectiveness of policies and their performance is key, in providing guidance on achievements or failures of interventions. Indicators offer an opportunity to simplify complex relationships in a concise way thus monitoring progress towards sustainable development. The development of indicators as key policy instruments will enhance national policies and help in the achievement of policy targets.

Types of data required: 58 indicators have been selected and placed into the following thematic framework: Social – equity, health, education, housing, security, population; Environmental – atmosphere, land, oceans, seas & coasts, freshwater, biodiversity; Economic – economic structure, consumption & production patterns; Institutional - institutional framework, institutional capacity

How are data processed in the indicator/index (organisation and mathematical approach)? Driving Force-State-Response (DSR) framework has been adapted from the Pressure-State-Response model. The DSR matrix incorporates three types of indicators horizontally and the different dimensions of sustainable development vertically. ‘Driving Force’ indicators comprise human activities, processes and patterns that impact on sustainable development. ‘State’ indicators measure the ‘state’ of sustainable development while ‘Response’ indicators highlight policy options and other responses to changes in the state of sustainable development.

18. Environmental Sustainability Index

Year(s) developed: 2000 – 2001 – 2002
Hazard(s): Multi – dimensional model – includes environmental hazards, anthropogenic activities, political institutions, environmental management
Responder(s): Social, economic and institutional systems and the natural environment
Organisation(s): World Economic Forum (Yale Centre for Environmental Law and Policy, Yale University Centre for International Earth Science Information Network, Columbia University).
Number of Indicators: 66 indicators

Purpose of Index: To provide a measure of factors that compromise environmental sustainability. The components describe the current environmental systems, stresses to those systems, the vulnerability of human populations to environmental disturbances and disasters, the social and institutional capacity to respond to environmental problems (including governance systems) and global stewardship or the degree to which an economy behaves responsibly with respect to other economies (through its consumption patterns and efforts to manage common environmental problems).

Types of data required: The ESI is based upon five components with 22 associated sub-indices – Environmental systems (with sub-indices air quality, water quality, biodiversity and terrestrial systems); Reducing stress (air pollution, water stress, ecosystem stress, waste & consumption pressures, population pressure); Reducing human vulnerability (basic human sustenance, environmental health); Social and institutional capacity (science/technology, capacity for debate, regulation and management, private sector responsiveness, environmental information, eco-efficiency, reducing public choice distortions); Global stewardship (international commitment, global-scale funding/participation, protecting international commons)

How are data processed in the indicator/index (organisation and mathematical approach)? All indicators were first adjusted to make them comparable by dividing by population, income or the percentage of a country's territory that was populated by 5 or more persons per square kilometre where necessary. ESI calculated by averaging 22 indicators and calculating standard normal percentile (5 components calculated in same way)

19. Sustainable Development Index (SDI)

Year(s) developed: 2002
Hazard(s): Human activities
Responder(s): Economic, environment and social systems
Organisation(s): Competencia de Estudios Ambientales, Instituto Mexicano del Petróleo
Number of Indicators: 22 indicators

Purpose of Index: To identify and prioritise the most urgent problems that need to be solved in order to obtain an improvement in the development of the municipalities in accordance with sustainable and resource mgmt criteria.

Types of data required: Human activities, GDP, electricity intensity, employment rate, potable water and sewerage availability, environmental assets consumption, soil use, environment and social status, hydrologic balance, water quality, air quality, soil use, erosion, poverty, health, endangered species, environmental and economic agents, water and garbage treatment and disposal, education, protected areas, reforestation

How are data processed in the indicator/index (organisation and mathematical approach)? The DSR model is based on a logic and holistic framework of action-response relationships between economy, society and environment. This study recommended flexibility on the number of core indicators and that the number should be determined in accordance with the level of information and the specific situation of the region under study as well as country's conditions. To integrate the indicators a modified multi-attribute decision theory methodology was used. Within the philosophy a tree was formed with 21 indicators representing production of social and natural systems of the studied region (main branches or general attributes). The number of indicators was defined by the availability of data and by their potential to represent an important characteristic of the region.

20. Sustainable Development Index (SDI)

Year(s) developed: 1995 –
Hazard(s): Human activities
Responder(s): Human, social and environmental systems
Organisation(s): IISDnet – Consultative Group on Sustainable Development Indicators (CGSDI)
Number of Indicators: variable - selection of indicators dependent on user. Index provides graphical approach to summarising indicators

Purpose of Index: To communicate problem areas to decision-makers quickly and accurately. Visual models of these indices must provide signals, in particular, warning signals of unsustainability that flag for decision-makers those areas requiring management action.

Types of data required: Options for clusters of sustainable development indicators:
Two clusters – human well-being and environmental well-being
Three cluster - environmental, societal and economic well-being
Four cluster – material wealth and economic development, equity and social aspects, environment and nature, democracy and human rights

How are data processed in the indicator/index (organisation and mathematical approach)? Dashboard of sustainability – three clusters of indicators. Four-sided pyramid, elliptical indicator cluster & compass of sustainability – four cluster approach to sustainable development indices.

21. Compass Index of Sustainability

Year(s) developed: 2000 -
Hazard(s): Human activities
Responder(s): Four aspects of sustainable development – nature, economy, society and well-being
Organisation(s): AtKisson & Associates Inc. Copyright.
Number of Indicators: variable – dependent on user selection

Purpose of Index: To provide a comprehensive measure of sustainability that is accessible, useful and attractive to decision makers and the general public. The Index is aimed at guiding policy developers and decision-makers towards sustainable development.

Types of data required: Data is required in the four categories of measurement – nature, economy, society and well-being of individuals. Examples of data required include: Nature - air quality, ecosystem health, energy use, environmental ethic, land consumption, waste and recycling, water quality; Economy - cost of living, housing, mobility, poverty, unemployment, wages; Society - crime, graduation rates, internet access, social capital, voting; Well-being - general health, infant health, mental health

How are data processed in the indicator/index (organisation and mathematical approach)? To create the Compass Point sub-indices for N, E, S, and W, a simple average is used, leaving out those items where data is deemed insufficient. The Sustainability Index is the average of the four Compass Point sub-indices. Each Compass Point therefore receives a 25 percent weighting factor in the Sustainability Index. Each individual indicator receives an equal weight within its Compass Point sub-index. Other weighting decisions could certainly be applied. The decision to weight will be dependent upon the user and its application. Each Compass Point, or sub-index is calculated on a 0-100 scale. Normative decisions based on both scientific and social values determine the conversion formula for each indicator. The four indices are the aggregated to produce and the overall SDI.

22. Redefining Progress – Genuine Progress Indicator

Year(s) developed: 1994 –
Hazard(s): Human activities
Responder(s): Human systems
Organisation(s): Redefining Progress
Number of Indicators: 1 indicator which is adjusted for 24 variables

Purpose of Index: To provide a comprehensive accurate measure of the nation's progress. GPI includes the economic contributions of household and volunteer work while subtracting factors like crime, pollution and family breakdown.

Types of data required: Economic values for human activities - personal consumption, income distribution index, personal consumption adjusted for income inequality, value of household work and parenting, value of volunteer work, services of household capital, services of highways and streets, cost of crime, cost of family breakdown, loss of leisure time, cost of underemployment, cost of consumer durables, cost of commuting, cost of household pollution abatement, cost of automobile accidents, cost of water pollution, cost of air pollution, cost of noise pollution, loss of wetlands, loss of farmland, depletion of non-renewable resources, long-term environmental damage, cost of ozone depletion, loss of old-growth forests, net capital investment, net foreign lending or borrowing, the genuine progress indicator (GPI), per capita GPI, gross domestic product (GDP), per capita GDP

How are data processed in the indicator/index (organisation and mathematical approach)? The GPI is designed to indicate genuine progress in people's quality of life, the GPI begins with the personal consumption component of the Gross Domestic Product (GDP), including capital investment, government spending, and net exports. Beyond these general economic measures, the GPI factors in social, environmental and economic phenomena that diminish or enhance quality of life. Many of these factors are not generally measured in monetary terms or included in typical economic analyses. The GPI considers who benefits from economic growth by including measures of social progress or decline, such as distribution of income and rates of underemployment. The GPI also tracks other indicators of the quality of social life —such as costs of crime and family breakdown, contributions made by unpaid housework and childcare—and even considers time to enjoy the benefits of economic growth by counting hours spent commuting or enjoying leisure. The GPI is designed to extract significant long-term trends from short-term accounting fluctuations. Some data are averaged over five years, as year-to-year fluctuations of a single value would distort understanding of long term progressions.

23. Human Development Index (HDI)

Year(s) developed: 1990 – 2002 –
Hazard(s): Human activities
Responder(s): Human systems
Organisation(s): United Nations Development Programme (UNDP)
Number of Indicators: HDI consists of 3 indices comprising of 16 indicators

Purpose of Index: To measure the average achievement in three basic dimensions of human development – a long and healthy life, knowledge and a decent standard of living. The HDI allows comparisons across countries and over time.

Types of data required: The HDI is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: a long and healthy life, as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight); a decent standard of living, as measured by GDP per capita (PPP US$).

How are data processed in the indicator/index (organisation and mathematical approach)? The HDI is an average aggregation of three sub-indices: Life expectancy index – measures the relative achievement of a country in life expectancy at birth; Education index – measures a country's relative achievement in both adult literacy and combined primary, secondary and tertiary gross enrolment. First an index for adult literacy and one for combined gross enrolment are calculated. Then these two indices are combined to create the education index, with two-thirds weight given to adult literacy and one third to combined gross enrolment. GDP index – is calculated using adjusted GDP per capita (PPP US$). In the HDI income serves as a surrogate for all the dimensions of human development not reflected in a long and health life and in knowledge. Income is adjusted because achieving a respectable level of human development does not require unlimited income accordingly a logarithm of income is used.

24. Index of Environmental Friendliness

Year(s) developed:
Hazard(s): Direct and indirect pressures from economic activities
Responder(s): Environment
Organisation(s): Statistics Finland
Number of Indicators: ~ 23 indicators

Purpose of Index: The Index of Environmental Friendliness combines ecological information on problem-specific impacts and societal valuation thus providing a comprehensive assessment of each economic activity. The separate aggregation of pressures to problem indices and the subjective valuation of environmental concerns makes the model steps more transparent and applicable for various users. The applicability of the Index is dependent upon the representativeness of the set of problems selected for the index.

Types of data required: Test data included industry related environmental data on the following issues greenhouse effect, ozone depletion, acidification, eutrophication, ecotoxicological effect and resource depletion. Also the most important indirect emissions of electricity and heat consumption, waste and waste water treatment were attributed to the data evaluation in proportion to their purchases.

How are data processed in the indicator/index (organisation and mathematical approach)? The model for the Index of Environmental Friendliness is a general model for the aggregation of direct and indirect pressure data to problem indices and further to an overall index. The core assumption of the model is that environmental problems are the most feasible basis for a comprehensive assessment. The model gathers both direct and indirect and total pressures of economic activities, the assessment of environmental pressures associated with both. This provides a complete picture of the environmental impact coupled with each economic activity. It also makes internal services and treatment operations comparable to those procured at the expense of the environment.

7.3.4 Vulnerability Indices

25. Economic Vulnerability Index

Year(s) developed: 1992 – 1997+
Hazard(s): Exposure to external economic factors
Responder(s): Economy
Organisation(s): Islands and Small States Institute, Malta
Number of Indicators: 5 indicators

Purpose of Index: To highlight the reality that economic success of many small states often hides their underlying economic fragility. The economic vulnerability index measures the precariousness of states, arising from their economic exposure, lack of protection and peripherality.

Types of data required: Data on trade openness (export, imports or both as a ratio of GDP); export concentration; peripherality (transport and freight costs in relation to foreign trade); energy dependence (imported energy as a ratio of energy consumed); financial dependence (aid or international debt as a ratio of GDP)

How are data processed in the indicator/index (organisation and mathematical approach)? The method to compute the index involves the "normalisation" of the index data components restricting the values between 0 and 1, with each observation adjusted to take a value within this range. The standardised variables for each country are then summed by assigning equal weights to each component.

26. Coral Reef "Vulnerability Index" of Exposure to Climate Change

Year(s) developed: 2000
Hazard(s): Climate change, population pressure, human activities
Responder(s): Coral reefs
Organisation(s): Greenpeace
Number of Indicators: 36 indicators

Purpose of Index: To provide a measure of vulnerability of coral reefs to human activities and climate change

Types of data required: GDP, demographic statistics, country characteristics, foreign aid, fisheries activities, tourism, political status

How are data processed in the indicator/index (organisation and mathematical approach)?
The overall risk assessment is mapped onto a vulnerability scale where 5 is extreme and 0 is no risk. Assessment of vulnerability was based upon the following:
Physical exposure from extreme = 5 to low = 1; Outer islands (vulnerable in socio-political terms as well as physically) Many or all = 5; few = 1 (Nauru special case = 3); Population density/pressure from very high = 5 to low = 1; Foreign aid per head from very high = 5 to low = 2 and none = 1; Subsistence activities in fisheries and agriculture most = 4 and some not = 2. As the range of factors act in different ways on each country and due to the limitation of the simple ranking approach each measure is weighed equally in the overall total score.

27. Vulnerability assessment to climate change and sea-level rise

Year(s) developed: 1995
Hazard(s): Climate change, sea-level rise
Responder(s): Natural – physical & biological systems, human, infrastructural, institutional, economic, cultural systems.
Leading author(s): Kazuhito Yamada, Patrick Nunn, Nobu Mimura, Satoshi Machida, Mitsuhiro Yamamoto
Number of Indicators: 20 indicators

Purpose of Index: To develop an index that assessed vulnerability to sea-level rise and climate change in the South Pacific which was based on methodology that was flexible and did not depend so much on data referring to natural and social conditions and can introduce indigenous characteristics of countries.

Types of data required: Data on natural systems – physical and biological, human systems, infrastructure, institutional, economic and cultural systems.

How are data processed in the indicator/index (organisation and mathematical approach)?
The concept of vulnerability and resilience were used to assess the weakness and strength of each system for the external and/or internal stresses. Vulnerability as defined is the susceptibility of the system to absorb the impacts of hazardous events on it without significant or adverse response. A range of scores from –3 to +3 are assigned to the degrees of vulnerability and resilience – indicative of the strength or weakness of the system. The difference of scores is combined into an index termed Sustainable Capacity Index (SCI) which is regarded as a measure of the system's overall ability to cope with external and internal stresses. A judgement method was used to evaluate the vulnerability and resilience of each sub-system by assigning scores in a semi-quantitative way where the degrees of vulnerability ranged from 0 to –3 and the resilience scores from 0 to +3 with +3

being the most resilient. Scenarios were also scored to determine potential future conditions and options for management.

28. Key Indicators for Global Vulnerability Mapping

Year(s) developed: 2002
Hazard(s): Natural hazards – tectonic, climatic, bio and human-induced hazards
Responder(s): Human environments
Organisation(s): United Nations Environment Programme (UNEP)
Number of Indicators: under development

Purpose of Index: To help decision makers prioritise populations facing greater threats through the use of a graphic mapping tool.

Types of data required: Information on each type of hazard and population at risk. The frequency – expected (or average) number of events per time period, population – number of exposed population and vulnerability – expected percentage of population loss due to socio-economical context are the key data required.

How are data processed in the indicator/index (organisation and mathematical approach)? The evaluation of risk is approximated as the total risk of various populations that are exposed to particular hazards and with associated vulnerability.

29. Composite human vulnerability index

Year(s) developed: 2001
Hazard(s): Climate change, extreme events and environmental change
Responder(s): Human and economic systems
Organisation(s): Indian Institute of Technology, Bombay
Number of Indicators: 19 indicators

Purpose of Index: To measure human vulnerability to environmental change and natural hazards using GIS.

Types of data required: Data is required for the following factors that affect human vulnerability: health, economic losses, poverty, loss of natural heritage, loss of IPR, conflicts, extreme events/climate change impacts

How are data processed in the indicator/index (organisation and mathematical approach)? Human vulnerability is defined as the exposure to hazard by external activity (e.g. climate change) and coping capacity of the people to reduce risk at a particular point in time. Therefore vulnerability is a function of exposure to hazard, population density and coping capacity over time. The HVI combines the exposure indicators using equal weightings and divided by the coping indicators. The exposure index only combines the total exposure indicators without dividing by the coping capacity indicator.

30. Island Indicators

Year(s) developed: 1998 –
Hazard(s): Natural and anthropogenic activities
Responder(s): Island ecosystems
Organisation(s): United Nations Earthwatch
Number of Indicators: ~ 15 indicators

Purpose of Index: To classify islands by various criteria so that comparisons between islands or areas as a basis for facilitating inter-island cooperation and sharing of solutions, and identifying conservation importance.

Types of data required: Indicators have been developed for the nature and isolation of the island, for features of conservation interest, for risks to that conservation interest and for the feasibility of conservation action. Indicators include: coastal index, sea-level rise index, isolation, threat, natural protection, ecosystem richness, species richness, endemism, special features, invasive species, urbanisation, human threat, economic pressure, protected area coverage, reliability of data.

How are data processed in the indicator/index (organisation and mathematical approach)? Data for each island are summarised in three aggregated indices to give an overall evaluation and to allow comparisons and rankings. Human Impact (HI) measures the overall human pressure or impact on the island and potential threat to remaining natural areas or endemic species. Terrestrial Conservation Importance (CI-T) gives an overall numerical evaluation of the significance of the land area of the island for the conservation of nature. It consists of the sum of a series of measures of conservation interest weighted for their relative importance. Both measure of biological importance and measures of their natural conservation status have been included since both are important for successful conservation action although biological factors are given higher weighting. The index formula reflects the evaluation process made by a conservation planner or protected area manager in selecting a protected area. Marine Conservation Importance (CI-M) provides an equivalent measure to the CI-T index but is adapted to the special characteristics of island marine environments down to 100 metres in depth. As there is limited data it is not always possible to calculate a viable marine indicator for many islands but it is included here to highlight the information needed.

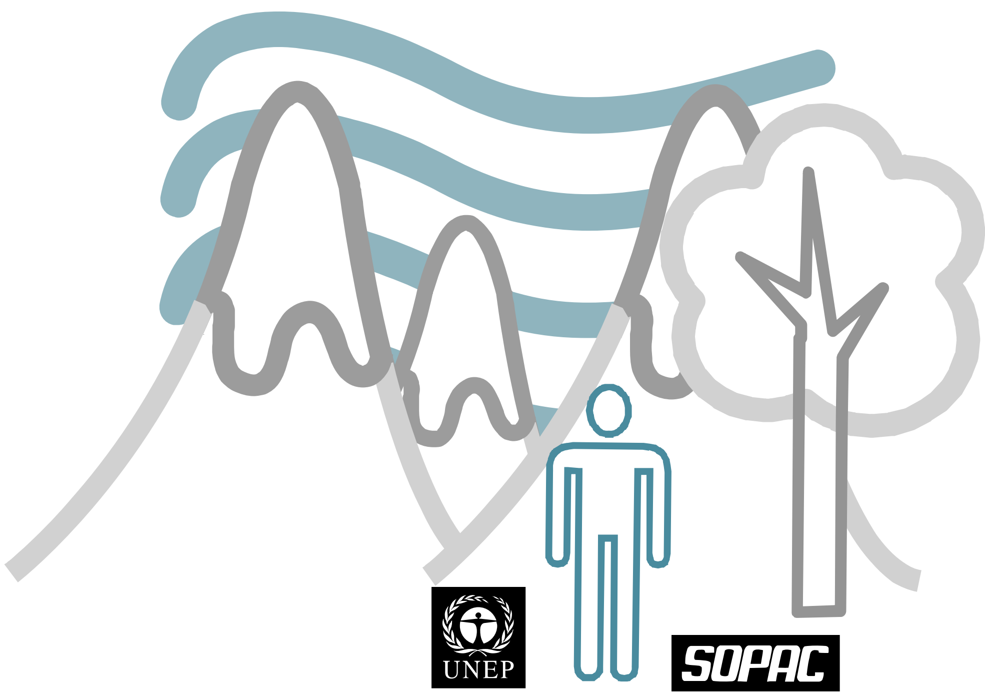
7.4 Analysis, natural distributions and EVI scaling for all indicators

evi

Environmental
Vulnerability Index

EVI: ANALYSIS OF INDICATORS

4 JANUARY 2005



CONTENTS

1. HIGH WINDS

1.1 Indicator Summary

Indicator number:	01
Indicator short name:	High Winds
Sub-index	Hazards
Categorisation	Weather & Climate
Indicator text:	Average annual excess wind over the last five years (summing speeds on days during which the maximum recorded wind speed is greater than 20% higher than the 30 year average maximum wind speed for that month) averaged over all reference climate stations.
Signals captured:	Vulnerability to cyclones, tornadoes, storms, erosion, habitat damage, disturbance. This indicator captures the likelihood of damage from frequent and severe wind that can affect forests, fan fires, create storm surges, dry soils, spread air pollution, and interact with other stressors. Because this indicator is expressed in relation to the 30 year monthly means, a high score could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards. The signal generated captures not only the frequency of high winds, but also their strength.
Notes on this indicator:	• Raw values of summed deviations were adjusted for each individual climate station to account for missing days of data. This was done by multiplying the summed deviations across days with more than 20% higher maximum wind speed, by the total number of days in the 5 year period (1826 days) and dividing by the number of days for that station that had data (many stations have missing days) = [(Σ Deviations * 1826) / days with data]. The adjustment was done to ensure stations with fewer days of data were comparable with those which had more. • In its original form, this indicator called for data on the number of days with >20% higher maximum wind speeds over the 30-year mean. We adjusted the indicator to sum all the deviations above the threshold so that countries with only slight excess could be distinguished from those with large ones.
Are suitable data available?	Yes
Sources of data:	• NOAA DATSAV3 Surface SOD 1973-2003. National Climatic Data Centre, 151 Patton Avenue, Asheville, NC 28801-5001
No. countries included in test:	184 of 235
Temporary modifications to data or indicator, if applicable:	• The 30 year means against which deviations were calculated and summed were extracted from the same datasets. The means were actually calculated over 31 years of data between the years 1973-2003. In future evaluations a 30 year mean will be used.
Notes on data age, completeness and quality:	No in-country data were available for this indicator
Basic units:	Values are total knots of excess wind per year. These are as annual averages over the past 5 years of summed deviations of daily maximum windspeeds that are more than 20% higher than the 30 year monthly mean maximum wind speeds, calculated for each climate station in a country and then averaged over all climate

	stations.	
Recommended transforms:	• LN(X)	
Proposed EVI Scale	EVI Score = 1	X ≤ 5
	EVI Score = 2	5 < X ≤ 5.3
	EVI Score = 3	5.3 < X ≤ 5.6
	EVI Score = 4	5.6 < X ≤ 5.9
	EVI Score = 5	5.9 < X ≤ 6.1
	EVI Score = 6	6.1 < X ≤ 6.4
	EVI Score = 7	6.4 < X
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	• Permanent mechanisms for easily procuring world weather data and extracting the relevant information for re-evaluations of this indicator are needed.	

1.2 Description of raw data

The data for this indicator comprise the excess of expected maximum wind speeds over the past 5 years, based on 30 year averages and calculated separately and then averaged for climate station. Values are only included if the maximum wind speed for any day for a station was more than 20% higher than its expected monthly average value, so minor deviations are omitted from the signal.

Data were available for 184 countries of the 235 included in the index. Some countries had only 1 climate station (e.g. Albania, Burundi) and the maximum number of stations for any country was 1587 (for USA). The 5 years assessed were 1999-2003, and the reference values for deviations were calculated from the 31 years between 1973-2003 (in future evaluations of the EVI, reference means will be from the last 30 years, not 31). The number of days with excess wind speeds (i.e. those with maximum wind speeds more than 20% above the expected mean) varied between 801 in Barbados and 1 in Equatorial Guinea, with a global mean of 267 days (standard deviation = 157).

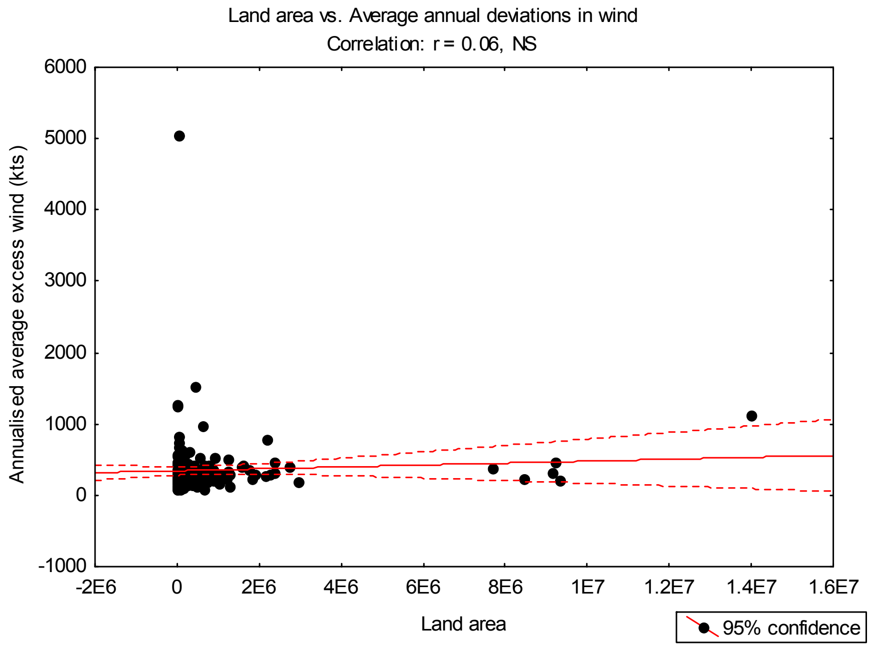
The average annual excess wind over the last 5 years varied between 89 (Jamaica) and 5049 (Belize) knots per year. The world average (based on 184 countries) was 354 knots, with the median value at 287 kts (Table 1.1). The standard deviation among observations was 402 kts, which is only 1.1 times the mean. The Standard Error (SE) was around 30, which is around 8% of the mean.

The average annual amount of excess wind recorded in countries did not correlate significantly with their size, as measured by land area (Figure 1.1).

Table 1.1: Basic statistics for excess wind in 184 countries

Statistic	Excess wind	LN(X) transformed data
Mean	354	5.68
Median	287	5.66
Valid n	184	184
Minimum	89.08	4.49
Maximum	5049.71	8.53
SD (Standard deviation)	402.33	0.54
SE (Standard error)	29.66	0.04
Skewness	9.10	1.09
SE Skewness	0.18	0.18
Kurtosis	102.57	4.41
SE Kurtosis	0.36	0.36

Figure 1.1: Graph of land area versus excess wind in countries.



1.3 Frequency distribution characteristics of the indicator data

The data for rainfall deficit were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 1.2).

The observed frequency distribution was not a good fit to the normal, rectangular or exponential distributions, with these K-S tests being significant. The K-S tests for the lognormal distribution resulted in a non-significant tests, indicating that the data may be better described on a logarithmic scale.

The excess wind data were transformed to their natural logarithms, LN(X), and compared with a normal distribution (Figure 1.3). The data transformed to a natural log scale did fit well with a normal distribution.

Figure 1.2: Frequency distribution of excess wind in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. The normal, rectangular and exponential distributions were significant, while that for the log normal was not at p=0.05.

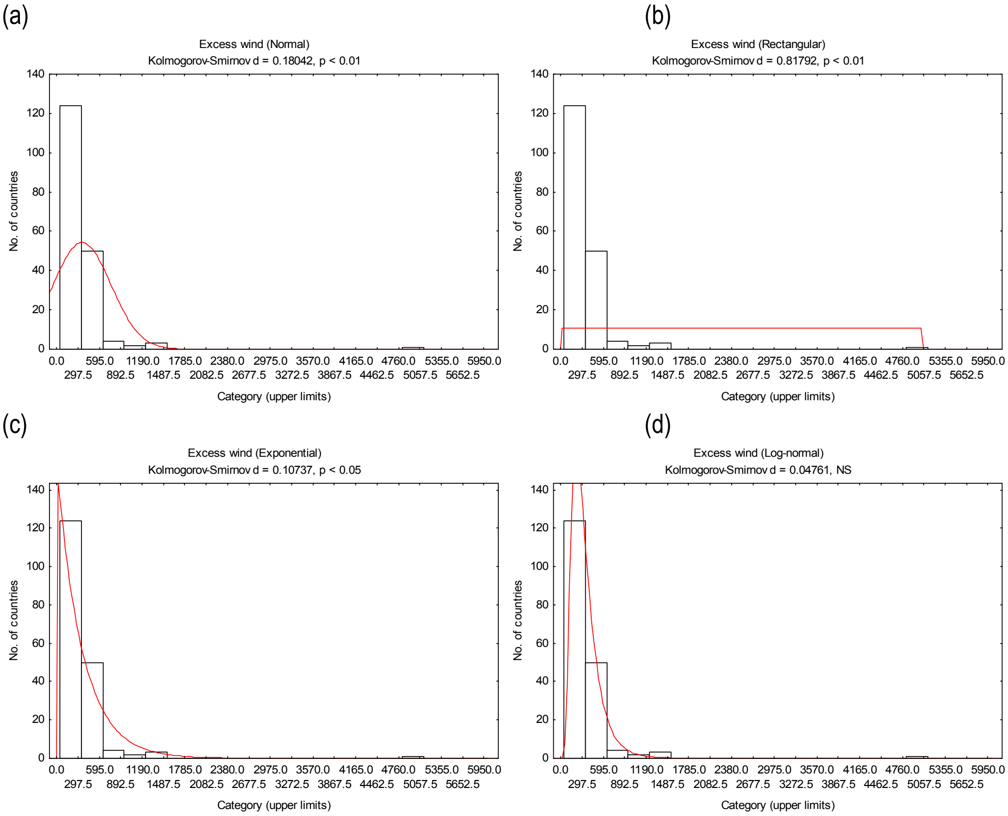
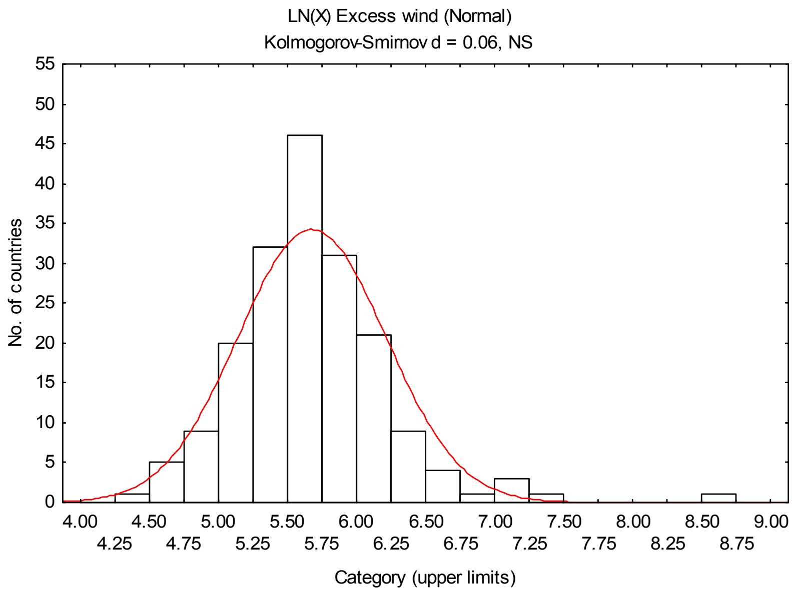


Figure 1.3: Frequency distribution of excess wind data transformed to their natural logarithm (LN(X)) spread over 20 categories (bars) and compared with a normal distribution. The transformed data were a good fit to the normal distribution.



1.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on excess wind be transformed to their natural logarithms LN(X). This renders the transformed data normally distributed and provides a better spread among countries, differentiating those at the lower end of the scale better, and clearly identifying those with very large excesses of wind (Figure 1.3). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with greater than expected wind speeds in countries.

The LN(X) transformed data were plotted as a frequency distribution with 7 categories (Figure 1.4). We designated the EVI score 1 to all countries with < 5 on the transformed scale (< 148 knots excess wind per year) and scaled the rest at even intervals up to 6.4 to score EVI 6. Countries with greater than 6.4 on the transformed scale were scored EVI=7 where the national average excess wind was more than 600 knots per year over the past 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 1.4. Less than 6% of countries fell on this scale at EVI value 1, with the greatest percentage of countries scoring EVI=4 (Table 1.2).

This scoring does not seek to simply spread countries in terms of their LN(X) scores, but focuses on identifying those with substantial risks from sustained or repeated high wind conditions detectable even across large numbers of climate stations. This indicator would not however, detect individual 'windy spots' within a country if the majority of stations did not experience higher than expected winds, as averaging across climate stations would tend to bury these. We consider this a correct signal for the EVI. It identifies countries for which high winds would affect most of the country (including cases in which there is only 1 climate station) and for which refugia from effects would therefore tend to be unavailable. This indicator could be applied by station within countries if vulnerabilities within a country became the focus, but this is outside the scope of the EVI being calculated at a national scale here. Examples of countries with the most vulnerability to high winds as identified using this indicator include Albania, Iraq and Rwanda (Table 1.3). Whether these countries are naturally prone to high winds or not, this indicator highlights that over the past 5 years they have experienced more winds than expected.

Figure 1.4: Frequency distribution of excess wind in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

(a) (b)

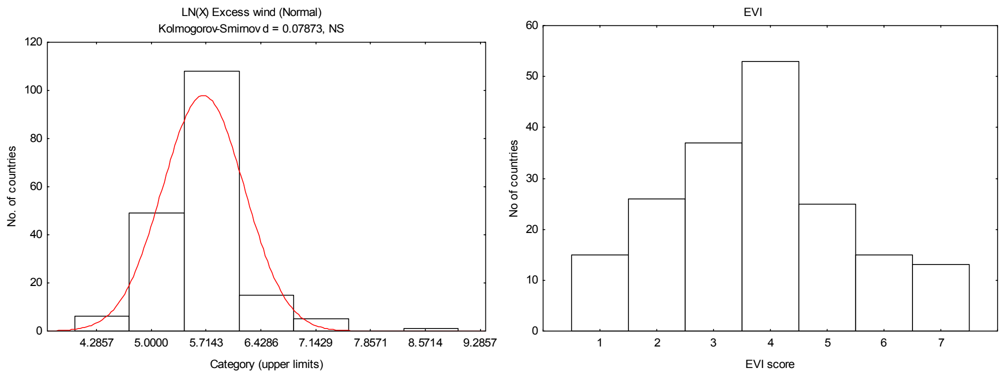


Table 1.2: Proposed EVI scaling for Indicator 1 on excess winds.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values LN(X)	Observed # countries	Observed % of countries
1	X ≤ 5	15	6.38
2	5 < X ≤ 5.3	26	11.06
3	5.3 < X ≤ 5.6	37	15.74
4	5.6 < X ≤ 5.9	53	22.55
5	5.9 < X ≤ 6.1	25	10.64
6	6.1 < X ≤ 6.4	15	6.38
7	6.4 < X	13	5.53
NA	☒ May not be used		
ND	☑ May be used	51	21.70

Table 1.3: Proposed EVI scaling for Indicator 1 showing equivalence on the EVI and LN(X) transformed scales and examples of countries with each score.

EVI Scale	Values LN(X) excess wind	Annual Excess wind (kts)	Countries
1	X ≤ 5	X≤ 148.4	Gambia, Peru, Zimbabwe
2	5 < X ≤ 5.3	148.4 < X ≤ 200.3	Ethiopia, Nepal, Thailand
3	5.3 < X ≤ 5.6	200.3 < X ≤ 270.4	Bangladesh, Mali, Taiwan
4	5.6 < X ≤ 5.9	270.4 < X ≤ 365.0	Botswana, Guyana, Tonga
5	5.9 < X ≤ 6.1	365.0 < X ≤ 445.9	Australia, Barbados, New Zealand
6	6.1 < X ≤ 6.4	445.9 < X ≤ 601.8	Canada, Nigeria, Chad
7	6.4 < X	601.8 < X	Albania, Iraq, Rwanda

1.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

1.6 Age, completeness and quality of the data

No data for this indicator were available from in-country sources.

1.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global daily wind data are generally not available.

1.8 Additional sources & contacts

Cook Is. - Data archive of Cook Islands Met Services (CIMS) Director, Met Services; Fiji - Ashmita Gosai (724888); Fiji - FMS Annual Weather Summary 1997 & 1998. Fiji Meteorological Service; Greece - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Kirion Kabunateiti. Climate Archive from Kiribati Meteorology Services (KMS); Nepal - Various Issues of Climatological Records of Nepal. Department of Hydrology and Meteorology. Kathmandu, Nepal; New Zealand - National Institute of Water and Atmospheric Research, New Zealand. Mr A. C Penney. E.Mail: a.penney@niwa.cri.nz; Niue - David Poihega (4196/ 4602/ upoihega@yahoo.com) Niue Meteorology Services; Palau - Federal Climate Complex Asheville; Singapore - Mr Wong Teo Suan ++(65) 5457191 ++(65) 5457192. Meteorological office Singapore; Thailand - Climatology Division Meteorology Department. 21/08/2001; Tonga - Ofa Fa'anunu (676 23401/ 24145/ Tongamet@kalianet.to) Climate Archive, Tonga Meteorology Services (TMS).

2. DRY PERIODS

2.1 Indicator Summary

Indicator number:	02
Indicator short name:	Dry periods
Sub-index	REI
Categorisation	Weather & Climate
Indicator text:	Average annual rainfall deficit (mm) over the past 5 years for all months with >20% lower rainfall than the 30 year monthly average, averaged over all reference climate stations.
Signals captured:	Vulnerability to drought, dry spells, stress on surface water resources. This indicator captures not only the number of months with significantly lower rainfall, but also the strength of the deficit. Two countries could have the same average number of months over the past 5 years with less than 20% lower than the monthly average rainfall, with one only having a small deficit, while another a very large one. This indicator ensures that the amount of rain 'missed' is captured. Frequent and severe drought months could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. fires, water movements, ability of ecosystems to attenuate pollution).
Notes on this indicator:	1. This indicator is focused on the size of the rainfall deficit across all climate stations in countries, so takes into account vastly different climates (assessing deficit only in terms of one climate station at a time and then averaging them across stations). 2. Contiguous months of drought are not captured separately from isolated months. Effects are likely to be worse for areas in which the deficit is on-going. 3. We upgraded the indicator from an earlier simpler form to measure the *strength* of the deficit, if one exists. This gives a better picture of vulnerability because it separates 'minor' droughts from major ones.
Are suitable data available?	Yes
Sources of data:	NOAA GHCN http://www.ncdc.noaa.gov/oa/pub/data/ghcn/v2/ghcnftp_zipd.html; In-country
No. countries included in test:	212
Temporary modifications to data or indicator, if applicable:	Indicator has been modified to include an expression of the strength of the rainfall deficit.
Notes on data age, completeness and quality:	• In-country data were not used.
Basic units:	Millimetres of rainfall deficit (negative value). Total rainfall deficit in mm over the past 5 years, averaged over all stations and months for which there were data. Final values expressed as annual figures.
Recommended transforms:	Data on total mm over 5 years rendered positive and transformed to LN(X) to create scale

Proposed EVI Scale for LN(X) total deficits over 5 years	EVI Score = 1	$X \leq 4$
	EVI Score = 2	$4 < X \leq 4.5$
	EVI Score = 3	$4.5 < X \leq 5$
	EVI Score = 4	$5 < X \leq 5.5$
	EVI Score = 5	$5.5 < X \leq 6$
	EVI Score = 6	$6 < X \leq 6.5$
	EVI Score = 7	$6.5 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

2.2 Description of raw data

The data for this indicator comprise the deficit of expected rainfall over the past 5 years, based on 30 year averages and calculated separately and then averaged for each month and climate station. Values are only included if the rainfall for any station/month was more than 20% lower than its expected value, so minor deviations are omitted from the signal.

Data were available for 212 countries of the 236 included in the index. Some countries had only 1 climate station (e.g. United Arab Emirates and American Samoa) and the maximum number of stations for any country was 224 (for USA). The 5 years assessed were 1999-2003 for most countries, though for a few countries, the most recent data used in the analysis were old (e.g. Albania: 1966-70, Iraq: 1976-80, Turks & Caicos 1965-69) and require updating. The percentage of dry months (i.e. those with rainfall more than 20% below the expected mean) varied between 22.6 in Tokelau and 84 in Oman.

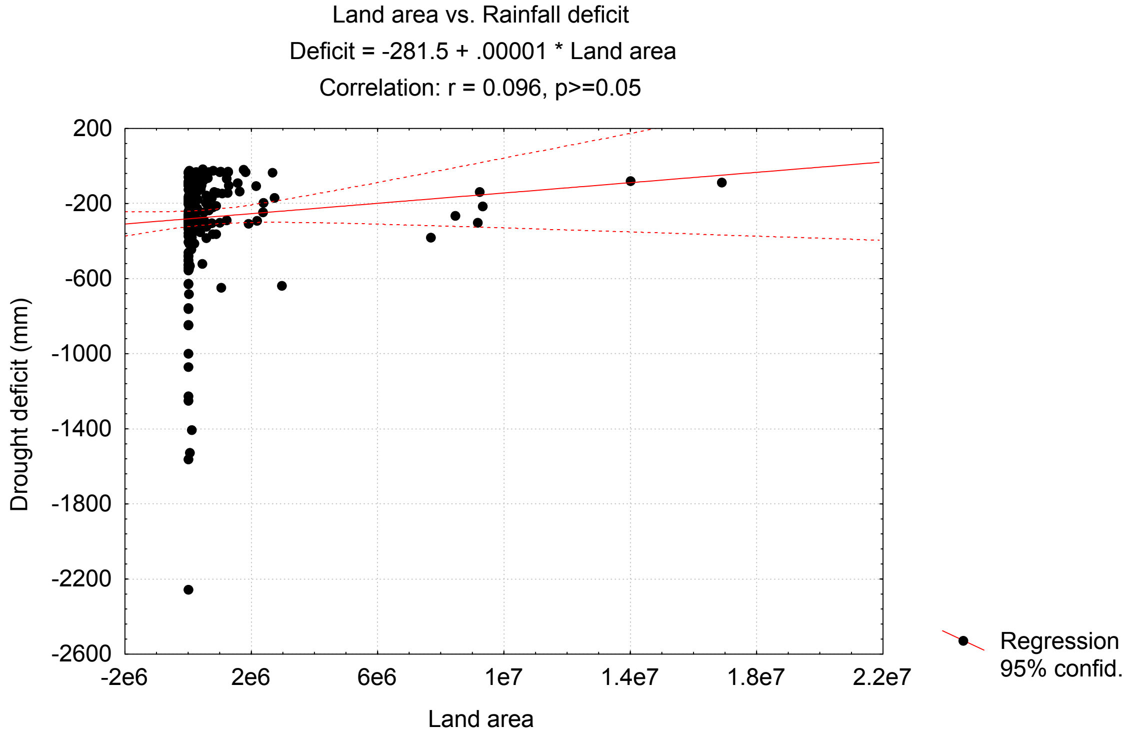
The deficit of expected rainfall over the latest 5 years varied between –16 mm (Cameroon) (lowest deficit) through to –2257 mm (American Samoa). The world average (based on 212 countries) was –272 mm, with the median value at -201 mm (Table 2.1). The standard deviation among observations was 290 mm, which is approximately the same size as the mean. The Standard Error (SE) was around 20, which is around 7% of the mean.

The size of the average rainfall deficit did not correlate significantly with the size of countries, as measured by land area (Figure 2.1). This is probably the result of calculating values in relation to the specific conditions expected at each station across countries, so already takes into account effects that could be associated with countries crossing a range of climate types. It is therefore proposed that this indicator be used in its raw form, and not be expressed as a density function in relation to land area.

Table 2.1: Basic statistics for rainfall deficit in 212 countries

Statistic	Value
Mean	-272.13
Median	-201.00
Valid n	212
Minimum	-16
Maximum	-2257
SD (Standard deviation)	290.13
SE (Standard error)	19.93
Skewness	-3.24
SE Skewness	0.17
Kurtosis	14.48
SE Kurtosis	0.33

Figure 2.1: Graph of land area versus rainfall deficit in countries.



2.3 Frequency distribution characteristics of the indicator data

The data for rainfall deficit were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 2.2).

The observed frequency distribution was not a good fit to either the normal or the rectangular distributions, with both these K-S tests being significant. The K-S tests for the exponential and lognormal distributions resulted in non-significant tests, indicating that functions of either of these two forms are reasonable fits to the observed data.

The rainfall deficit data were transformed to their natural logarithms, LN(x), and compared with a normal distribution (Figure 2.3). The data transformed to a natural log scale did fit well with a normal distribution.

Figure 2.2: Frequency distribution of Rainfall deficit in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Data normally expressed as negative values were reversed for the analysis. Each comparison was made using a K-S test for fit. The normal and rectangular distributions were significant, while those for exponential and log normal were not at p=0.05.

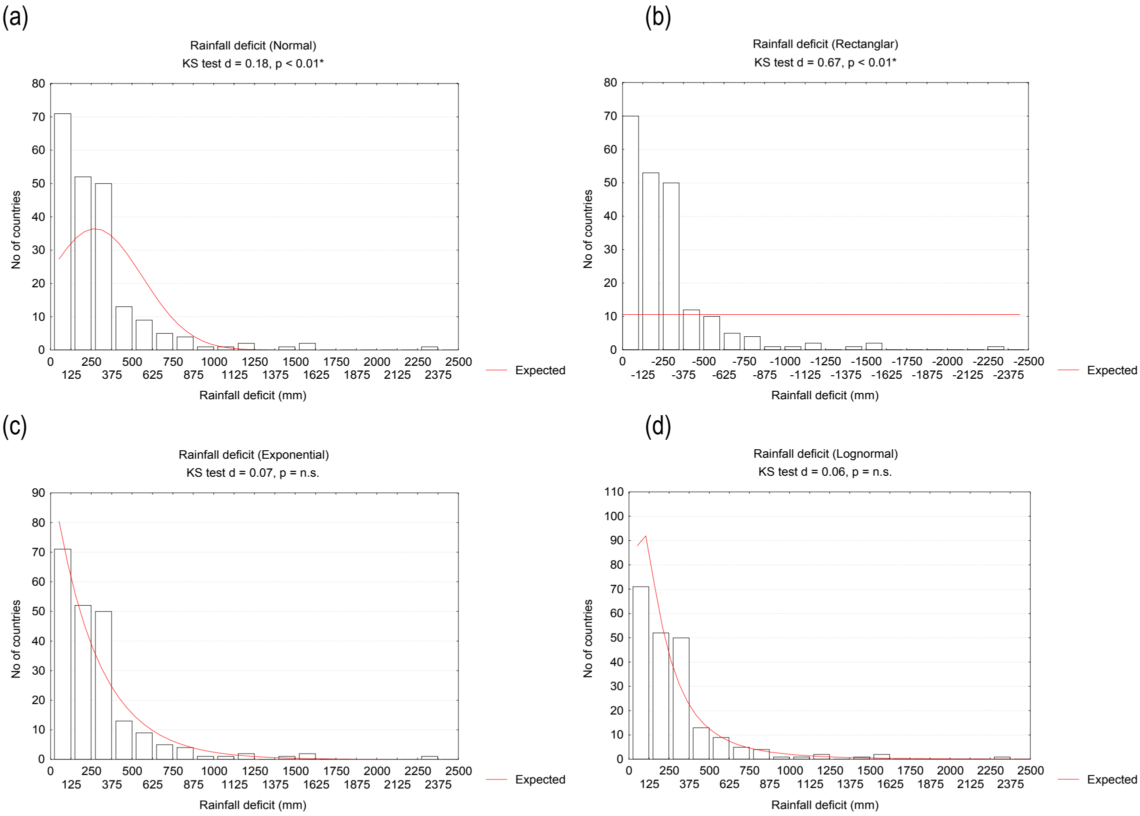
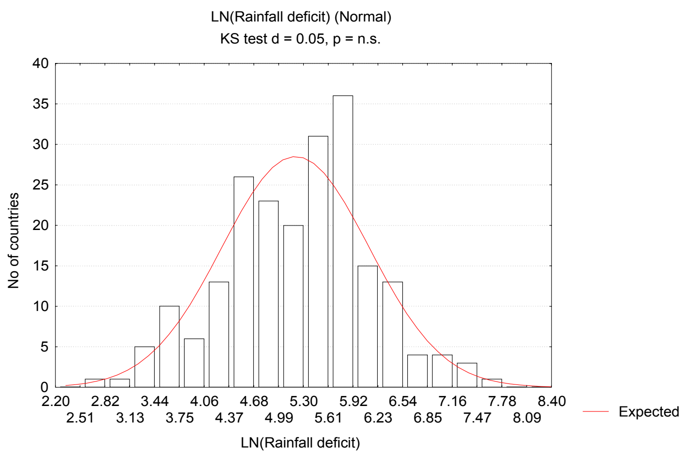


Figure 2.3: Frequency distribution of Rainfall deficit data transformed to their natural logarithm (LN(X)) spread over 20 categories (bars) and compared with a normal distribution.



2.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on rainfall excess be transformed to their natural logarithms LN(X). This renders the transformed data normally distributed and provides a better spread among countries, differentiating those at the lower end of the scale better, and clearly identifying those with a very large rainfall deficits (Figure 2.3). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with lower than expected rainfall in countries.

The LN(X) transformed data were plotted as a frequency distribution with 7 categories (Figure 2.4). This showed that in most countries (with any deficit) there was a shortage of around 100-250 mm of rainfall over the past 5 years, averaged over the available climate stations. There were, however, a significant number of countries with very much larger averaged totals of rainfall deficit, which would tend to make them even more vulnerable to ecological damage.

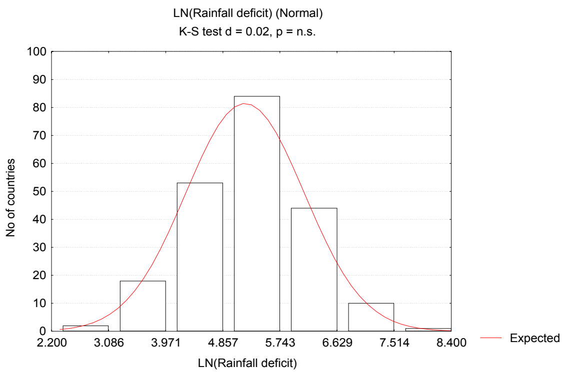
We designated the EVI score 1 to all countries with ≤ 4 on the transformed scale (≤55 mm) and scaled the rest at even intervals up to 6.5 (665 mm) to score EVI 6. Countries with greater than 6.5 on the transformed scale were scored EVI=7 where the national average rainfall deficit was more than 665 mm over the past 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 2.4.

Less than 9% of countries fell on this scale at EVI value 1, with the greatest percentage of countries scoring EVI=5 (Table 2.2).

This scoring does not seek to spread countries in terms of their LN(X) scores, but focuses on identifying those with substantial risks from sustained or repeated low rainfall periods detectable even across large numbers of climate stations. This indicator would not however, detect individual ‘dry spots’ within a country if the majority of stations did not experience low rainfall, as averaging across climate stations would tend to bury these. We consider this a correct signal for the EVI. It identifies countries for which low rainfall would affect most of the country (including cases in which there is only 1 climate station) and for which refugia from effects would therefore tend to be unavailable. This indicator could be applied by station within countries if vulnerabilities within a country became the focus, but this is outside the scope of the EVI being calculated at a national scale here. Examples of countries with the most vulnerability to a deficit of rainfall identified using this indicator include Nauru, New Caledonia and Reunion (Table 2.3).

Figure 2.4: Frequency distribution of rainfall deficits in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

(a)



(b)

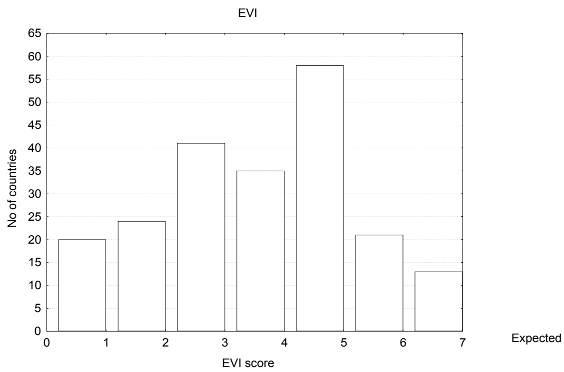


Table 2.2: Proposed EVI scaling for Indicator 2 for droughts.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values LN(X) total	Observed # countries	Observed % of countries
1	X ≤ 4	20	8.47%
2	4 < X ≤ 4.5	24	10.17%
3	4.5 < X ≤ 5	41	17.37%
4	5 < X ≤ 5.5	35	14.83%
5	5.5 < X ≤ 6	58	24.58%
6	6 < X ≤ 6.5	21	8.90%
7	6.5 < X	13	5.51%
NA	☒ May not be used		
ND	☑ May be used		

Table 2.3: Proposed EVI scaling for Indicator 3 showing equivalence on the EVI, LN(X) and raw rainfall deficit scales and examples of countries in each score.

EVI Scale	Values LN(X) total deficit	Values Total Rainfall Deficit	Values Annual Rainfall Deficit	Countries
1	X≤4	X≤54.6	X≤10.9	Afghanistan, Cameroon, Indonesia
2	4<X≤4.5	54.6<X≤90.0	10.9<X≤18.0	Gabon, Kyrgyzstan, Latvia
3	4.5<X≤5	90.0<X≤148.4	18.0<X≤29.7	Lithuania, Namibia, Poland
4	5<X≤5.5	148.4<X≤244.7	29.7<X≤48.9	Nicaragua, Portugal, Rwanda
5	5.5<X≤6	244.7<X≤403.4	48.9<X≤80.7	Singapore, Thailand, Samoa
6	6<X≤6.5	403.4<X≤665.1	80.7<X≤133.0	Marshall Is, Norfolk, Taiwan
7	6.5<X	665.1<X	133.0<X	Nauru, New Caledonia, Reunion

2.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

2.6 Age, completeness and quality of the data

The data collected from in-country collaborators was considered by them to be of good age, completeness and quality (Table 2.4). The data from GHCN are current for most countries, with several notable exceptions where the most recent data are several decades old.

Table 2.4: Characteristics of age, completeness and quality of the data obtained for vertical relief for 169 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Valid n	20	20	20
Mean value across countries:	2.2	2.75	3.00
SD	5.2	0.44	0
SE	0.12	0.10	0

2.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global daily rainfall data are generally not available. In-country data were not used here because the method of analysis was changed to incorporate a signal of how much excess rainfall was found in countries, rather than just the number of months more than 20% below the monthly means.

2.8 Additional sources & contacts

Cook Islands - Meteorology Office. Nga Rauraa (+682 20603/ 682 21603); Federated States of Micronesia - NOAA/ NCDC – 1999 Local Climate Data/ NCDC. Caesar Hadley. WSO Pohnpei – NWSPR/ NOAA; Fiji - Ashmita Gosai (+679-724888); Greece - Dr Paula Scott (ph&f: +30-81-861219, cariad@her.forthnet.gr); Kiribati - Kirion Kabunateiti. Climate Archive from Kiribati Meteorology Services (KMS); Marshall Islands - NOAA NCDC Ashville. Local Climatological Data (LCD). Lee Z Jacklick; Nauru - Nauru Meteorology Services. Frank W Davey; Nepal - Various issues of Climatological records of Nepal. Soroj Kumar Baidhya (MR) Phone ++(1) 255920; New Zealand - National Institute of Water and Atmospheric Research, New Zealand. Mr A. C Penney. E.Mail: a.penney@niwa.cri.nz ; Niue - Sionetasi Pulehetoa. Meteorology Department Palau - Maria Ngemaes (680 4881034, maria.ngemaes@noaa.gov) Weather Service Office (National Weather Service); Papua New Guinea - Climatic Tables for PNG. McAlphine, J. R.; Keig, G.; and Short, K. PNG National Weather Service; Philippines - Climatological Normals. Ms Panfila E. Gica / Climate Data Section / PAGASA Samoa - Niko Tualevao. Apia Observatory/ Samoa Meteorology; Singapore - Mr Wong Teo Suan ++(65) 5457191 ++(65) 5457192. Meteorological office Singapore; Thailand - Climatology Division Meteorological Department 21 Aug 2001 local_climate@tmdnet.motc.go.th ; Tonga - Ofa Fa'anunu (676 23401/ 24145/ Tongamet@kalianet.to) Climate Archive, Tonga Meteorology Services (TMS); Trinidad & Tobago - Debbie Ramnarine; Tuvalu - Tuvalu Meteorology Services (TMS). Hilia Vavae; Vanuatu - Vanuatu Meteorology Services (VMS). Mr Kaniaha Salesa (678 23866/ 22310/ climate@meteo.vu).

3. WET PERIODS

3.1 Indicator Summary

Indicator number:	03
Indicator short name:	Wet periods
Sub-index	REI
Categorisation	Weather & Climate
Indicator text:	Average annual excess rainfall (mm) over the past 5 years for all months with >20% higher rainfall than the 30 year monthly average, averaged over all reference climate stations.
Signals captured:	Vulnerability to floods, cyclones, wet periods, stress on land surfaces and ecosystems subject to flooding and disturbance. This indicator captures not only the number of months with significantly higher rainfall, but also the amount of the excess. Two countries could have the same number of months of the past 60 (5 years) with more than 20% higher rainfall than the monthly average, with one only having a small excess, while another a very large one. The modification to this indicator ensures that the amount of rain 'in excess' is captured. Frequent and severe wet months could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. water movements, the spread of and ability of ecosystems to attenuate pollution).
Notes on this indicator:	1. This indicator is focused on the size of the rainfall excess across all climate stations in countries, so takes into account vastly different climates (assessing excess only in terms of one climate station at a time and then averaging them across stations). 2. Contiguous months of high rainfall are not captured separately from isolated months. Effects are likely to be worse for areas in which the excess is sustained. 3. We upgraded the indicator from a simpler form to measure the *strength* of the excess, if one exists. This gives a better picture of vulnerability because it separates 'minor' excesses from severe ones. 4. Dividing the total excess by the number of climate stations is necessary to prevent apparently excessive rainfall caused because data are being collected from different numbers of stations in countries. That means that in large countries with many stations, severe excessive rainfall at one or a small number of stations may be lost by averaging over a very large number of stations with normal rainfall. We consider this appropriate since the averaging over many stations puts damage into the context of the entire area likely to be affected.
Are suitable data available?	Yes
Sources of data:	NOAA GHCN http://www.ncdc.noaa.gov/oa/pub/data/ghcn/v2/ghcnftp_zipd.html; In-country
No. countries included in test:	212
Temporary modifications to data or indicator, if applicable:	Indicator has been modified to include an expression of the strength of the rainfall excess.
Notes on data age, completeness and quality:	• In-country data were not used. • In-country data were generally considered of good age,

	completeness & quality by collaborators.	
Basic units:	Millimetres of excess rainfall. Total excess rainfall in mm over the past 5 years, averaged over all stations and months for which there were data. In their final form results are expressed as annual excess.	
Recommended transforms:	Data transformed to SQRT(X)	
Proposed EVI Scale For SQRT(X) total excess mm over 5 years	EVI Score = 1	$X \leq 5$
	EVI Score = 2	$5 < X \leq 7$
	EVI Score = 3	$7 < X \leq 9$
	EVI Score = 4	$9 < X \leq 11$
	EVI Score = 5	$11 < X \leq 13$
	EVI Score = 6	$13 < X \leq 15$
	EVI Score = 7	$15 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

3.2 Description of raw data

The data for this indicator comprise the additional rainfall over that expected over the past 5 years, based on 30 year averages. These values are calculated separately for each month and climate station. They are added up over the most recent 5 years of data but averaged over all climate stations, so data are a total 'excess' of rainfall over the past 5 years per climate station. Values are only included if the rainfall for any station/month was more than 20% greater than its expected value, so minor deviations are omitted from the signal.

Data were available for 212 countries of the 236 included in the index. Some countries had only 1 climate station (e.g. United Arab Emirates and American Samoa) and the maximum number of stations for any country was 224 (for USA). The 5 years assessed were 1999-2003 for most countries, though for a few countries, the most recent data used in the analysis were old (e.g. Albania: 1966-70, Iraq: 1976-80, Turks & Caicos 1965-69) and require updating. The percentage of wet months (i.e. those with rainfall more than 20% above the expected mean) varied between 50% in Honduras and 6.3% in Oman. Oman has the distinction of having the lowest percentage of both dry months and wet months in relation to long term means.

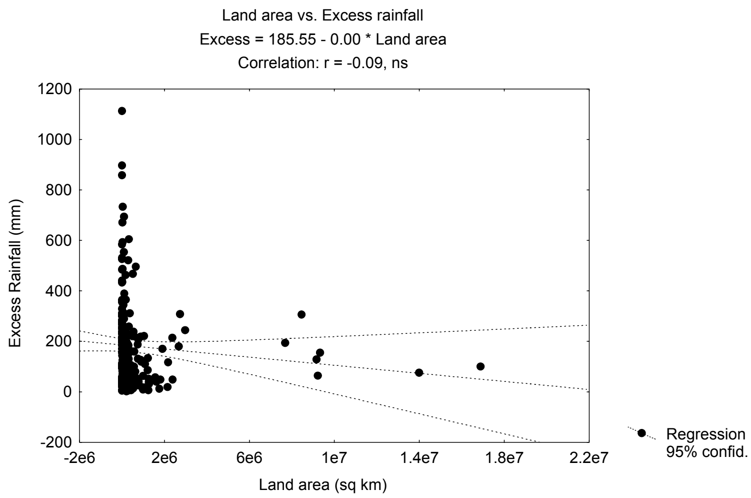
The excess over expected rainfall over the latest 5 years (above 20% greater than each monthly mean) varied between 1113 mm (Nauru) (greatest excess) through to only 2 mm (Oman). The world average (based on 212 countries) was 180 mm, with the median value at 128 mm (Table 3.1). The standard deviation among observations was 177 mm, which is approximately the same size as the mean. The Standard Error (SE) was around 12, which is around 6.7% of the mean.

The size of the average rainfall excess did not correlate significantly with the size of countries, as measured by land area (Figure 3.1). This is probably the result of calculating values in relation to the specific conditions expected at each station across countries, so already takes into account effects that could be associated with countries crossing a range of climate types. It is therefore proposed that this indicator be used in its raw form, and not be expressed as a density function in relation to land area.

Table 3.1: Basic statistics for rainfall excess in 212 countries.

Statistic	Value
Mean	180.11
Median	127.50
Valid n	212
Minimum	2
Maximum	1113
SD (Standard deviation)	177.28
SE (Standard error)	12.18
Skewness	2.03
SE Skewness	0.17
Kurtosis	5.43
SE Kurtosis	0.33

Figure 3.1: Graph of land area versus excess rainfall in countries. Excess rainfall is defined as that >20% higher than the 30 year mean for any month for any climate station.



3.3 Frequency distribution characteristics of the indicator data

The data for rainfall excess were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 3.2).

The observed frequency distribution was not a good fit to either the normal or the rectangular distributions, with both these K-S tests being significant. The K-S tests for the exponential and lognormal distributions resulted in non-significant tests, indicating that functions of either of these two forms are reasonable fits to the observed data. The excess rainfall data were transformed to their square roots, SQRT(x), and compared with a normal distribution (Figure 3.3). The square-root transformed data did fit well with a normal distribution.

Figure 3.2: Frequency distribution of excess rainfall in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. The normal and rectangular distributions differed significantly from the observed data, while those for exponential and lognormal were not significantly different from the observed data at p=0.05.

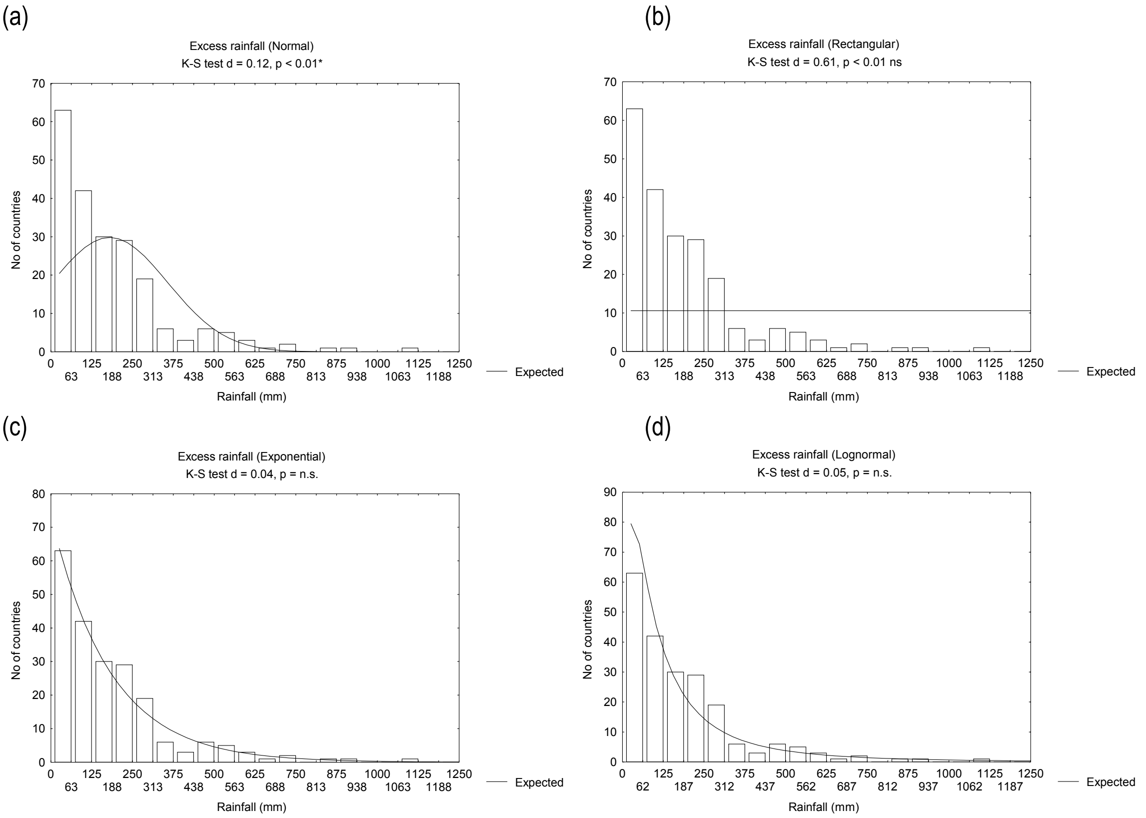
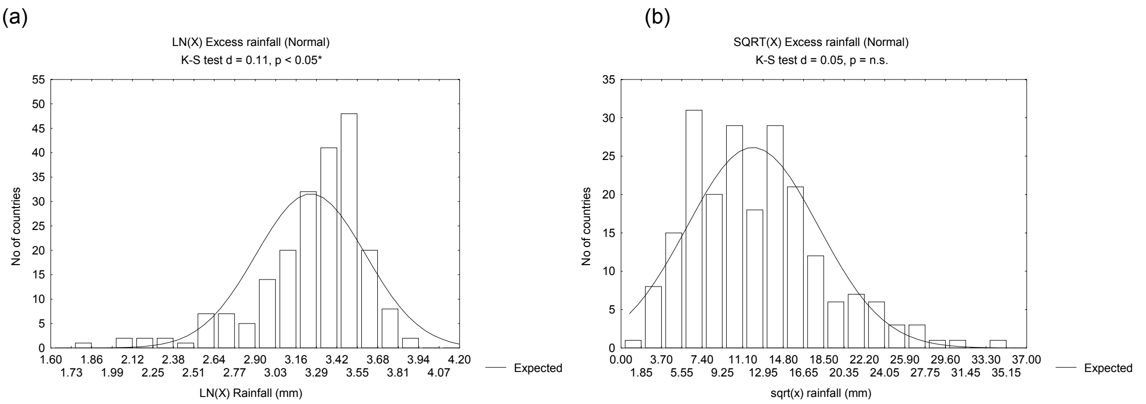


Figure 3.3: Frequency distribution of Excess rainfall deficit data transformed to their (a) natural logarithm LN(X) and (b) square root SQRT(X), spread over 20 categories (bars) and compared with a normal distribution.



3.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on rainfall excess be transformed to SQRT(X), rather than their natural logarithms. The reasoning behind this is that using the SQRT(X) transform, data are normally distributed and provide a better spread among countries, differentiating those at the lower end of the scale better, and clearly identifying those with a very large rainfall excess (Figure 3.3 a versus b). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with larger than expected rainfall in countries.

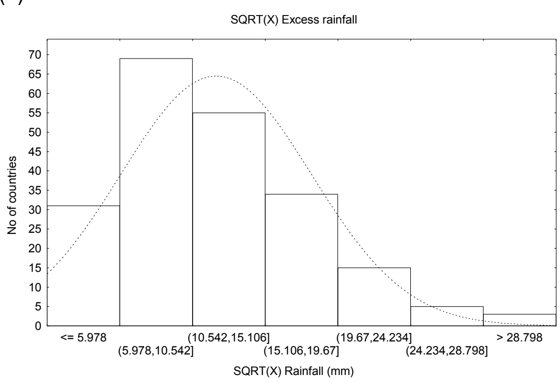
The SQRT(X) transformed data were plotted as a frequency distribution with 7 categories (Figure 3.4). This showed that in most countries with any excess, there was a total of between 34 and 228 mm of excess rainfall, averaged over the available climate stations over the past 5 years. There was, however, a significant number of countries with very much larger averaged totals of excess rainfall, which would tend to make them more vulnerable to ecological damage.

We designated the EVI score 1 to all countries with ≤ 5 on the transformed scale (25mm) and scaled the rest at even intervals up to 15 (225mm) to score EVI 6. Countries with greater than 15 on the transformed scale were scored EVI=7 where the national average excess rainfall was more than 225 mm over the past 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 3.4.

Less than 10% of countries fell on this scale at EVI value 1, with a more-or-less even distribution scoring EVI=2-6. More than 27% of countries scored EVI=7 (Table 3.2). This scoring does not seek to spread countries in terms of their SQRT(X) scores, but focuses on identifying those with substantial risks from sustained or repeated high rainfall events detectable even across large numbers of climate stations. This indicator would not however, detect individual ‘wet spots’ within a country if the majority of stations did not experience excess rainfall, as averaging across climate stations would tend to bury these. We consider this a correct signal for the EVI. It identifies countries for which the excess rain would affect most of the country (including cases in which there is only 1 climate station) and for which refugia from effects would therefore tend to be unavailable. This indicator could be applied by station within countries if vulnerabilities within a country became the focus, but this is outside the scope of the EVI being calculated at a national scale here. Examples of countries with the most vulnerability to excess rainfall identified using this indicator include Seychelles, Uruguay and Samoa (Table 3.3).

Figure 3.4: Frequency distribution of Excess rainfall in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

(a)



(b)

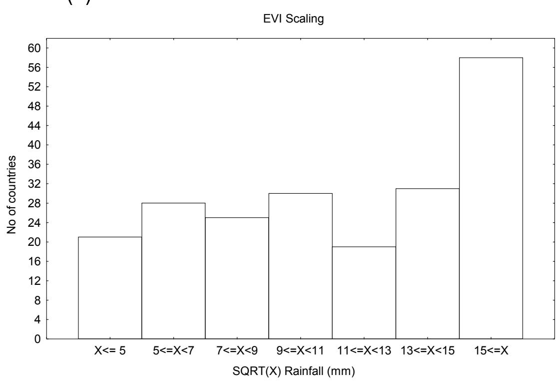


Table 3.2: Proposed EVI scaling for Indicator 3 for excess rainfall with number of observed countries.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values SQRT(X)	Observed # countries	Observed % of countries
1	X ≤ 5	21	9.91%
2	5 < X ≤ 7	28	13.21%
3	7 < X ≤ 9	25	11.79%
4	9 < X ≤ 11	30	14.15%
5	11 < X ≤ 13	19	8.96%
6	13 < X ≤ 15	31	14.62%
7	15 < X	58	27.36%
NA	☒ May not be used		
ND	☑ May be used		

Table 3.3: Proposed EVI scaling for Indicator 3 showing equivalence on the EVI, SQRT(X) and raw rainfall deficit scales and examples of countries in each score.

EVI Scale	Values SQRT(X)	Values Total Excess Rainfall	Values Annual Excess Rainfall	Countries
1	X≤5	X≤25	X≤5	Angola, Ecuador, Kuwait
2	5<X≤7	25<X≤49	5<X≤9.8	Cameroon, Israel, Pakistan
3	7<X≤9	49<X≤81	9.8<X≤16.2	Morocco, Senegal, Tajikistan
4	9<X≤11	81<X≤121	16.2<X≤24.2	New Zealand, PNG, Tuvalu
5	11<X≤13	121<X≤169	24.2<X≤33.8	Panama, Sweden, Ukraine
6	13<X≤15	169<X≤225	33.8<X≤45.0	Cook Is., St Lucia, Venezuela
7	15<X	225<X	45.0<X	Seychelles, Uruguay, Samoa

3.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

3.6 Age, completeness and quality of the data

The data collected from in-country collaborators was considered by them to be of good age, completeness and quality (Table 3.4). The data from GHCN are current for most countries, with several notable exceptions where the most recent data are several decades old.

Table 3.4: Characteristics of age, completeness and quality of the data obtained for rainfall deficits.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Valid n	21	21	21
Mean value across countries:	2.19	2.71	3.00
SD	0.40	0.46	0
SE	0.09	0.01	0

3.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global daily rainfall data are generally not available. In-country data were not used here because the method of analysis was changed to incorporate a signal of how much excess rainfall was found in countries, rather than just the number of months more than 20% above the monthly means.

3.8 Additional sources & contacts

Cook Islands - Meteorology Office. Nga Rauraa (+682 20603/ 682 21603); Federated States of Micronesia - NOAA/ NCDC – 1999 Local Climate Data/ NCDC. Caesar Hadley. WSO Pohnpei – NWSPR/ NOAA; Fiji - Ashmita Gosai (+679-724888); Greece - Dr Paula Scott (ph&f: +30-81-861219, cariad@her.forthnet.gr); Kiribati - Kirion Kabunateiti. Climate Archive from Kiribati Meteorology Services (KMS); Marshall Islands - NOAA NCDC Ashville. Local Climatological Data (LCD). Lee Z Jacklick; Nauru - Nauru Meteorology Services. Frank W Davey; Nepal - Various issues of Climatological records of Nepal. Soroj Kumar Baidhya (MR) Phone +641 255920; New Zealand - National Institute of Water and Atmospheric Research, New Zealand. Mr A. C Penney. E.Mail: a.penney@niwa.cri.nz ; Niue - Sionetasi Pulehetoa. Meteorology Department Palau - Maria Ngemaes (680 4881034, maria.ngemaes@noaa.gov) Weather Service Office (National Weather Service); Papua New Guinea - Climatic Tables for PNG. McAlphine, J. R.; Keig, G.; and Short, K. PNG National Weather Service; Philippines - Climatological Normals. Ms Panfila E. Gica / Climate Data Section / PAGASA Samoa - Niko Tualevao. Apia Observatory/ Samoa Meteorology; Singapore - Mr Wong Teo Suan ++(65) 5457191 ++(65) 5457192. Meteorological office Singapore; Thailand - Climatology Division Meteorological Department 21 Aug 2001 local_climate@tmdnet.motc.go.th ; Tonga - Ofa Fa'anunu (676 23401/ 24145/ Tongamet@kalianet.to) Climate Archive, Tonga Meteorology Services (TMS); Trinidad & Tobago - Debbie Ramnarine; Tuvalu - Tuvalu Meteorology Services (TMS). Hilia Vavae; Vanuatu - Vanuatu Meteorology Services (VMS). Mr Kaniaha Salesa (678 23866/ 22310/ climate@meteo.vu).

4. HOT PERIODS

4.1 Indicator Summary

Indicator number:	04
Indicator short name:	Hot periods
Sub-index	Hazards
Categorisation	Weather & Climate
Indicator text:	Average annual excess heat (degrees Farenheit) over the past 5 years for all days more than 9F (5°C) hotter than the 30 year mean monthly maximum, averaged over all reference climate stations.
Signals captured:	Vulnerability to heat waves, desertification, water resources, temperature stress, bleaching. This indicator is designed to capture stress on land surfaces and nearshore or shallow aquatic environments to periods of high temperatures that can affect productivity, oxygen levels, pollution, reproduction and symbiotic relationships and lead to mass mortality. On land, periods of high temperatures can also lead to interactive effects such as fires. This indicator captures not only the number of days with significantly higher temperatures, but also the amount of the excess. Two countries could have the same number of days with more than 5ºC higher temperatures than the monthly average, with one only having a small excess, while another a very large one. Frequent and severe hot days could also indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. ability of forests to regenerate if disturbed).
Notes on this indicator:	• Raw values were supplied in Farenheit, so calculations have been made in those units, with the threshold at 9F used for measuring deviations. • Raw values of summed deviations were adjusted for each individual climate station to account for missing days of data. This was done by multiplying the summed deviations across days with more than 5˚C (9˚F) higher daily maximum temperature, by the total number of days in the 5 year period (1826 days) and dividing by the number of days for which that station had data (many stations have missing days) = [(Σ Deviations * 1826) / days with data]. The adjustment was done to ensure stations with fewer days of data were comparable with those which had more. • In its original form, this indicator called for data on the number of days with >5C higher daily maximum temperatures over the 30-year monthly mean. We adjusted the indicator to sum all the deviations above the threshold so that countries with only slight excess could be distinguished from those with large ones.
Are suitable data available?	Yes
Sources of data:	• NOAA DATSAV3 Surface SOD 1973-2003. National Climatic Data Centre, 151 Patton Avenue, Asheville, NC 28801-5001
No. countries included in test:	184 of 235
Temporary modifications to data or indicator, if applicable:	• The 30 year means against which deviations were calculated and summed were extracted from the same datasets. The means were actually calculated over 31 years of data between the years 1973-2003. In future evaluations a 30 year mean will

	be used.	
Notes on data age, completeness and quality:	No in-country data were available for this indicator	
Basic units:	Values are total degrees (Farenheit) of excess heat per year. These are as annual averages over the past 5 years of summed deviations of daily maximum temperatures that are more than 9F higher than the 30 year monthly mean maximum temperatures, calculated for each climate station in a country and then averaged over all climate stations.	
Recommended transforms:	• LN(X)	
Proposed EVI Scale	EVI Score = 1	$X \leq 3.5$
	EVI Score = 2	$3.5 < X \leq 4$
	EVI Score = 3	$4 < X \leq 4.5$
	EVI Score = 4	$4.5 < X \leq 5$
	EVI Score = 5	$5 < X \leq 5.5$
	EVI Score = 6	$5.5 < X \leq 6$
	EVI Score = 7	$6 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	• Permanent mechanisms for easily procuring world weather data and extracting the relevant information for re-evaluations of this indicator are needed.	

4.2 Description of raw data

The data for this indicator comprise the excess of expected daily maximum temperatures over the past 5 years, based on 30 year averages and calculated separately and then averaged for climate station. Values are only included if the maximum temperature for any day for a station was more than 9˚F higher than its expected monthly average value, so minor deviations are omitted from the signal.

Data were available for 184 countries of the 235 included in the index. Some countries had only 1 climate station (e.g. Albania, Burundi) and the maximum number of stations for any country was 1587 (for USA). The 5 years assessed were 1999-2003, and the reference values for deviations were calculated from the 31 years between 1973-2003 (in future evaluations of the EVI, reference means will be from the last 30 years, not 31). The number of days with excess heat (i.e. those with maximum daily temperatures more than 9˚F above the expected mean) varied between zero (in 12 countries, including Burundi, Guam and Jamaica) and 407 in Leichtenstein, with a global mean of 70 days (standard deviation = 94).

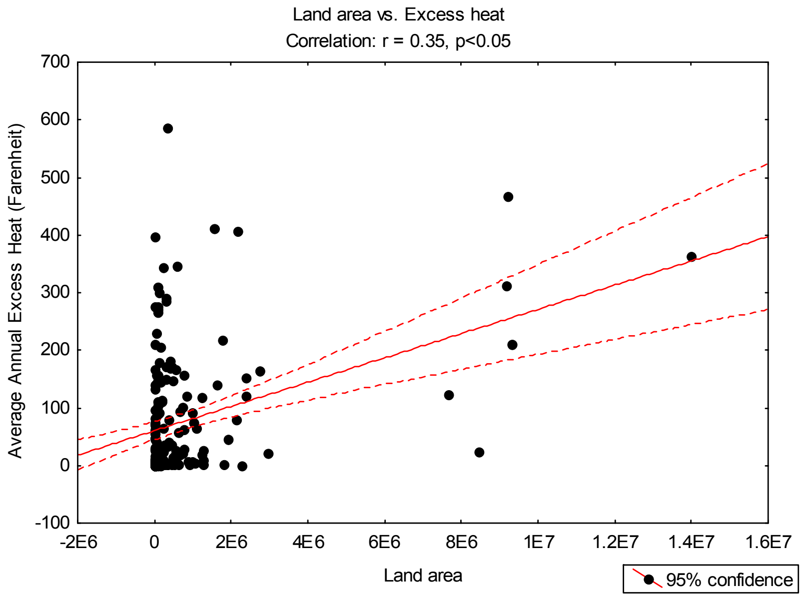
The average annual excess heat over the last 5 years varied between zero (in 12 countries including Barbados, Guam and Jamaica) and 585 (Germany) ˚F per year. The world average (based on 184 countries) was 74 ˚F, with the median value at 20.7 ˚F (Table 4.1). The standard deviation among observations was 107.7 ˚F. The Standard Error (SE) was around 7.9, which is around 10.6% of the mean.

The average annual amount of excess heat recorded in countries correlated significantly with the size of countries, as measured by land area (Figure 4.1).

Table 4.1: Basic statistics for excess heat in 184 countries

Statistic	Excess heat	LN(X+1) transformed data
Mean	74.45	2.98
Median	20.74	3.08
Valid n	184	184
Minimum	0	0
Maximum	585.40	6.37
SD (Standard deviation)	107.67	1.89
SE (Standard error)	7.92	0.14
Skewness	1.97	-0.02
SE Skewness	0.18	0.18
Kurtosis	4.06	-1.35
SE Kurtosis	0.36	0.36

Figure 1.1: Graph of land area versus excess heat in countries.



4.3 Frequency distribution characteristics of the indicator data

The data for excess heat were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 4.2).

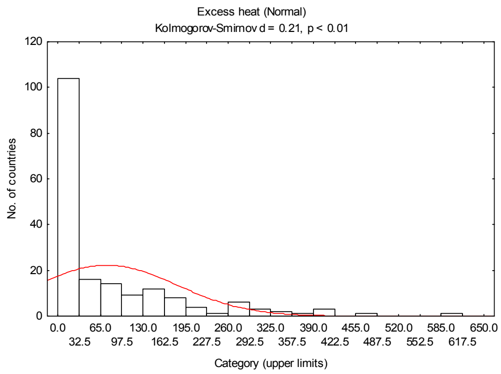
The observed frequency distribution was not a good fit to the normal, rectangular or exponential distributions, with these K-S tests being significant. The K-S tests for the lognormal distribution resulted in a non-significant test, indicating that the data may be better described on a logarithmic scale.

The excess heat data were transformed to their natural logarithms, LN(X+1), and compared with a normal distribution (Figure 4.3). The data transformed to a natural log scale was appear to be bimodally distributed, though the K-S test detected no significant difference from a fitted normal distribution.

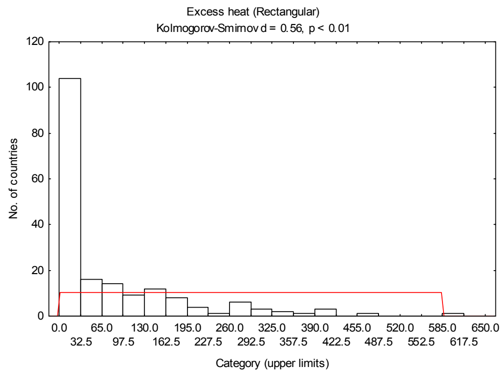
Figure 4.2: Frequency distribution of excess heat in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. The normal, rectangular and exponential distributions were significant, while that for the log normal was not at p=0.05.

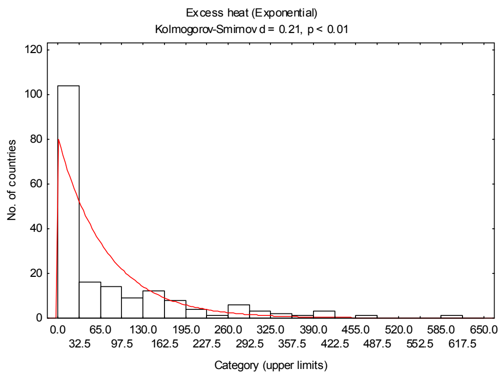
(a)



(b)



(c)



(d)

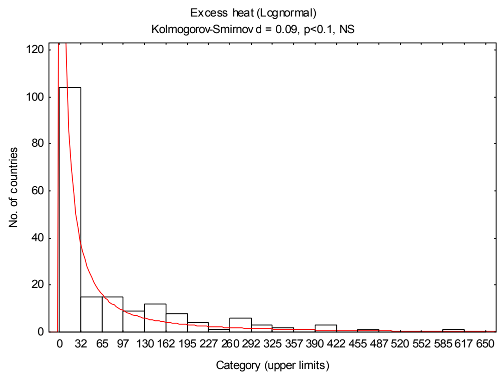
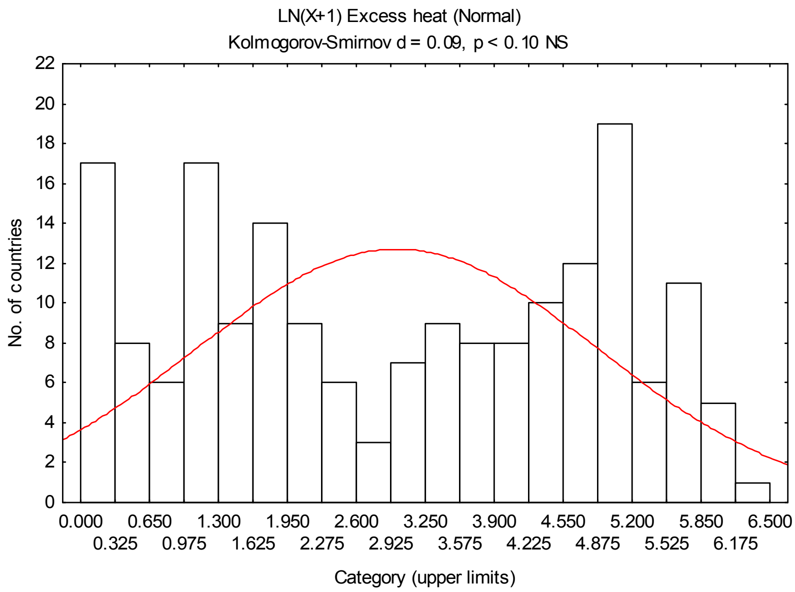


Figure 1.3: Frequency distribution of excess heat data transformed to their natural logarithm (LN(X+1)) spread over 20 categories (bars) and compared with a normal distribution. The transformed data were a good fit to the normal distribution, but appear to be bimodally distributed, with a group centred around a value of about 1.3 and another at around 4.8.



4.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on excess heat be transformed to their natural logarithms LN(X+1). This renders the transformed data more evenly distributed and provides a better spread among countries, differentiating those at the lower end of the scale better, and clearly identifying those with very large excesses of heat (Figure 4.3). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with greater than expected annual heat in countries.

The LN(X+1) transformed data were plotted as a frequency distribution with 7 categories (Figure 4.4). We designated the EVI score 1 to all countries with ≤ 3.5 on the transformed scale (≤ 17.8 ˚C excess heat per year) and scaled the rest at even intervals up to 6 to score EVI=6. Countries with greater than 6 on the transformed scale were scored EVI=7 where the national average excess heat across climate stations was more than 223 ˚C per year over the past 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 4.4. More than 44% of countries fell on this scale at EVI value 1 (Table 4.2).

This scoring does not seek to simply spread countries in terms of their LN(X+1) scores, but focuses on identifying those with substantial risks from sustained or repeated high temperature conditions detectable even across large numbers of climate stations. This indicator would not however, detect individual 'hot spots' within a country if the majority of stations did not experience higher than expected temperatures, as averaging across climate stations would tend to bury these. We consider this a correct signal for the EVI. It identifies countries for which high temperatures would affect most of the country (including cases in which there is only 1 climate station) and for which refuges from effects would therefore tend to be unavailable. This indicator could be applied by station within countries if vulnerabilities within a country became the focus, but this is outside the scope of the EVI being calculated at a national scale here. Examples of countries with the most vulnerability to high temperatures identified using this indicator include Canada, Germany, Mongolia and Greenland (Table 4.3). Whether these countries are naturally prone to high temperatures or not, this indicator highlights that over the past 5 years they have experienced more hot days than expected.

Figure 4.4: Frequency distribution of excess wind in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

(a) (b)

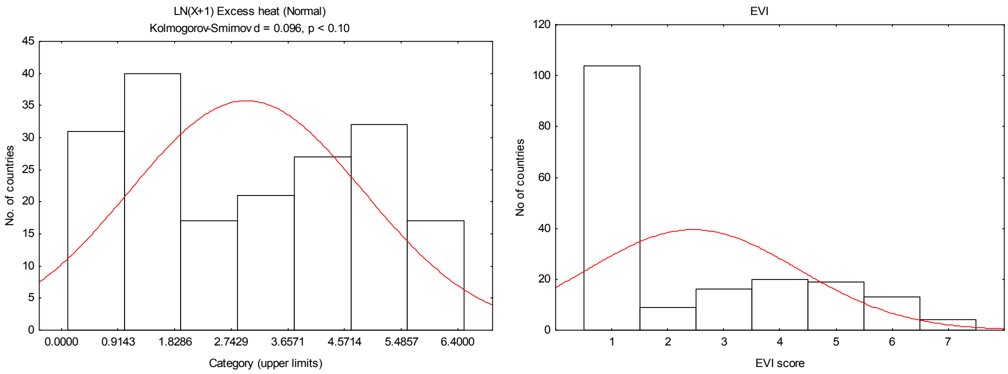


Table 4.2: Proposed EVI scaling for Indicator 1 on excess heat.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values LN(X+1)	Observed # countries	Observed % of countries
1	X ≤ 3.5	104	44.3
2	3.5 < X ≤ 4	9	3.8
3	4 < X ≤ 4.5	16	6.8
4	4.5 < X ≤ 5	20	8.5
5	5 < X ≤ 5.5	19	8.1
6	5.5 < X ≤ 6	13	5.5
7	6 < X	4	1.7
NA	☒ May not be used		
ND	☑ May be used	50	21.3

Table 4.3: Proposed EVI scaling for Indicator 1 showing equivalence on the EVI and LN(X) transformed scales and examples of countries with each score.

EVI Scale	Values LN(X+1) excess heat	Annual Excess heat (˚F)	Annual Excess heat (˚C)	Countries
1	X ≤ 3.5	X ≤ 32.1	X ≤ 17.8	Angola, Bangladesh, Oman
2	3.5 < X ≤ 4	32.1 < X ≤ 53.6	17.8 < X ≤ 29.8	Iraq, Mexico, Samoa
3	4 < X ≤ 4.5	53.6 < X ≤ 89.0	29.8 < X ≤ 49.5	Bahrain, Marshall Is., Malta
4	4.5 < X ≤ 5	89.0 < X ≤ 147.4	49.5 < X ≤ 81.9	Spain, Namibia, Uganda
5	5 < X ≤ 5.5	147.4 < X ≤ 243.7	81.9 < X ≤ 135.4	Belgium, Jordan, Netherlands
6	5.5 < X ≤ 6	243.7 < X ≤ 402.43	135.4 < X ≤ 223.6	Austria, Hungary, Ukraine
7	6 < X	402.43 < X	223.6 < X	Canada, Germany, Mongolia

4.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

4.6 Age, completeness and quality of the data

No data for this indicator were available from in-country sources.

4.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global weather data are generally not available.

4.8 Additional sources & contacts

Cook Islands - Meteorology Office. Nga Rauraa (+682 20603/ 682 21603); Federated States of Micronesia - NOAA/ NCDC – 1999 Local Climate Data/ NCDC. Caesar Hadley. WSO Pohnpei – NWSPR/ NOAA; Fiji - Ashmita Gosai (+679-724888); Greece - Dr Paula Scott (ph&f: +30-81-861219, cariad@her.forthnet.gr); Kiribati - Kirion Kabunateiti. Climate Archive from Kiribati Meteorology Services (KMS); Marshall Islands - NOAA NCDC Ashville. Local Climatological Data (LCD). Lee Z Jacklick; Nauru - Nauru Meteorology Services. Frank W Davey; Nepal - Various issues of Climatological records of Nepal. Soroj Kumar Baidhya (MR) Phone +641 255920; New Zealand - National Institute of Water and Atmospheric Research, New Zealand. Mr A. C Penney. E.Mail: a.penney@niwa.cri.nz ; Niue - Sionetasi Pulehetoa. Meteorology Department Palau - Maria Ngemaes (680 4881034, maria.ngemaes@noaa.gov) Weather Service Office (National Weather Service); Papua New Guinea - Climatic Tables for PNG. McAlphine, J. R.; Keig, G.; and Short, K. PNG National Weather Service; Philippines - Climatological Normals. Ms Panfila E. Gica / Climate Data Section / PAGASA Samoa - Niko Tualevao. Apia Observatory/ Samoa Meteorology; Singapore - Mr Wong Teo Suan ++(65) 5457191 ++(65) 5457192. Meteorological office Singapore; Thailand - Climatology Division Meteorological Department 21 Aug 2001 local_climate@tmdnet.motc.go.th ; Tonga - Ofa Fa'anunu (676 23401/ 24145/ Tongamet@kalianet.to) Climate Archive, Tonga Meteorology Services (TMS); Trinidad & Tobago - Debbie Ramnarine; Tuvalu - Tuvalu Meteorology Services (TMS). Hilia Vavae; Vanuatu - Vanuatu Meteorology Services (VMS). Mr Kaniaha Salesa (678 23866/ 22310/ climate@meteo.vu).

5. COLD PERIODS

5.1 Indicator Summary

Indicator number:	05
Indicator short name:	Cold periods
Sub-index	Hazards
Categorisation	Weather & Climate
Indicator text:	Average annual heat deficit (degrees) over the past 5 years for all days more than 5°C cooler than the 30 year mean monthly minimum, averaged over all reference climate stations.
Signals captured:	Vulnerability to cold snaps, unusual frosts, effects on water resources, temperature stress, pollution attenuation rates, reproductive success. This indicator is designed to capture stress on land surfaces and nearshore or shallow aquatic environments to periods of low temperatures that can affect productivity, oxygen levels, pollution, reproduction and symbiotic relationships and lead to mass mortality. This indicator captures not only the number of days with significantly lower temperatures, but also the amount of the "heat deficit". Two countries could have the same number of days with more than 5ºC lower temperatures than the monthly average, with one only having a small deficit, while another a very large one. Frequent and severe cold days could also indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. ability of lakes and rivers to attenuate pollutants).
Notes on this indicator:	• Raw values were supplied in Farenheit, so calculations have been made in those units, with the threshold at 9F used for measuring deviations. • Raw values of summed deviations were adjusted for each individual climate station to account for missing days of data. This was done by multiplying the summed deviations across days with more than 5˚C (9˚F) lower daily minimum temperature, by the total number of days in the 5 year period (1826 days) and dividing by the number of days for which that station had data (many stations have missing days) = [(Σ Deviations * 1826) / days with data]. The adjustment was done to ensure stations with fewer days of data were comparable with those which had more. • In its original form, this indicator called for data on the number of days with >5C lower daily minimum temperatures over the 30-year monthly mean. We adjusted the indicator to sum all the deviations above the threshold so that countries with only slight excess could be distinguished from those with large ones.
Are suitable data available?	Yes
Sources of data:	• NOAA DATSAV3 Surface SOD 1973-2003. National Climatic Data Centre, 151 Patton Avenue, Asheville, NC 28801-5001
No. countries included in test:	185 of 235
Temporary modifications to data or indicator, if applicable:	• The 30 year means against which deviations were calculated and summed were extracted from the same datasets. The means were actually calculated over 31 years of data between the years 1973-2003. In future evaluations a 30 year mean will be used.

Notes on data age, completeness and quality:	No in-country data were available for this indicator	
Basic units:	Values are total degrees (Farenheit) of heat deficit per year. These are as annual averages over the past 5 years of summed deviations of daily minimum temperatures that are more than 9F lower than the 30 year by month, mean daily minimum temperatures, calculated for each climate station in a country and then averaged over all climate stations.	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale	EVI Score = 1	$X \leq 3.5$
	EVI Score = 2	$3.5 < X \leq 4$
	EVI Score = 3	$4 < X \leq 4.5$
	EVI Score = 4	$4.5 < X \leq 5$
	EVI Score = 5	$5 < X \leq 5.5$
	EVI Score = 6	$5.5 < X \leq 6$
	EVI Score = 7	$6 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	• Permanent mechanisms for easily procuring world weather data and extracting the relevant information for re-evaluations of this indicator are needed.	

5.2 Description of raw data

The data for this indicator comprise the deviations from expected daily minimum temperatures over the past 5 years, based on 30 year averages and calculated separately and then averaged for climate station. Values are only included if the minimum temperature for any day for a station was more than 9˚F lower than its expected monthly average value, so minor deviations are omitted from the signal.

Data were available for 185 countries of the 235 included in the index. Some countries had only 1 climate station (e.g. Albania, Burundi) and the maximum number of stations for any country was 1587 (for USA). The 5 years assessed were 1999-2003, and the reference values for deviations were calculated from the 31 years between 1973-2003 (in future evaluations of the EVI, reference means will be from the last 30 years, not 31). The number of cool days (i.e. those with minimum daily temperatures more than 9˚F below the expected mean) varied between zero (in 10 countries, including Barbados, Guam, Singapore) and 219 in USA, with a global mean of 38 days (standard deviation = 49.5).

The average annual heat deficit over the last 5 years varied between zero (in 10 countries) and 431 (Finland) ˚F per year. The world average (based on 185 countries) was 49.43 ˚F, with the median value at17.55 ˚F (Table 5.1). The standard deviation among observations was 75.65 ˚F. The Standard Error (SE) was around 5.56, which is around 11% of the mean.

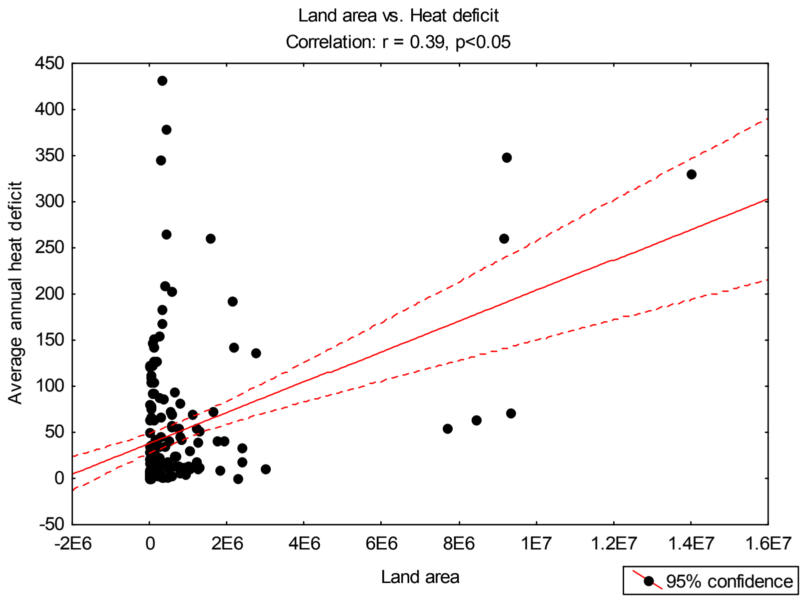
The average annual heat deficit recorded in countries correlated significantly with the size of countries, as measured by land area (Figure 5.1).

Table 5.1: Basic statistics for heat deficit in 184 countries

Statistic	Heat deficit	LN(X+1) transformed data
Mean	49.43	2.93
Median	17.55	2.92
Valid n	185	185

Minimum	0	0
Maximum	431.87	6.07
SD (Standard deviation)	75.65	1.52
SE (Standard error)	5.56	0.11
Skewness	2.67	-0.07
SE Skewness	0.18	0.18
Kurtosis	7.97	-0.78
SE Kurtosis	0.36	0.36

Figure 5.1: Graph of land area versus heat deficit in countries.



5.3 Frequency distribution characteristics of the indicator data

The data for heat deficit were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 5.2).

The observed frequency distribution was not a good fit to the normal, rectangular or exponential distributions, with these K-S tests being significant. The K-S tests for the lognormal distribution resulted in a non-significant test, indicating that the data may be better described on a logarithmic scale.

The excess heat data were transformed to their natural logarithms, LN(X+1), and compared with a normal distribution (Figure 5.3).

Figure 5.2: Frequency distribution of excess heat in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. The normal, rectangular and exponential distributions were significant, while that for the log normal was not at p=0.05.

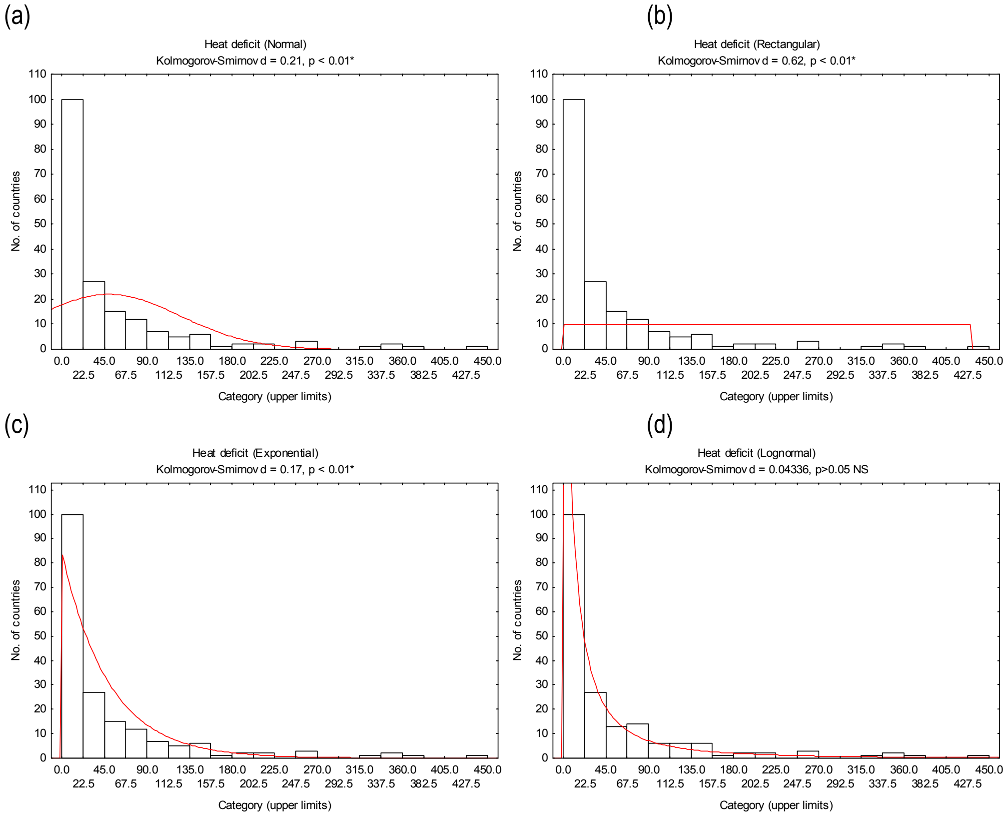
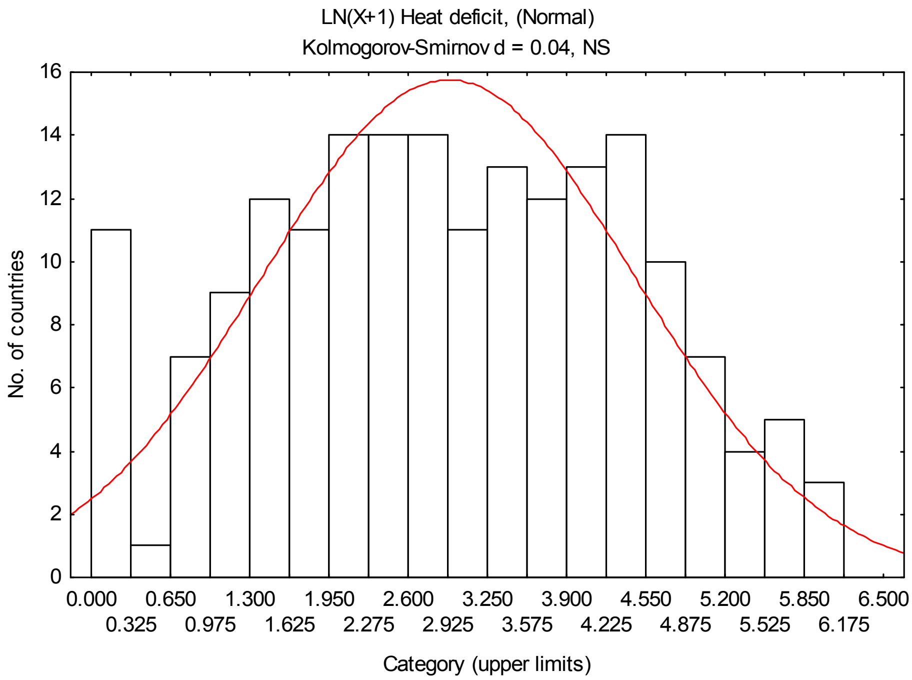


Figure 1.3: Frequency distribution of excess heat data transformed to their natural logarithm (LN(X+1)) spread over 20 categories (bars) and compared with a normal distribution. The transformed data were a good fit to the normal distribution, but appear to be mildly bimodally distributed.



5.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on heat deficit be transformed to their natural logarithms LN(X+1). This renders the transformed data more evenly distributed and provides a better spread among countries, differentiating those at the lower end of the scale better, and clearly identifying those with very large excesses of heat (Figure 5.3). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with greater than expected annual heat in countries.

The LN(X+1) transformed data were plotted as a frequency distribution with 7 categories (Figure 5.4). We designated the EVI score 1 to all countries with ≤ 3.5 on the transformed scale (≤ 17.8 ˚C heat deficit per year) and scaled the rest at even intervals up to 6 to score EVI=6. Countries with greater than 6 on the transformed scale were scored EVI=7 where the national average heat deficit across climate stations was more than 223 ˚C per year over the past 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 5.4. More than 48.5% of countries fell on this scale at EVI value 1 (Table 5.2).

This scoring does not seek to simply spread countries in terms of their LN(X+1) scores, but focuses on identifying those with substantial risks from sustained or repeated low temperature conditions detectable even across large numbers of climate stations. This indicator would not however, detect individual 'cold spots' within a country if the majority of stations did not experience lower than expected temperatures, as averaging across climate stations would tend to bury these. We consider this a correct signal for the EVI. It identifies countries for which low temperatures would affect most of the country (including cases in which there is only 1 climate station) and for which refuges from effects would therefore tend to be unavailable. This indicator could be applied by station within countries if vulnerabilities within a country became the focus, but this is outside the scope of the EVI being calculated at a national scale here. Only one country, Finland, scored EVI=7 for this indicator. Canada, Ecuador and Sweden scored EVI=6 (Table 5.3). Whether these countries are naturally prone to low temperatures or not, this indicator highlights that over the past 5 years they have experienced more cold days than expected.

Figure 5.4: Frequency distribution of excess wind in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

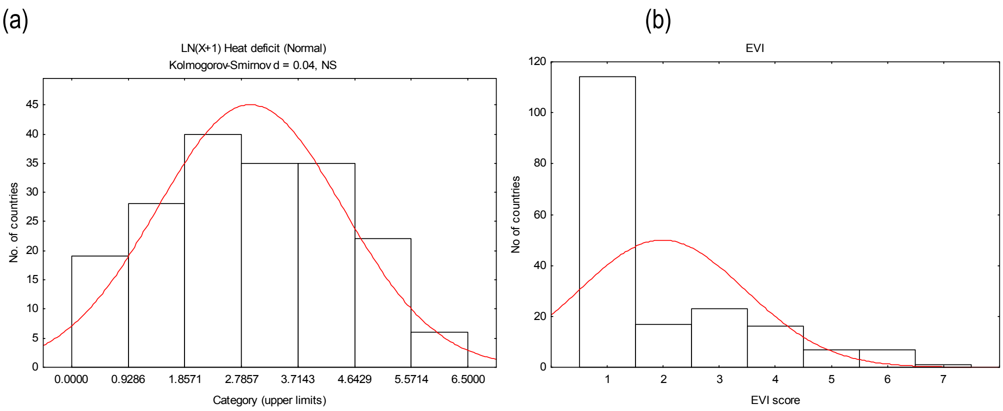


Table 4.2: Proposed EVI scaling for Indicator 1 on excess heat.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values LN(X+1)	Observed # countries	Observed % of countries
1	X ≤ 3.5	114	48.5
2	3.5 < X ≤ 4	17	7.2
3	4 < X ≤ 4.5	23	9.8
4	4.5 < X ≤ 5	16	6.8
5	5 < X ≤ 5.5	7	2.98
6	5.5 < X ≤ 6	7	2.98
7	6 < X	1	0.43
NA	☒ May not be used		
ND	☑ May be used	50	21.3

Table 4.3: Proposed EVI scaling for Indicator 1 showing equivalence on the EVI and LN(X) transformed scales and examples of countries with each score.

EVI Scale	Values LN(X+1) excess heat	Annual Excess heat (˚F)	Annual Excess heat (˚C)	Countries
1	X ≤ 3.5	X ≤ 32.1	X ≤ 17.8	Bahama, Costa Rica, Fiji
2	3.5 < X ≤ 4	32.1 < X ≤ 53.6	17.8 < X ≤ 29.8	Greece, Mexico, Syria
3	4 < X ≤ 4.5	53.6 < X ≤ 89.0	29.8 < X ≤ 49.5	Australia, Denmark, Italy
4	4.5 < X ≤ 5	89.0 < X ≤ 147.4	49.5 < X ≤ 81.9	Croatia, Icealand, New Caledonia
5	5 < X ≤ 5.5	147.4 < X ≤ 243.7	81.9 < X ≤ 135.4	Hungary, Poland, Saudi Arabia
6	5.5 < X ≤ 6	243.7 < X ≤ 402.43	135.4 < X ≤ 223.6	Canada, Ecuador, Sweden
7	6 < X	402.43 < X	223.6 < X	Finland

5.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

5.6 Age, completeness and quality of the data

No data for this indicator were available from in-country sources.

5.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global weather data are generally not available.

5.8 Additional sources & contacts

Cook Islands - Meteorology Office. Nga Rauraa (+682 20603/ 682 21603); Federated States of Micronesia - NOAA/ NCDC – 1999 Local Climate Data/ NCDC. Caesar Hadley. WSO Pohnpei – NWSPR/ NOAA; Fiji - Ashmita Gosai (+679-724888); Greece - Dr Paula Scott (ph&f: +30-81-861219, cariad@her.forthnet.gr); Kiribati - Kirion Kabunateiti. Climate Archive from Kiribati Meteorology Services (KMS); Marshall Islands - NOAA NCDC Ashville. Local Climatological Data (LCD). Lee Z Jacklick; Nauru - Nauru Meteorology Services. Frank W Davey; Nepal - Various issues of Climatological records of Nepal. Soroj Kumar Baidhya (MR) Phone +641 255920; New Zealand - National Institute of Water and Atmospheric Research, New Zealand. Mr A. C Penney. E.Mail: a.penney@niwa.cri.nz ; Niue - Sionetasi Pulehetoa. Meteorology Department

Palau - Maria Ngemaes (680 4881034, maria.ngemaes@noaa.gov) Weather Service Office (National Weather Service); Papua New Guinea - Climatic Tables for PNG. McAlphine, J. R.; Keig, G.; and Short, K. PNG National Weather Service; Philippines - Climatological Normals. Ms Panfila E. Gica / Climate Data Section / PAGASA Samoa - Niko Tualevao. Apia Observatory/ Samoa Meteorology; Singapore - Mr Wong Teo Suan ++(65) 5457191 ++(65) 5457192. Meteorological office Singapore; Thailand - Climatology Division Meteorological Department 21 Aug 2001 local_climate@tmdnet.motc.go.th ; Tonga - Ofa Fa'anunu (676 23401/ 24145/ Tongamet@kalianet.to) Climate Archive, Tonga Meteorology Services (TMS); Trinidad & Tobago - Debbie Ramnarine; Tuvalu - Tuvalu Meteorology Services (TMS). Hilia Vavae; Vanuatu - Vanuatu Meteorology Services (VMS). Mr Kaniaha Salesa (678 23866/ 22310/ climate@meteo.vu).

6. SEA TEMPERATURES

6.1 Indicator Summary

Indicator number:	06	
Indicator short name:	Sea surface temperatures	
Sub-index	REI (Hazards)	
Categorisation	Weather & Climate	
Indicator text:	Average annual deviation in Sea Surface Temperatures (SST) in the last 5 years in relation to the 30 year monthly means (1961-1990)	
Signals captured:	This indicator captures vulnerability to fluctuations in productivity, fisheries, currents, eddies, ENSO, cyclones & storms, blooms and coral bleaching. The indicator captures the total amount of the anomalies in SST, either as excess or deficit (using absolute values). Frequent and severe deviations from the 30 year moving average could herald shifts in currents, upwelling, weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. for water movements, the spread of and ability of ecosystems to attenuate pollution). Effects would be especially important when other stresses have already driven populations to low levels.	
Notes on this indicator:	1. Where countries had data for two or more regions or seas, we calculated average anomalies separately and then averaged them across seas (e.g. Japan, Germany, USA, Turkey) 2. This indicator was considered generally not applicable (NA) to land-locked countries 3. Three countries considered land-locked by UNCTAD and Wikipedia (Azerbaijan, Kazakhstan and Turkmenistan) had data from their associated seas. The available data were used, so an EVI score is available for those countries.	
Are suitable data available?	Yes	
Sources of data:	1. Climatic Research Unit, University of East Anglia, Norwich, UK. http://www.cru.uea.ac.uk/cru/data/temperature/#datdow 2. Data masked and extracted for EEZs by University of British Columbia	
No. countries included in test:	193 (excludes most land-locked countries)	
Temporary modifications to data or indicator, if applicable:	None	
Notes on data age, completeness and quality:	Data from in-country sources were not available	
Basic units:	Absolute values of temperature anomalies in relation to the 30 year monthly (1961-1990) averages in degrees C	
Recommended transforms:	None	
Proposed EVI Scale	EVI Score = 1	$X \leq 0.5$
	EVI Score = 2	$0.5 < X \leq 0.75$
	EVI Score = 3	$0.75 < X \leq 1.0$
	EVI Score = 4	$1.0 < X \leq 1.25$
	EVI Score = 5	$1.25 < X \leq 1.5$
	EVI Score = 6	$1.5 < X \leq 1.75$
	EVI Score = 7	$1.75 < X$
	NA (not applicable)	☑ May be used
	ND (no data)	☑ May be used

Future work on this indicator:	

6.2 Description of raw data

The data for this indicator comprise the average annual deviations from 30 year monthly means of sea surface temperatures (SST) in the waters surrounding a country (EEZ and inland seas). The absolute values of anomalies were summed across the last 5 years for each month and annualised. For some countries data were available separately for different regions of seas (e.g. USA had separate data for mainland, Alaska and Hawaii). Anomalies were calculated separately for the seas, and the overall anomalies averaged across them.

Data were available for 193 countries of the 235 included in the index. Forty-two of these are land-locked (UNCTAD) for which the indicator would not normally be considered applicable, but 3 of them (Azerbaijan, Kazakhstan and Turkmenistan) have data for SST of inland seas (Caspian Sea). The 5 years assessed were from December 1998 to November 2003, with the 30 year means calculated over the period 1961-1990. Because anomalies are assessed against a moving 30 year mean, large values will herald either very variable SSTs, or changing conditions (related to long term shifts or climate change), or both.

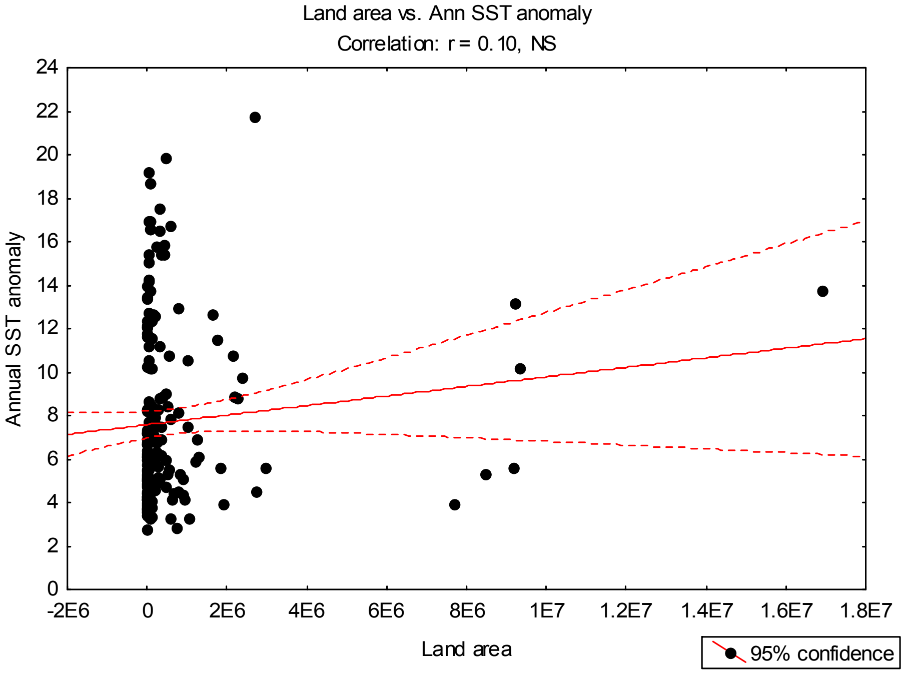
The lowest value of average annual SST anomaly was found in Marshall Islands (1.1º/year), and the highest in Kazakhstan (9.0º/yr), with a global average of 3.2º/yr (Table 6.1). The world median value was 2.6º/yr. The standard error is 0.12, which is around 3% of the mean.

The size of the average annual SST anomaly did not correlate with the size of countries, as measured by land area (Figure 6.1), so no correction was applied for country size.

Table 6.1: Basic statistics for SST anomalies.

Statistic	Average annual SST anomaly	LN(X)
Mean	7.71	1.92
Median	6.17	1.82
Valid n	193	193
Minimum	2.75	1.01
Maximum	21.75	3.08
SD (Standard deviation)	4.12	0.49
SE (Standard error)	0.30	0.04
Skewness	1.17	0.43
SE Skewness	0.17	0.17
Kurtosis	0.59	-0.81
SE Kurtosis	0.35	0.35

Figure 6.1: Graph of land area versus SST anomalies around countries.



6.3 Frequency distribution characteristics of the indicator data

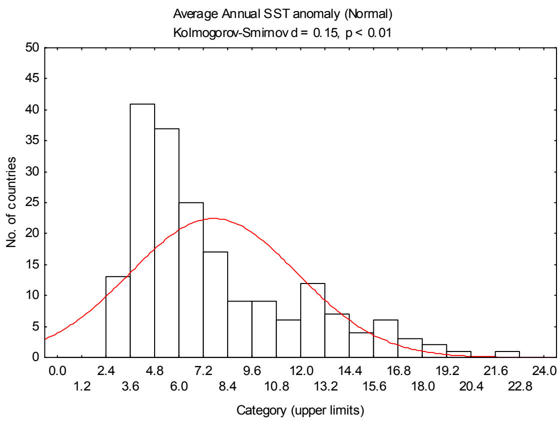
The data for average annual SST anomalies were plotted as frequency distributions in 20 categories to identify any underlying distributions. Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function). The test for fit used was the Kolmogorov-Smirnov test (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit (Figure 6.2).

The observed frequency distribution was not a good fit to the normal, rectangular or exponential distributions, with all of these K-S tests being significant at p=0.05. The K-S test for the lognormal distribution was non-significant, indicating that a functions of this form might be a reasonable fits to the observed data. The average annual SST anomalies were therefore transformed to their natural logarithms, LN(x), and compared with a normal distribution (Figure 6.3). The LN(X) transformed data fit well with a normal distribution.

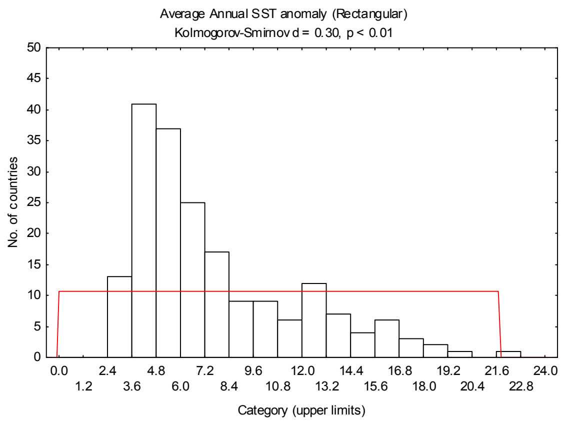
Figure 6.2: Frequency distribution of average annual SST anomalies in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. The normal, rectangular and exponential distributions differed significantly from the observed data, while that for the lognormal distribution was not significantly different from the observed data at p=0.05.

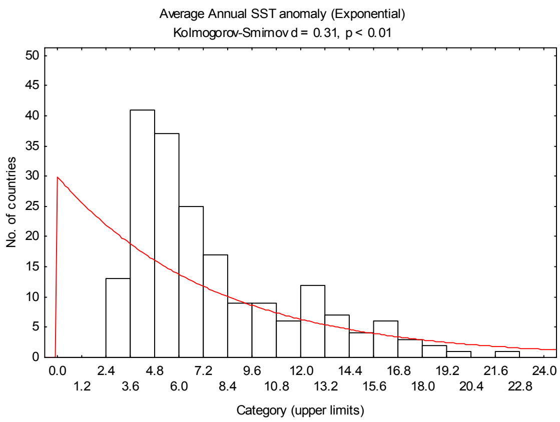
(a)



(b)



(c)



(d)

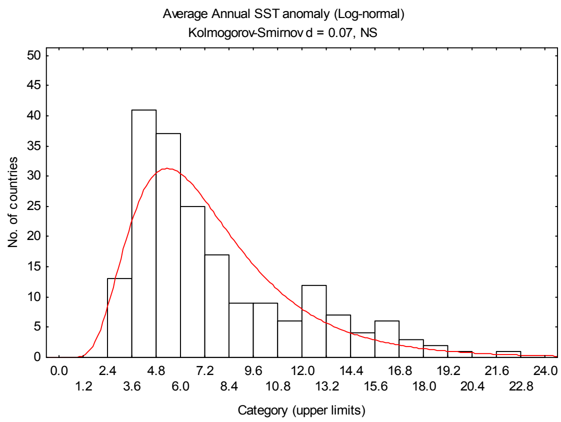
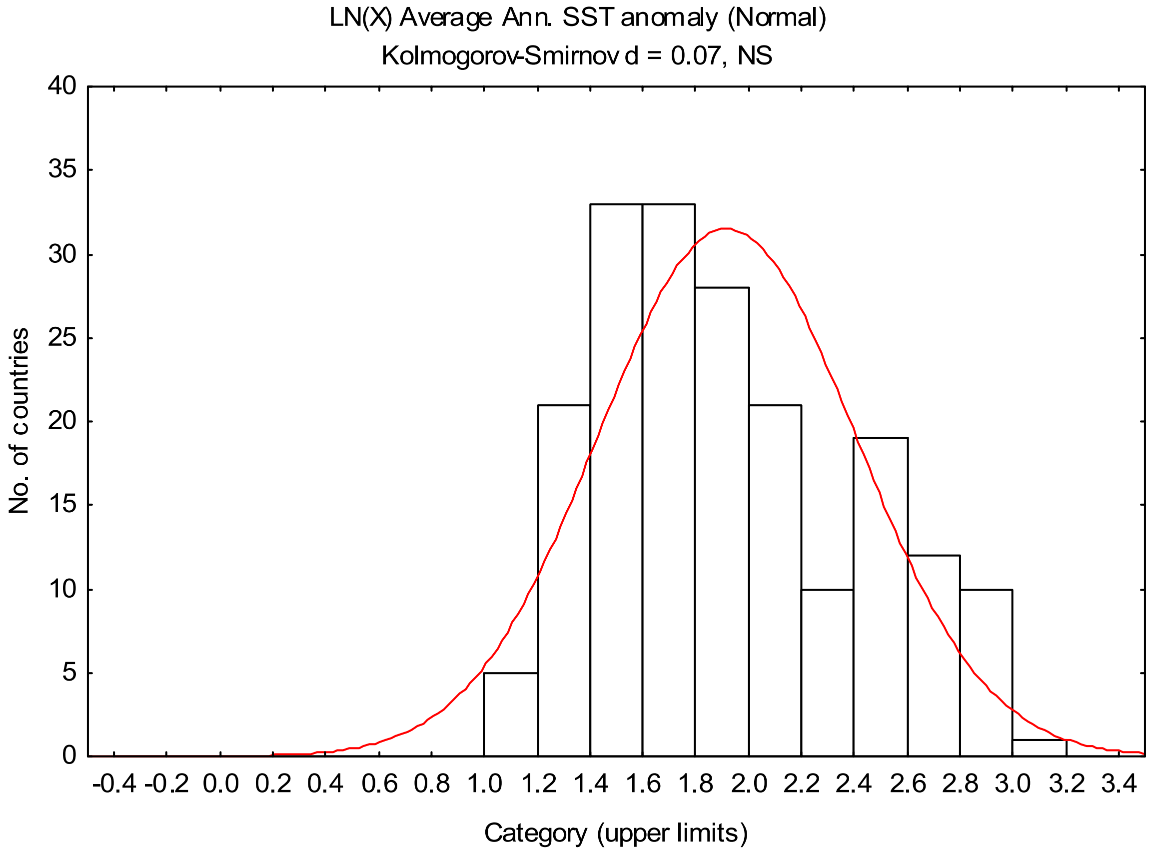


Figure 6.3: Frequency distribution of average annual SST anomalies transformed to their natural logarithm LN(X), spread over 20 categories (bars) and compared with a normal distribution.



6.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the data on average annual SST anomalies be transformed to LN(X) to provide data that are normally distributed, a better spread among countries, and able to clearly identify those with a very large anomalies (Figure 6.3). We consider this scale to be an appropriate one for identifying and indicating the stresses associated with large deviations in sea surface temperature in the waters surrounding a country.

The LN(X) transformed data were plotted as a frequency distribution with 7 categories (Figure 6.4). We designated the EVI score 1 to all countries with $\leq$ 0.5 on the transformed scale (1.6°/yr) and scaled the rest at even intervals up to 1.75 (5.8°/yr) to score EVI 7. The distribution of countries plotted on the proposed EVI scale is shown in Figure 6.4 b.

Around 10% of countries fell on this scale at EVI value 1, with a more-or-less even distribution scoring EVI=2-4. 20% of countries scored EVI=7 (Table 6.2). This scoring does not seek to spread countries simply in terms of their LN(X) scores, but focuses on identifying those with substantial risks from sustained or repeated changes in SST over the 5 year period in relation to monthly values calculated over 30 years. Examples of countries with the most vulnerability to fluctuations in SST identified using this indicator include Iraq, Lithuania and Georgia (Table 6.3).

Figure 6.4: Frequency distribution of average annual SST anomalies in countries in seven categories for (a) 7 evenly-spaced intervals, and (b) the proposed EVI scale.

(a) (b)

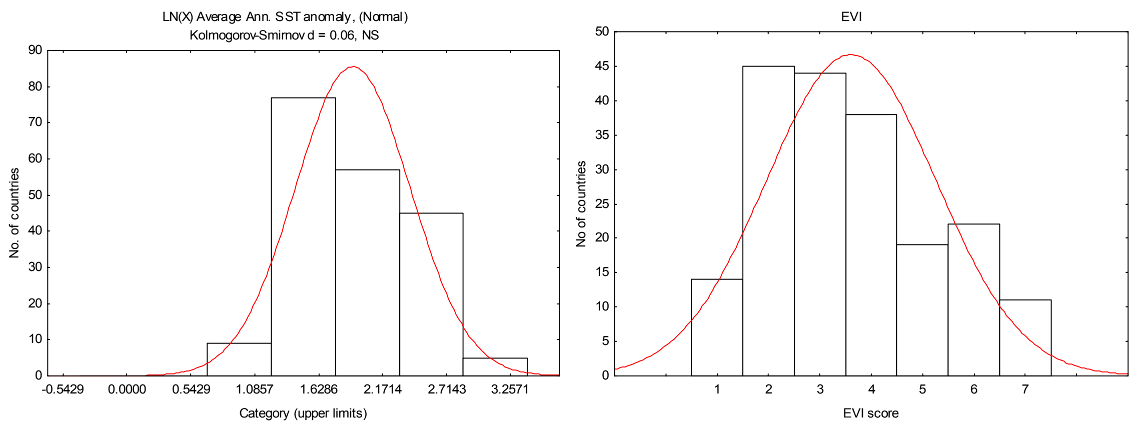


Table 6.2: Proposed EVI scaling for Indicator 6 on SST anomalies with number of observed countries.

NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Values LN(X)	Observed # countries	Observed % of countries
1	X ≤ 1.3	14	7.25
2	1.3 < X ≤ 1.6	45	23.32
3	1.6 < X ≤ 1.9	44	22.80
4	1.9 < X ≤ 2.2	38	19.69
5	2.2 < X ≤ 2.5	19	9.84
6	2.5 < X ≤ 2.8	22	11.40
7	2.8 < X	11	5.70
	Missing (NA or ND)	42	21.76
NA	☑ May be used		
ND	☑ May be used		

Table 6.3: Proposed EVI scaling for Indicator 6 showing equivalence on the EVI, LN(X) and raw SST anomaly scales and examples of countries with each score.

EVI Scale	Values LN(X)	Values Average annual anomaly	Countries
1	X ≤ 1.3	X≤3.67	
2	1.3 < X ≤ 1.6	3.67<X≤4.95	
3	1.6 < X ≤ 1.9	4.95<X≤6.69	
4	1.9 < X ≤ 2.2	6.69<X≤9.03	
5	2.2 < X ≤ 2.5	9.03<X≤12.18	
6	2.5 < X ≤ 2.8	12.18<X≤16.44	
7	2.8 < X	16.44<X	

6.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

6.6 Age, completeness and quality of the data

No data were available from in-country sources.

6.7 Variations among sources of data

Data from other sources, including in-country, were not available for this indicator.

6.8 Additional sources & contacts

www.pmel.noaa.gov/pmel (Papua New Guinea); www.seafdec.org/inform/survey.htm (24/05/01) (Thailand); www.start.or.th/got/data/dblink.html (21/05/01); Fiji - Simon McGree. Fiji Meteorological Service; Kiribati - Smith & Reynolds 1998 (61-90); Nauru - Climate Change Response. Nauru's National Committee on Climate Change & SOPAC's Energy Unit. 1999; New Zealand - M.J Uddstrom and N.A. Oien, 1999, On the use of high resolution satellite data to describe the spatial and temporal variability of SSTS's in the New Zealand Region, JGR, 104 (cq) 20729 – 20751; Palau - Coral Reef Research Foundation; Philippines - Monthly mean and annual climatic Data Dry Bulb temperature. Data collected by Panfila. Gica. Climate Data Section/ Philippine Atmospheric, Geophysical and Astronomical Services Administration; Trinidad & Tobago - Della Harripaul.

7. VOLCANOES

7.1 Indicator Summary

Indicator number:	07
Indicator short name:	Volcanoes
Sub-index	REI (Hazards)
Categorisation	Geology
Indicator text:	Cumulative volcano risk (CumVEI) as the weighted number of volcanoes with the potential for eruption greater than or equal to a Volcanic Explosively Index (VEI) of 2 within 100km of the country land boundary, divided by the area of land.
Signals captured:	Vulnerability to Eruptions, landslides, geysers, gas (e.g. SO_2 and CO_2), fires, ash, dust, marine kills, biodiversity of habitat & species, potential for repeated and long term habitat disturbance. This indicator captures the risk of damage to ecosystems from the physical, chemical and biological disturbances associated with volcanic eruptions. Because the risk associated with volcanoes varies according to size and type, the signal incorporates the number of volcanoes capable of affecting a country, and its potential for damage.
Notes on this indicator:	1. The indicator is calculated as CumVEI = (VEI2*2) + (VEI3*3) + (VEI4*4) + (VEI5*5) + (VEI6*6) + (VEI7*7) + (VEI8*8) 2. This indicator is focused on disturbance. At Think Tank I, it was determined that a country that has volcanoes with a high VEI is susceptible to having large areas damaged by explosive eruptions, which though may not be common, can have geographically far-reaching effects for long periods of time. 3. At Think Tank II, the modified to include all volcanoes of VEI 2+. Volcanoes that erupt periodically and smoke over a long period of time may be just as destructive to the environment as the largest cataclysmic eruptions. Total number of live volcanoes (TNLV) or cumulative VEI may be better indicators for the EVI. 4. The concept of VEI has been criticised because it is largely based on the observed behaviour of a volcano during witnessed eruptions and is keyed-in to the effects of eruptions on humans. For the purposes of the EVI, we are more interested in effects on the environment as life-support to humans.
Are suitable data available?	Yes
Sources of data:	NOAA / NESDIS / National Geophysical Data Centre / World Data Centre-A / Colorado USA; In-country
No. countries included in test:	236
Temporary modifications to data or indicator, if applicable:	
Notes on data age, completeness and quality:	1. Where multiple values for these measures were reported, these were reduced to the lowest given value for use in the analysis. That is, if 2 and 3 were returned for a measure, the value 2 was used in the analysis. If no value was given by a country, the datum was excluded.

	2. Data from countries sometimes conflicted with NOAA information. For this test, NOAA data were used. Data conflicts were found in Kiribati, New Zealand, Philippines, PNG and Vanuatu.	
Basic units:	Volcano Explosively Index (VEI) is a 0-8 scale based on observations (e.g. description, plume height, volume, classification, and frequency of eruptions). Volcanic activity of this scale has the potential to cause significant changes in the environment, loss of ecosystems and biodiversity. Reference for the VEI scale can be found at website: http://volcano.und.nodak.edu/vwdocs/eruption_scale.html.	
Recommended transforms:	None	
Proposed EVI Scale LN(X+1) scale	EVI Score = 1	$X \leq 2$
	EVI Score = 2	$2 < X \leq 3$
	EVI Score = 3	$3 < X \leq 4$
	EVI Score = 4	$4 < X \leq 5$
	EVI Score = 5	$5 < X \leq 6$
	EVI Score = 6	$6 < X \leq 7$
	EVI Score = 7	$7 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

7.2 Description of the raw data

We tested six forms of this indicator in a bid to capture the level of vulnerability of a country's environment to volcanic damage. Tests were made on (i) a measure of the number of volcanoes with a Volcano Explosively Index (VEI) of 4 or greater (VEI $\geq$ 4); (ii) VEI $\geq$ 3; (iii) Cumulative VEI (CumVEI) calculated by multiplying all volcanoes in a country by their VEI score and adding these figures to give a weighted measure of the total volcano explosivity in the country; (iv) total number of live volcanoes (TNLV) in the country (as a simple measure that does not include the destructiveness of each volcano within the signal); (v) TNLV per 1,000 sq km land; and (vi) VEI $\geq$ 4 volcanoes per 1,000,000 sq km land. It was decided that even small volcanoes can present an environmental risk, so all volcanoes present in a country with a VEI of at least 2 were included in the final indicator, which is a weighted cumulative VEI score that takes the size and destructiveness of a volcano into account by weighting for larger volcanoes as follows:

CumVEI = (VEI 2*2)+(VEI 3*3)+(VEI 4*4)+(VEI 5*5)+(VEI 6*6)+(VEI 7*7)+(VEI 8*8)

The VEI scale varies between 0 and 8 and is based on characteristics of plume height, volume, classification and frequency of eruptions. A full description with examples is given in http://volcano.und.nodak.edu/vwdocs/eruption_scale.html. According to NOAA, the world's 3,644 active volcanoes can be classified in terms of VEI as shown below. A total of 3,002 volcanoes worldwide are rated at VEI 2 or higher. There are no VEI 8 volcanoes recorded, and only a single VEI 7 volcano located in Indonesia.

VEI 0	VEI 1	VEI 2	VEI 3	VEI 4	VEI 5	VEI 6	VEI 7	VEI 8
250	392	2213	598	160	20	10	1	0

The cumulative VEI scores for countries varied between 0 and 1744, with a mean of 29.90 per country $\pm$ SD of 156.89.

Table 7.1: Basic statistics for the volcano measures across the 235 countries examined.

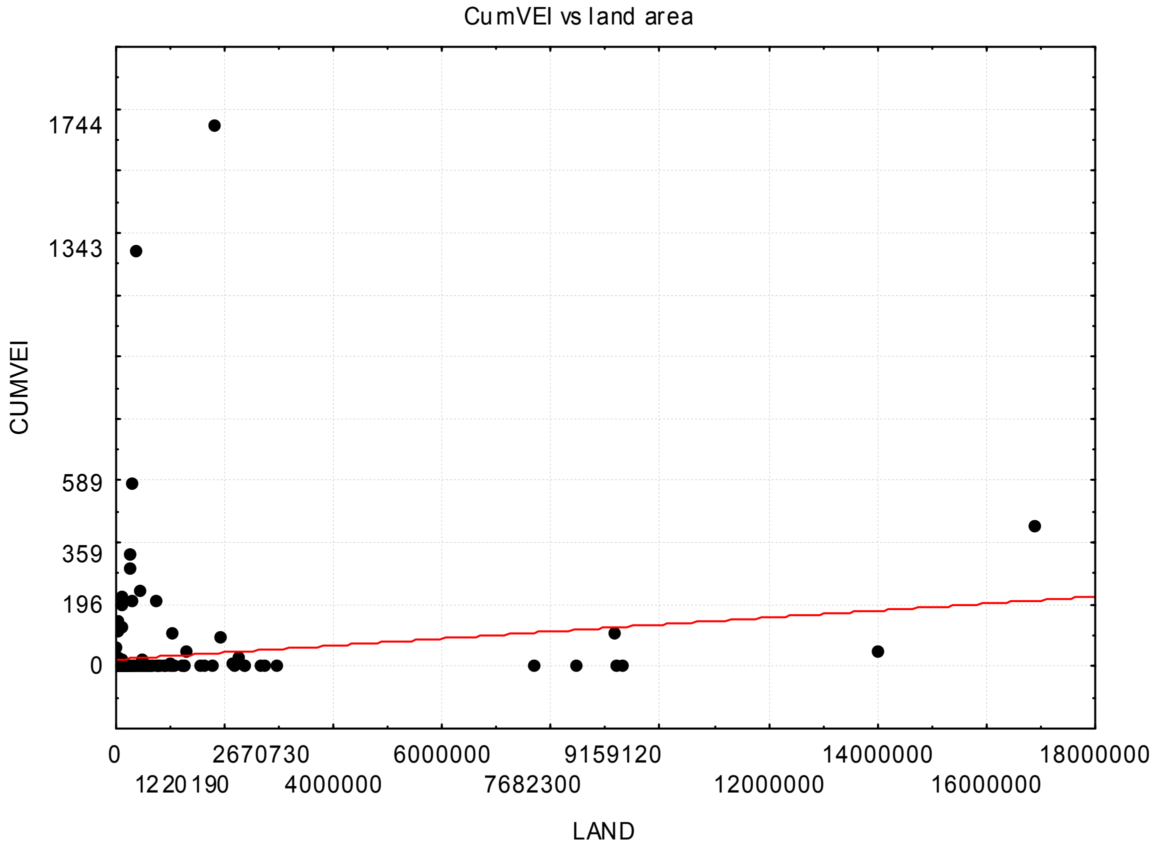
Statistic	CumVEI≥2 (all countries)	CumVEI≥2 (countries with VEI2+volcanoes)	CumVEI/Million km^2 (all countries)	CumVEI/million km2 (countries with VEI2+volcanoes)
Mean	29.90	200.77	667.02	4478.54
Median	0	96.00	0	541.01
Valid n	235	35	235	35
Minimum	0	2	0	0.21
Maximum	1744	1744	80,779	80,780
SD (Standard deviation)	156.89	366.19	5,726	14,427
SE (Standard error)	10.23	61.90	373.56	2,439
Skewness	8.53	3.26	12.55	4.82
SE Skewness	0.16	0.40	0.16	0.40
Kurtosis	82.06	11.20	168.95	24.66
SE Kurtosis	0.32	0.78	0.32	0.78

7.3 Correlations with size of country

The correlation between CumVEI 2+ and land area shows that the number and type of volcanoes found weakly correlates with the size of a country. Stated simply, larger countries tend to have more volcanoes. These results (Figure 7.1) and other tests on total number of volcanoes also show that if there are few volcanoes in a country, there are unlikely to be many highly-destructive ones as indicated by the VEI scale. Conversely, if there are many volcanoes in a country, there is a good chance that at least some of them will be very destructive. This result is not surprising, and suggests that the simpler measure of number of live volcanoes in a country, regardless of potential for destruction, might be enough to capture risk for the purposes of the EVI. Further, the use of number of live volcanoes (rather than VEI-related measures) moves us away from the idea that explosive volcanoes are the only ones of concern from an environmental perspective. The long term emissions of SO_2, CO_2 and other gases, and the habitat destruction related to lava and ash in gentle shield volcanoes could be just as damaging to the environment as volcanoes with high VEI scores.

Figure 7.1: Graph of land area versus CumVEI 2+.

The correlation coefficient is significant at r=0.14 ($p<0.05$).



CumVEI 2+ was expressed as a density per million km2 of land area. When this measure was correlated with land area, the correlation disappeared. The mean CumVEI 2+ / million km2 of land 667 ± SD of 5,726, and reaches a maximum of 80,779 (or as high as 0.8 VEI=2-equivalent volcanoes per square km).

7.4 Frequency distribution characteristics of the indicator data

Density of CumVEI 2+ volcanoes across the globe was plotted as frequency distributions in 20 categories to identify any underlying distributional patterns (Figure 7.2). Each distribution was examined against normal (there is some world-wide average that individual countries deviate from), rectangular (there are about the same number in each category), exponential (power function) and lognormal (logarithmic function) for fit using Kolmogorov-Smirnov tests (K-S) to test the null-hypothesis of no difference between the observed distribution (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

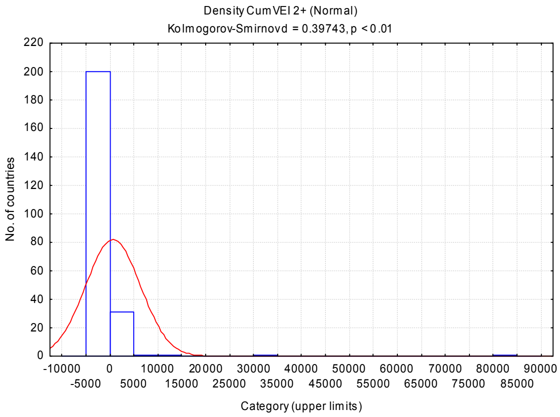
The expected normal, rectangular, and lognormal distributions were significantly different form the observed values, indicating that the fit was not good (and that these types of distributions did not explain the data well). The exponential distribution was found to be the best fit using 20 categories.

The data were transformed to an LN(X+1) scale to provide a better spread among countries (Figure 7.3). The transformed data were not a good fit to the normal distribution.

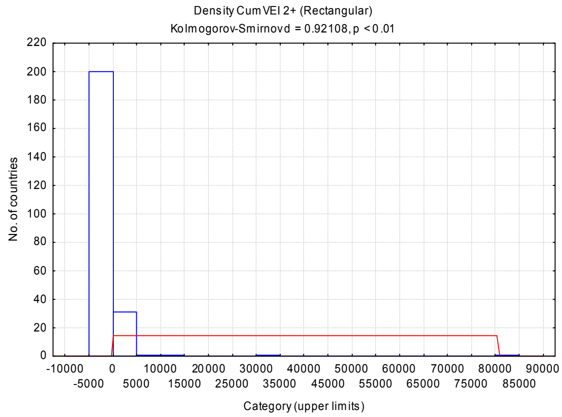
Figure 7.2: Frequency distribution of Density CumVEI 2+ volcanoes in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. All comparisons resulted in significant K-S tests, except for the exponential distribution.

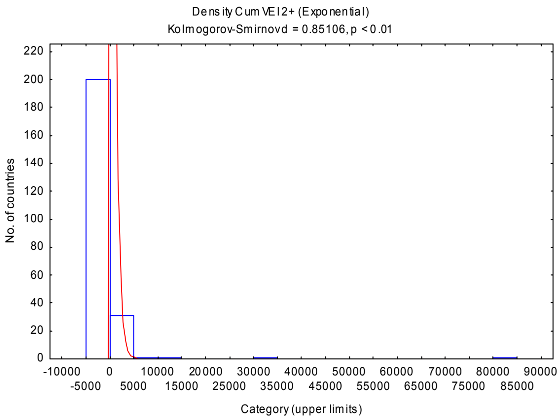
(a)



(b)



(c)



(d)

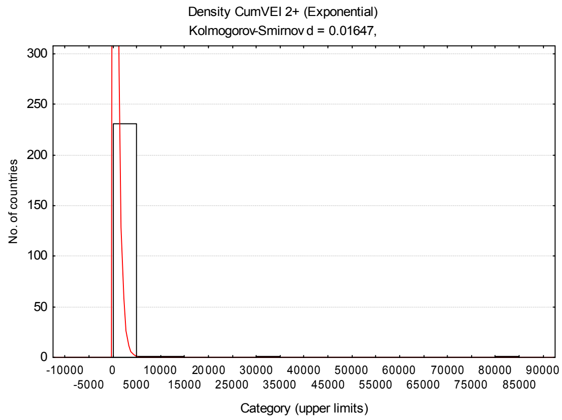
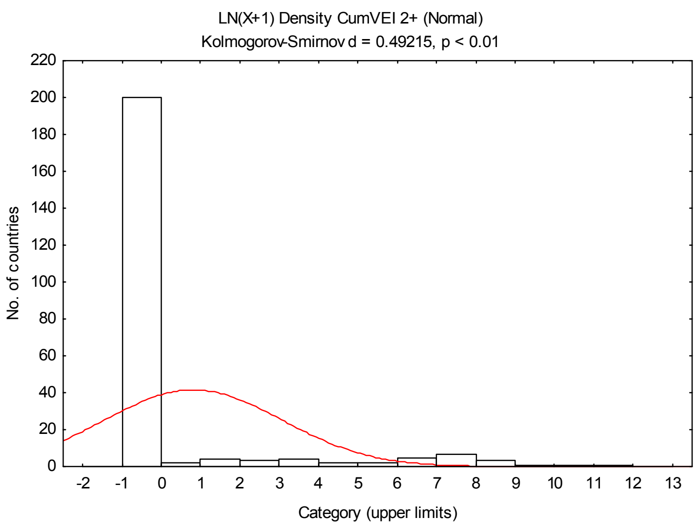


Figure 7.3: LN(X+1) transformed density of CumVEI 2+ volcanoes.



7.5 Proposed EVI scaling and distribution of the data on the new scale

It was suggested during think Tank II that all countries without volcanoes be omitted, regarding the question as “non-applicable” in their case. The question of non-applicability may be considered in future work on the EVI. The scale proposed here covers all countries using a regular intervals on the logarithmic scale to separate countries with little or no risk from (their own) volcanoes, and those with very large numbers of explosive volcanoes. The data on density of VEI 2+ were plotted as a frequency distribution with 7 categories (Figure 7.4). We designated EVI score 1 to all countries with either no, or ≤2 CumVEI 2+ volcanoes and scaled the remaining scores to 7. The distribution of countries plotted on the proposed EVI scale is shown in Figure 7.4.

The majority of countries (88%) fell on this scale at EVI value 1 (Table 7.3). Thirteen countries scored an EVI of 7. This scoring does not seek to spread countries in terms of their VEI 2+ counts (not possible because of so many zero values), but focuses on identifying those with substantial risks from volcanoes.

Figure 7.4: Frequency distribution of countries with LN(X+1) Density CumVEI 2+ in seven categories and the proposed EVI scale.

(a) (b)

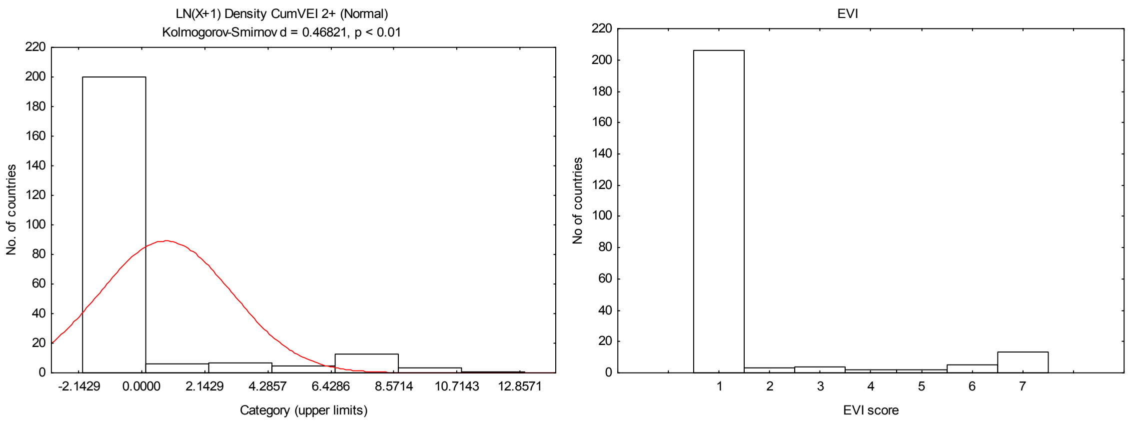


Table 7.2: Proposed EVI scaling for Indicator 7 on number of volcanoes with VEI 2+ in countries.

NA=Not applicable in a country; ND=No data currently available

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	X ≤ 2	206	87.7
2	2 < X ≤ 3	3	1.3
3	3 < X ≤ 4	4	1.7
4	4 <X ≤ 5	2	0.9
5	5 < X ≤ 6	2	0.9
6	6 < X ≤ 7	5	2.1
7	7 < X	13	5.5
NA	☒ May not be used		
ND	☑ May be used		

7.6 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

7.7 Age, completeness and quality of the data

The age of the data obtained by NOAA for this indicator was current (1800's-present) while that provided by the countries had a mean age value of 1.44 (meaning that most of it was from the mid-1990's. Data from NOAA were considered complete, while those obtained from the collaborating countries tended to be incomplete and only of moderate quality. We propose that for this indicator public data are likely to be the most reliable and up-to-date.

Table 7.3: Characteristics of age, completeness and quality of the data obtained for volcanoes from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Valid n	41	41	41
Mean value across countries:	1.44	1.24	2.00
SD	0.78	0.66	0.45
SE	0.12	0.10	0.07

7.8 Variations among sources of data

Data for this indicator were available from NOAA, and in some cases, in-country. For Kiribati, New Zealand, Pakistan, Philippines and Vanuatu there was a discrepancy between these two sources in the number of VEI ≥ 4 volcanoes reported. This will require further investigation. We did not locate any alternative comprehensive public sources of VEI data across the globe. If the version of the indictor used in the final EVI is changed to total number of live volcanoes (TNLV), it is expected that the indicator will be simpler for use, and that a range of sources of information will become available.

7.9 Additional sources & contacts

www.ngdc.noaa.gov/cgi-bin/seg/haz/ffq_result.pl (24/08/01); Cook Islands - Roro Taia. Cook Islands Meteorological Services. (CIMS); Cooke & Ravian. 1981. Volume of volcanological papers. Edited by Jonson, R W. Geological Survey of PNG Memoir 10; Kiribati - Ministry of Natural Resources & Development (MNRD). Naomi Atauea (686 21099/ 686 21120); Nauru - Department of Island Development and Industry. Davey Agadio; New Zealand - Volcanic hazard information series 1-8: Ministry of civil defence/ ministry of energy management. Dr Brent Alloway. Ph: +64 73760160, Fax +64 73748199. E-Mail b.alloway@gns.cri.nz ; Philippines - Dr. Ernesto Corpus / Chief, Volcanology Monitoring, Eruption and Prediction Division, Philippine Institute of Volcanology (PHILVOCS); Samoa - Meteorology Division. L. Talia, PO Box 3020, Apia, Samoa; Thailand - The Royal Thai Survey Department. Tel 66 2 2982253 Fax 66 2 2982240 e-mail: marinepollution_pcd@yahoo.com ; Tonga - A Volcanic Hazards Assesment Following the January 1999 Eruption of Sb-marine Volcano III Tofua Volcanic Arc, Kingdom of Tonga. 1999. Paul W Taylor, Australian Volcanological Investigations, PO Box 291, NSW, Australia; Tuvalu - Department of Lands and Surveys. Tesimita Ailesi; Vanuatu - Department of Geology, Mines & Water Resources.

8. EARTHQUAKES

8.1 Indicator Summary

<table>
<tr><td>Indicator number:</td><td colspan="2">08</td></tr>
<tr><td>Indicator short name:</td><td colspan="2">Earthquakes</td></tr>
<tr><td>Sub-index</td><td colspan="2">REI</td></tr>
<tr><td>Categorisation</td><td colspan="2">Geology</td></tr>
<tr><td>Indicator text:</td><td colspan="2">Cumulative earthquake energy within 100km of country land boundaries measured as Local Magnitude (ML) ≥ 6.0 and occurring at a depth of less than or equal to fifteen kilometres (≤15km depth) over 5[1] years (divided by land area)</td></tr>
<tr><td>Signals captured:</td><td colspan="2">Vulnerability to habitat disturbance through movements of land, water and slides. This indicator captures the risks of damage to the environment from large-scale disturbances such as fluidisation of soils and muds, diversion of rivers and other water bodies, tsunamis, slides, and direct damage to organisms associated with earth movements.</td></tr>
<tr><td>Notes on this indicator:</td><td colspan="2">1. Deeper earthquakes are considered to present less risk to the environment. It is considered that shallow earthquakes of depths less that 15 km are likely to cause the most significant environmental changes and have the most impacts on the overlying environments.
2. The indicator may also function as a proxy for habitat disturbance through avalanches, slides and rifts and could damage structures of ecological significance (e.g. aquifers).</td></tr>
<tr><td>Are suitable data available?</td><td colspan="2">Yes</td></tr>
<tr><td>Sources of data:</td><td colspan="2">• NOAA/NESDIS/NGCC/World Data Centre-A, Colorado
• In-country</td></tr>
<tr><td>No. countries included in test:</td><td colspan="2">238</td></tr>
<tr><td>Temporary modifications to data or indicator, if applicable:</td><td colspan="2">• Raw data on number of earthquakes ≥ ML 6.0 (and ≤ 15km depth) were used, without dividing by land area. Although number of earthquakes is correlated with land area, the indicator became skewed strongly towards zero values when divided by land area.
• Data were accumulated over 6 years, not 5 as required.</td></tr>
<tr><td>Notes on data age, completeness and quality:</td><td colspan="2">Where multiple values for these measures were reported, these were reduced to the lowest given value for use in the analysis. That is, if 2 and 3 were returned for a measure, the value 2 was used in the analysis. If no value was given, but data supplied, 0 was used.</td></tr>
<tr><td>Basic units:</td><td colspan="2">X = Number of earthquakes (ML ≥ 6, Depth ≤ 15 km)</td></tr>
<tr><td>Recommended transforms:</td><td colspan="2">None</td></tr>
<tr><td rowspan="6">Proposed EVI Scale</td><td>EVI Score = 1</td><td>0 ≤ X < 1</td></tr>
<tr><td>EVI Score = 2</td><td>1 ≤ X < 2</td></tr>
<tr><td>EVI Score = 3</td><td>2 ≤ X < 3</td></tr>
<tr><td>EVI Score = 4</td><td>3 ≤ X < 4</td></tr>
<tr><td>EVI Score = 5</td><td>4 ≤ X < 5</td></tr>
<tr><td>EVI Score = 6</td><td>5 ≤ X < 6</td></tr>
</table>

[1] In its final form, this indicator will include earthquakes over a 5 year period, not 6.

	EVI Score = 7	6 ≤ X
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	The data used in this test were accumulated over the period 1996-2001 inclusive, which is an actual observation period of 6 years.	

8.2 Description of raw data

The raw data for this indicator comprise the number of earthquakes recorded in a country's land boundaries which are of a magnitude of ML ≥ 6 and depth of ≤ 15 km of the surface. The Local ("Richter") Magnitude, or ML = log A - log Ao as defined by Richter (1935) where A is the maximum trace amplitude in millimetres recorded on a standard short-period seismometer and log Ao is a standard value as a function of distance where distance ≤ 600 km (see http://wwwneic.cr.usgs.gov/neis/phase_data/mag_formulas.html).

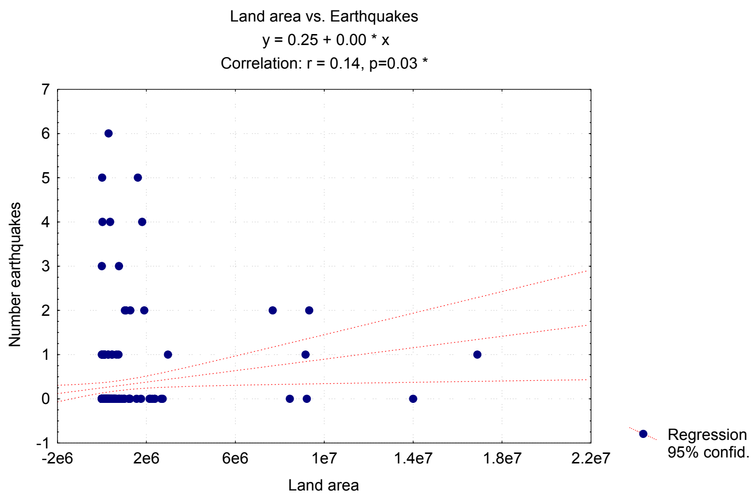
For the 238 countries examined, values varied between 0-6 earthquakes fitting our definition over a 6 year period, with an average across all tested of 0.29 earthquakes over 6 years. The greatest number of ML ≥ 6 earthquakes (six) was recorded in Philippines, with five being recorded in Vanuatu and Iran, and four in Indonesia and Japan. Venezuela, Turkey and Solomon Islands had 3 significant earthquakes over the same period. Most countries, 202 of 238, had no earthquakes reaching the trigger point over the observation period. The standard deviation (SD) was 0.87, which was 300% of the mean and the standard error (SE) was 0.06, which around 20% of the mean.

A positive correlation between number of earthquakes and land area was found (Figure 8.1), but the plot is triangular in nature, with a bigger variance in the number of earthquakes occurring in smaller countries than in the larger ones. Although the correlation coefficient was significant, we consider the correlation weak. For this reason, and because of a problem with skewing the data towards zero (see below), we suggest that this indicator should be used in its raw state, that adjustments to remove any signal of country size would be unproductive and that this indicator should not be transformed to a density of earthquakes per unit of land area.

Table 8.1: Basic statistics for earthquakes and density of earthquakes in a country.

Statistic	Earthquakes	Earthquakes per million sq km
Mean	0.29	326.47
Median	0	0
Valid n	238	235
Min	0	0
Max	6	71,428.57
SD	0.87	4666.07
SE	0.06	304.38
Skewness	4.06	15.25
SE Skewness	0.16	0.16
Kurtosis	18.25	233.36
SE Kurtosis	0.31	0.32

Figure 8.1: Graph of land area versus number of earthquakes (ML ≥ 6, Depth ≤ 15km) in 238 test countries. The correlation coefficient result shows that the number of earthquakes correlates with the size of a country.



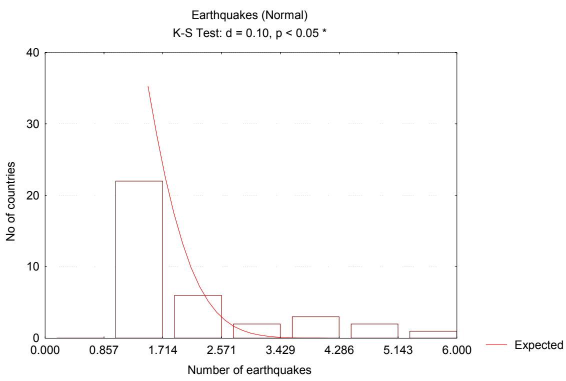
8.3 Characteristics of the indicator data

Numbers of earthquakes in countries were initially plotted as frequency distributions in 7 categories to identify any underlying distributions (Figure 8.2) (the standard use of 20 categories in other indicators would not have applied in this case because the spread was among 7 integers). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were then used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in all of the 4 distributions tested, indicating that the fit was not good (Figure 8.3). The data for this indicator were as a result used in their raw form.

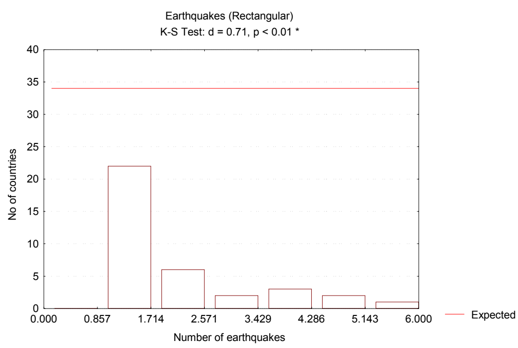
Figure 8.2: Kolmogorov-Smirnov goodness-of-fit tests for number of earthquakes (ML≥6, Depth ≤15km) in countries spread over 7 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. All comparisons resulted in significant K-S tests, suggesting that the data can be mapped directly onto the linear EVI scale.

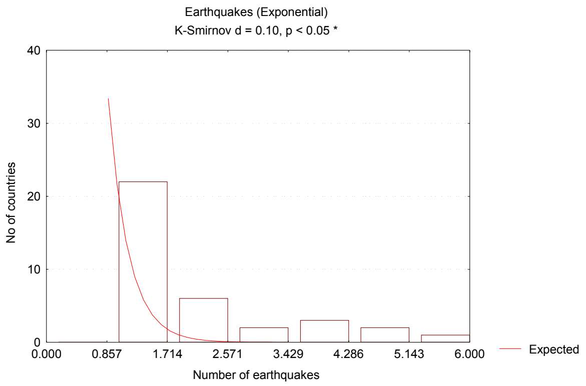
(a)



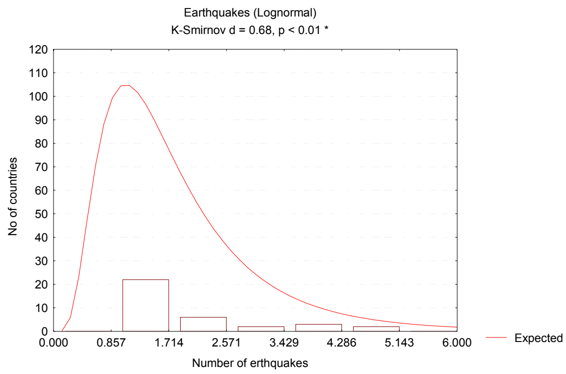
(b)



(c)



(d)



8.4 Proposed EVI scaling and distribution of the data on this scale

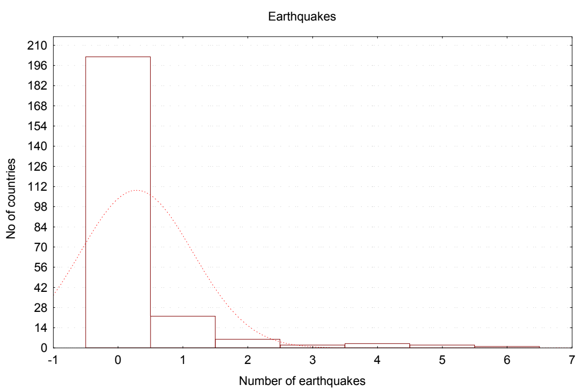
We propose that the EVI scale be a simple linear one with even intervals based on the raw number of earthquakes (ML ≥ 6, D ≤ 15km) recorded over a 5 year period. The reasoning behind this is that that data are already in integer form, ranging between values of 0 and 6 (a span of 7) (Figure 8.3 a) and there is a reasonable expectation that the more frequent earthquakes of higher magnitudes are, risks and cumulative disturbance to the environment, which could interact with human stresses, will also increase. Countries with repeated disturbances by strong earthquakes are more likely to be prone to interactive effects.

We set the EVI scale at even intervals of 1 earthquake, so that EVI Score 1 = no earthquakes; and EVI Score 7 = six earthquakes over 5 years. The distribution of countries plotted on the proposed EVI scale is shown in Figure 8.3 b. The majority of countries (202, 84.5%) fell on this scale at EVI value 1, with less than 2% scoring an EVI value of 6 or 7 (Table 8.2).

Figure 8.3: Frequency distribution of countries in terms of number of earthquakes in seven evenly-spaced categories.

Graph (a) is a plot of frequency distributions of countries from 0-6 earthquakes; Graph (b) is a frequency distribution of EVI scores.

(a)



(b)

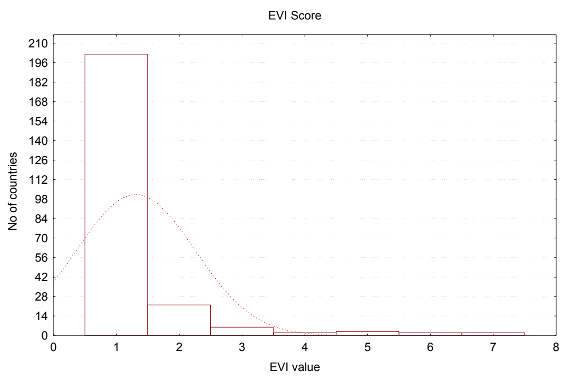


Table 8.2: Proposed EVI scaling for Indicator 8 on number of ML ≥ 6, Depth ≤ 15km earthquakes in countries over 5 years.

NA=Not applicable in a country; ND=No data currently available

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	$0 \leq X < 1$	202	84.52%
2	$1 \leq X < 2$	22	9.21%
3	$2 \leq X < 3$	6	2.51%
4	$3 \leq X < 4$	2	0.84%
5	$4 \leq X < 5$	3	1.26%
6	$5 \leq X < 6$	2	0.84%
7	$6 \leq X$	2	0.84%
NA	☒ May not be used		
ND	☑ May be used		

8.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later stage when scales have been set for all indicators.

8.6 Age, completeness and quality of the data

The age of the data for this indicator from NOAA/NESDIS/NGCC was considered current (2001), complete and of good quality (scoring a value of 3 for all indicators of data reliability) (Table 8.3). In-country data on earthquakes was provided for only 16 countries, with an average age score of 2 for age (most recent data are between 1995 and 1999). The data tended to be incomplete and of moderate quality (Table 8.3). It is clear that the NOAA source is likely to be the most accessible and reliable for this indicator.

Table 8.3: Characteristics of age, completeness and quality of the data obtained for earthquakes in 238 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
NOAA score	3	3	3
In-country score	2.00	2.31	2.53
Valid n (in-country)	16	16	15
SD (in-country)	0.89	0.87	0.64
SE (in-country)	0.22	0.23	0.17

8.7 Variations among sources of data

Alternative public sources of data exist for this indicator and will be tested in the future to evaluate the size of differences among sources and any effect on the EVI calculations.

8.8 Additional sources & contacts

www.ngdc.noaa.gov/seg/hazard/sig_srch.shtml (2/03/99); Botswana - Dept of Geological survey. Mr Hendrick Holmes, ph.336770: E-mail hholmes@gov.bw ; Botswana - Ngwisanyi. T, Kwadiba. M. 1999 Catalogue of earthquakes in Botswana from 1950- 1991; a 1999 internal Report of the Department of Geological Survey; Cook Islands - Roro Taia. Cook Islands Meteorological Services. (CIMS); Fiji - Raw data sheets on Earthquakes. Minerals Resource Department. Arvin Singh (381611); Greece - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Ministry of Natural Resources Development. Naomi Atauea (686 21099/ 686 21120); Kyrgyzstan - Institute of Seismology, National Academy of Sciences. Mr. Djanuzakov; Nepal - Society for Environment and Development. Damodar Adhikari, Phone/Fax +1 499700, dadhikar@wlink.com.np ; New Zealand - http/www.seismology.Harvard. edu/cmtsearch.html; Papua New Guinea - Geophysical Observatory Earthquake Database. PNG Geological Survey; Philippines - Earthquake Catalogue PHILVOCS Annual Report. Mr. BARTOLOME C. BAUTISTA / Chief, Seismology Observation and Earthquake Prediction Division / PHILVOCS; Samoa - Geophysics Section (Meteorology Division). L. Talia, PO Box 3020, Apia, Samoa. Apia Observatory; Thailand - http://tmd.motc.go.th/quake/e-stat.html (6/6/01); Vanuatu - National Earthquake Information Center, USGS. Jean Philippe Caminade.

9. TSUNAMIS

9.1 Indicator Summary

Indicator number:	09
Indicator short name:	Tsunamis
Sub-index	REI
Categorisation	Geology
Indicator text:	Number of tsunamis or storms surges with run-up greater than 2 metres above Mean High Water Spring tide (MHWS) per 1000 km coastline since 1900
Signals captured:	This indicator captures the potential loss of shorelines, coastal ecosystems and resources, and loss of species due to catastrophic run up of seawater onto coastal lands. Countries with frequent and severe tsunamis are at risk of severe or permanent damage to biodiversity, productivity and the ability to recover from other stressors.
Notes on this indicator:	1. Indicator is tested raw, in relation to length of coastline and in relation to land area of each country. 2. The tsunamis per length of coast is better multiplied by 1000 to create a range that extends between zero and whole numbers up to 25. For tsunamis per area of land, the multiplier used was 1 million. 3. Because these are geological events, the time series covers the period since 1900. The figure calculated may change through additional tsunami events being recorded in a country. 4. Only tsunamis with a run-up of >2m are included. Those smaller are considered of minimal threat to coastal systems, and are expected to have an impact within the range of more common storms. 5. For landlocked countries the risk of tsunamis is considered zero and the data designation NA (not applicable) is used. In terms of EVI scaling, landlocked countries are scored the lowest EVI value (1) unless it can be shown that the shorelines and coastal areas of large lakes have been the subject of tsunami-like events, in which case they would record values like any other country.
Are suitable data available?	Yes
Sources of data:	• NOAA/NESDIS/NGCC • In-country • Land area and length maritime coast from WRI 2000-2001 and CIA 2001
No. countries included in test:	196, plus landlocked countries counted as NA
Temporary modifications to data or indicator, if applicable:	• Basic units are multiplied by 1000 instead of 100. • Landlocked countries excluded as “not applicable”. These are given the minimum EVI score of 1 for the indicator. In later testing, the EVI will also be examined with NA indicators excluded from the calculations because a score of 1 may artificially reduce the average EVI score for that country. • The EVI scaling was set using applicable countries only, though the scoring was applied to NA countries once set.
Notes on data age, completeness and quality:	Few in-country data were returned for this indicator. Where they were provided, age, completeness and quality were generally low. We assumed the NOAA data to be up-to-date, complete and of

	good quality for this indicator. The data range covered the entire required period from 1900-2000.	
Basic units:	X = Number of tsunamis with run-up >2m above MHWS (years 1900-2000) / length of coastlines (maritime) * 1000	
Recommended transforms:	Use "Tsunami Density". Express indicator as the number of tsunamis between 1900 and 2000 as a density over length of maritime coasts (per thousand kilometres).	
Proposed EVI Scale (for # tsunamis per million sq km land, 1900-2000)	EVI Score = 1	X = 0, or NA
	EVI Score = 2	0 < X ≤ 1
	EVI Score = 3	1 < X ≤ 2
	EVI Score = 4	2 < X ≤ 5
	EVI Score = 5	5 < X ≤ 10
	EVI Score = 6	10 < X ≤ 15
	EVI Score = 7	X > 15
	NA (not applicable)	☑ May be used
	ND (no data)	☑ May be used
Future work on this indicator:	Length of lake coastlines needs to be added to length of maritime coasts to produce a figure of total coastlines for each country as a denominator for 'tsunami density' for this indicator.	

9.2 Description of raw data

The raw data for this indicator comprise the number of tsunamis recorded anywhere in the country in the period 1900-2000 and which have a run-up of 2m or more. These raw values were then tested against area of land and length of maritime (i.e. non-river and non-lake) coastline for correlation and possible use to create a density of tsunamis in the country. In general, it is expected that tsunamis affect countries with maritime coasts, and that the risk of tsunamis in landlocked countries would be zero. This indicator would allow, however, for tsunamis generated in large inland lakes in all countries. Where ever possible the length of coastline data (taken from Indicator 11) does include the length of lake shorelines, but this did not affect the countries used in this study because the two measurements were the same in all cases. The two possible scales were tsunamis per million sq km land area, or tsunamis per 1000 km maritime coastline. Both of these differ from the original form of the indicator which called for numbers of tsunamis per 100 km coastline.

Tsunami data were available for 196 countries (the 236 we have examined, less landlocked countries). The number of tsunamis recorded in countries since 1900 varied between 0 and 29, and the average number of tsunamis recorded was just under 1 tsunami over the past century (Table 9.1). 29 countries across the globe recorded tsunamis between 1900 and 2000 with the most severely affected countries being Papua New Guinea (10), Solomon Islands (10), Chile (11), Russian Federation (15), Indonesia (21), Japan (27) and USA (29). When examined in terms of total number of tsunamis per square km of land, American Samoa, Jamaica, Japan, French Polynesia, Puerto Rico, Tonga, Vanuatu and Samoa become the countries with the highest density of tsunamis.

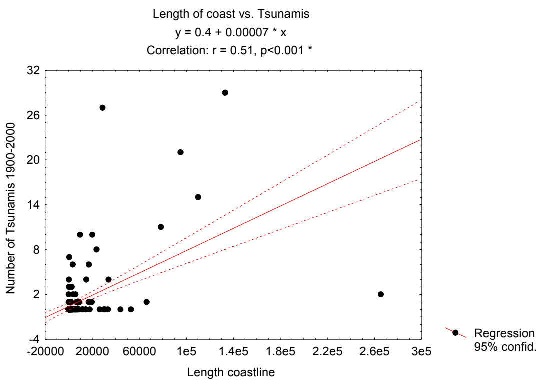
The number of tsunamis recorded in a country correlated significantly both with the land area and length of maritime shoreline (Figure 9.1). Larger countries tend to experience more tsunamis because they have more area exposed to risk. To remove the underlying signal of size of a country from the indicator we examined both of these measures (land area and length of shoreline) as denominators for the indicator to create an expression of "tsunami density". Both denominators rendered non-significant the correlation between number of tsunamis in a country and its size. We chose to use length of maritime coasts as the denominator. Length of lake shorelines tends to be poorly documented in public databases and tends to be subject to significant deviations among estimation methods.

Table 9.1: Basic statistics for number of tsunamis recorded in 196 countries as (i) raw numbers; (ii) as a density per 1000 km of coastline; and (iii) as a density per 1 million sq km of land area. Tsunami data are from NOAA and cover the period 1900-2000; land area and coastline data are from WRI 2000-2001 and CIA 2001.

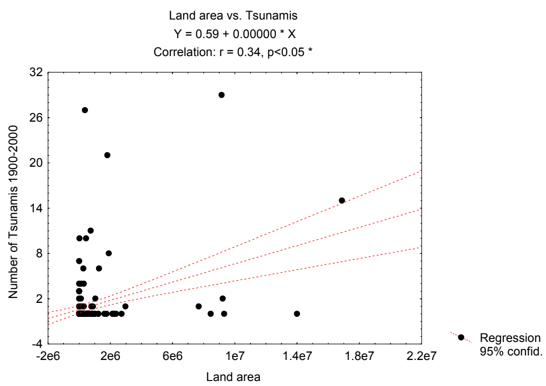
Statistic	(i) Tsunamis (NOAA)	(ii) Tsunamis per 1000 km shoreline	(iii) Tsunamis per million sq km land
Mean	0.97	442.58	145.44
Median	0	0	0
Valid n	195	195	195
Min	0	0	0
Max	29	25000	10050.25
SD	3.70	2528.71	1062.36
SE	0.27	181.08	76.27
Skewness	5.51	7.46	8.72
SE Skewness	0.17	0.17	0.17
Kurtosis	33.86	60.27	78.04
SE Kurtosis	0.35	0.35	0.35

Figure 9.1: Graph of the number of tsunamis (with run up of 2m+) between 1900 and 2000 versus (a) Length of coastline and (b) land area in 196 test countries. The correlation coefficient result shows that the number of tsunamis correlates with both variables.

(a)



(b)

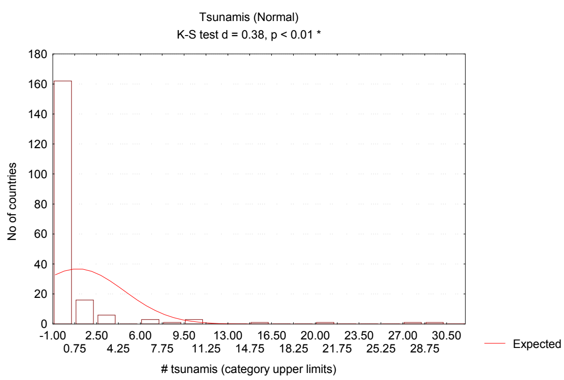


9.3 Distributional characteristics of the indicator data

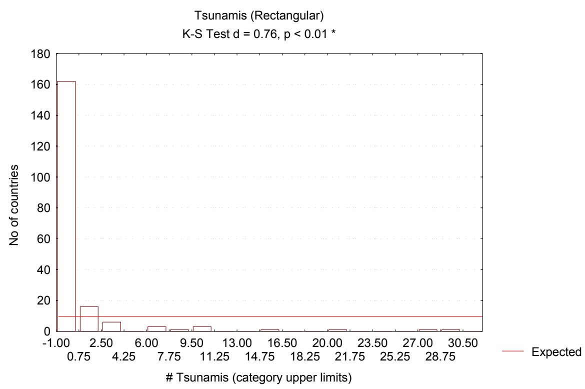
The raw numbers of tsunamis was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 9.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in all of the 4 distributions tested, indicating that the fit was not good (Figure 9.2). A similar pattern was found using the two "tsunami density" measures (tsunamis per 1000 km shoreline and tsunamis per million sq km of land). In all cases, the distributions were heavily skewed at the zero end of the scale, with few observations and spread among countries at higher values.

Figure 9.2: Kolmogorov-Smirnov goodness-of-fit tests for raw number of tsunamis between in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

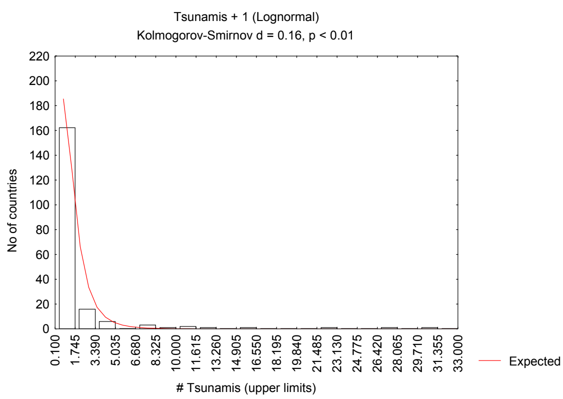
(a)



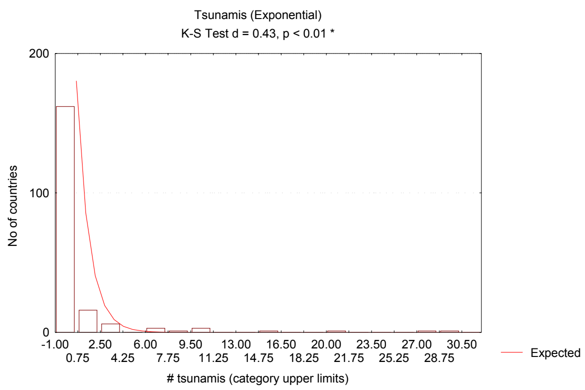
(b)



(c)



(d)



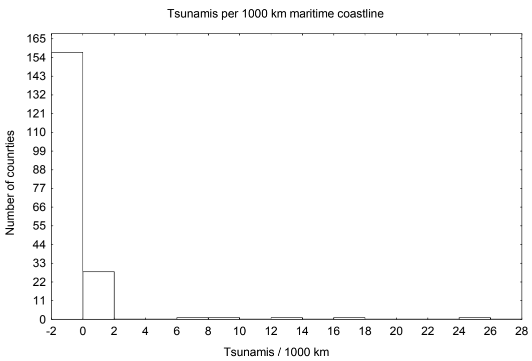
9.4 Proposed EVI scaling and distribution of the data on this scale

We propose that the EVI scale be uneven to create better spread towards the low end of the scale and be able to identify countries with moderate to high tsunami density as being at greatest risk. There is very little information on the likely effects of tsunamis on ecosystems, so trigger points cannot be set independently of the observed data. There is, however a reasonable expectation that the more frequent tsunamis are, and the more dense with respect to the environment which receives them, there will be more risk and cumulative disturbance to the environment. Tsunami damage could then interact with on-going human stresses. That is, countries with a high tsunami density are more likely to be prone to interactive effects.

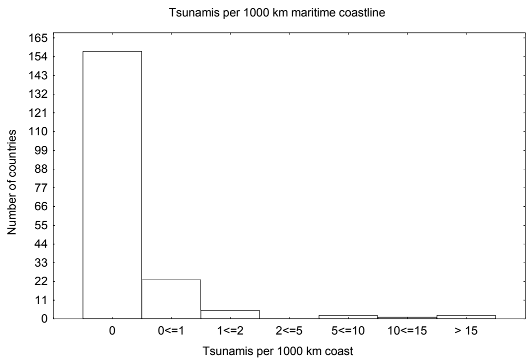
We set the EVI scale at increasing intervals with an EVI Score of 1 for no tsunamis (or not applicable if the country is landlocked); the next 3 EVI scores spreading across tsunami densities of 50-100-500 tsunamis per million sq km land; and scores of 5-7 encompassing countries with thousands of tsunamis per million sq km of land. The distribution of countries plotted on the proposed EVI scale is shown in Figure 9.3. The majority of countries (206, 88%) fell on this scale at EVI value 1, with less than 2% scoring an EVI value of 6 or 7 (Table 9.2).

Figure 9.3: (a) Frequency distribution of tsunami densities across non-landlocked countries (tsunamis per 1000 km maritime coastline) in integer categories. Graph (b) is a frequency distribution of tsunami density plotted in seven categories on an uneven scale; and (c) is the resulting EVI scoring.

(a)



(b)



(c)

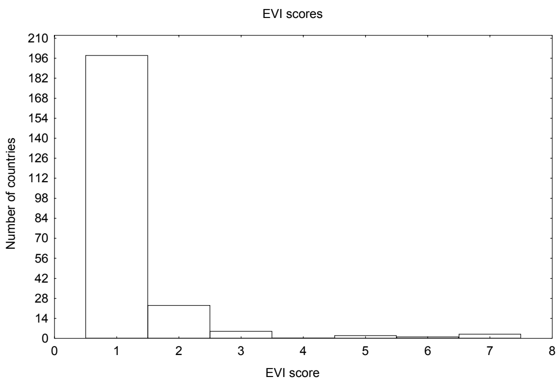


Table 9.2: Proposed EVI scaling for Indicator 9 on tsunami density in countries between 1900 and 2000. Values refer to number of tsunamis per 1000 km of maritime coastline. NA=Not applicable in a country; ND=No data currently available. Note that all NA countries are included.

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	X = 0, or NA	198	85.3
2	0 < X ≤ 1	23	9.9
3	1 < X ≤ 2	5	2.2
4	2 < X ≤ 5	0	0
5	5 < X ≤ 10	2	0.9
6	10 < X ≤ 15	1	0.4
7	X > 15	3	1.3
Missing	5 countries without estimate of length of shoreline, or no data on tsunamis		
NA	☑ Used for landlocked countries (results in score = 1)		
ND	☑ May be used (results in no score)		

9.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

9.6 Age, completeness and quality of the data

The data obtained for this indicator on number of tsunamis from NOAA/NESDIS/NGCC was considered current (2001), complete and of good quality (scoring a value of 3 for all indicators of data reliability) (Table 9.3). Data on length of shoreline was obtained from

WRI (2000-2001) and CIA (2001) and there are discrepancies between the two sets. In-country data on tsunamis was provided for only 13 countries, most of which recorded that they lacked information. The data are so incomplete; we believe that public datasets would be of greater reliability in this case (Table 9.3). It is clear that the NOAA source is likely to be the most accessible and reliable for this indicator.

Table 9.3: Characteristics of age, completeness and quality of the data obtained for tsunamis in 196 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
NOAA score	3	3	3
In-country score	1.73	1.55	1.82
Valid n (in-country)	11 (2 ND)	11 (2 ND)	11 (2 ND)
SD (in-country)	1.01	0.82	0.87
SE (in-country)	0.30	0.25	0.26

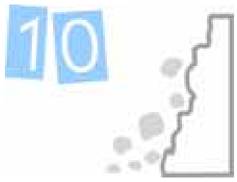
9.7 Variations among sources of data

Alternative public sources of data have not yet been located for this indicator. There are differences between estimates of length of shorelines, with some estimates giving non-zero values for landlocked countries, suggesting that lakes have been included. We specifically chose to use only length of maritime coasts for this indicator, but future refinements will include the length of inland coasts.

9.8 Additional sources & contacts

www.start.or.th/got/data/dblink.htm (Thailand); www.ngdc.noaa.gov/cgi-bin/seg/haz/ffq_result.pl (24/08/01); Federated States of Micronesia - Michael Gawel. 1993 Federated States of Micronesia State of Environment Report. (pp34); Greece - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Niue - Forbes, TR 233 Coastal Geology and Hazards in Niue; Papua New Guinea - Moihoi, M and Anton, L. 1999. Significant Tsunamis in PNG (A Review); Philippines - National Disaster Coordinating Council (NDCC) administrative reports. Mr. Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph ; Tuvalu - New Zealand Meteorology Service (Kerr; p 103 – 104); Vanuatu - DESS of Sandrine Wallez. Vanuatu ORSTOM & National Disaster Management Office (NDMO) & Co.

10. SLIDES



10.1 Indicator Summary

Indicator number:	10	
Indicator short name:	Slides	
Sub-index	REI	
Categorisation	Geology	
Indicator text:	1. Number of slides recorded in the last 5 years (see EMDAT definitions), divided by land area. 2. Number of slides (landslides, mudslides and avalanches) lasting more than 30 seconds recorded over the past 5 years, divided by the area of mountainous lands. Mountainous lands are any over 1000m above sea level.	
Signals captured:	This indicator captures the risk of habitat disturbance and persistence of ecosystems and species from catastrophic shifts in the land surface. The primary and cumulative effects of slides would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. It may be possible to obtain data for this indicator from seismological records. Landslides may be part of the background noise in seismological records taken continuously. 2. The effects of slides are likely to be relatively localised (though they may mobilize runoff and mudflows which could travel down water courses and into the sea). 3. Data on slides included the following categories for inclusion: 10 or More people killed; 100 or more people affected; Significant disaster; Significant damage; Declaration of state of emergency or/and appeal for an international assistance; Disaster entered at the country level without data, because it has affected several countries/region.	
Are suitable data available?	Yes	
Sources of data:	• EMDAT OFDA/CRED International Disaster Database 2001 • In-country	
No. countries included in test:	218 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	5 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (value >2 of 3 for age, completeness and quality).	
Basic units:	Number of slides recorded between 1996-2000, divided by area of land (km^2).	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	X=0
	EVI Score = 2	0<X≤0.5
	EVI Score = 3	0.5<X≤1
	EVI Score = 4	1<X≤1.5
	EVI Score = 5	1.5<X≤2
	EVI Score = 6	2<X≤2.5
	EVI Score = 7	2.5<X

	NA (not applicable)	☒ May not be used.
	ND (no data)	☑ May be used
Future work on this indicator:	• Obtain updated data and data for remaining 17 countries.	

10.2 Description of raw data

The raw data for this indicator are comprised of the total number of slides recorded in countries between 1996 and 2000. Data are from the EMDAT OFDA/CRED International Disaster Database 2001 and include landslides, mudslides and avalanches under the following categories: (i) 10 or More people killed; (ii) 100 or more people affected; (iii) Significant disaster; (iv) Significant damage; (v) Declaration of state of emergency or/and appeal for an international assistance; and (vi) Disaster entered at the country level without data, because it has affected several countries/region. Data were available for a total of 218 countries.

The number of slides recorded in countries between 1996-2000 varied between 0 and 11 (Table 10.1). Zero values were recorded in 177 of the countries examined. The highest values were observed in India, China and Costa Rica. The mean value across the globe was 0.495 slides in the five year period. Variance among countries was moderate, with a standard deviation which was around 3 times the mean.

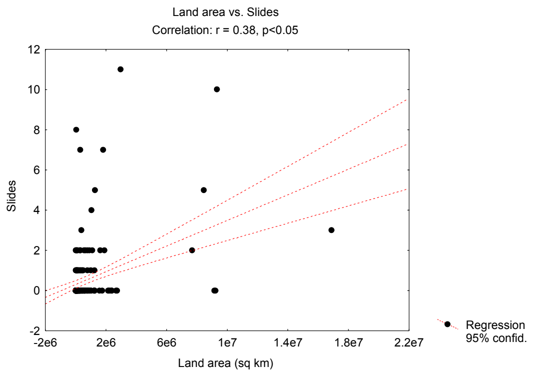
The number of slides recorded was correlated with the size of a country (see significant correlation coefficient in Figure 10.1). Since the risks associated with slides are related to the area of land they affect in relation to that available (for persistence and recovery), we expressed this indicator as a density function, dividing the number of slides recorded over the 5 year period by total land area and expressing the results as slides per million km^2 of land (to obtain whole numbers). When the density of slides was, in turn, tested against country size, the correlation with size of country disappeared (Figure 10.1 b). The density of slides varied from 0 to 1,639 slides per million km2 of land over the period 1996-2000, with the maximum density of slides being recorded for St. Lucia, French Polynesia and Costa Rica.

Table 10.1: Basic statistics for slides recorded between 1996 and 2000. Data are from EMDAT 2001 and in-country sources.

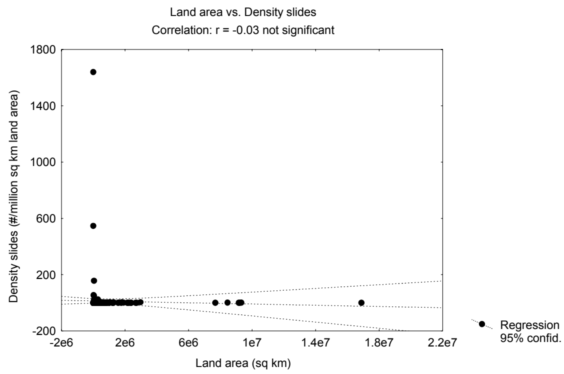
Statistic	Slides	Density slides (slides / million km^2 land)	LN(X+1) Density slides
Mean	0.495	12.14	0.38
Median	0.00	0.00	0.00
Valid n	218	218	218
Min	0	0.00	0.00
Max	11	1639.344	7.40
SD	1.497	117.31	1.03
SE	0.10	7.95	0.07
Skewness	4.54	12.86	3.79
SE Skewness	0.16	0.16	0.16
Kurtosis	23.56	174.37	17.41
SE Kurtosis	0.33	0.33	0.33

Figure 10.1: Graphs of slides vs. size of countries. (a) Number of slides 1996-2000 vs. size of country (sq km); and (b) Density of slides (# / million sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a)



(b)



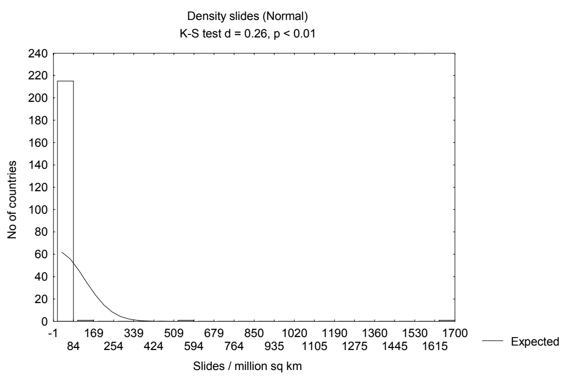
10.3 Distributional characteristics of the indicator data

The density of slides in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 10.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

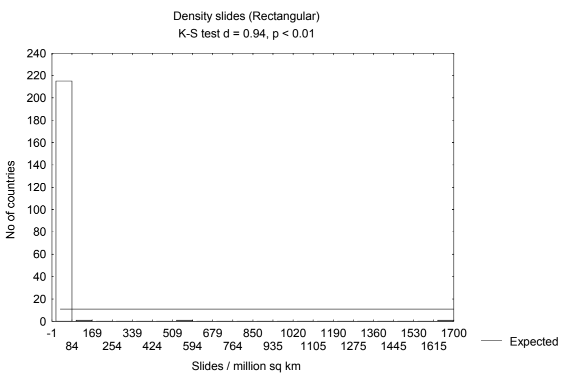
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 10.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 10.2: Kolmogorov-Smirnov goodness-of-fit tests for density of slides in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

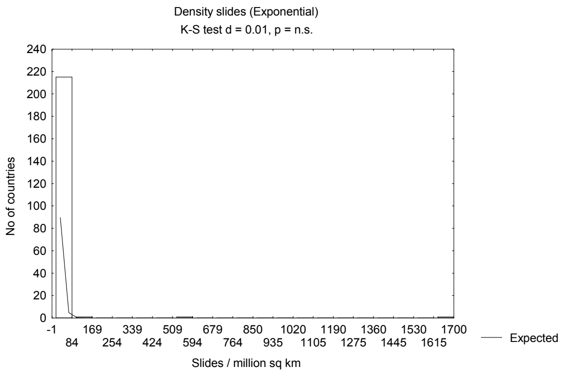
(a)



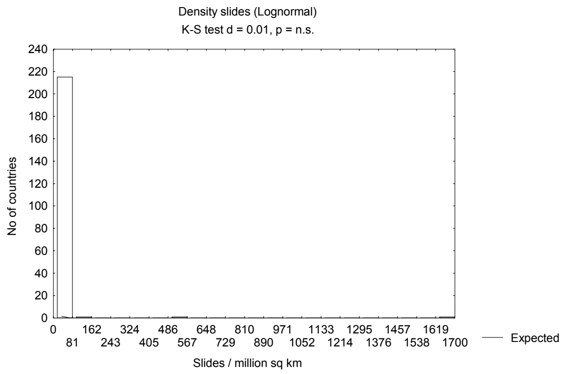
(b)



(c)



(d)

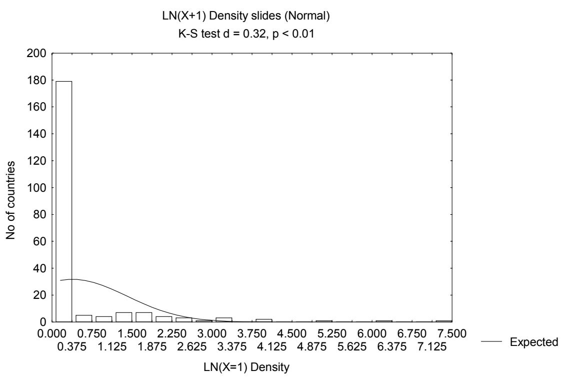


10.4 Proposed EVI scaling and distribution of the data on this scale

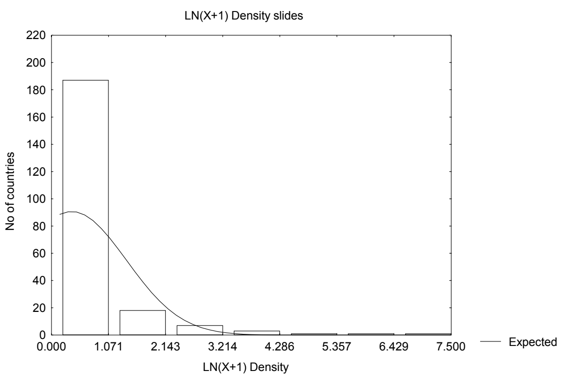
We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries and compress the scale to between 0 and 7.4, with countries having the greatest density of slides per million km^2 being considered more vulnerable and attracting a higher EVI score. We identified those countries with zero values as those at least at risk of environmental damage from slides. Note however, that a zero score in 1996-2000 does not mean that slides have not occurred in the past or that they will not occur in the future. Countries with > 2.5 on the LN(X+1) transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1996-2000 had a density of 11 or more slides per million km^2 of their land area (as a national average). The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 10.3, Table 10.2, 10.3).

Figure 10.3: Frequency distribution of LN(X+1) density of slides in even categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories; (b) is the same distribution compressed to a 7 category (even) scale; (c) Is the proposed EVI scale which clumps all countries with >11 slides per million km^2 of land (note the maximum is 1,639).

(a)



(b)



(c)

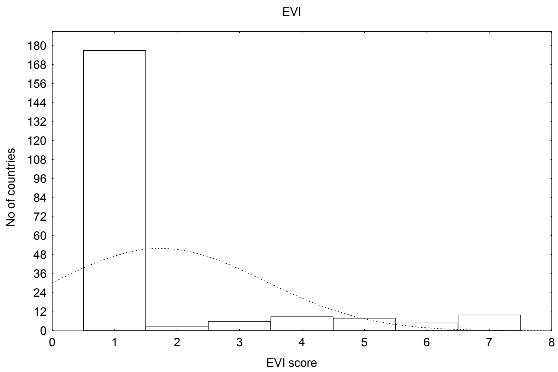


Table 10.2: Proposed EVI scaling for density of slides showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	LN(X+1) Density	Observed # countries	Observed % of countries
1	X=0	177	81.19
2	0<X≤0.5	3	1.38
3	0.5<X≤1	6	2.75
4	1<X≤1.5	9	4.13
5	1.5<X≤2	8	3.67
6	2<X≤2.5	5	2.29
7	X>2.5	10	4.59
No data		17	7.80
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 10.3: Proposed EVI scaling for density of slides showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fall into each of the EVI scores.

Score	LN(X+1) Density	Scale for Density slides	Examples
EVI=1	X=0	X=0	Albania, Canada, Denmark
EVI=2	0<X≤0.5	0<X<0.65	Australia, Brazil, Russia
EVI=3	0.5<X≤1	0.65<X≤1.72	China, Ethiopia, Mexico
EVI=4	1<X≤1.5	1.72<X≤3.48	Bolivia, Italy, Papua New Guinea
EVI=5	1.5<X≤2	3.48<X≤6.39	Colombia, Indonesia, India
EVI=6	2<X≤2.5	6.39<X≤11.18	Guatemala, Japan, Nepal
EVI=7	X>2.5	X>11.18	Azerbaijan, Costa Rica, Philippines

10.5 Age, completeness and quality of the data

The data obtained for this indicator were from the EMDAT OFDA/CRED International Disaster Database 2001, as well as in-country sources. In-country data were available for 5 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 10.4).

Table 10.4: Characteristics of age, completeness and quality of the data obtained for slides from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.6	2.5	3.0
Valid n (in-country)	5	4	4
SD (in-country)	0.89	1.00	0.00
SE (in-country)	0.40	0.50	0.00

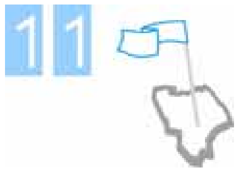
10.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

10.7 Additional sources & contacts

Encarta 2000 Maps; Botswana - Contact - Sarah E. A. Kabaija (Mrs)267 – 352200 Phone267 – 352201 Faxskabaija@gov.bw . Principal StatisticianHead of environment Statistics. Central Statistics Office; Costa Rica - Comision nacional de emergencia 2002; Fiji - Media (Fiji TV, Fiji Times) EVI Team; Kiribati - Contact - Ms Naomi Atauea. Mineral Unit/Ministry of Natural Resources and Development.

11. LAND AREA



11.1 Indicator Summary

Indicator number:	11	
Indicator short name:	Land area	
Sub-index	IRI	
Categorisation	Geography	
Indicator text:	Total land area (km^2)	
Signals captured:	This indicator captures the richness of habitat types and diversity, availability of refugia if damage is sustained or for protection, and species and habitat redundancy. It is generally considered that larger countries will have more options and the 'critical mass' required for ecological systems to persist and re-seed each other in the face of ecosystem stressors. There will also be more options for the human populations to allow areas that have been damaged to recover.	
Notes on this indicator:	1. Indicator is tested raw. 2. The total land area may prove to be correlated with many other indicators. 3. Area of land is calculated from MHWM (mean high water on maritime coasts). Estimates differ among sources and are subject to errors depending on the scale of maps used and the definition of where land begins in relation to sea-level. These differences are not considered of significance.	
Are suitable data available?	Yes	
Sources of data:	• WRI 2000-2001 • CIA Fact sheets 2001 • In-country	
No. countries included in test:	235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the age, completeness and quality of the data were generally considered good. We compiled a composite using data from WRI, CIA and in-country sources in that order of preference.	
Basic units:	X = total land area of a country (accumulated across islands, if present) in square kilometres.	
Recommended transforms:	Data transformed to natural logarithm (LN) land area for easier analysis.	
Proposed EVI Scale (Scale refers to the natural logarithm of land area in sq km – the untransformed scale in sq km is available in this test sheet).	EVI Score = 1	X>14
	EVI Score = 2	12<X≤14
	EVI Score = 3	10<X≤12
	EVI Score = 4	8<X≤10
	EVI Score = 5	6<X≤8
	EVI Score = 6	4<X≤6
	EVI Score = 7	X<4
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

11.2 Description of raw data

The raw data for this indicator are comprised of the area of land defined for each country, taken from mean high water mark on maritime, lake and river coasts and the defined land border elsewhere. Data were available for all 235 countries examined.

The land area of countries as defined politically varied between 0.44 and 16,888,500 square kilometres, with Vatican City State being the smallest, and the Russian Federation being the largest examined (Table 11.1). Although the mean country size around the globe is around 623,000 square kilometres (the size of Afghanistan or Central African Republic), the variance among countries is large (the standard deviation is around 3 times larger than the mean).

Table 11.1: Basic statistics for land area in 235 countries as raw values in square kilometres and as the natural log of land area. Data are from WRI 2000-2001, CIA 2001 and in-country sources, with preference where more than one source was available being taken in that order.

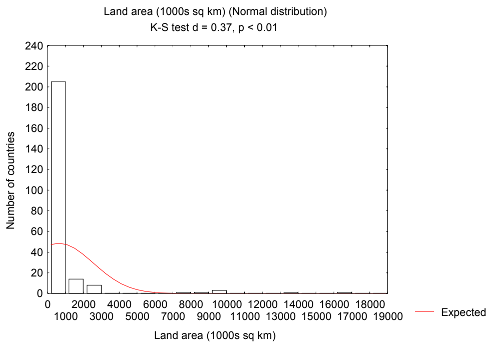
Statistic	Land area (sq km)	LN land area
Mean	622,965	10.3
Median	77,280	11.26
Valid n	235	235
Min	0.44	-0.82
Max	16,888,500	17
SD	1,927,901	3
SE	125,762	0.2
Skewness	5.70	-0.69
SE Skewness	0.16	0.16
Kurtosis	36.61	-0.22
SE Kurtosis	0.32	0.32

11.3 Distributional characteristics of the indicator data

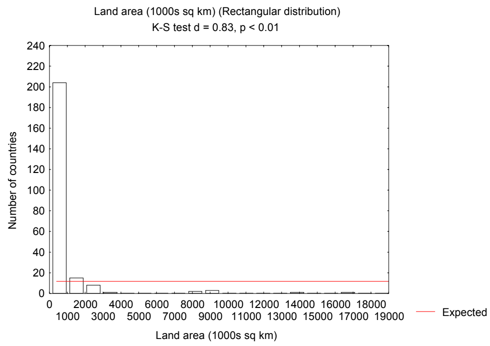
The sizes of countries were plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 11.1). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in the normal and rectangular models, indicates that the sizes of countries defined around the globe do not approximate some average, and that there are not similar numbers of countries through a range of sizes. The distribution of country size was a better fit to the exponential and lognormal functions (both non-significant in the K-S tests). The observed distribution of country size was heavily skewed at the small end of the scale, with few countries at higher values.

Figure 11.1: Kolmogorov-Smirnov goodness-of-fit tests for size of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

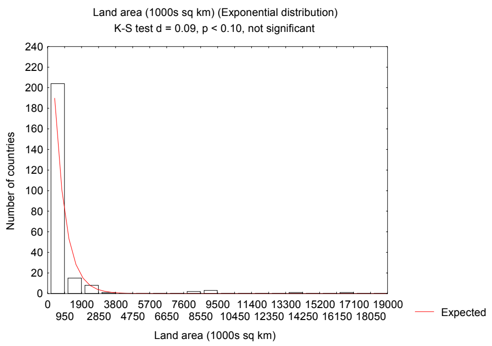
(a)



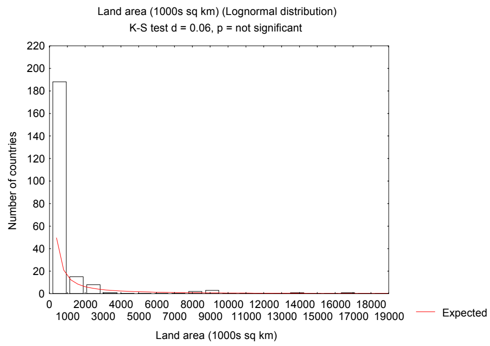
(b)



(c)



(d)



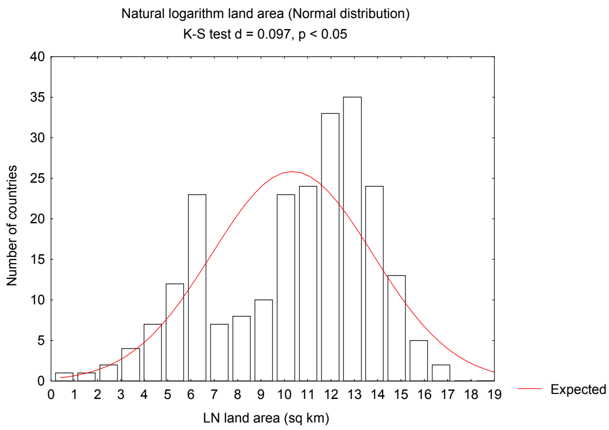
11.4 Proposed EVI scaling and distribution of the data on this scale

With countries varying in size by 5 orders of magnitude across the globe (Figure 11.2) we propose that the raw values be transformed to a natural log scale to give a more compressed range between –0.82 and 17, rather than 0.44 to 16,888,500 and to provide better spread among the smaller countries. These values would in turn be scaled unevenly to create EVI scores that group countries of medium to large size and low vulnerability and put more emphasis on differences in the remaining range. There is little formal information on the likely effects of small country sizes on the persistence of ecosystems so trigger points cannot be set independently of the observed data. In terms of island biogeography, studies on patch size and persistence, and species-area curves, ecological systems do respond to geographic limits. Combined with the political, economic and social forces operating at the scale of countries, the interaction between people and the environment is likely to be related to the area of land available, particularly during periods of either environmental or human stress. There is a reasonable expectation that the larger a country, the more intrinsic resilience there will be to disturbances to the environment because the extent of any one hazard is likely to affect a relatively smaller proportion of the ecosystems and species present.

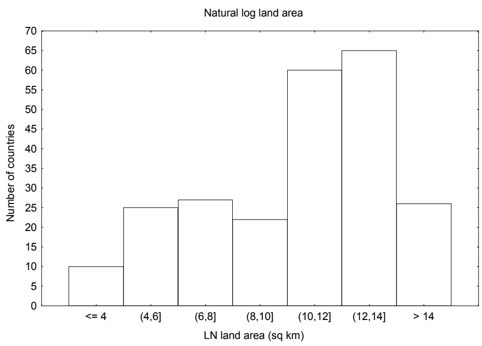
We set the EVI on a reverse scale, with the largest countries attracting the lowest scores (1-2). The scale proposed tends to spread countries at mid scales and separately groups large and very small countries to highlight the extremes. The distribution of countries plotted on the proposed EVI scale is shown in Figure 11.2, Table 11.2, 11.3.

Figure 11.2: (a) Frequency distribution of LN land area values in 20 categories; (b) is a the frequency distribution over 7 categories with values <4 (small countries) and >14 (large countries) grouped; (c) is the reverse of (b) forming the 1-7 EVI scale for this indicator.

(a)



(b)



(c)

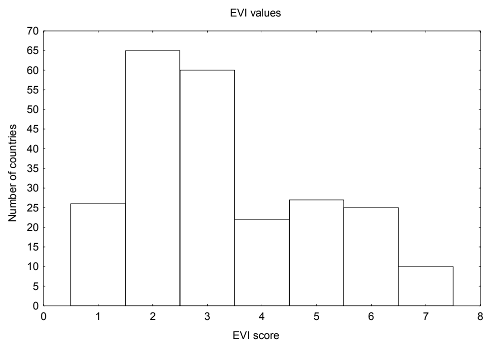


Table 11.2: Proposed EVI scaling for land area showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X>14	26	11.06
2	12<X≤14	65	27.66
3	10<X≤12	60	25.53
4	8<X≤10	22	9.36
5	6<X≤8	27	11.49
6	4<X≤6	25	10.64
7	X<4	10	4.26
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 11.3: Proposed EVI scaling for Indicator 11 on land area (size of country) showing the scale as defined on LN transformed data and the equivalent sizes in square kilometres. Also shown are examples of countries that fit into each of the EVI scores.

Score	Scale for LN Land area	Scale for Land area sq km	Examples
EVI=1	X>14	X>1,202,604.28	Angola, Argentina, India
EVI=2	12<X≤14	162,754.79<X≤1,202,604.28	Kenya, Malaysia, Senegal
EVI=3	10<X≤12	22,026.47<X≤162,754.79	Paraguay, Slovakia, Taiwan
EVI=4	8<X≤10	2,980.96<X≤22,026.47	Israel, Puerto Rico, Qatar
EVI=5	6<X≤8	403.43<X≤2,980.96	Andorra, Guadeloupe, St Lucia
EVI=6	4<X≤6	54.60<X≤403.43	Cook Is., Grenada, Mayotte
EVI=7	X<4	X<54.60	Gibraltar, Macau, Tuvalu

11.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

11.6 Age, completeness and quality of the data

The data obtained for this indicator were from two public sources (WRI 2000-2001 and CIA 2001 and from in-country sources. Of the public sources, WRI data were used in preference to CIA data, with the latter being used where data were not given by WRI. In-country data were available for 19 of the 32 collaborating countries, with data being of good age and quality.

Table 11.4: Characteristics of age, completeness and quality of the data obtained for land area in 235 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.06	1.74	2.39
Valid n (in-country)	16	19	18
SD (in-country)	0.75	0.93	0.61
SE (in-country)	0.19	0.21	0.14

11.7 Variations among sources of data

There were differences in the estimates of land area between all three sources (WRI, CIA and in-country) for this indicator. The average difference between WRI and CIA data was 0.77% averaged over the 154 countries for which they both provided data. This scale of difference in the data is unlikely to affect the final EVI scores that would be obtained using either data set.

11.8 Additional sources & contacts

www.bartleby.com/151/a6.html (20/02/2002); www.linz.govt.nz/rcs/linz/pub/web /root/home/index.jsp (New Zealand); Cook Islands - Cook Islands NEMS (National Environmental Management Strategy) Report. SPREP (South Pacific Regional Environment Programme); Greece - Greece Govt Information. Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Internal record (Digitized 1:25000 Paper Maps), Ordinance Surveys, UK. Land Management Division (LMD); Marshall Islands - Land in Micronesia & its Resources: An Annotated Bibliography/ E. H. Bryan, Jr. 1971; Nauru - Thaman, R R and Hassall, D C. 1999. Nauru National Environmental Management Strategy (NEMS); Niue - Niue National Environmental Management Strategy (NEMS) Report. SPREP, UNDP; Palau - Various maps. Bureau of Land Survey. Contact - Jerry Knight (680 4882332/ 4883195/ bls@palaunet.com); Philippines - Philippine Forestry Statistics. Ms MAYUMI Ma. QUINTOS / Chief, Forest Economics Division / Forest Management Bureau (FMB); Samoa - State of Environment Report: Samoa, Government of Samoa. 1998. Tu'u'uleti Taulealo, National Environmental Management Strategy (NEMS) Consultant; Thailand - National Geography Committee. (1984) Series Document of Thailand Geography volume 1: Physical Characteristic of

Thailand ISBN 974-07-5303-5; Tonga - www.spc.org.nc/demog/pop_data200.html ; Tuvalu - Tuvalu National Environmental Management Strategy (NEMS) Report; WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resources Institute, UNDP, UNEP, World Bank. Washington, D.C.

12. COUNTRY DISPERSION

12.1 Indicator Summary

Indicator number:	12	
Indicator short name:	Country dispersion	
Sub-index	IRI	
Categorisation	Geography	
Indicator text:	Ratio of length of borders (land and maritime) to total land area	
Signals captured:	This indicator captures the degree to which a country's land area is fragmented and 'thin'. Countries which are highly fragmented, comprised of many islands, or which have many peninsulas or land areas in thin strips are likely to be prone to more transboundary effects. The land areas may also be more exposed to damage from natural disasters and human impacts (e.g. cyclones, fires, effects of war) in such areas, because the presence of refugia and ecosystem types that may form breaks are likely to be limited. Although fragmentation may also bring with it the possibility that damage could be limited by intervening areas of land or sea, there are likely to be higher risks that ecosystems and species (particularly if many are endemic) will not persist. This could be especially true if there are interactions with on-going human impacts. Larger countries with fragmentation are likely to be less at risk from this stressor than small ones and this indicator would need to be examined in tandem with Indicator 10 on country size.	
Notes on this indicator:	1. Indicator is tested raw. 2. The degree of dispersion of countries may prove to be correlated with overall land area. 3. Length of borders includes all land and coastlines.	
Are suitable data available?	Yes	
Sources of data:	• WRI 2000-2001 • CIA Fact sheets 2001, 2002 • In-country	
No. countries included in test:	235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the age, completeness and quality of the data were generally considered good. We compiled a composite value for this indicator using data from WRI, CIA and in-country sources in that order of preference.	
Basic units:	X = total length of land and sea borders (km) / land area of country (accumulated across islands, if present) (1000 sq km).	
Recommended transforms:	• Basic units used are km border per 1000 sq km land area to bring values to integer numbers • Data transformed to LN(x) to linearise scale.	
Proposed EVI Scale	EVI Score = 1	X≤2
	EVI Score = 2	2<X≤3
	EVI Score = 3	3<X≤4
	EVI Score = 4	4<X≤5
	EVI Score = 5	5<X≤6

	EVI Score = 6	6<X≤7
	EVI Score = 7	X>7
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

12.2 Description of raw data

The raw data for this indicator are comprised of the total length of borders surrounding a country (km) divided by total land area (sq km) and multiplied by 1000 to make the numbers easier to handle. Data were available for 234 (of 235) countries examined.

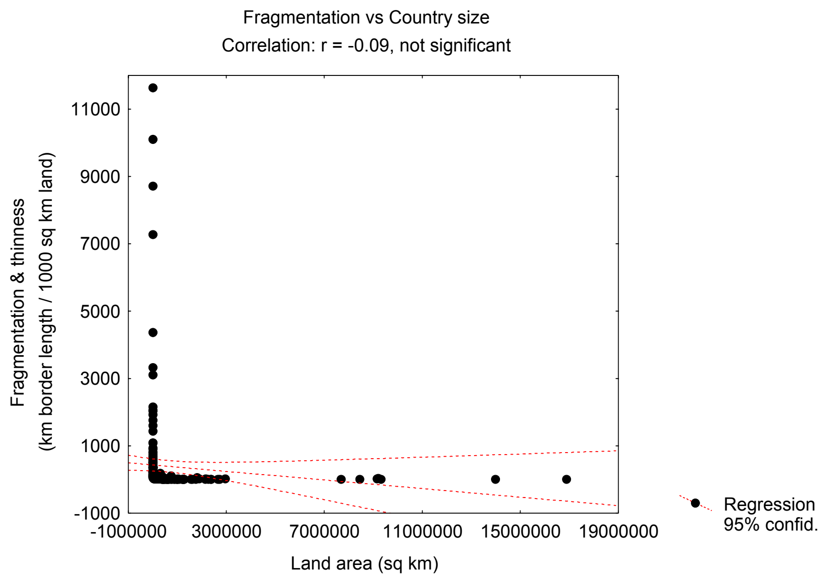
The degree of fragmentation and 'thinness' of countries varied between 0.22 and 11,633 kilometres of border per 1000 square kilometres of land area across the globe (Table 12.1). The least fragmented country examined was Swaziland and the most fragmented was British Indian Ocean Territory. Other highly fragmented or 'thin' countries include Tokelau, Palau, Northern Marianas, Monaco and Federated States of Micronesia. The mean degree of fragmentation / 'thinness' around the globe is around 400 km of border per 1000 sq km of total land area, or 0.4 km of border per sq km of land. Variance among countries is high, with a standard deviation which is 3.3 times the mean.

The degree to which a country is fragmented or 'thin' is apparently unrelated to its size. In Figure 12.1 we plotted our measure of dispersion against land area and tested the relationship using a standard correlation coefficient (r was not significant with 232 degrees of freedom). Countries fell into two groups, with the largest countries tending to be unfragmented, while among the smaller countries, the full range of fragmentation found across the globe was apparent.

Table 12.1: Basic statistics for dispersion (fragmentation and thinness) of the land area (plus LN transformed data, see below) in 234 countries as raw values in km of borders (maritime and land) per 1000 sq km of land area. Data are derived from WRI 2000-2001, CIA 2001, 2002 and in-country sources, with preference where more than one source was available being taken in that order.

Statistic	Dispersion (km / 1000 sq km)	LN transformed dispersion
Mean	392.36	4.07
Median	44.33	3.79
Valid n	234	234
Min	0.22	-1.49
Max	11,633.33	9.36
SD	1,324.25	1.83
SE	86.57	0.12
Skewness	6.26	0.48
SE Skewness	0.16	0.16
Kurtosis	43.19	0.07
SE Kurtosis	0.32	0.32

Figure 12.1: Graph of the degree of fragmentation or 'thinness' vs. size of countries. The correlation coefficient result shows that there is no correlation between these variables.



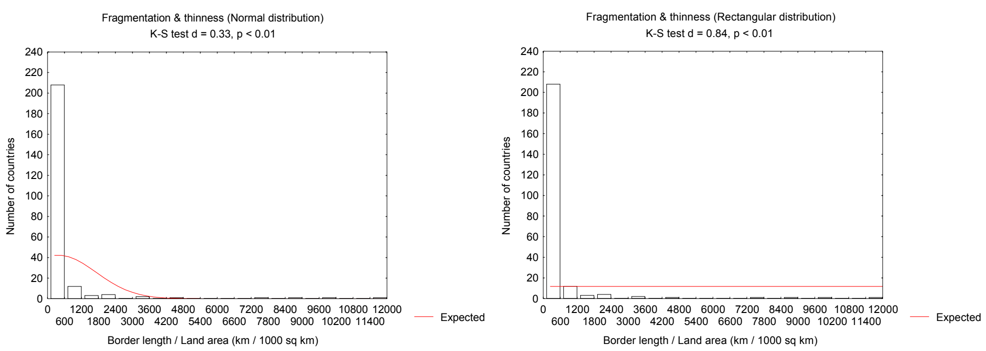
12.3 Distributional characteristics of the indicator data

The sizes of countries were plotted as frequency distributions in 20 evenly-spaced categories to identify any patterns in the distribution (Figure 12.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

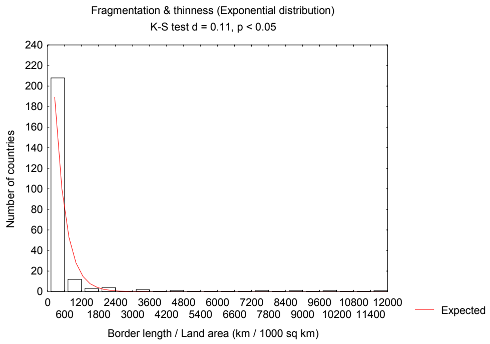
A significant difference between observed and expected values was found in all tests except the lognormal one. The degree of fragmentation and thinness of countries defined around the globe do not approximate some average, and that there are not similar numbers of countries through a range of sizes. The distribution was a better fit to the lognormal function and was heavily skewed at the small (unfragmented) end of the scale, with few countries at higher values (Figure 12.2).

Figure 12.2: Kolmogorov-Smirnov goodness-of-fit tests for fragmentation and 'thinness' of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit.

(a) (b)



(c)



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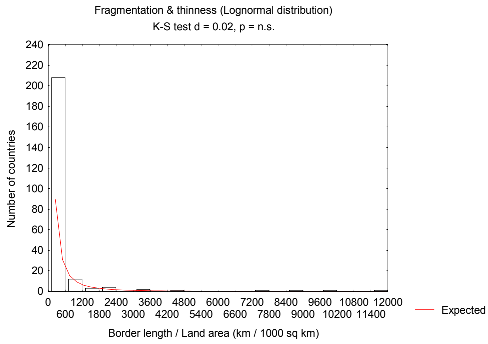


12.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in fragmentation / thinness by three orders of magnitude, which when transformed to a natural log scale were normally distributed (Figure 12.3 a). We propose that the raw values be transformed the natural log (LN(x)) scale to give a more compressed range between –1.49 and 9.36, rather than 0.22 to 11,633. This leads to better separation among the more fragmented countries. These values were then reversed (so that highly fragmented countries were given the highest EVI scores (vulnerable) and scaled unevenly to group countries of greatest and least fragmentation at either end of the scale. Countries with LN fragmentation scores of between 2 and 7 were spread evenly among EVI scores of 2-6 (Figure 12.3 b, Table 12.2, 12.3). The grouping at either end of the scale serves to simplify the EVI scoring, collecting the tails of the distribution and implies that at certain levels of fragmentation, there would be little functional difference in the levels of fragmentation.

There is little information on the likely effects of fragmentation on the resilience or persistence of ecosystems so trigger points cannot be set independently of the observed data. In terms of island biogeography, studies on patch size and persistence and species-area curves suggest that ecological systems do respond to geographic limits and the size of the patches within which they are found. Combined with the political, economic and social forces operating at the scale of countries, the interaction between people and the environment is likely to be related to the area of land available in patches within a country, particularly during periods of either environmental or human stress. There is a reasonable expectation that the more consolidated the land areas of a country, the more intrinsic resilience there will be to disturbances to the environment because the extent of any one hazard is likely to affect a relatively smaller proportion of the ecosystems and species present and re-seeding can occur from adjacent areas.

Figure 12.3: (a) Frequency distribution of LN fragmentation & thinness in 20 categories (note the transformation renders the data normally distributed); (b) is the distribution on the proposed EVI scale with values <2 being attributed to EVI score=1 (unfragmented countries) and >7 attributed to EVI score=7 (fragmented and/or thin countries).

(a) (b)

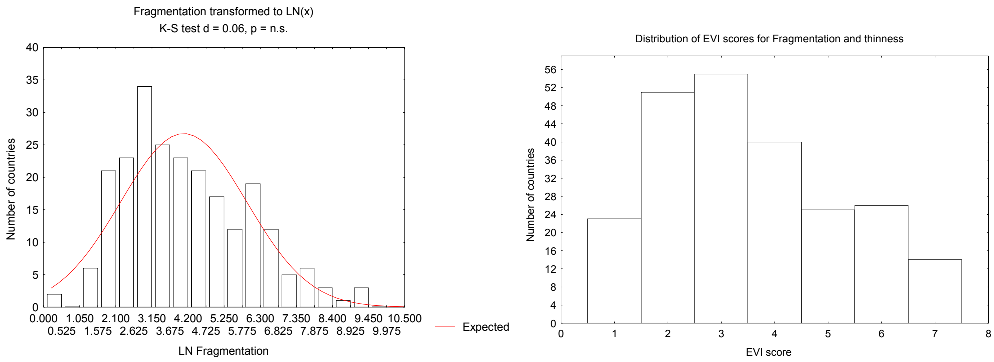


Table 12.2: Proposed EVI scaling for land fragmentation showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X≤2	23	9.83
2	2<X≤3	51	21.79
3	3<X≤4	55	23.50
4	4<X≤5	40	17.09
5	5<X≤6	25	10.68
6	6<X≤7	26	11.11
7	X>7	14	5.98
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 12.3: Proposed EVI scaling for Indicator 11 on fragmentation showing the scale as defined on LN transformed data and the equivalent sizes in the raw data (km borders / sq km land area). Also shown are examples of countries that fit into each of the EVI scores.

Score	Scale for LN Fragmentation	Scale for Land area sq km	Examples
EVI=1	X≤2	X≤7.39	Angola, Bolivia, Brazil
EVI=2	2<X≤3	7.39<X≤20.09	Burkina Faso, Australia, Turkey
EVI=3	3<X≤4	20.09<X≤54.60	Belgium, Tajikistan, Vietnam
EVI=4	4<X≤5	54.60<X≤148.41	Bangladesh, Finland, Haiti
EVI=5	5<X≤6	148.41<X≤403.43	Vanuatu, Martinique, Comoros
EVI=6	6<X≤7	403.43<X≤1096.63	Lichtenstein, Cook Is., B. Virgin Is.
EVI=7	X>7	X>1096.63	Bermuda, FSM, Kiribati.

12.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

12.6 Age, completeness and quality of the data

The data obtained for this indicator were from two public sources (WRI 2000-2001 and CIA 2001, 2002 and from in-country sources. Of the public sources, WRI data were used in preference to CIA data for land area and length of maritime borders, but only CIA data were used for length of land borders. In-country data were available for 17 of the 32 collaborating countries, with data being of good age and quality (Table 12.4).

Table 12.4: Characteristics of age, completeness and quality of the data obtained for land fragmentation in 235 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.46	1.82	2.29
Valid n (in-country)	13	17	17
SD (in-country)	0.78	1.01	0.69
SE (in-country)	0.22	0.25	0.17

12.7 Variations among sources of data

There were differences in the estimates of land area and border lengths between all three sources (WRI, CIA and in-country) for this indicator. The average difference between WRI and CIA data on land area was 0.77% averaged over the 154 countries for which they both provided data. This scale of difference in the data is unlikely to affect the final EVI scores that would be obtained using either data set.

12.8 Additional sources & contacts

www.bartleby.com/151/a9.html (26-02-2002); WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute, UNDP, UNEP, World Bank,. Washington, D.C.; Bangladesh - Bangladesh State of the Environment Report. 1999; Cook Islands - Marine Resources. Works, Energy and Physical Planning (MOWEPP). Timoti Tangiruaine (682 24484/ 682 21134); Kiribati - Internal record (Digitised 1:25000 Paper Maps), Ordinance Surveys, UK. Land Management Division (LMD); Nauru - Lands & Survey. Contact - Porthos Bop (674 4443845); New Zealand - http://www.linz.govt.nz/rcs/linz/pub/web /root/home/index.jsp ; Niue - GIS – Coastal layer. Lands & Survey. Contact - Coral Pasisi (Fax: 683 4231/ coral.ca@mail.gov.nu); Palau - Various maps. Bureau of Land Surveys. Contact - Jerry Knight (680 4882332/ 4883195/ bls@palaunet.com); Samoa - W. Samoa, EEZ Report, Mapping, DLSE. FFA Publcation. Boyes, G and Leo, O.; Tuvalu - Tuvalu Maps. Government of the United Kingdom and D.O.S. Department of Lands and Survey.

13. GEOGRAPHIC ISOLATION

13.1 Indicator Summary

Indicator number:	13
Indicator short name:	Geographic Isolation
Sub-index	IRI
Categorisation	Geography
Indicator text:	1. Distance to nearest continent 2. Distance to the nearest continent within 10 degrees of latitude
Signals captured:	This indicator captures the proximity of a country to the nearest continent. Note that if a country is within a continent, this value is zero. Isolated countries may have a greater risk of loss of ecosystem types and species during periods of stress if they are far away from refugia and sources of recolonisation. Isolated countries also likely to support fewer species than those which are close to large continents, or biogeographic centres of radiation. Additionally, there is less chance of genetic interchange (part of genetic resilience) in isolated areas. The likelihood of isolation being an important part of a country's ecological resilience would be especially important if there are interactions with on-going human impacts. Countries close to sources of recolonisation are likely to be less at risk of permanent species losses, compared with those far away, particularly if they are small or fragmented. This indicator would need to be examined in conjunction with Indicators 10 and 11.
Notes on this indicator:	1. Indicator is tested raw.
Are suitable data available?	Yes
Sources of data:	• Times Comprehensive World Atlas 2000 used by EVI Team to estimate distances using the given scales. • In-country
No. countries included in test:	235
Temporary modifications to data or indicator, if applicable:	• None
Notes on data age, completeness and quality:	13 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good, but the values given were sometimes very different from those calculated by the EVI Team. The differences will be investigated further.
Basic units:	X = distance (km) to the closest continent.
Recommended transforms:	• None.
Proposed EVI Scale	EVI Score = 1 | X≤0 EVI Score = 2 | 0<X≤50 EVI Score = 3 | 50<X≤100 EVI Score = 4 | 100<X≤400 EVI Score = 5 | 400<X≤800 EVI Score = 6 | 800<X≤1600 EVI Score = 7 | X>1600 NA (not applicable) | ☒ May not be used ND (no data) | ☑ May be used

Future work on this indicator:	

13.2 Description of raw data

The raw data for this indicator are comprised of the shortest linear distance (as estimated from maps) between a country and its nearest continent in kilometres. Data were collected for all of the 235 countries examined.

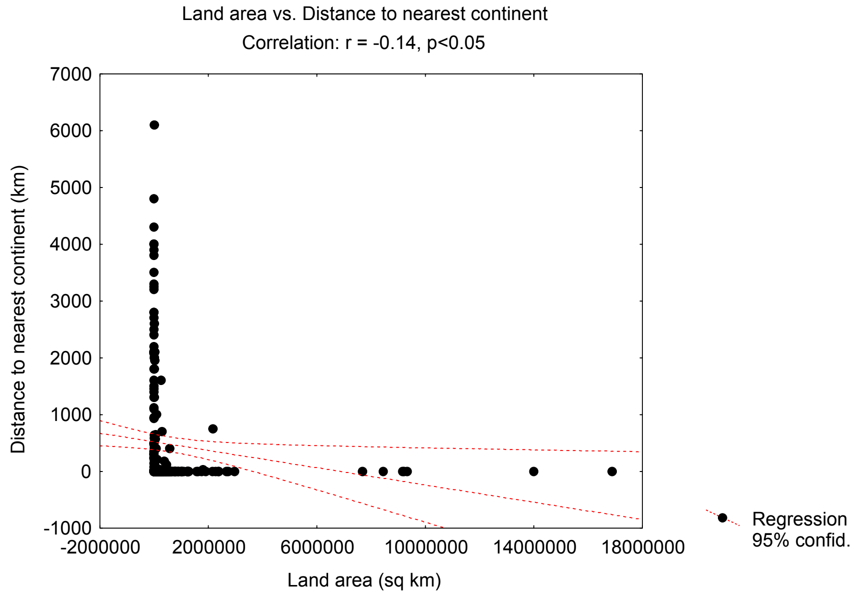
The distances involved varied between 0 and 6,100 km (Table 13.1). One hundred and fifty-two countries are located within continents, so the resulting distance to the nearest continent was zero. The country located furthest from any continent was French Polynesia. The mean distance that countries are located away from continents on the globe is 473 km, a value largely driven by the presence of so many countries that are within continents. If these are excluded, the average distance between a country that is detached from a continent and the nearest continent is 1,341 km. Variance among countries is high, with a standard deviation which is more than twice the mean.

The distance of countries to their nearest continent is related to country size (see significant correlation coefficient in Figure 13.1). The correlation is, however, a weak one and countries largely fall into two categories lying close to each axis. That is, the size of countries within continents (zero on the y-axis) is variable and covers the entire range of country sizes, while its is only the smaller countries that tend to be the furthest away from continents. Of course, this result is largely a definitional one – larger countries can be defined as continents in themselves (e.g. Australia).

Table 13.1: Basic statistics for isolation in 235 countries as raw values in distance from nearest continent (km). Data are derived from Times Comprehensive Atlas of the World 2000.

Statistic	Isolation (km)
Mean	473.73
Median	0.00
Valid n	235
Min	0
Max	6100
SD	1031.00
SE	67.25
Skewness	2.63
SE Skewness	0.16
Kurtosis	7.13
SE Kurtosis	0.32

Figure 13.1: Graph of isolation vs. size of countries. The correlation coefficient result shows that there is a significant correlation between these two variables.



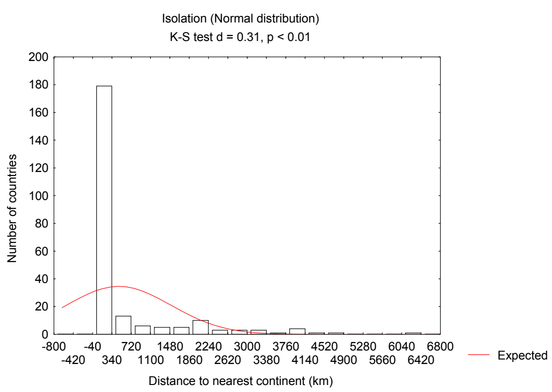
13.3 Distributional characteristics of the indicator data

The isolation of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any patterns in the distribution (Figure 13.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

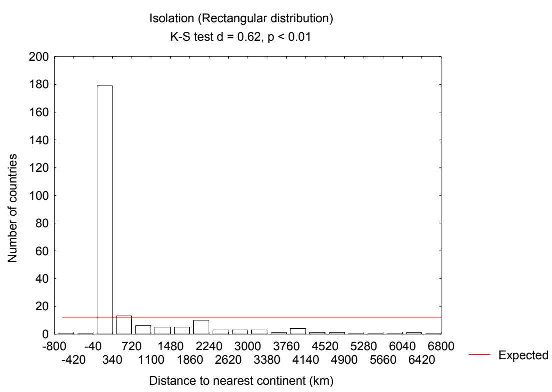
A significant difference between observed and expected values was found in all tests (Figure 13.3). The isolation of countries defined around the globe does not approximate some average, and there are not similar numbers of countries in categories across the available isolation range. The distribution did not fit any of the more common models used. There was a large number of countries at zero isolation, and variable numbers in categories of increasing isolation.

Figure 13.2 Kolmogorov-Smirnov goodness-of-fit tests for isolation of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit.

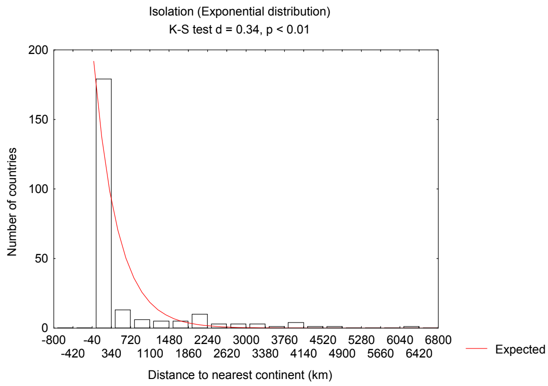
(a)



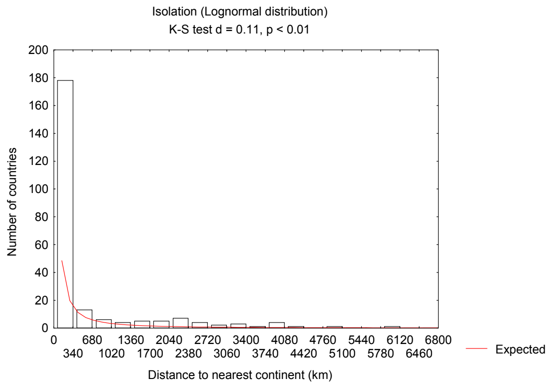
(b)



(c)



(d)



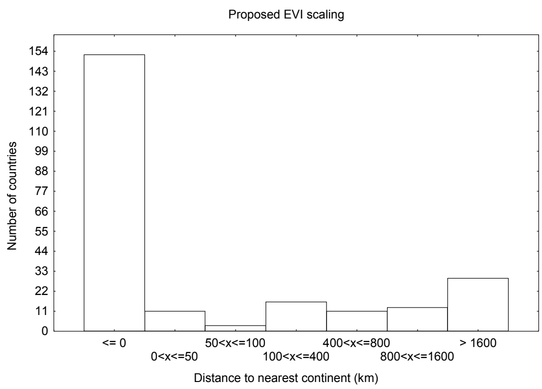
13.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in isolation by three orders of magnitude. We propose that the raw values be used for this indicator, with countries of increasing distance from continents being considered more vulnerable and attracting a higher EVI score. We identified those countries with zero distance from a continent as being the least vulnerable (EVI score =1), and any further than 1600 km the most vulnerable (EVI score =7) (Figure 13.3, Table 13.2, 13.3). Countries between these two categories were divided unevenly, with increasing emphasis on those furthest away from large land masses. The scaling used is intended to focus on the decreasing opportunity for organisms (oceanic larvae, migrating birds, or other organisms using other mechanisms) to successfully traverse the distances involved to either recolonise or add elements to isolated gene pools.

There is little information on the exact distances that are likely to be important for recolonisation and genetic mixing to occur. Further, values that might be obtained are likely to differ vastly among species, and no general rule is likely to apply. There is a reasonable expectation that the more isolated a country, the less chance there will be for genetic mixing and recolonisation to occur if there is damage to ecosystems. This might be of particular importance in areas already subject to other stresses (human and natural) and interactions between the two.

Figure 13.3: (a) Frequency distribution of isolation measures in seven uneven categories across the global range; (b) is the distribution on the proposed EVI scale with values ≤0 being attributed to EVI score=1 (countries within continents) and >1600 attributed to EVI score=7 (very isolated countries).

(a)



(b)

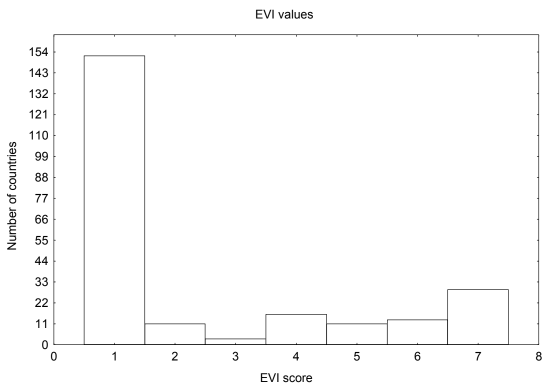


Table 13.2: Proposed EVI scaling for isolation showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X≤0	152	64.68
2	0<X≤50	11	4.68
3	50<X≤100	3	1.28
4	100<X≤400	16	6.81
5	400<X≤800	11	4.68
6	800<X≤1600	13	5.53
7	X>1600	29	12.34
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 13.3: Proposed EVI scaling for Indicator 13 on isolation showing examples of countries that fit into each of the EVI scores.

Score	Scale for LN Isolation	Examples
EVI=1	X≤0	Belgium, China, Egypt
EVI=2	0<X≤50	Aruba, Cocos Is., Indonesia
EVI=3	50<X≤100	Netherlands Antilles, Sri Lanka, Cyprus
EVI=4	100<X≤400	Bahamas, Cuba, Grenada
EVI=5	400<X≤800	Greenland, Haiti, Jamaica
EVI=6	800<X≤1600	Iceland, Mauritius, New Caledonia
EVI=7	X>1600	Anguilla, Cook Is., Montserrat

13.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

13.6 Age, completeness and quality of the data

The data obtained for this indicator were derived by the EVI Team using a single public source (Times Comprehensive World Atlas 2000) and from in-country sources. Distance to nearest continent was calculated from maps using simple mechanical measurements and the scale provided with each. In-country data were available for 13 of the 32 collaborating countries, with data being of good age and quality (Table 13.4).

Table 13.4: Characteristics of age, completeness and quality of the data obtained for isolation in 235 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.60	2.23	2.50
Valid n (in-country)	10	13	12
SD (in-country)	0.70	1.01	0.80
SE (in-country)	0.22	0.28	0.23

13.7 Variations among sources of data

There were differences in the estimates of distances to nearest continent between the values derived by the EVI Team and those provide by in-country collaborators. These varied between a few percent, up to several orders-of-magnitude. The differences are probably definitional and in-country sources will be examined in greater detail in the future.

13.8 Additional sources & contacts

Cook Islands - Marine Resources. Works, Energy and PhysicalPlanning (MOWEPP)-Lands Dept., GIS; Kiribati - MapInfo Data from SOPAC. Land Management Division; Marshall Islands - Jacaranda Atlas 4th Edition; Nepal - World Atlas; New Zealand - NZMS 260 sheet A45 Topographic Map AUSLIG Place Names Database http://www.linz.govt.nz/rcs/linz/pub/web /root/home/index.jsp ; Niue - Justice, Lands and Survey – data taken from SOPAC 1997; Palau - Encarta Encyclopedia, Microsoft. Office of Planning & Statistics (OPS); Philippines - National Mapping and Resource Information Authority (NAMRIA); Samoa - Lands, Surveys & Environment; Singapore - Cadastral maps and IoF base system. Singapore land authority/ local survey's dept; Thailand - GIS Database. Pollution Control Dept; The Times Atlas of the World, Millenium Edition. 2000 Times Books, ISBN 0 7230 0792 6; Tuvalu - McLean, R. F. and Hosking, P. L. 1991 Land Resource Survey Report.

14. RELIEF

14.1 Indicator Summary

Indicator number:	14
Indicator short name:	Vertical relief
Sub-index	IRI
Categorisation	Geography
Indicator text:	Altitude range (highest point subtracted from the lowest point in country)
Signals captured:	Biodiversity of habitat & species, potential for habitat disturbance through movements of water and slides. A country with a large altitude range is likely to have a greater variety of ecosystems, which in very high altitude areas, or very low ones (e.g. the Black Sea) leads to the formation of "endemic habitat types". These can be an integral part of the character of a country, and if lost, the same arguments as for endemic species applies
Notes on this indicator:	1. This indicator is a proxy for ecosystem diversity. 2. The indicator may also function as a proxy for habitat disturbance through avalanches, slides and large rivers.
Are suitable data available?	Yes
Sources of data:	CIA World Fact Book 2001; In-country
No. countries included in test:	169
Temporary modifications to data or indicator, if applicable:	None.
Notes on data age, completeness and quality:	Where multiple values for these measures were reported, these were reduced to the lowest given value for use in the analysis. That is, if 2 and 3 were returned for a measure, the value 2 was used in the analysis. If no value given, 0 was used.
Basic units:	Metres
Recommended transforms:	None
Future work on this indicator:	Test data on +/- deviations from sea-level rather than just total relief to capture unusual countries at risk because they have areas below sea level.

14.2 Description of raw data

The raw data for this indicator comprise the vertical height difference between the highest and lowest point in a country. In some cases, the lowest point in a country can be many metres below sea-level. Very high altitudes and very ecosystems located in areas well below sea-level tend to be associated with unique or fragile ecosystems (e.g. Black Sea).

For the 169 countries examined, values varied between 5m and nearly 8,800m, with an average across all tested of more than 2,800m (Table 14.1). The countries with the greatest relief were Nepal, China, Pakistan and India. Those with the least relief were Tuvalu, Marshall Islands, Gambia and Nauru. Slovenia and Honduras were two countries with average relief (as calculated from the test countries listed below). The standard deviation (SD) was 2057, which was smaller than the mean (Table 14.1). The standard error (SE) was 158, which was less than 6% of the mean.

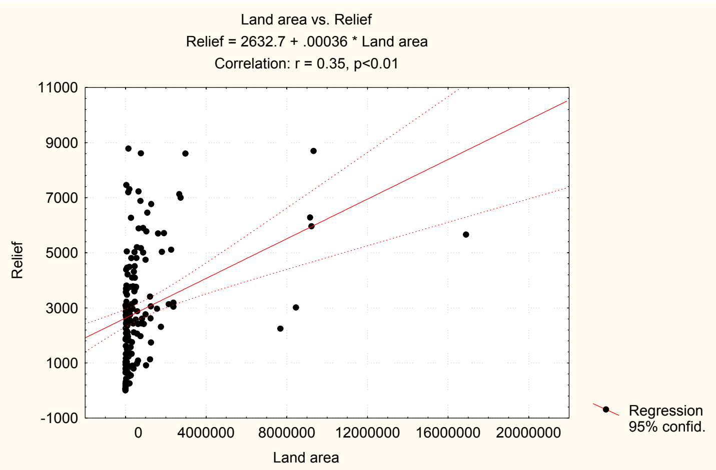
Vertical relief in countries did correlate significantly with the size, as measured by land area (km^2) (Figure 14.1). This result is largely driven by the results obtained in 5 countries (Russia, China, Canada, USA and Brazil) which have very large land areas and moderately-large vertical relief. The graph also shows, however, that there is a large range in vertical relief in much smaller countries that show the entire range of relief found in this test. Although it is true that one might, on average, expect greater relief in larger countries simply because there is a greater area of land available for different landforms and geology to occur, we do not propose that this indicator should be treated as a density function. We suggest that this indicator should be used in its raw state and that adjustments to remove any signal of country size are unnecessary.

Table 14.1: Basic statistics for vertical relief (m) calculated as vertical distance between lowest and highest point, in 169 countries.

Statistic	Value
Mean	2,860.18
Median	2,576.00
Valid n	169
Min	5
Max	8,780
SD	2,057.01
SE	158.23
Skewness	0.87
SE Skewness	0.19
Kurtosis	0.34
SE Kurtosis	0.37

Figure 14.1: Graph of land area versus vertical relief in 169 test countries.

The results show that the vertical relief found in a country does actually correlate with the size of a country.



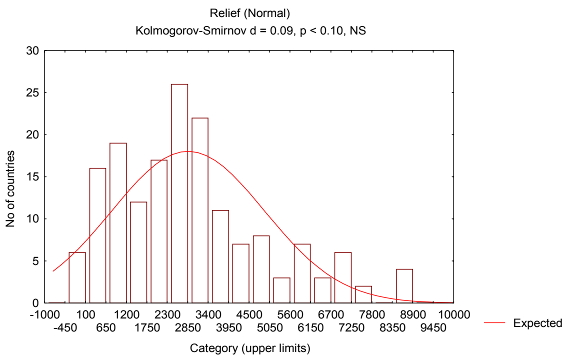
14.3 Characteristics of the indicator data

Vertical relief data were plotted as frequency distributions in 20 categories to identify any underlying distributions (Figure 14.2). The four classes of distributions examined were normal (linear), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). The K-S tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. For the rectangular, exponential and lognormal distributions, a significant difference between observed and expected values was found, indicating that the fit was not good (Figure 14.2). The normal distribution was found to be the best fit for the observed distribution of vertical relief in countries. The data for this indicator were as a result used without transformation.

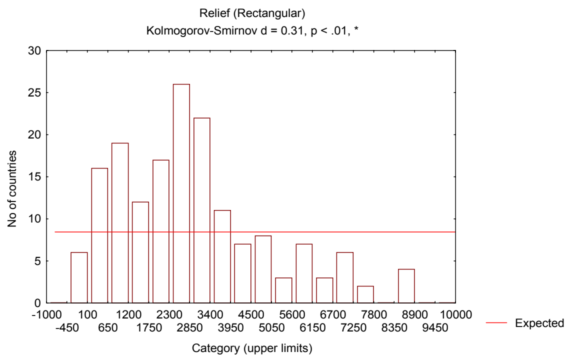
Figure 14.2: Frequency distribution of vertical relief in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. All comparisons resulted in significant K-S tests, except for the normal distribution, suggesting that the data can probably be mapped directly onto the linear EVI scale.

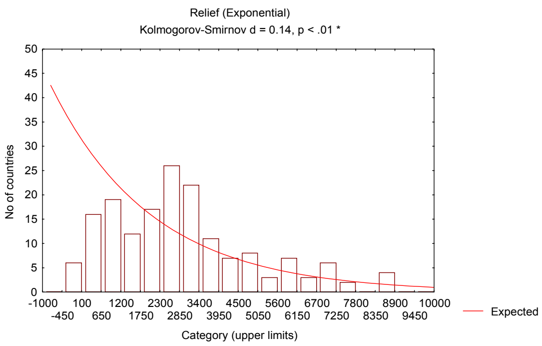
(a)



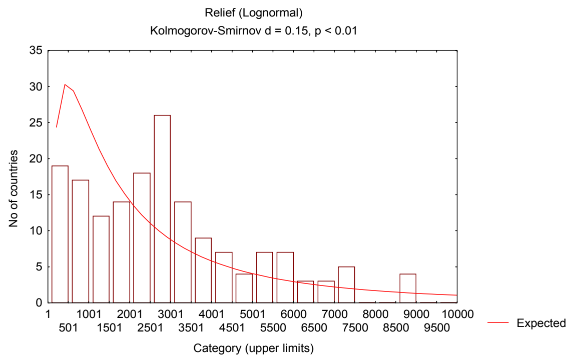
(b)



(c)



(d)



14.4 Proposed EVI scaling and distribution of the data on this scale

We propose that the EVI scale be a simple linear one with slightly varying intervals and a reversal for countries with very low relief. The reasoning behind this, is that countries with very high relief are at risk of losing unique ecosystems and of disturbances associated with land and water movements under gravity, while those with very low relief of say, <50m, may have low resilience to maritime influences and also support unique ecosystems (e.g. atolls, salt seas). Countries with low relief may also be vulnerable because they have limited refugia.

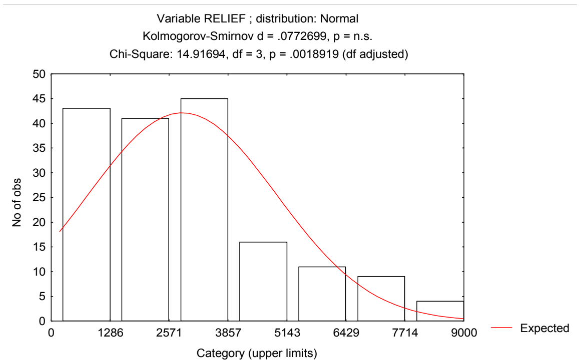
The data on vertical relief were plotted as a frequency distribution with 7 categories to identify a possible scale for the EVI (Figure 14.3 a). This resulted in a spacing of around 1200m, up to a maximum of 9000m in relief, with countries appearing in two distinct categories below and above the 3860m mark. We modified the scale in two ways to make the EVI scoring more sensitive at very high and very low levels of relief. We set the EVI scale at even intervals of 1500m to 6000m, with an interval reduced to 1000m thereafter to capture those countries at the upper end of the spectrum. Countries with <50m vertical relief were given an EVI score of 7, so were added to the scale at the highest vulnerability level. The distribution of countries plotted on the proposed EVI scale is shown in Figure 14.3 b.

The majority of countries (58, 34%) fell on this scale at EVI value 2, with 27% of countries scoring an EVI value of 1 (Table 14.2). About 28% of countries scored an EVI value of 3 or 4. About 10% of countries scored in the upper ranges of the EVI scale (values 5-7).

Figure 14.3: Frequency distribution of countries in terms of vertical relief in seven evenly-spaced categories.

Graph (a) is a plot of frequency distributions from 50m to the maximum observed and shows the calculated cut-off values that could be used for EVI scoring; Graph (b) is a frequency distribution generated for discrete spacings, initially 1500m apart and at higher values 1,000m apart, starting from 50m and plotted on the EVI scale. Countries with <50m vertical relief were added to EVI category 7.

(a)



(b)

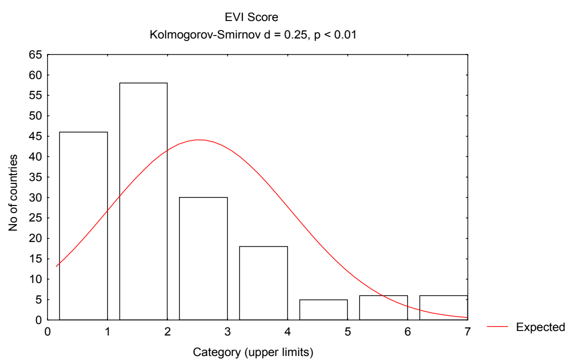


Table 14.2: Proposed EVI scaling for Indicator 14 on vertical relief in countries.

NA=Not applicable in a country; ND=No data currently available

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	X < 1500	46	27.22
2	1500 ≤ X < 3000	58	34.32
3	3000 ≤ X < 4500	30	17.75
4	4500 ≤ X < 6000	18	10.65
5	6000 ≤ X < 7000	5	2.96
6	7000 ≤ X < 8000	6	3.55
7	8000 ≤ X	6	3.55
NA	☒ May not be used		
ND	☑ May be used		

14.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later stage when scales have been set for all indicators.

14.6 Age, completeness and quality of the data

The age of the data for this indicator was generally low, with the average score across all countries being 2.83 of a possible best of 3.00 (i.e. latest data<2 years old) (Table 14.3). Completeness and the quality of data from in-country sources was generally low, but because these data are available from the CIA Fact Book, we were able to obtain published estimates for a large number of countries.

Table 14.3: Characteristics of age, completeness and quality of the data obtained for vertical relief for 169 countries.

Characteristic	Age	Completeness	Quality
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Mean value across countries:	2.83	1.02	1.99
SD	0.66	0.22	0.19
SE	0.05	0.07	0.01

14.7 Variations among sources of data

Alternative public sources of data exist for this indicator and will be tested in the future to evaluate the size of differences among sources and any effect on the EVI calculations.

14.8 Additional sources & contacts

www.rtsd.mi.th/ (7/6/01).(Thailand); www.bartleby.com/151/a13.html (18/01/02); Cook Islands - Cook Islands National Environmental Management Strategy (NEMS) Report. SPREP; Federated States of Micronesia - Gawel, M. 1993. SoE FSM. SPREP; Greece - Greece Government Statistics; Kiribati - Maps from National Mapping and Resource Information Authority. Digitised 1:25000 Paper Maps, Ordinance Surveys, UK; Kyrgyzstan - State Agency for Registration of rights on real estate. Contact - Ms. Goncharova E; Nauru - Lands & Survey. Porthos Bop (674 4443845); Nepal - State of the Environment, Nepal (2001). Ministry of Population and Environment and Development. Nepal/UNEP/ICIMOD/NORAD/SACEP. Kathmandu; Niue - Survey Data – Surveyors. Department of Justice, Land & Surveys; Palau - Bureau of Land Surveys. GIS Development. USGS Topographic Map; Papua New Guinea - Papua New Guinea Resource Information System. Raw data provided from source; Samoa - Topographic Maps (Mapping Section), NZ Map Series. Lands, Surveys & Environment-Samoa; Tuvalu - National Tidal Facility (NTF). Reduced level – Fongafale, Funafuti. Department of Lands and Survey; Vanuatu - Bellamy, J. Commonwealth Scientific and Industrial Research Organisation (CSIRO).

15. LOWLANDS

15.1 Indicator Summary

Indicator number:	15	
Indicator short name:	Lowlands	
Sub-index	IRI	
Categorisation	Geography	
Indicator text:	1. Percentage of land area ≤50m above sea level 2. Percentage of land area ≤10m above sea level	
Signals captured:	This indicator focuses on the presence of lowlands in a country with implied impacts associated with pollution, ecosystem disturbance, flooding and coastal vulnerability. Areas of lowlands are those that will tend to be the first to flood, will tend to accumulate pollution that is mobilised by surface run-off, provide an important entry point (and extraction point) for groundwaters and if on the coasts of the sea or lakes may be subject to storm surges, tsunamis or sea level rise. They tend to be areas of high biodiversity and/or form critical habitats. They may also be critical areas for productivity, soil formation, erosion, natural resources and pollution attenuation. A country's resilience to future hazards will be related to risks on lowland areas. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.	
Notes on this indicator:	1. Although this indicator was originally defined in relation to land areas ≤10 above sea level, data were difficult to obtain. Although maps are available locally in some countries that could be used to calculate area of land at or below this level, coverage was generally poor. It was necessary to redefine the indicator to include all land areas ≤50m which is shown on global maps. 2. We consider the use of ≤50m a proxy for this indicator. The indicator will be more valuable when data for land area ≤10m become generally available. 3. Data were extracted by the EVI Team on Encarta 2004 Maps using a point intercept method on electronic maps at a scale 1:7.4million.	
Are suitable data available?	Yes, but only for ≤50m above sea level.	
Sources of data:	• Encarta 2004 World Atlas • In-country	
No. countries included in test:	236	
Temporary modifications to data or indicator, if applicable:	• Data include all lowlands ≤50m instead of ≤10m below sea level.	
Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data was generally considered good (> value of 2 of 3) by collaborators.	
Basic units:	Percentage of total land area which is ≤50m above sea level anywhere in the country.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	X≤15
	EVI Score = 3	15<X≤30
	EVI Score = 4	30<X≤45
	EVI Score = 5	45<X≤60

	EVI Score = 6	60<X≤75
	EVI Score = 7	75<X
	NA (not applicable)	☒ May not be used. All countries may have lowlands.
	ND (no data)	☑ May be used
Future work on this indicator:	This indicator was originally designed to include land area ≤10m above sea level. We generally consider that land between 10 and 50m should not be included as it is significantly less at risk than the truly lowlands. A source of data is needed that can return values for land ≤10m.	

15.2 Description of raw data

The raw data for this indicator are comprised of the percentage of total land area of a country which is at or below 50m above sea level. We consider that an increasing percentage of lowlands in a country indicates increasing vulnerability to flooding, pollution accumulation, and in coastal areas (including lakes) storm surges, tsunamis, sea level rise and critical habitats. Data were available for all 236 countries examined. Data were extracted from electronic maps available through Encarta 2004 using a point intercept method. Overlays with a large number of regularly-spaced dots were placed over maps. These were enumerated for the whole country and again for those parts shaded as being ≤50 above sea level. Note that because the method used is a statistical one, it is possible for a country to have a small area of its land below 50m that was not detected by the method, resulting in a value of 0%. The converse is true for countries recorded as having 100% of their land below 50m above sea level. In-country data were supplied for area ≤10m above sea level by collaborators, but only for 11 countries, a number insufficient for this indicator. As a result the in-country data were not used in this analysis.

The percentage of land at or below 50m above sea level varied between 0 and 100% across the globe. Countries with no land at or below 50m include Armenia, Colombia and Finland. Belgium, Cook Islands and Gibraltar are examples of countries with 100% of their land area ≤50m below sea level. The mean and median percentage of land at or below 50m above sea level in countries across the globe was approximately 49% (Table 15.1).

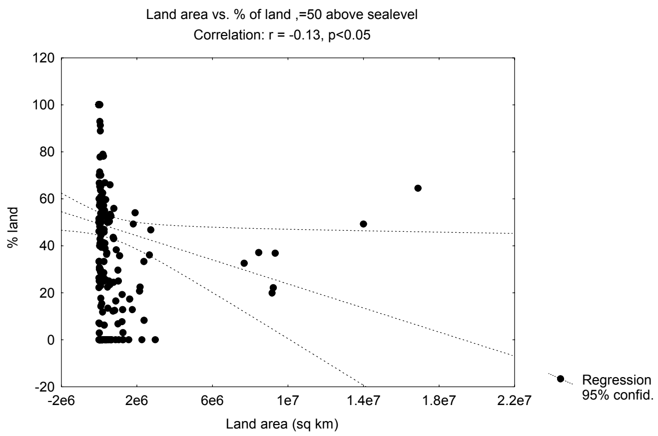
The percentage of lowland area is weakly (negatively) correlated with the size of countries (see significant correlation coefficient in Figure 15.1), but countries may be arranged in two groups. The first group consists of the largest countries which generally tend to have a moderate to lower percentage of their land areas below 50m above sea level. This is to be expected as the larger a country is, the more likely different geomorphological types will occur there so at least part of the country is likely to include higher land areas. Smaller countries (those <2 million sq km) have a variable percentage of their land area below 50m above sea level, with the full range between 0 and 100% observed.

Although the percentage of land are below 50m below sea level does weakly correlate with the size of countries, we chose to use this indicator in its raw state because the figure relates to the vulnerability signal well without removing the signal of country size. Small countries show both high and low values of this indicator (high spatial autocorrelation), and it is a true reflection of vulnerability that large countries will have parts of their land area vulnerable and other parts which will be less vulnerable to low land risks.

Table 15.1: Basic statistics for percentage of land area ≤50m above sea level.

Statistic	% Land ≤50m
Mean	47.82
Median	46.39
Valid n	236
Min	0
Max	100
SD	36.67
SE	2.39
Skewness	0.22
SE Skewness	0.16
Kurtosis	-1.29
SE Kurtosis	0.32

Figure 15.1: Graph of percentage of land area ≤50m above sea level vs. size of countries.

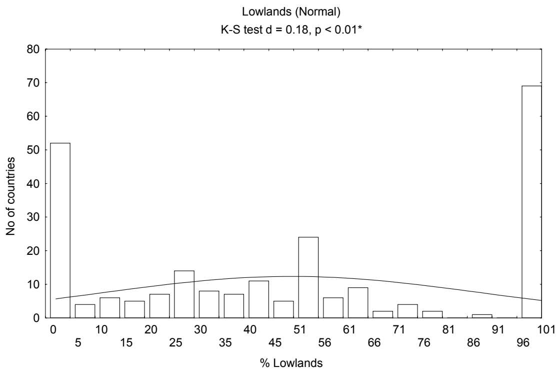


15.3 Distributional characteristics of the indicator data

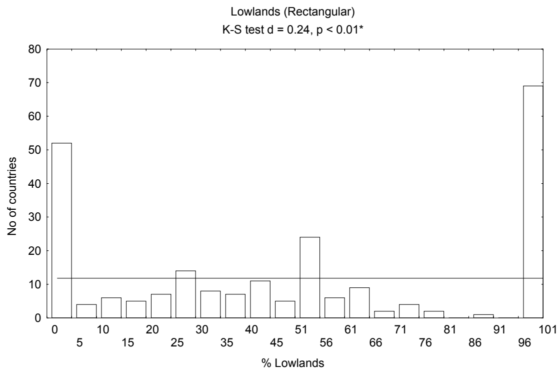
The percentage of land area below 50m below sea level was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 15.2). This resulted in a distribution in which about a large number of countries had very low, and a large number very high percentages of their land area as lowlands (Figure 15.2). This pattern is driven by the large number of small countries, with the larger countries tending to occupy intermediate parts of the range. The four classes of distributions examined to characterise the observations were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in all of the types of distributions tested (Figure 15.2).

Figure 15.2: Kolmogorov-Smirnov goodness-of-fit tests for percentage of lowland areas spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. None of the distributions were a good fit of the observed data.

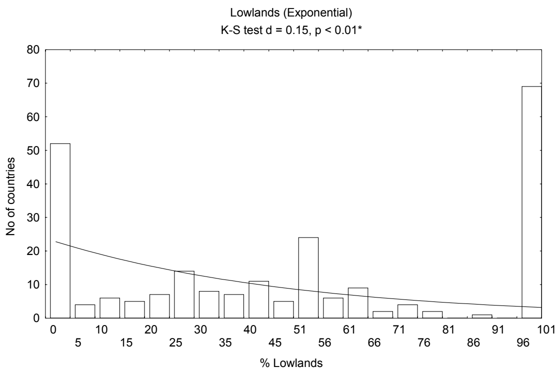
(a)



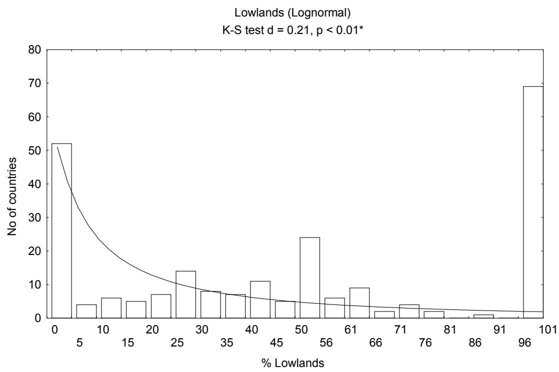
(b)



(c)



(d)



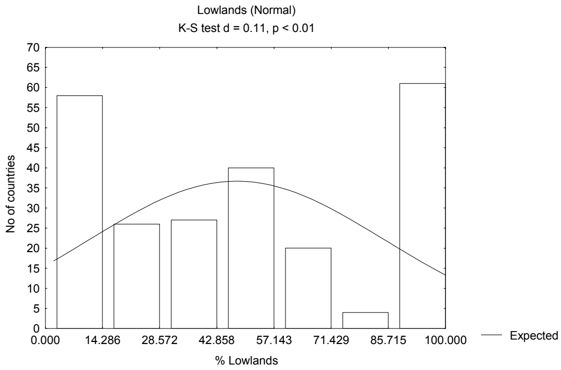
15.4 Proposed EVI scaling and distribution of the data on this scale

We considered that countries with more than 75% of their total land area as lowlands would be most vulnerable to hazards associated with pollution accumulation, flooding, seawater incursions and other threats, regardless of their overall size. Those countries with no low lands were attributed an EVI score =1; and those with >75% given an EVI score of 7. The remaining EVI scores were assigned at regular intervals of 15% within that range, reflecting a direct likelihood of higher vulnerability to selected hazards with greater area of lowlands (Figure 15.3, Table 15.2, 15.3).

The most vulnerable countries in terms of percentage of area of lowlands are small, with no areas of higher ground that would provide refuges from flooding, water accumulation of pollution, erosion and incursions of water from adjacent bodies. These include the countries of Poland, Ghana and Ireland.

Figure 15.3: Frequency distribution of percentage of land area ≤50 above sea level in even and uneven categories and the EVI scale. (a) Frequency distribution in 7 even categories. (b) is the distribution in seven uneven categories which shows the proposed EVI scale.

(a)



(b)

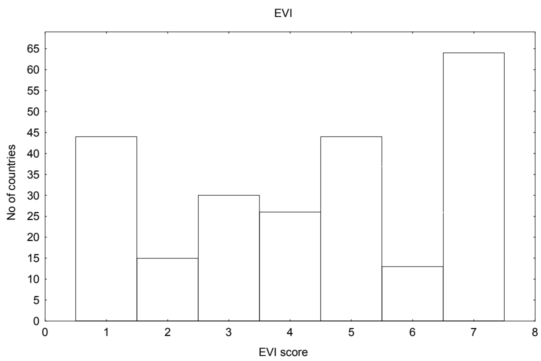


Table 15.2: Proposed EVI scaling for percentage of lowland area, showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Lowland Area ≤50m above sea-level (%)	Observed # countries	Observed % of countries
1	X=0	44	18.64
2	X≤15	15	6.36
3	15<X≤30	30	12.71
4	30<X≤45	26	11.02
5	45<X≤60	44	18.64
6	60<X≤75	13	5.51
7	75<X	64	27.12
No data			
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 15.3: Proposed EVI scaling for Indicator 15 on percentage area of lowlands ≤ 50m above sea-level showing examples of countries that fit into each of the EVI scores.

Score	Lowland Area ≤50m above sea-level (%)	Examples
EVI=1	X=0	Belize, Myanmar, Philippines
EVI=2	X≤15	Cameroon, Algeria, Zambia
EVI=3	15<X≤30	Switzerland, Egypt, Nepal
EVI=4	30<X≤45	Bolivia, Costa Rica, Comoros
EVI=5	45<X≤60	Argentina, Iraq, Somalia
EVI=6	60<X≤75	Fiji, Poland, Sierra Leone
EVI=7	75<X	Gambia, Latvia, Palau

15.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

15.6 Age, completeness and quality of the data

The data obtained for this indicator were from Encarta 2004 World Atlas and were derived by sampling points over maps showing height above sea level. Both the lack of detail in the maps and the technique used are likely to have resulted in only broad estimates of percentage of land area as lowlands. In-country data were available for 11 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 15.4).

Table 15.4: Characteristics of age, completeness and quality of the data obtained for in-country data.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.64	2.73	2.24
Valid n (in-country)	11	11	17
SD (in-country)	0.50	0.65	0.90
SE (in-country)	0.15	0.19	0.22

15.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

15.8 Additional sources & contacts

www.bcas.net/Publication/SoE/SoE_index.htm (16/01/03) (Bangladesh); Marshall Islands - CIA World Fact Book website. Contact – Wilfredo Rada. Ministry of Internal Affairs/ Division of Lands and Surveys; Singapore - Singapore topographical map, 1998. Land Survey's Department; Kiribati - Digitised 1:25000 Paper Maps, Ordinance Surveys, UK. Kiribati Land Management Division; Niue - GIS/ Visual. Departmet of Justice, Lands and Survey; Palau - Bureau of Land Surveys. GIS Development. USGS Topographic Map; Samoa - Topographic Maps (Mapping Section), NZ Map Series. Lands, Surveys & Environment-Samoa; Kyrgyzstan - Department of State Ecological Control and Environment Utilisation. Contact - Mr Narynbek Mersaliev; Thailand - The Royal Thai Survey Department. Contact - Tel 66 2 2982253 Fax 66 2 2982240 marinepollution_pcd@yahoo.com ; Barbados - Lands and Surveys Department. Contact - Mr Nigel Marshall; Trinidad and Tobago - Arnold Balgaroo; Cook Islands - Ministry of Works, Energy & Physical Planning (MOWEPP) Contact - Timoti Tangiruaine (682 24484/ 682 21134); Federated States of Micronesia - Land & Natural Resources (Pohnpei). Contact - Herson Anson; Nauru - Lands & Survey. Conatct - Porthos Bop (674 4443845); New Zealand - Land Information New Zealand; Tuvalu - Department of Lands and Survey. Contact - Tesimita Ailesi.

16. SHARED BORDERS

16.1 Indicator Summary

Indicator number:	16	
Indicator short name:	Shared borders	
Sub-index	IRI	
Categorisation	Geography	
Indicator text:	Number of land and sea borders shared with other countries.	
Signals captured:	This indicator captures the risk to terrestrial and aquatic ecosystems from transboundary risks including species introductions, lack of control of effects from neighbouring countries, lack of control of straddling stocks of resources, and uncontrolled migrations of humans (e.g. refugees). We consider that the greater the number of different jurisdictions broidering a country by land or sea, the greater the risks of neighbour effects – that is risks to the environment caused by the policies and behaviours of other countries. The effects of these factors would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. High seas areas are not considered, though they are usually under some form of management that has implications for surrounding countries. 2. For sea borders, assessments were made by the EVI team using a 200 nm limit from the coast of a country.	
Are suitable data available?	Yes	
Sources of data:	• CIA Fact file 2000 • Encarta World Atlas 1999, 2000 • SOPAC EEZ Maps for the Pacific • In-country	
No. countries included in test:	232 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	Only 3 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (value >2 of 3 for age, completeness and quality).	
Basic units:	Number of borders shared with other countries, regardless of whether they are on land or in the sea.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	0<X≤2
	EVI Score = 3	2<X≤4
	EVI Score = 4	4<X≤6
	EVI Score = 5	6<X≤8
	EVI Score = 6	8<X≤10
	EVI Score = 7	X>10
	NA (not applicable)	☒ May not be used.
	ND (no data)	☑ May be used
Future work on this indicator:	None.	

16.2 Description of raw data

The raw data for this indicator are comprised of the total number of countries with which any country has a shared border, whether by land or sea. Data are a status in 2000 and can change as boundaries are redefined, particularly for EEZs. Of the 235 countries examined, these data were available for 232.

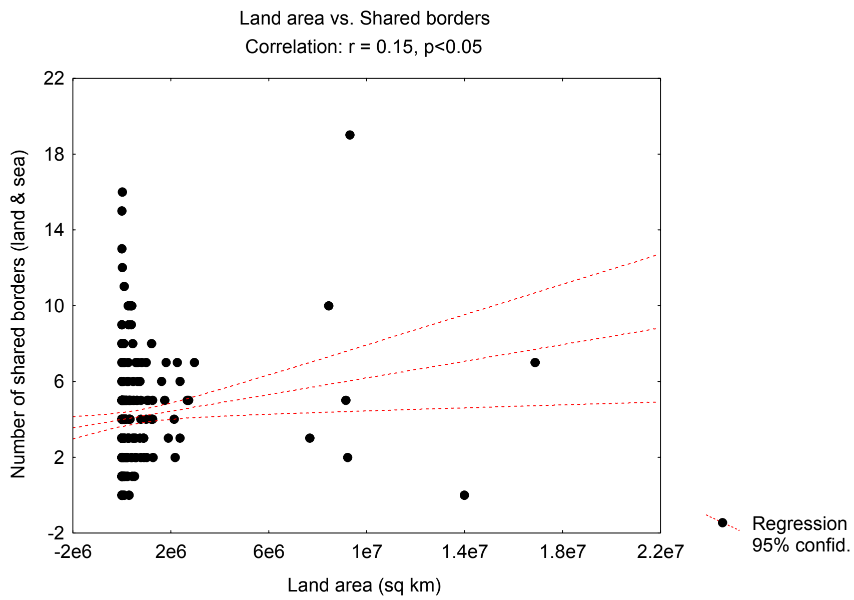
The number of shared borders in countries across the globe varied between 0 and 19 (Table 16.1). The lowest value of zero was recorded in 9 countries; including Seychelles, Iceland and Bermuda, and the highest values were recorded in China, Russian Federation and Turkey. The mean value across the globe was over 4.13 shared borders, with half of the countries examined having 4 or less (the median) (Table 16.1). Variance among countries is low, with a standard deviation that is around 0.67 times the mean.

The number of shared borders is significantly correlated with the size of a country (Figure 16.1). Despite this correlation, we considered that the risks associated with borders were more a function of the total number of unique borders a country shared and therefore the total number of unique species, issues and policies, rather than the density function over size of a country. We used data on number of shared borders in its raw form.

Table 16.1: Basic statistics for shared borders.

Statistic	# Shared borders
Mean	4.13
Median	4.00
Valid n	232
Min	0
Max	19
SD	2.75
SE	0.18
Skewness	1.72
SE Skewness	0.16
Kurtosis	5.50
SE Kurtosis	0.32

Figure 16.1: Graphs of number of shared borders vs. size of countries. The correlation is significant.



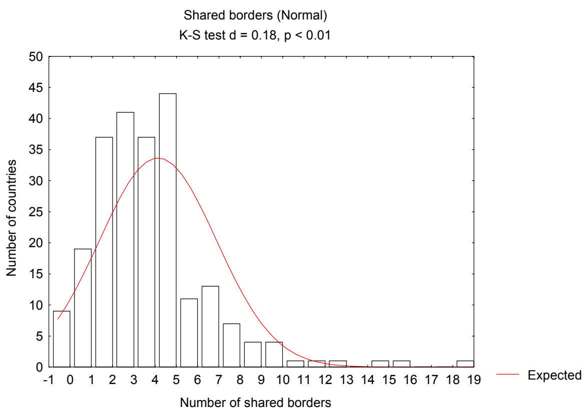
16.3 Distributional characteristics of the indicator data

The number of shared borders was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 16.2). This resulted in a distribution that was skewed towards the lower end of the scale, but with a reasonable spread between 0 and 10. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

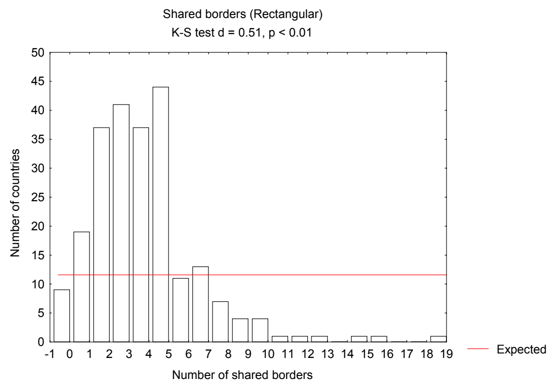
A significant difference between observed and expected values was found in all of the distributions tested (Figure 16.2). Transforming the values would probably provide little benefit to providing an EVI scale for these data.

Figure 16.2: Kolmogorov-Smirnov goodness-of-fit tests for shared borders in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. None of the tested distributions was a good fit of the observed data.

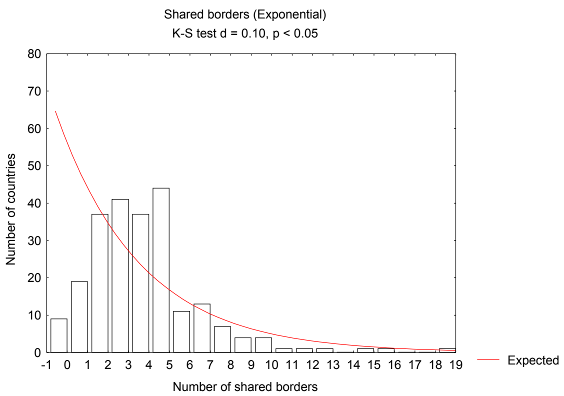
(a)



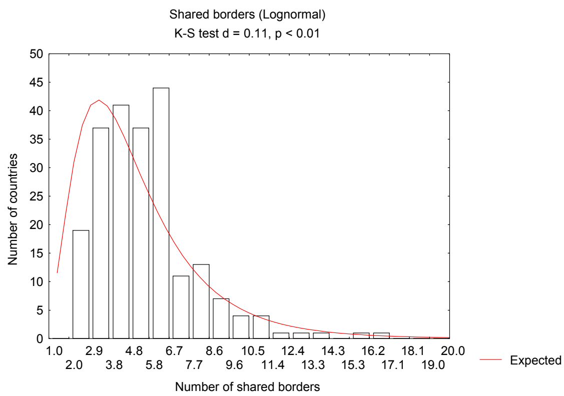
(b)



(c)



(d)

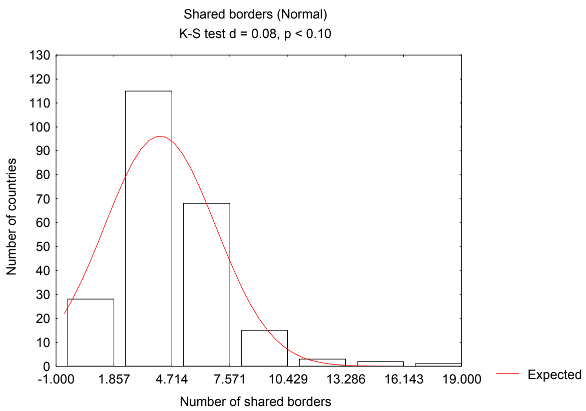


16.4 Proposed EVI scaling and distribution of the data on this scale

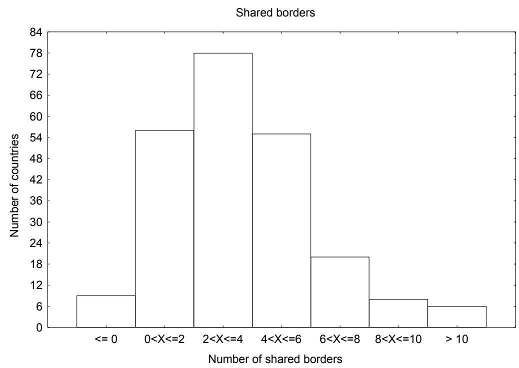
Countries varied in the number of shared borders between zero and 19, and there was a clumping of countries at the lower end of the scale. We propose that the data be used in their raw form, with countries having the greatest numbers of shared borders being considered more vulnerable and attracting a higher EVI score. We identified those countries with 0 shared borders as being the least at risk of environmental damage due to transboundary effects (EVI=1). Countries with > 10 shared borders were considered the most vulnerable (EVI=7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 16.3, Table 16.2, 16.3).

Figure 16.3: Frequency distribution of shared borders in even categories and the EVI scale. (a) Frequency distribution in 7 even categories, (b) and (c) the distribution on the proposed EVI scale.

(a)



(b)



(c)

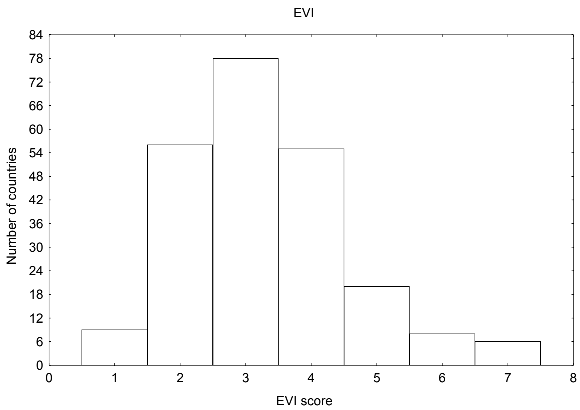


Table 16.2: Proposed EVI scaling for shared borders showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Number of shared borders	Observed # countries	Observed % of countries
1	X=0	9	3.88
2	0<X≤2	56	24.14
3	2<X≤4	78	33.62
4	4<X≤6	55	23.71
5	6<X≤8	20	8.62
6	8<X≤10	8	3.45
7	X>10	6	2.59
No data		3	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 16.3: Proposed EVI scaling for shared borders showing examples of countries that fit into each of the EVI scores.

Score	Scale for number of shared borders	Examples
EVI=1	X=0	Bermuda, St Helena, Seychelles
EVI=2	0<X≤2	Andorra, Canada, Ecuador
EVI=3	2<X≤4	Cuba, Estonia, Guadeloupe
EVI=4	4<X≤6	Georgia, Guam, Lao
EVI=5	6<X≤8	Jamaica, Yugoslavia, Tanzania
EVI=6	8<X≤10	Brazil, Germany, Kiribati
EVI=7	X>10	Iran, Italy, Saudi Arabia

16.5 Age, completeness and quality of the data

The data obtained for this indicator were from CIA Factfile, Encarta World Atlases, SOPAC EEZ Maps and in-country sources. In-country data were available for only 3 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 16.4).

Table 16.4: Characteristics of age, completeness and quality of the data from in-country sources.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	3	2.33	2.67
Valid n (in-country)	3	3	3
SD (in-country)	0	1.15	0.58
SE (in-country)	0	0.67	0.33

16.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

16.7 Additional sources & contacts

www.odci.gov/cia/publications/factbook/fields/land_boundaries.html (18/01/2002); Encarta 1999; SOPAC EEZ Map; Botswana - Tourism Statistics, 2001. Central Statistics Office; Costa Rica - Instituto Geográfico Nacional de Costa Rica; New Zealand - Contact - Hine-Wai Loose. Ministry for the Environment.

17. ECOSYTEM IMBALANCE

17.1 Indicator Summary

Indicator number:	17
Indicator short name:	Ecosystem Imbalance
Sub-index	Damage
Categorisation	Resources & Services
Indicator text:	Weighted average change in trophic level since fisheries began (for trophic level slice ≤3.35)
Signals captured:	Ecosystem stress, loss of diversity, damage to the trophic structure of ecosystems, loss of balance. This indicator captures the risk to aquatic ecosystems from risks associated with shifting the natural relationships, diversity and energy-flows within and among ecosystems. Although fisheries are used here, the indicator is more generally concerned with the downstream effects on habitats and other organisms. The greater the downward (negative) trend in trophic level change, the more likely that the marine biomass and trophic structures have been damaged. Such changes could lead to outbreaks or overgrowth of unexpected or pest organisms, monopolies of certain species, and losses of ecosystem elements that may be dependent on the behaviour or populations of others. The effects of these factors would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.
Notes on this indicator:	• This indicator includes only those species with a trophic level of 3.35 or below. This constitutes a trophic slice, intended to exclude large pelagic fisheries usually caught offshore • A positive (+) change indicates an increase in trophic level present in the catch, which would be consistent with an increase in the catch of larger fish-eating fishes. This is usually associated with an expansion of the fishery and a move to greater use of large pelagic species, usually offshore. • A negative (-) change is usually associated with loss of fishes in the higher trophic levels and indicates fishing down of the food web, ecosystem damage and overfishing. • This indicator is sensitive to over aggregation of taxa in the country catch data. This may lead to a reduced ability to detect changes in trophic level.
Are suitable data available?	Yes
Sources of data:	• University of British Colombia; Fisheries Centre, Lower Mall Research Station; Methods described in: http://data.fisheries.ubc.ca/references/pdfs/MappingFF.pdf and http://data.fisheries.ubc.ca/references/pdfs/whatsleft.pdf • See also www.seaaroundus.org
No. countries included in test:	181 of 235
Temporary modifications to data or indicator, if applicable:	• None
Notes on data age, completeness and quality:	• No in-country data available for this indicator
Basic units:	+ or – change in trophic level calculated by weighting each trophic level present in the national catch by the tonnes reported.
Recommended transforms:	• None

Proposed EVI Scale	EVI Score = 1	X≥0
	EVI Score = 2	0>X≥-0.02
	EVI Score = 3	-0.02>X≥-0.04
	EVI Score = 4	-0.04>X≥-0.06
	EVI Score = 5	-0.06>X≥-0.08
	EVI Score = 6	-0.08>X≥-0.10
	EVI Score = 7	X<-0.10
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	• Future evaluations should be on change in trophic level over the past 5 years. • A terrestrial component of this indicator would be a valuable addition.	

17.2 Description of raw data

The raw data for this indicator are comprised of the change in trophic level recorded in the fish catch of a country since fisheries began (defined as the first year in which catches exceed 10% of the all time annual maximum catch). Each trophic level is weighted by its catch in tonnes. Of the 235 countries examined, data were available for 181.

The change in trophic level since fisheries began in countries varied between -0.52 in and +0.61, with the highest figures being recorded in Benin, Hong Kong and Qatar. The lowest values were found in Nauru, American Samoa and Poland. The mean number across the countries examined was +0.064 and the median was +0.049 (Table 17.1). Variance among countries was moderate, with a standard deviation which was around 2.8 times the mean.

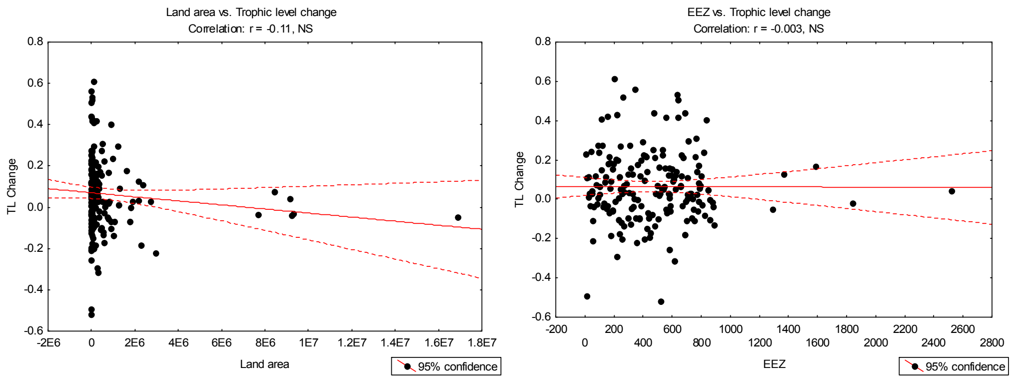
The observed change in trophic level was correlated with neither the land area of countries, nor the size of their EEZ (Figure 19.1).

Table 17.1: Basic statistics for change in trophic level of the fish catch.

Statistic	Migratory species spp.
Mean	0.064
Median	0.049
Valid n	181
Min	-0.519
Max	0.610
SD	0.180
SE	0.013
Skewness	0.289
SE Skewness	0.181
Kurtosis	1.173
SE Kurtosis	0.359

Figure 17.1: Graphs of trophic level change vs. size of countries. (a) TL change vs. land area (km^2); and (b) TL change vs. size of the EEZ (km^2). Neither correlation was significant.

(a) (b)



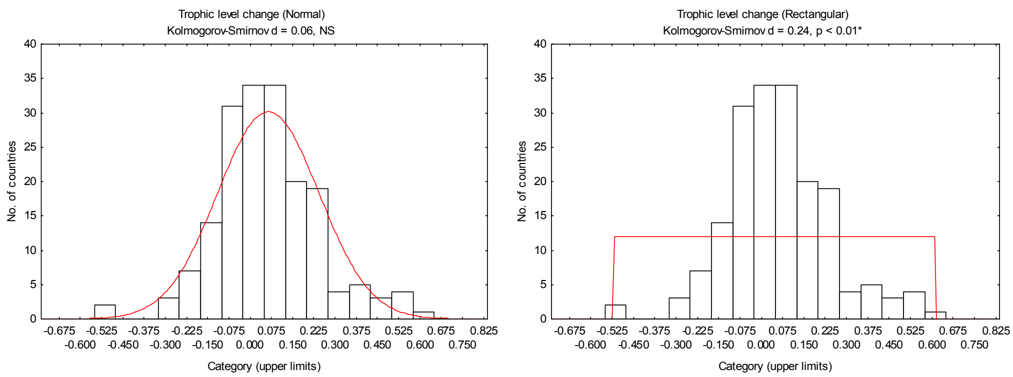
17.3 Distributional characteristics of the indicator data

The TL change was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 17.2). Because the presence of negative numbers is significant in this indicator, we did not test the resulting distributions against exponential or logarithmic functions. The two classes of distributions examined were normal (distributed around some average) and rectangular (evenly distributed). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

The distribution of the observed data did not differ significantly from a normal distribution, but the rectangular distribution was not a good fit. These results suggest that the values observed should be retained in their original form and not be transformed.

Figure 17.2: Kolmogorov-Smirnov goodness-of-fit tests for density of migratory species countries spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions were the best fit of the observed data.

(a) (b)



17.4 Proposed EVI scaling and distribution of the data on this scale

We propose that all countries with zero or positive trophic level changes be assigned an EVI score of 1. These are the countries that have either had no change in the relative contribution of the different trophic levels to the national catch since fishing started, or they are countries that may have expanded their fishing effort into higher trophic groups. In the latter case, the ability to extend into those trophic groups shows that they must still be present, though coming problems if these groups are now being overfished would be masked, until through repeated re-evaluations the TL change started to decline. At least for now, a positive value probably indicates that the trophic structure is largely intact. All countries with negative values were given EVI scores of between 2 and 7, with the highest score (EVI=7) assigned to countries with a TL change of greater than -0.10 (Figure 17.3, Table 17.2). Countries showing this level of change in their trophic levels are likely to have created major changes in the trophic, biomass and community structure of their aquatic ecosystems and are likely to be more vulnerable to future fishing pressure, invasions, outbreaks (e.g. blooms, algal overgrowth), monopolies and other signs of ecosystem imbalance.

A similar terrestrial measure would be a valuable addition to this indicator. Note: in the terrestrial environment, hunting (a form of 'terrestrial fishing') works very differently. Typically, people hunt grazers which are at a lower tropic level, but humans also hunt higher tropic level carnivores (such as wolves, bears, lions etc) if they threaten us or our livestock, or if we want their fur or body parts (e.g. for Chinese medicine). On land the lower tropic level organisms are usually large compared to their predators, though this is mirrored with marine mammals, such as killer whales that attack larger whales. In the marine environment high trophic level fish are typically the largest, and hence more vulnerable and sought after by fishers and are often removed first (R. Watson, UBC, pers. comm.).

Figure 17.3: Frequency distribution of trophic level change and the EVI scale.

(a) Frequency distribution in 7 even categories; and (b) Is the distribution on the proposed EVI scale.

(a) (b)

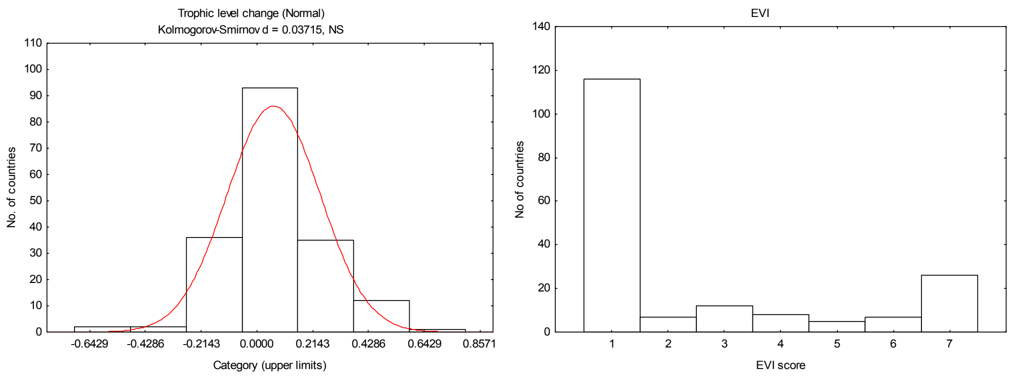


Table 17.2: Proposed EVI scaling showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	LN(X+1) Migratory species / 1000 sq km	Observed # countries	Observed % of countries
1	X≥0	116	49.36
2	0>X≥-0.02	7	2.98
3	-0.02>X≥-0.04	12	5.11
4	-0.04>X≥-0.06	8	3.40
5	-0.06>X≥-0.08	5	2.13
6	-0.08>X≥-0.10	7	2.98
7	X<-0.10	26	11.06
NA	☒ May not be used		
ND	☑ May be used	54	22.98

Table 17.3: Proposed EVI scaling showing examples of countries in each of the EVI scores.

Score	LN(X+1) Migratory species / 1000 sq km	Examples
EVI=1	X≥0	Albania, Bangladesh, Costa Rica
EVI=2	0>X≥-0.02	Sierra Leone, Trinidad & Tobago, Uruguay
EVI=3	-0.02>X≥-0.04	Belize, Palau, Ukraine
EVI=4	-0.04>X≥-0.06	Chile, Guatemala, Pakistan
EVI=5	-0.06>X≥-0.08	Columbia, Cuba, Maldives
EVI=6	-0.08>X≥-0.10	UK, Kiribati, Morocco
EVI=7	X<-0.10	Estonia, India, Macau

17.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

17.6 Age, completeness and quality of the data

No data for this indicator were available from in-country sources.

17.7 Variations among sources of data

Data from other sources, including in-country, were not assessed for this indicator. Other sources of global trophic level data are generally not available.

17.8 Additional sources & contacts

Philippines - Bureau of Fisheries and Aquatic Resources (BFAR) Administrative Reports; Singapore - Communicable disease surveillance in Singapore 2000. Quarantine and Epidemiology Department; Fiji - Return of Notifiable Diseases for Year 1992-1998. Fisheries Department; Federated States of Micronesia - Reported Notifiable Diseases Summary. NHSO, Department of Health, Education and Social Affairs; Marshall Islands - Crawford, M. 1992. RMI National Environmental Management Strategy (NEMS) Report: Part A (State of Environment); Tonga - Bureau of Public Health: Monthly Report. Environmental Planning & Conservation Section. Lupe Matoto & Asipeli Palaki (676 23611/ 23216/ imepacs@candw.to , Vailala@candw.to); Kyrgyzstan - Inspectorate of Sanitation and Epidemiological Control. Contact - Mr. Usenbaev; Thailand - Pollution Control Dept. Thailand, Water Quality Management Division. Tel 66 2 2982253 Fax 66 2 2982240 e-mail: marinepollution_pcd@yahoo.com ;Costa Rica - Ministerio de Salud; Greece - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Cook Islands - Totokoitu Research Station. Contact - Brian Tairea (682 28711 or 28720) Ministry of Agriculture; Kiribati - T Tebaitongo. Fisheries Division; New Zealand - Ministry of Health. Contact - Hine-Wai Loose: Ministry of Foreign affairs and Trade; Niue - Niue Department of Agriculture, Forestry & Fisheries. Contact - Sauni Tongatule (4032/ 4079/ tongatules@mail.gov.nu); Tonga - Lupe Matoto & Asipeli Palaki (676 23611/ 23216/ imepacs@candw.to, Vailala@candw.to); Tuvalu - Agriculture. Contact - C. Howells.

18. ENVIRONMENTAL OPENNESS

18.1 Indicator Summary

Indicator number:	18	
Indicator short name:	Environmental openness	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	1. Total USD freight imports per year over the past 5 years by any means / sq km land area 2. Total tonnage of freight imported per year over the past 5 years by any means / sq km land area	
Signals captured:	This indicator captures the risk of damage to a country through the importation of foreign materials (physical, chemical and biological) by land, air or sea through the large volumes of freight that move around the globe annually. Countries with large amounts of freight moving into them are considered more at risk of inadvertent introductions of diseases, species and genetically modified organisms, than those with lower levels of freight movements. The likelihood of such introductions negatively affecting a country's resilience would be especially important if there are many endangered species, sensitive ecosystems that could be affected by key species, and interactions with on-going human impacts. This includes the importing of hazardous wastes. Freight imports may also be a mechanism for the introduction of pollution risks not normally found in a country – e.g. the import of radioactive substances, oil, chemicals.	
Notes on this indicator:	1. Data on tonnages were provided by 14 of the 32 collaborators, but were not available from public sources. 2. The public data available are expressed in $ values of freight imports and are not averages over 5 years, but are limited to 1997 (WRI 2000-2001).	
Are suitable data available?	No public databases found in the correct units; substitute data used in units of $ rather than tonnes	
Sources of data:	• WRI 2000-2001 • In-country	
No. countries included in test:	235	
Temporary modifications to data or indicator, if applicable:	• Data used are freight in 1000s $ per sq km of land area because data on tonnages are generally not publicly available • Data are from a single year (1997) and are not averages 1996-2000 (not available) • Data from in-country sources, where available, were provided as tonnes / sq km, but could not be used to supplement the public source because units could not be converted from tonnes to $ (contents of the freight are not provided).	
Notes on data age, completeness and quality:	14 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Freight density as X = thousands of dollars of freight moved into the country per sq km of land.	
Recommended transforms:	• Data transformed to the natural logarithm of freight density LN(USD 1000s / sq km)	
Proposed EVI Scale	EVI Score = 1	X≤1

	EVI Score = 2	1<X≤1.5
	EVI Score = 3	1.5<X≤2
	EVI Score = 4	2<X≤2.5
	EVI Score = 5	2.5<X≤3
	EVI Score = 6	3<X≤3.5
	EVI Score = 7	X>3.5
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Sources of yearly data on tonnages imported are needed.	

18.2 Description of raw data

The raw data for this indicator are comprised of the freight movements into a country expressed as millions of USD for a single year (1997) (WRI 2000-2001). Of the 235 countries examined, data were available for 145.

The total USD value of freight imports to countries in 1997 varied between 107 million recorded in Guinea-Bissau and 1,043,477 million in the USA. The mean value of imports across the globe in 1997 was 43,370 million USD, which is close to the values for Portugal and Poland. Half of the countries examined imported 4,681 million worth of goods or less in 1997 (the median), indicating that the distribution of import millions is heavily skewed, with relatively few countries importing very large amounts (Table 18.1). Variance among countries is high, with a standard deviation which is around 2.7 times the mean.

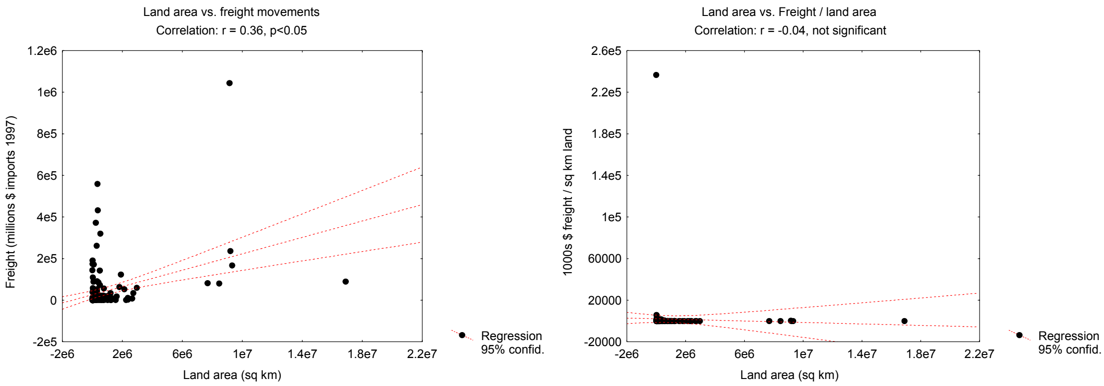
The value of freight imports is correlated with the size of a country (see significant correlation coefficient in Figure 18.1). There is also, however, a range of import values found among the smaller countries, with some smaller countries having large import values in 1997 (e.g. Singapore).

The risks associated with imports from an environmental perspective are related to the area of land over which exposure can occur and damage can be attenuated. This means that this indicator needs to be divided by total land area in a country to examine the amount of exposure to freight over the land area (or 'freight density'). When the freight density is, in turn, tested against country size, this correlation disappears (Figure 18.1 b). The maximum freight density observed was in Singapore, with 236,341 USD imported per sq km of land in 1997.

Table 18.1: Basic statistics for freight movements in 235 countries. Data are from WRI 2000-2001 and cover only the year 1997.

Statistic	Freight imports USD millions (1997)	Freight density USD 1000s / sq km	LN Freight density LN(USD 1000 / sq km)
Mean	43,370.37	1877.38	1.46
Median	4,681	23.81	1.38
Valid n	145	145	145
Min	107	0.34	-0.47
Max	1,043,477	236,341.00	5.37
SD	116,738.30	19621.25	0.98
SE	9,694.59	1629.46	0.08
Skewness	5.65	12.01	0.61
SE Skewness	0.20	0.20	0.20
Kurtosis	40.46	144.55	0.97
SE Kurtosis	0.40	0.40	0.40

Figure 18.1: Graphs of freight imports vs. size of countries. (a) Freight in US Millions $ vs. size of country (sq km); and (b) Freight density (1000s $ / sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).



18.3 Distributional characteristics of the indicator data

The freight density of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 18.2). This resulted in a distribution in which all countries except Singapore were clustered in the first category (0-13,000 USD,000 / sq km) (Figure 18.2). We excluded Singapore from the analysis to examine the world distribution of freight density, creating a better spread among countries. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in all tests except the lognormal distribution (Figure 18.3). This suggests that the values observed are distributed according to some logarithmic function and that transforming the values to their natural logarithm might provide a better scale for comparison.

Figure 18.2: Frequency distribution for freight density of all examined countries spread over 20 categories.

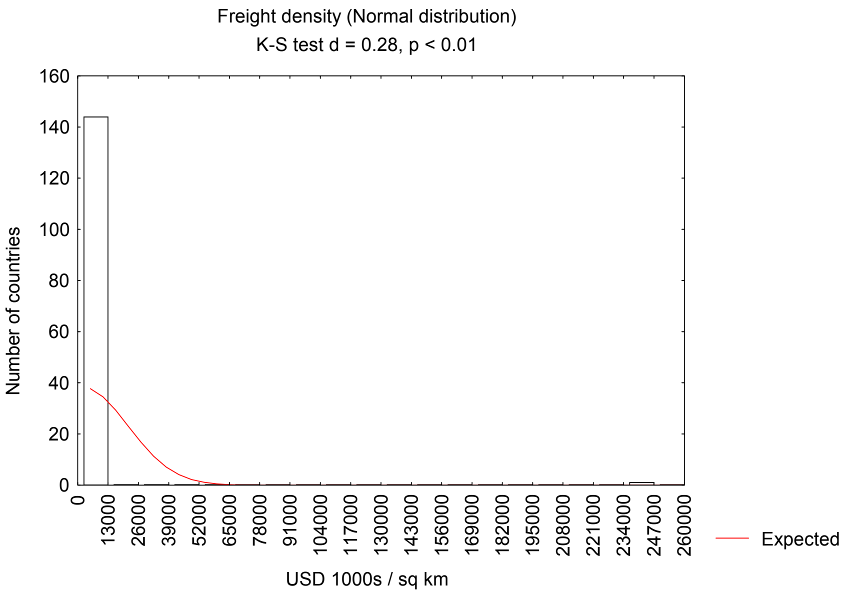
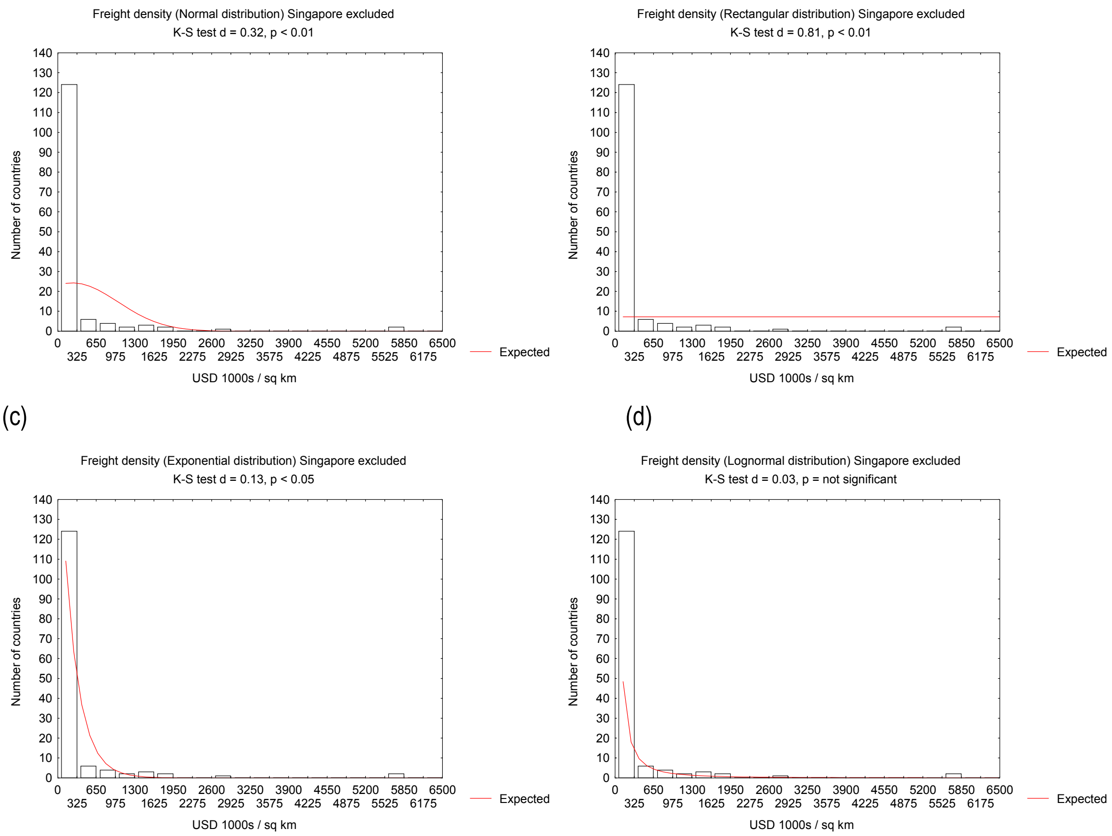


Figure 18.3: Kolmogorov-Smirnov goodness-of-fit tests for freight density of countries (except Singapore) spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution was the best fit of the observed data.

(a) (b)

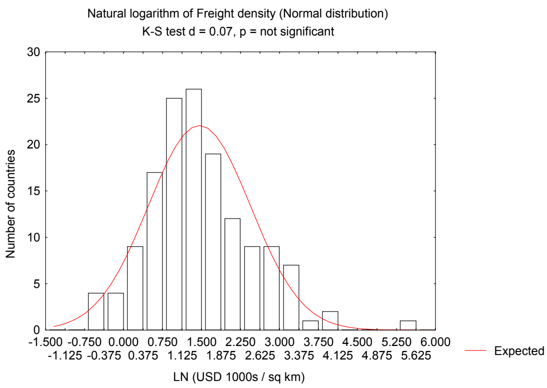


18.4 Proposed EVI scaling and distribution of the data on this scale

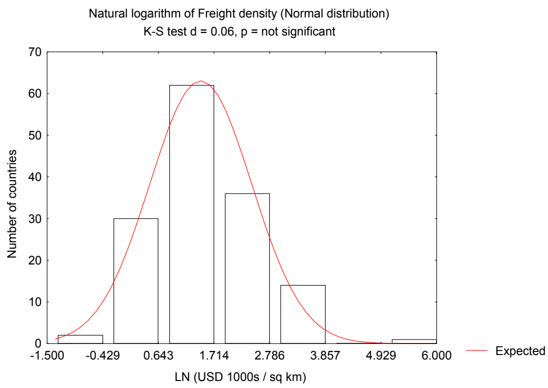
Countries varied in freight density by six orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms (LN) for this indicator to provide better spread among the countries and compress the scale to between –0.47 and 5.37, with countries having the greatest import densities being considered more vulnerable and attracting a higher EVI score. We identified those countries with ≤ 1 on the transformed (LN freight density) scale as likely to be the least at risk of environmental damage because the amount of imports is small in relation to the area of land available to absorb / attenuate any damage (less than $2,720 per sq km land, EVI score = 1). Countries with > 3.5 were considered the most vulnerable (EVI score =7) – these are the countries that in 1997 imported more than $33,000 of freight per sq km of their land area. The country values between these extremes were spaced evenly to form the EVI scale (Figure 18.4, Table 18.2, 18.3).

Figure 18.4: Frequency distribution of LN Freight densities in even and uneven categories and the EVI scale. (a) Frequency distribution of LN Freight density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN Freight density in seven uneven categories which clump countries with low and high freight densities. (d) The proposed EVI scale.

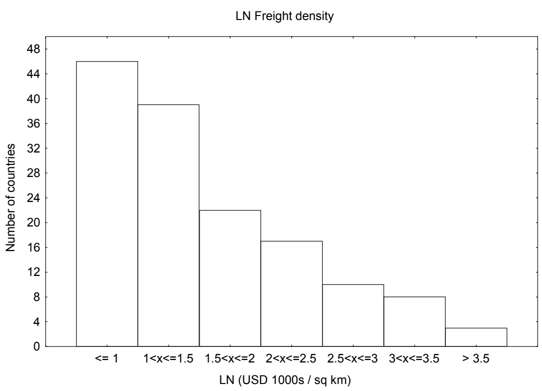
(a)



(b)



(c)



(d)

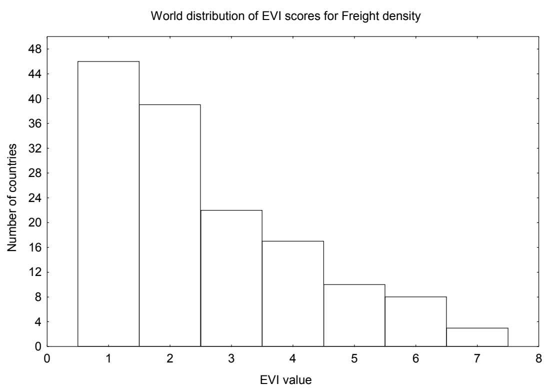


Table 18.2: Proposed EVI scaling for freight density showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X≤1	46	31.72
2	1<X≤1.5	39	26.90
3	1.5<X≤2	22	15.17
4	2<X≤2.5	17	11.72
5	2.5<X≤3	10	6.90
6	3<X≤3.5	8	5.52
7	X>3.5	3	2.07
No data		90	62.07
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 18.3: Proposed EVI scaling for Indicator 18 on freight density showing equivalence on the LN and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN Freight density	Equivalent scale in USD 1000s / sq km	Examples
EVI=1	X≤1	X ≤ 2.72	Angola, Cameroon, Kazakhstan,
EVI=2	1<X≤1.5	2.72 < X ≤ 4.48	India, Nigeria, Syria
EVI=3	1.5<X≤2	4.48 < X ≤ 7.34	Indonesia, Mexico, Vietnam
EVI=4	2<X≤2.5	7.34 < X ≤ 12.18	Finland, Greece, Sri Lanka
EVI=5	2.5<X≤3	12.18 < X ≤ 20.09	Ireland, Kuwait, Portugal
EVI=6	3<X≤3.5	20.09 < X ≤ 33.12	Switzerland, UK, Japan
EVI=7	X>3.5	X > 33.12	Belgium, Netherlands, Singapore

18.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

18.6 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 and from in-country sources. The two sources could not be merged to extend the number of countries with data because they were given in different scales (WRI in USD and in-country in tonnes). Data were expected to be averages over 5 years (1996-2000) but those provided by WRI were from a single year (1997).

Although the dollar freight import values provide a proxy for the risks to the natural environment from imports, it is likely that tonnage of freight would be a better measure. Dollar values will bias the data towards high value goods that as freight imports might not be of significance to the environment (except as waste). These might include finished metals and electronic goods. The higher weight / volume goods of lower dollar value may be of more significance from and environmental perspective, including food, genetically modified organisms, agricultural chemicals, ores etc.

In-country data were available for 14 of the 32 collaborating countries, with data being of good age, completeness and quality (all >2 of 3) (Table 18.4).

Table 18.4: Characteristics of age, completeness and quality of the data obtained for freight movements in 235 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.36	2.50	2.79
Valid n (in-country)	14	14	14
SD (in-country)	0.50	0.65	0.58
SE (in-country)	0.13	0.17	0.15

18.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

18.8 Additional sources & contacts

www.motc.go.th (6/6/01)(Thailand); www.stats.govt.nz/ (New Zealand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Greece - Statistical Yearbook of Greece 1998-99, EU Trade Statistics 1999-2000; Federated States of Micronesia - 1999 FSM Statistical Yearbook. FSM DEA/ SD (Statistical Dept); Fiji - Customs Annual Report 1997, Parliamentary Paper No. 16 of 1998; Tonga - 1994 – 1995 Annual Reports. Ministry of Marine and Ports (MMP); Barbados - Summary of Operations Table, 1999. Barbados Port Authority; Samoa - Annual Statistical Abstract 1998, pp79. Department of Statistics; Kyrgyzstan - State Customs Inspectorate. Contact - Mrs. Baitakova Marta; Singapore - Ministry of transport. Contact - Mr Harvey Yeo, tel ++(63) 757725 Harvey.Yeo@mot.gov.sg ;Costa Rica - Ministerio de Hacienda; Cook Islands - Air Cargo Manifest, Cargo Division, Rarotonga; Palau - Lee Wally Customs; Tuvalu - Internal records (estimates). Shipping Agent. Contact - Christopher Ikae.

19. MIGRATORY SPECIES

19.1 Indicator Summary

Indicator number:	19
Indicator short name:	Migratory species
Sub-index	IRI
Categorisation	Resources & Services
Indicator text:	Number of known species that migrate outside the territorial area at any time during their life spans (include land and aquatic species) / area of land.
Signals captured:	This indicator focuses of species which pass outside of the control of the country and which during that time may be affected by actions of surrounding countries, or distant nations utilising them as a resource. It focuses on biodiversity, resilience and persistence of species with large variances in population numbers and or /that are susceptible to local extinctions. Straddling stocks of migrating mammals and fishes may also be key species in determining ecosystem conditions in a country, and damage to these while they are outside the country may lead to indirect effects on ecosystems within the country (e.g. migrating mammals as determinants of grasslands in Africa and America). Species could become endangered or threatened in a country, despite good internal management, with implied impacts on biodiversity, ecosystem integrity and resilience to future hazards. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.
Notes on this indicator:	1. Data are likely to be incomplete and biased towards obvious species such as mammals and birds, and economically important species such as tunas. Insects, marine invertebrates and microorganisms are unlikely to be correctly represented. 2. Categories of GROMS migrants include intracontinental, intercontinental, nomadising, emigration, range extension, interoceanic, intraoceanic, and for fishes: anadromous, catadromous, amphidromous, potamodromous, limnodromous, oceanodromous. 3. Not all of the migrating species in a country necessarily migrate outside a country's borders.
Are suitable data available?	Yes. Data are likely to underestimate small, cryptic, rare and undescribed organisms, unless they are obvious or of some human interest (e.g. tourism).
Sources of data:	• GROMS Database (includes: IUCN Red Book of Endangered Organisms 2000; African mammal database (AMD) 1998; Erasien Anatidae Atlas; Artic Bird Database 1998; WCMC Turtle Database 1999; Fishbase 1998; Slender-billed curlew database 2000; Maps of non passerine birds 1992-2001). • In-country
No. countries included in test:	229 of 235
Temporary modifications to data or indicator, if applicable:	• None
Notes on data age, completeness and quality:	Only 2 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data

	were generally considered good (value of 3 of 3).	
Basic units:	Density of migratory species expressed as number of species per 1000 sq km land area under various categories of GROMS migrants.	
Recommended transforms:	LN(X+1)	
Proposed EVI Scale	EVI Score = 1	X≤1
	EVI Score = 2	1<X≤1.5
	EVI Score = 3	1.5<X≤2
	EVI Score = 4	2<X≤2.5
	EVI Score = 5	2.5<X≤3
	EVI Score = 6	3<X≤3.5
	EVI Score = 7	X>3.5
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

19.2 Description of raw data

The raw data for this indicator are comprised of the total numbers of species in countries considered to be at the most risk of damage through the parts of their lifecycles that involve migration. Of the 235 countries examined, data were available for 229.

The total number of known migratory species in countries varied between 1 and 159, with the highest figures being recorded in Russia and the USA. The lowest values were found in Cocos (Keeling) Islands, Pitcairn and Niue. The mean number across the countries examined was 37 species and half of the countries had 36 or more known migratory species (the median) (Table 19.1). Variance among countries was low, with a standard deviation which was around 0.6 times the mean.

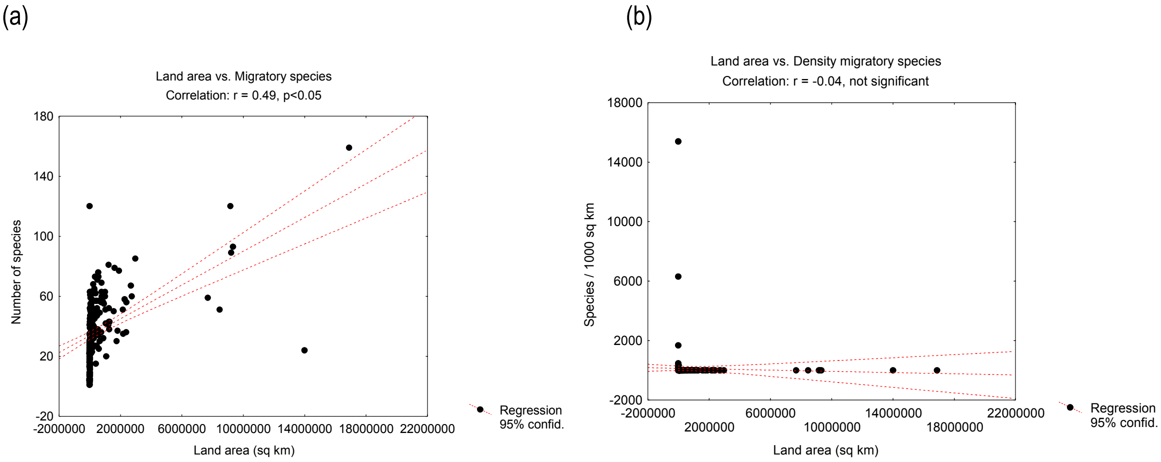
The number of known migratory species is, as expected from species-area theory, correlated with the size of a country (see significant correlation coefficient in Figure 19.1). This correlation disappears if the data are expressed as density of migratory species, or migratory species per 1000 sq km of land. The risks to natural resources, biodiversity and the complex ecological processes that could be disrupted as species are lost from ecosystems is expected to be related to the overall diversity in a country, which is in turn related to the diversity of habitat and climate types developed (related to size of the country). This means that this indicator is best expressed as a density function so that risks associated with migratory species can be evaluated independently of overall size of countries.

The density of migratory species varied between 0.0017 and 15,385 species per sq km, with the lowest values being recorded in Antarctica, Brazil and Australia, and the highest in Monaco, Gibraltar and Macau. The mean density of migratory species across all countries examined was 120 per 1000 sq km, while the median value was 0.54 species per sq km (Table 19.1).

Table 19.1: Basic statistics for total number of migratory species and number per 1000 sq km of land. Data are from GROMS Database.

Statistic	Migratory species spp.	Density migratory species spp / 1000 sq km	LN(X+1) Density
Mean	37.37	121.01	1.31
Median	36.00	0.54	0.43
Valid n	229	229	229
Min	1	0.0017	0.002
Max	159	15,384.62	9.64
SD	22.34	1,101.69	1.79
SE	1.48	72.80	0.12
Skewness	1.19	12.56	1.79
SE Skewness	0.16	0.16	0.16
Kurtosis	4.14	167.37	3.17
SE Kurtosis	0.32	0.32	0.32

Figure 19.1: Graphs of number of migratory species vs. size of countries. (a) Total number of migratory species vs. size of country (sq km); and (b) Density of migratory species (number per 1000 sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

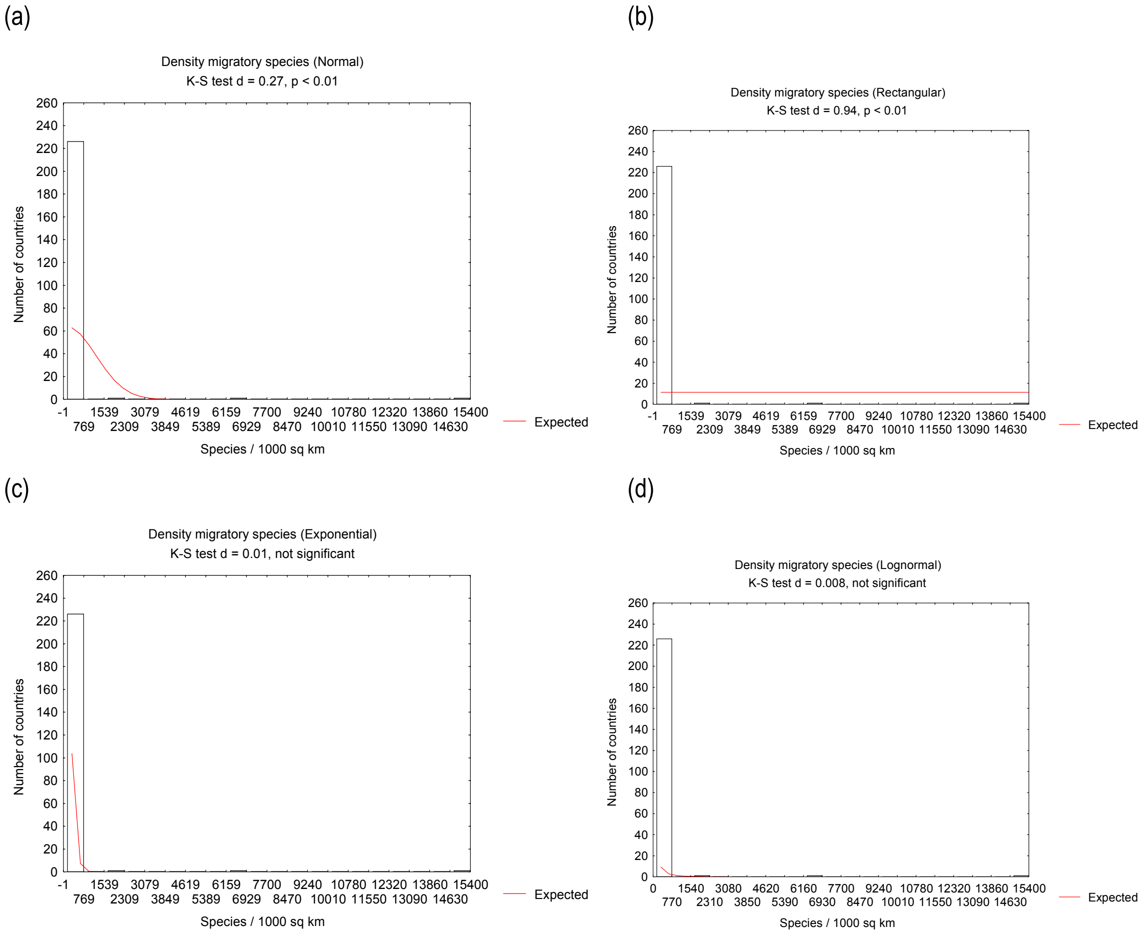


19.3 Distributional characteristics of the indicator data

The density of migratory species was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 19.2). This resulted in a distribution in which most countries were clustered at the lower end of the scale (Figure 19.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal and rectangular distributions (Figure 19.2), but not for the exponential and lognormal distributions. This suggests that the values observed could be distributed according to a power or logarithmic function and that transforming the values to their root or natural logarithm might provide a better scale for comparison.

Figure 19.2: Kolmogorov-Smirnov goodness-of-fit tests for density of migratory species countries spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions were the best fit of the observed data.



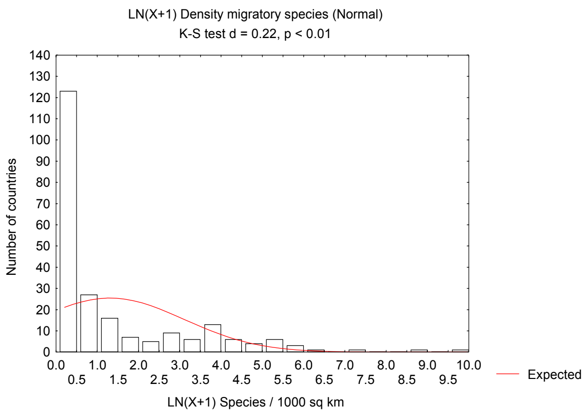
19.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in the density of endangered species by seven orders of magnitude, and there was a strong clumping of countries at the lower end of the scale (Figure 19.2, 19.3). We applied a logarithmic transformation to the data (LN(X+1)) which provided a better spread among countries at the lower end of the scale (Figure 19.3 a,b). All countries with greater than 32 migratory species per 1000 sq km (Values >3.5 on the logarithmic scale) were considered at high risk of ecological damage, and we attributed the highest EVI score (7) to all countries with this level. Values below this figure were spaced evenly down to a value of 1.72 species / 1000 sqkm (1 on the log scale) to create the remainder of the EVI scale (Figure 19.3, Table 19.2).

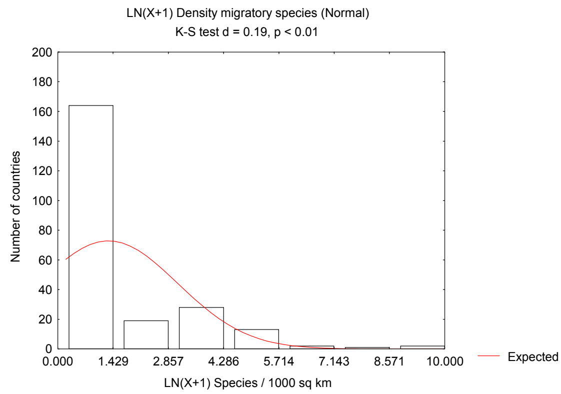
Figure 19.3: Frequency distribution of density of migratory species in even and uneven categories and the EVI scale.

(a) Frequency distribution of density in 20 even categories for LN(X+1) transformed data; (b) is the distribution compressed to a 7 category (even) scale; (c) and (d) Is the distribution of density of migratory species in seven uneven categories which shows the proposed EVI scale with the 7 categories shown in the graph representing EVI scores from 1-7.

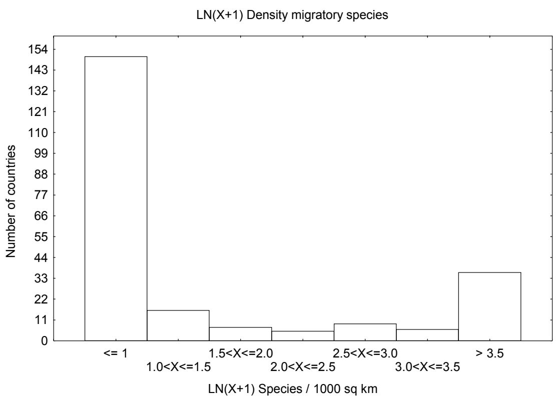
(a)



(b)



(c)



(d)

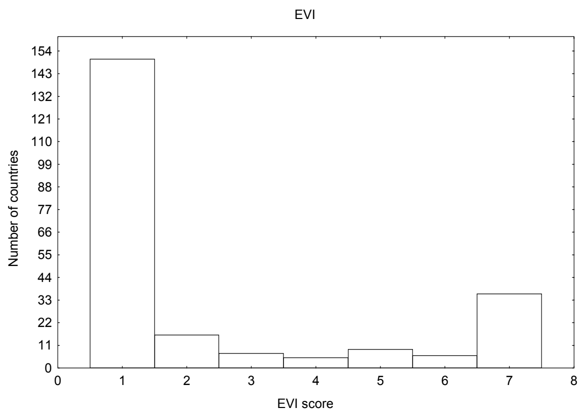


Table 19.2: Proposed EVI scaling for density of migratory species showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	LN(X+1) Migratory species / 1000 sq km	Observed # countries	Observed % of countries
1	X≤1	150	65.50
2	1<X≤1.5	16	6.99
3	1.5<X≤2	7	3.06
4	2<X≤2.5	5	2.18
5	2.5<X≤3	9	3.93
6	3<X≤3.5	6	2.62
7	X>3.5	36	15.72
No data		6	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 19.3: Proposed EVI scaling for density of migratory species showing examples of countries that fit into each of the EVI scores.

Score	LN(X+1) Migratory species / 1000 sq km	Migratory species / 1000 sq km	Examples
EVI=1	X≤1	X≤1.72	Albania, Belize, Kenya
EVI=2	1<X≤1.5	1.72<X≤3.48	Bahamas, Cyprus, Jamaica
EVI=3	1.5<X≤2	3.48<X≤6.39	Gambia, Lebanon, Mauritius
EVI=4	2<X≤2.5	6.39<X≤11.18	Kiribati, Comoros, Luxembourg
EVI=5	2.5<X≤3	11.18<X≤19.09	FSM, Guadeloupe, Martinique
EVI=6	3<X≤3.5	19.09<X≤32.12	Cook Is., Malta, American Samoa
EVI=7	X>3.5	X>32.12	Aruba, Grenada, St. Lucia

19.5 Age, completeness and quality of the data

The data obtained for this indicator were from the GROMS Database and from in-country sources. In-country data were available for only 2 of the 32 collaborating countries, with data being of good age, completeness and quality (value of 3 of 3) (Table 19.4).

Table 19.4: Characteristics of age, completeness and quality of the data obtained for earthquakes in 238 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	3	3	3
Valid n (in-country)	2	2	2
SD (in-country)	0	0	0
SE (in-country)	0	0	0

19.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

19.7 Additional sources & contacts

www.biologie.uni-freiburg.de/data/zoology/riede/grooms/Getting_Started/Definition/ (24/01/2003); Costa Rica - Escuela de Biología, Universidad de Costa Rica.

20. ENDEMIC SPECIES

20.1 Indicator Summary

Indicator number:	20	
Indicator short name:	Endemic species	
Sub-index	IRI	
Categorisation	Resources & services	
Indicator text:	Number of known endemic species per square kilometre land area	
Signals captured:	Biodiversity and the risk of losing unique species. The more endemic species a country has, the more vulnerable it is because localised extinction cannot be resupplied from elsewhere by natural or augmented recolonisation. Losses of key species can affect ecosystems and potential for sustainable activities for foreign exchange.	
Notes on this indicator:		
Are suitable data available?	Yes, but incomplete	
Sources of data:	WRI 2000-2001; In-country	
No. countries included in test:	166	
Temporary modifications to indicator, if applicable:	Numbers of endemic species include only mammals, birds, reptiles, amphibians and plants. Other groups should be included in future EVI calculations.	
Notes on data age, completeness and quality:	Where multiple values for these measures were reported, these were reduced to the lowest given value for use in the analysis. That is, if 2 and 3 were returned for a measure, the value 2 was used in the analysis. If no value given, 0 was used.	
Basic units:	Species per million km^2	
Recommended transforms:	1. No. Endemic spp / total land area in sq km 2. Multiplied by 1,000,000 to create larger values 3. Ln(X+1) transform to normalise and place on near-linear scale	
Proposed EVI Scale	EVI Score = 1	$0 \le X$
	EVI Score = 2	$0 < X \le 2$
	EVI Score = 3	$2 < X \le 4$
	EVI Score = 4	$4 < X \le 6$
	EVI Score = 5	$6 < X \le 8$
	EVI Score = 6	$8 < X \le 10$
	EVI Score = 7	$10 < X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

20.2 Description of raw data

The raw data for this indicator are the total number of known endemic species recorded in the country. For the 166 countries examined, values varied between zero and more than 18,500 (e.g. there were large numbers of endemic plants in China and Indonesia). The average value was 1,055 endemic species per country, with a very large standard deviation (SD) approximately twice the size of the mean (Table 20.1). The standard error (SE) (standard deviation of means) was 225, which is around 21% of the mean.

The frequency distribution of the raw values showed that most countries (more than 112 of the 166, 67%) had between 1 and 1,000 endemic species. Nineteen countries (11%) had zero endemic species and a further 16 (10%) had between 1,000 and 2,000 endemic species (Figure 20.1). There was a long tail to the distribution with the remaining 19 (11%) of countries being more-or-less evenly distributed throughout the remaining range up to 18,500+ endemic species.

The number of known endemic species recorded correlated significantly with the size of country as measured by total land area (Figure 20.2). This result suggests that calculating a density of endemic species (i.e. the number per unit of land area) might be a better measure for this indicator than the raw value used on its own.

Table 20.1: Basic statistics for number of endemic species in 166 countries.

Statistic	Value
Mean	1055.36
Median	76.50
Min	0.00
Max	18550.00
SD	2898.93
SE	225.00
Skewness	4.37
SE Skewness	0.19
Kurtosis	20.70
SE Kurtosis	0.37

Figure 20.1: Frequency distribution of numbers of known endemic species found in countries. Note the long tail on the distribution and non-normality (i.e. the plotted frequency distribution is dissimilar to the red predicted normal curve). A Kolmogorov-Smirnov (K-S) test for normality (mean and SD known) resulted in a significant max D = 0.36, p<0.01.

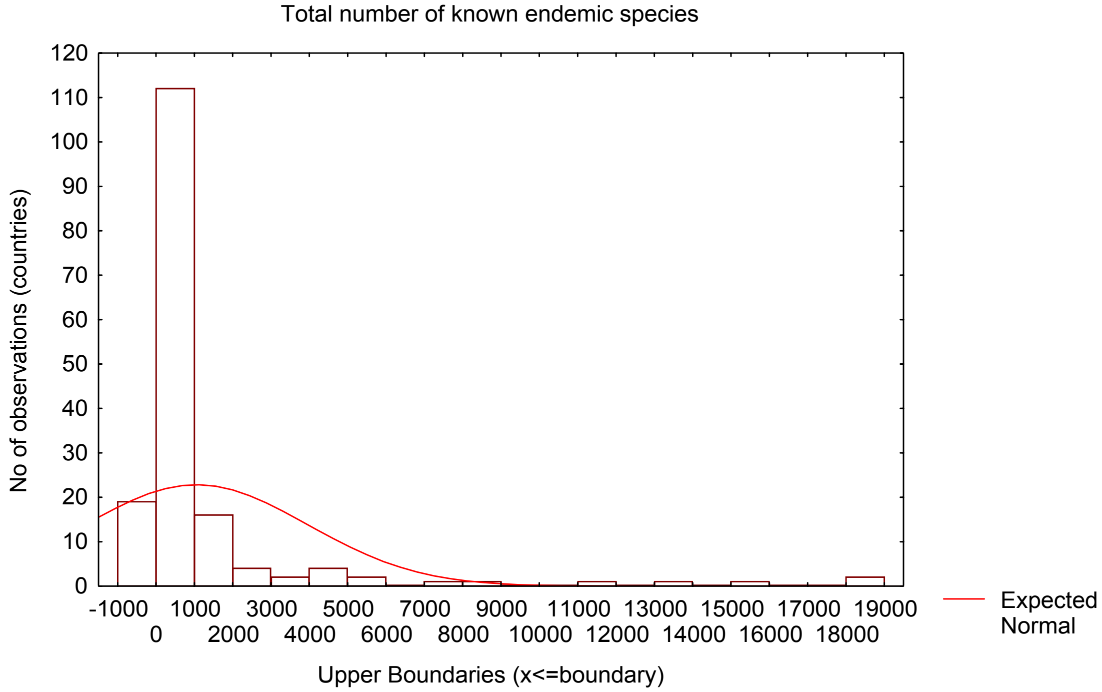
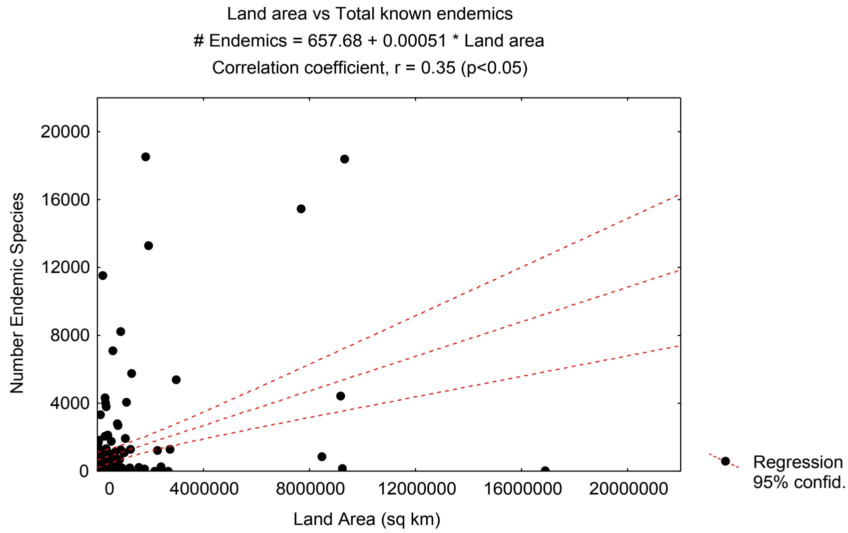


Figure 20.2: Graph of land area versus number of known endemic species in 166 test countries.

The results show that number of endemic species is significantly correlated with land area (p<0.05).



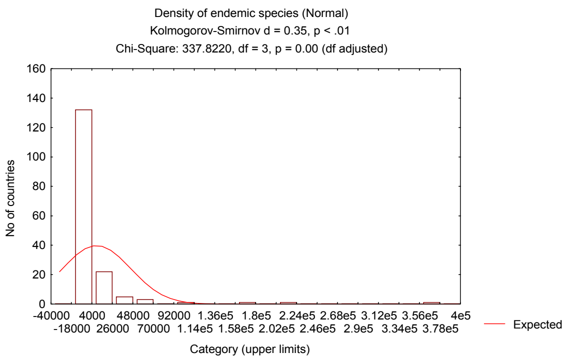
20.3 Characteristics of the indicator data

The data used for testing this indicator were number of known endemic species, divided by total land area for the country and multiplied by 1,000,000 to bring values up to integers (and avoid the need to handle very small fractions requiring exponential notation). These values, ranging between 0 and 360,000, were then plotted as frequency distributions in 20 categories to identify any underlying distribution (Figure 20.3). The four classes of distributions examined were normal, rectangular, exponential and lognormal. The K-S tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. For the normal, rectangular and exponential distributions, a significant difference was found (Figure 20.3). The lognormal distribution was found to be the best fit for the observed distribution of number of endemics / land area, so data were transformed to their natural logarithm, LN(X+1), for further analysis.

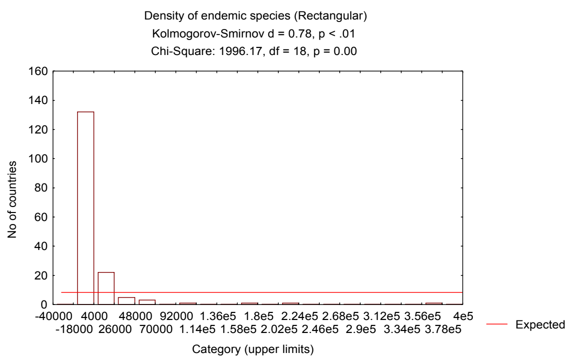
Figure 20.3: Frequency distribution of density of endemic species in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. All comparisons resulted in significant K-S tests, except for the lognormal distribution, suggesting that a logarithmic transform may be useful for mapping these data on the EVI scale.

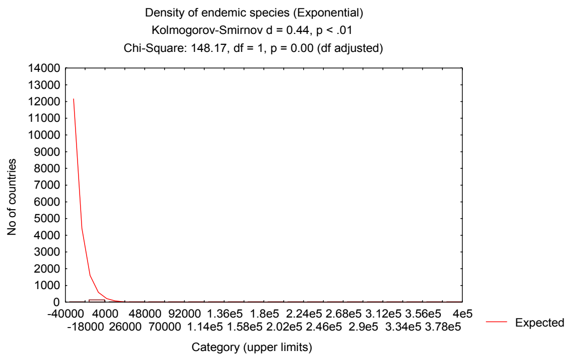
(a)



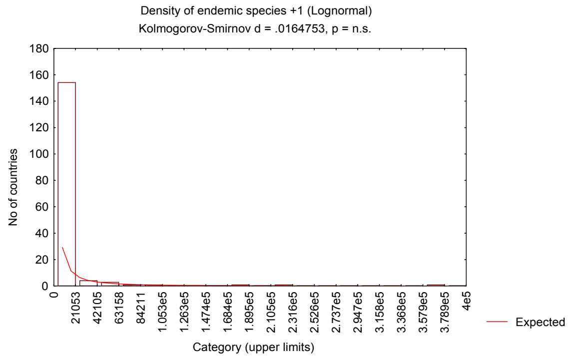
(b)



(c)



(d)



The LN(X+1) transformed data, re-plotted as a frequency distribution were found to be roughly normally-distributed (Figure 20.4). This suggests that the use of the LN(X+1) transform is likely to be an appropriate one for comparing and mapping the density of endemic species on the EVI scale. Using this transform, the resulting data vary between 0 and <13, with an average of 5.57 and a SE which is about 4% of the mean (Table 20.2).

Figure 20.4: Frequency distribution of LN(X+1) transformed data on density of endemic species.

The observed distribution does not differ significantly from the expected normal distribution, indicating that the data are now on a linear scale (K-S results d=0.08, not significant).

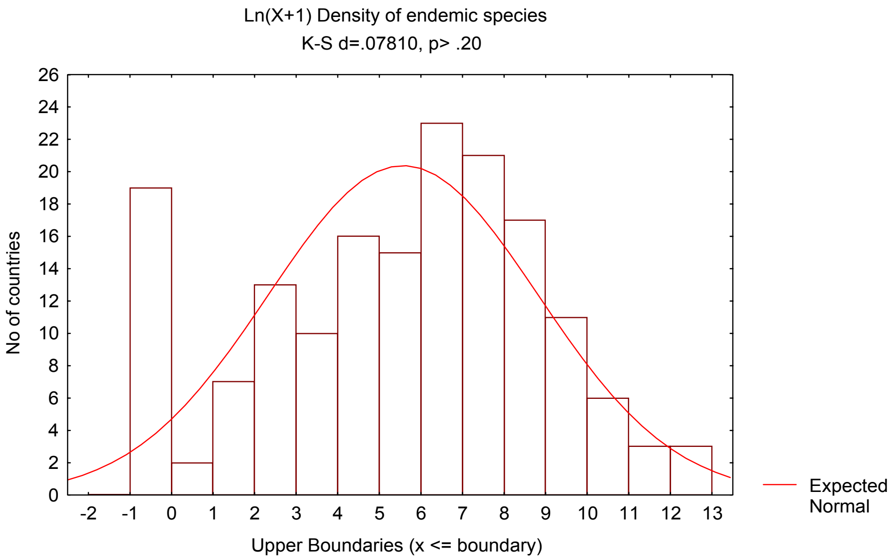


Table 20.2: Characteristics of the data for density of endemic species and the LN(X+1) transformed values.

Statistic	Value for density of endemics	Value LN(X+1) transformed
Mean	9,051.87	5.57
Median	411.69	6.02
Min	0.00	0.00
Max	358,059.90	12.79
SD	36,612.17	3.25
SE	2,841.66	0.25
Skewness	7.12	-0.18
SE Skewness	0.19	0.19
Kurtosis	58.20	-0.78
SE Kurtosis	0.37	0.37

20.4 Proposed EVI scaling and distribution of the data on the new scale

We propose that the EVI scale be a simple linear one using the transformed LN(X+1) data, and with the EVI value increasing as the density of endemic species increases. In this case, an EVI score of 1 (most resilient) would go to countries with no or very few endemic species per unit of land area, and the highest score of 7 (greatest vulnerability) would go to countries with the greatest density of endemics, regardless of the size of the country. The reasoning behind this is that countries with a high density of endemic species have more to lose if their endemic species start to disappear. These species can not recolonise from neighbouring countries and are an integral part of the country's biodiversity. The loss of endemics can mean that ecosystems and interacting communities of organisms are damaged with down-stream effects on ecosystem structure and function. Finally, the loss of endemic organisms could mean that options for foreign exchange through environmentally-sustainable means may become more limited (e.g. ecotourism based on high endemicity) and more unsustainable practices could be adopted instead.

An EVI score of 1 identifies countries with no endemic species, with the scale stepped 2 units up to a maximum of 10+ on the transformed scale. The majority of countries would receive the score of 3, 4 or 5 on the EVI scale for this indicator, and 12 countries would receive a score of 7 (vulnerable because they have a large density of endemic species which if lost could mean major and/or irreversible changes to their natural environments).

Table 20.3: Proposed EVI scaling for Indicator 20 on endemic species.

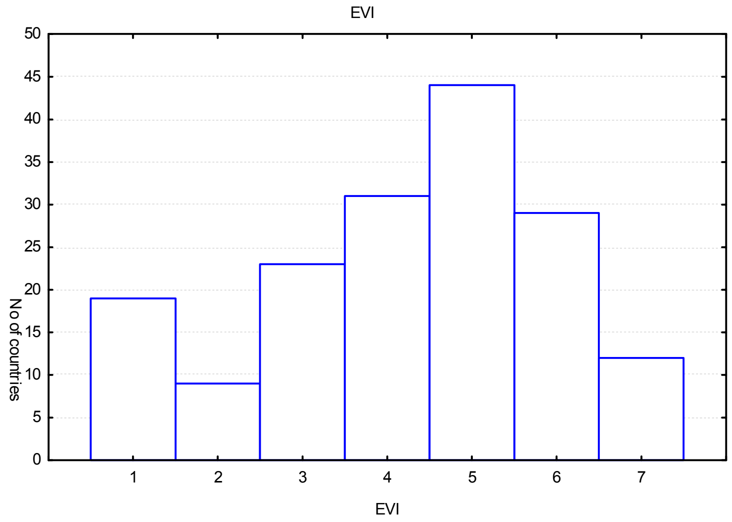
NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	0≤X	19	11.4
2	0 < X ≤ 2	9	5.4
3	2 < X ≤ 4	23	13.8
4	4 < X ≤ 6	31	18.6
5	6 < X ≤ 8	44	26.3
6	8 < X ≤ 10	29	17.4
7	10 < X	12	7.2
	Missing	68	40.7
NA	☒ May not be used		
ND	☑ May be used		

Table 20.4: Proposed EVI scaling for density of endemic species showing examples of countries that fit into each of the EVI scores.

Score	LN(X+1) Endemic species / 1000000 sq km	Endemic species / 1000000 sq km	Examples
EVI=1	0≤X	X≤0	Ireland, Kuwait, Marshall Is.
EVI=2	0 < X ≤ 2	0<X≤6.39	Norway, Chad, Suriname
EVI=3	2 < X ≤ 4	6.39<X≤53.60	Iraq, Poland, Syria
EVI=4	4 < X ≤ 6	53.60<X≤402.43	Israel, Lesotho, Uruguay
EVI=5	6 < X ≤ 8	402.43<X≤2979.96	Uzbekistan, Slovenia, Nicaragua
EVI=6	8 < X ≤ 10	2979.96<X≤22025.47	Nepal, Pakistan, Tanzania
EVI=7	10 < X	X>22025.47	Jamaica, Thailand, Haiti

Figure 20.5: Plot of the frequency distribution on the proposed EVI scale.



20.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later stage when scales have been set for all indicators.

20.6 Age, completeness and quality of the data

The age of the data for this indicator was generally very low, with the average score across all countries being 2.83 of a possible best of 3.00 (i.e. data<2 years old) (Table 20.5). There was a problem with completeness and the quality of data. This appears to have been largely driven by the universal difficulties associated with cataloguing small, cryptic and/or little studied taxa (see WRI 2000-2001). The data for this indicator should ultimately include all taxa, but is at present limited to known mammals, birds, reptiles, amphibians and plants. This leaves a lot of scope for the values to change as knowledge of the world's biodiversity is improved.

Table 20.5: Characteristics of age, completeness and quality of the data obtained for 166 countries on the number of endemic species.

Characteristic	Age	Completeness	Quality
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Mean value across countries:	2.83	1.02	1.98
SD	0.60	0.28	0.36
SE	0.05	0.02	0.03

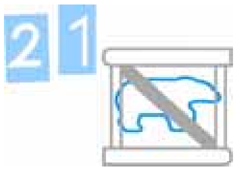
20.7 Variations among sources of data

No alternative public sources of data have been found for this indicator at this time so data can not be evaluated for differences among sources.

20.8 Additional sources & contacts

UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Cook Islands - Cook Islands Biodiversity & Natural Heritage Database. Natural Heritage Project; Federated States of Micronesia - The Nature Conservancy. Contact - Bill Raynor (691 3204267/ 691 3207422); Fiji - Draft of Fiji Biodiversity Strategy Action Plan (1999) National Trust for Fiji; Greece - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Birds of Christmas Island. Information for Visitors – Christmas Island Wildlife Sanctuary (Wildlife Conservation Unit). Department of Environment & Conservation (E & C); Kyrgyzstan - Department of State Ecological Control. Contact - Mr. Narynbek Mersaliev; Marshall Islands - Crawford, M. 1992 Republic of the Marshall Islands National Environmental Strategy (NEMS); Nauru - Thaman, R R and Hasall D C. 1999. Nauru National Environmental Strategy (NEMS); Nepal - Bio-diversity profiles, Annual Publications of plant resources. His Majesty's Government of Nepal and Department of Plant Resources, Netherlands; Niue - Niue SoE Report, 1994. SPREP (pp 15); Palau - Freifeld, H and Otobed, D O. 1997. A Preliminary Wildlife Management Plan for the Republic of Palau; Papua New Guinea - Sekhrau, N and Miller, S (eds). PNG Country Study on Biological Diversity, 1991 – 1993; Samoa - Government of Samoa National Report to the Convention of Biological Diversity. 1998. Division of Environment & Conservation, Department of Lands, Survey & Environment; Thailand - Office of Environmental Policy and Planning (1996) Thailand's Biodiversity; Tonga - A) Watling. D. 1982 Birds of Fiji, Tonga & Samoa. B) Yunker T. G. 1959 Plants of Tonga; Tuvalu - Conservation Unit. Watling, D; Vanuatu - National Biodiversity Survey & Big Bay Conservation Area Report. Environment Unit, SPBCP.

21. INTRODUCTIONS



21.1 Indicator Summary

Indicator number:	21
Indicator short name:	Introductions
Sub-index	AVI
Categorisation	Resources & Services
Indicator text:	Number of introduced species per 1000 square kilometre of land area.
Signals captured:	This indicator captures past species introductions to a country with implied impacts on biodiversity and ecosystem integrity. This may include impacts at the levels of populations, genetics, species and ecosystems through complex ecological interactions. Past introductions of species could negatively affect a country's resilience to future hazards. This would be especially important if there are many endangered species, sensitive ecosystems that could be affected by key species, and interactions with on-going human impacts.
Notes on this indicator:	1. All known introductions are included, regardless of the year. The earliest recorded in this data set are from the 14th Century in Romania, but most are since the 19th and 20th Centuries. 2. Data are likely to be incomplete and biased towards obvious species such as mammals and birds. Insects, marine invertebrates and microorganisms are unlikely to be correctly represented. 3. Data from in-country sources were used in preference to FAO data only in cases where the two were less than 10x different. Several in-country sources gave extremely high values not likely to be correct, possibly because they misunderstood the data required. For example, one country returned a value of 1500 introduced species of fungi. 4. The overall number of introductions in the FAO database is likely to be low, even for obvious species. Most countries would have several hundred species of imported agricultural and domestic plants and animals that do not appear to be in this list.
Are suitable data available?	Yes, partially. Datasets are likely to underestimate small, cryptic, unknown and rare organisms, unless they are obvious.
Sources of data:	• In-country • FAO 2002 website
No. countries included in test:	202 of 235
Temporary modifications to data or indicator, if applicable:	• Data used are density of introductions expressed as number of species introduced per 1000 sq km of land. • We did not use raw numbers because although every species introduced could affect the entire country, effects can be limited by large country sizes. The area available is expected to be related to whether introduced species will overlap and/or interact (cumulative effects). There may also be limits to dispersal through the presence of barriers (e.g. unsuitable habitats or climates). • Data were transformed to LN(X+1) to set the EVI scale. The purpose of this was to expand the lower end of the world

	distribution where the number of introductions per 1000 sq km is lower and the resulting vulnerability more variable. We considered any country with >19 introductions per 1000 sq km to be highly vulnerable and grouped them into EVI score =7 (note the maximum density of introductions was 221).	
Notes on data age, completeness and quality:	15 of the 32 collaborating countries returned data for this indicator. Age and quality of the in-country data were generally considered good (> value of 2/3), while completeness was considered more problematic (score of 1.8). Accuracy of data is a problem for the in-country and FAO sources.	
Basic units:	Density of introductions as X = number of species introduced per 1000 sq km of land area.	
Recommended transforms:	• Data transformed to the natural logarithm of density of introductions + 1; or LN(introductions / 1000 sq km + 1)	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	0<X≤1
	EVI Score = 3	1<X≤1.5
	EVI Score = 4	1.5<X≤2
	EVI Score = 5	2<X≤2.5
	EVI Score = 6	2.5<X≤3
	EVI Score = 7	X>3
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	The true number of species introductions is likely to be much higher than the values given. Better data are needed.	

21.2 Description of raw data

The raw data for this indicator are comprised of the number of species that have been introduced into a country (FAO 2002 and in-country sources). Of the 235 countries examined, data were available for 202.

The number of species introduced into countries by humans by 2002 varied between zero and 122 (Table 21.1). Countries with no recorded introductions include Aruba, Guinea-Bissau and Tajikistan. The country with the highest number of recorded introductions was USA, with the global mean being around 15 introduced species. It is likely that these numbers are very underestimated. In addition to missing small, cryptic, unknown or rare species, the number of introduced agricultural and domestic animals and plants is likely to be high. Half of the world's included countries had 9 introduced species or less (the median). Variance among countries is moderate to high, with a standard deviation which is around 119% of the mean.

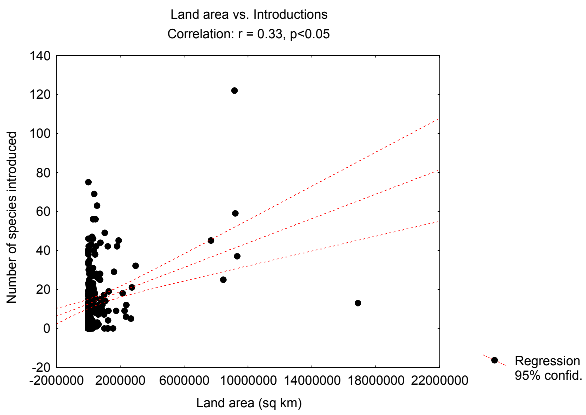
The number of recorded introductions is significantly correlated with the size of a country (see significant correlation coefficient in Figure 21.1). The risks associated with the introduction of species into the environments of a country from an environmental perspective are related to the area of land, despite the potential for species to disperse over the entire country. The area available is expected to be related to whether introduced species will overlap and/or interact (cumulative effects). There may also be limits to dispersal through the presence of barriers (e.g. unsuitable habitats or climates). This means that this indicator needs to be divided by total land area in a country to examine the density of introductions, which when tested against country size, results in no significant correlation (Figure 21.1 b). The maximum density of introductions observed was in Bermuda, with 221 introductions recorded per 1000 sq km of land.

Table 21.1: Basic statistics for total number of species introduced and number of introductions per 1000 sq km of land. Data are from FAO 2002 and cover all known introductions back as far as 14th Century.

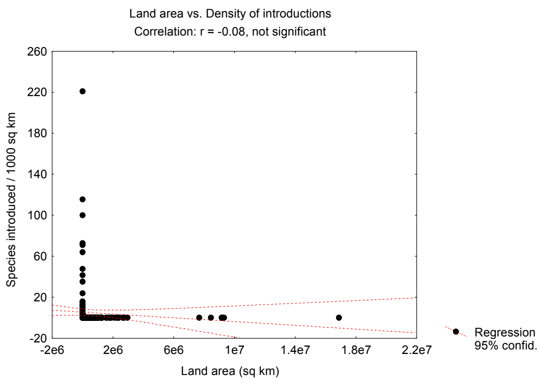
Statistic	Species introduced spp.	Introductions / land area spp / 1000 sq km	LN Introductions LN (spp / 1000 sq km + 1)
Mean	14.53	4.91	0.54
Median	9.00	0.06	0.06
Valid n	202	202	202
Min	0	0.00	0.00
Max	122	221.09	5.40
SD	17.23	21.07	1.07
SE	1.21	1.48	0.08
Skewness	2.21	7.12	2.52
SE Skewness	0.17	0.17	0.17
Kurtosis	7.80	61.23	5.96
SE Kurtosis	0.34	0.34	0.34

Figure 21.1: Graphs of introductions vs. size of countries. (a) total recorded number of species introductions vs. size of country (sq km); and (b) Density of introductions (species / 1000 sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a)



(b)

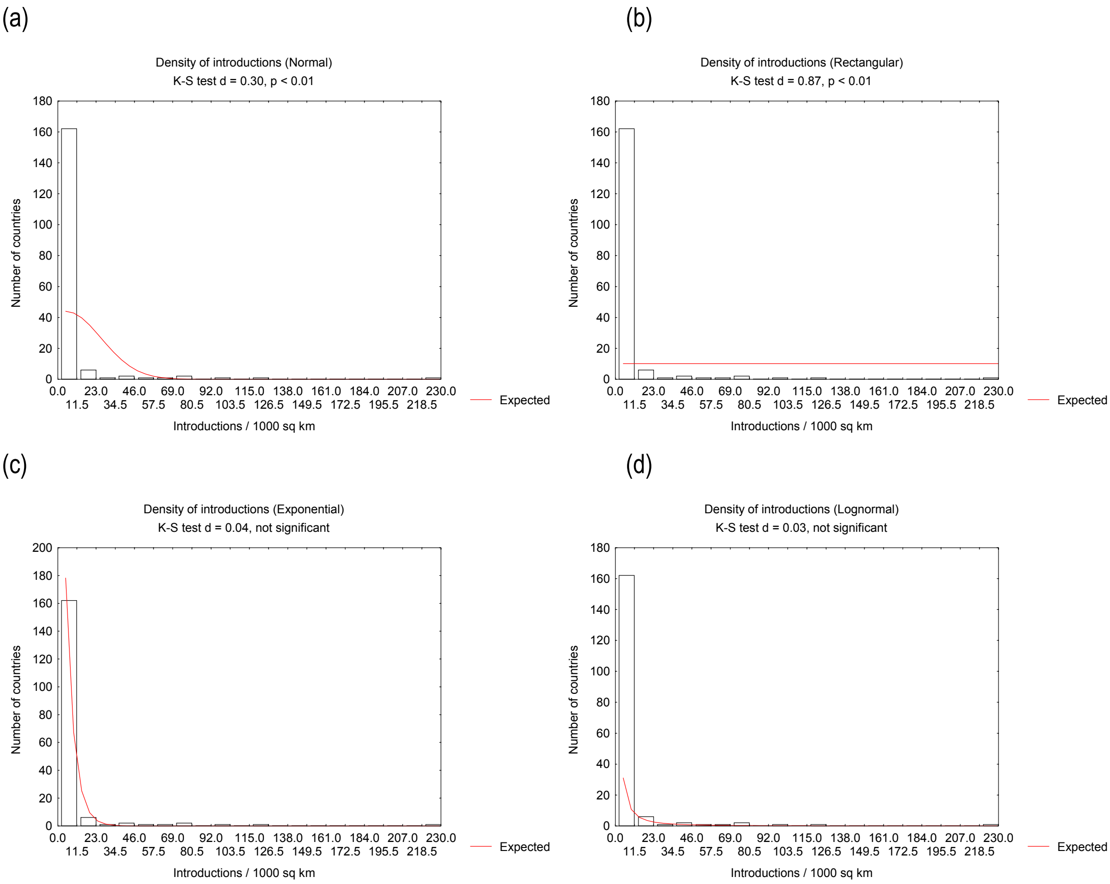


21.3 Distributional characteristics of the indicator data

The density of introductions in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 21.2). This resulted in a distribution in which most countries were clustered in the first category (0-11.5 species / 1000 sq km), and a large spread of values with few countries (Figure 21.2). These distributions were compared with normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function) distributions for goodness-of-fit. Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal and rectangular distributions, indicating that values are neither approximately normally distributed around some world mean, nor are they relatively even across the world range (Figure 21.2). The exponential and lognormal distributions were not significantly different from the observed distributions, suggesting that root or logarithmic functions could be used to transform the values to a better scale for comparison. Such transforms would tend to provide spread among countries at lower introduction densities, where differences are likely to be more critical.

Figure 21.2: Kolmogorov-Smirnov goodness-of-fit tests for density of introductions in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

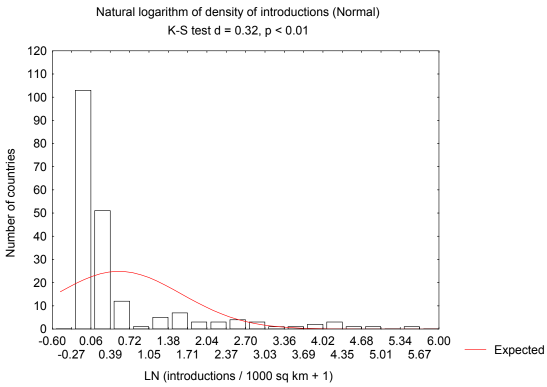


21.4 Proposed EVI scaling and distribution of the data on this scale

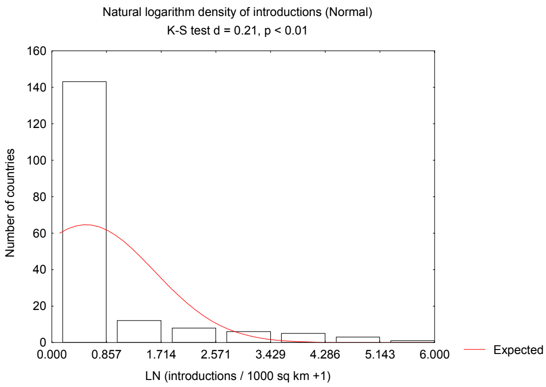
Countries varied in freight density by three orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms (LN(X+1)) for this indicator to provide better spread among the countries and compress the scale to between 0 and 5.4, with countries having the greatest densities of introductions being considered more vulnerable and attracting a higher EVI score. We identified those countries with 0 introductions on all scales (raw, density and LN(X+1) transformed) as the least at risk of environmental damage (EVI score = 1). Countries with a value of > 3 (19.09 introductions / 1000 sq km) were considered the most vulnerable (EVI score =7). The country values between these extremes were spaced evenly to form the EVI scale (Figure 21.3, Table 21.2, 21.3).

Figure 21.3: Frequency distribution of LN(X+1) density of introductions in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density of introductions in 20 even categories. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) density of introductions which groups countries with the highest densities. (d) The proposed EVI scale.

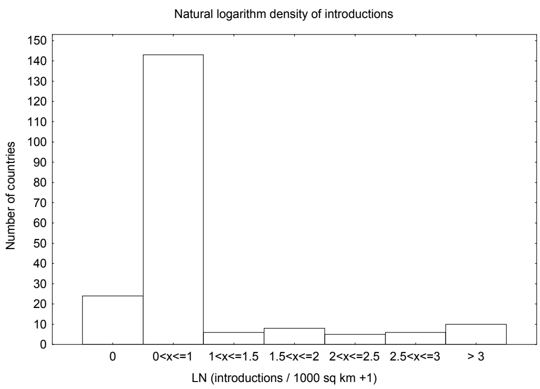
(a)



(b)



(c)



(d)

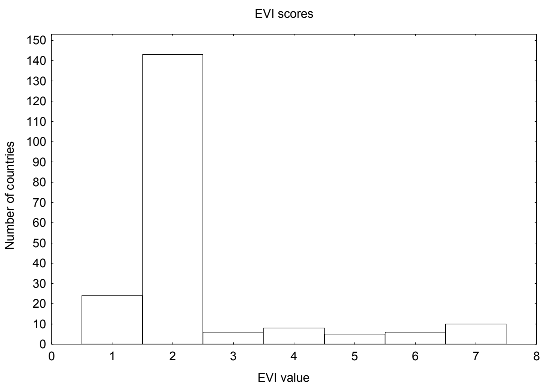


Table 21.2: Proposed EVI scaling for density of introductions showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X=0	24	11.88
2	0<X≤1	143	70.79
3	1<X≤1.5	6	2.97
4	1.5<X≤2	8	3.96
5	2<X≤2.5	5	2.48
6	2.5<X≤3	6	2.97
7	X>3	10	4.95
No data		33	16.34
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 21.3: Proposed EVI scaling for Indicator 21 on species introductions showing equivalence on the LN(X+1) and untransformed density scales, and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(x+1) Density of introductions	Equivalent scale in Density of introductions Introductions / 1000 sq km	Examples
EVI=1	X=0	X=0	Azerbaijan, Djibouti, Mauritania
EVI=2	0<X≤1	0<X≤1.72	Afghanistan, Germany, Guatemala
EVI=3	1<X≤1.5	1.72<X≤3.48	Fiji, Maldives, US Virgin Is.
EVI=4	1.5<X≤2	3.48<X≤6.39	Netherlands Antilles, Grenada, Cayman Is.
EVI=5	2<X≤2.5	6.39<X≤11.18	Antigua & Barbuda, Niue, French Polynesia
EVI=6	2.5<X≤3	11.18<X≤19.09	Kiribati, Malta, FSM
EVI=7	X>3	X>19.09	American Samoa, Nauru, Singapore

21.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

21.6 Age, completeness and quality of the data

The data obtained for this indicator were from FAO 2002 and from in-country sources. The two sources could only be partially merged to extend the number of countries with data, because there were orders-of-magnitude differences for some countries where both sources were available. For example, the FAO 2002 value given for Nepal was 18 and the in-country estimate was 15,312. This large difference requires further investigation.

In-country data were available for 15 of the 32 collaborating countries, with data being of good age and quality (>2 of a possible score of 3) (Table 21.4). Collaborators rated the completeness of their data lower (1.8 of possible score of 3).

Table 21.4: Characteristics of age, completeness and quality of the data obtained for earthquakes in 238 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	1.80	2.57
Valid n (in-country)	12	15	14
SD (in-country)	0.74	0.86	0.76
SE (in-country)	0.21	0.22	0.20

21.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

21.8 Additional sources & contacts

www.fao.org/scripts/acqintro/query/retrive.idc (15/02/2002); Cook Islands - Cook Islands Biodiversity & Natural Heritage Database. Natural Heritage Project. Contact - Gerald McCormack (682 20959); Federated States of Micronesia - The Nature Conservancy. Contact - Bill Raynor (691 3204267/ 691 3207422); Fiji - National Trust for Fiji; Kiribati - Thaman & Tebano. 1994. Kiribati Plant and Fish Names. A Preliminary Listing; Kyrgyzstan - Department of State Ecological Control. Contact - Mr. Narynbek Myrsaliev; Nauru - Thaman, R R and Hassall, D C. 1999.Nauru National Environmental Management Strategy (NEMS); Nepal - IUCN (1999), Nepal Country Report on Biological Diversity, Kathmandu, Nepal; Palau - Freifeld, H and Otobed, D O. 1997 A Preliminary Wildlife Management Plan for the Republic of Palau; Papua New Guinea - Sekhrau, N and Miller, S (eds). Papua New Guinea Country; Samoa - Government of Samoa National Report to the Convention of Biological Diversity. 1998. Division of Environment & Conservation, Department of Lands, Survey & Environment; Study on Biological Diversity, 1991 – 1993; Thailand - Thailand's Biodiversity. (1996) Office of Environmental Policy and Planning. Pollution Control Department; Tonga - Watling. D. 1982 Birds of Fiji, Tonga and Samoa; Tuvalu - Seluka. S. Cultural Significance & Utility of Plants and Fisheries.

22. ENDANGERED SPECIES

22.1 Indicator Summary

Indicator number:	22	
Indicator short name:	Endangered species	
Sub-index	AVI	
Categorisation	Resources & Services	
Indicator text:	Number of endangered and vulnerable species per 1000 sq km land area (IUCN definitions).	
Signals captured:	This indicator focuses on those species that have become endangered or threatened in a country with implied impacts on biodiversity and ecosystem integrity. These are the species most likely to next become extinct, and may already be resulting, by their reduced numbers, in impacts at the levels of populations, genetics, species and ecosystems through complex ecological interactions. The reduction of populations of species could negatively affect a country's resilience to future hazards. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.	
Notes on this indicator:	1. All known critically endangered, endangered and vulnerable species are included, as categorised by IUCN between the years of 1981 and 2000. 2. Data are likely to be incomplete and biased towards obvious species such as mammals and birds. Insects, marine invertebrates and microorganisms are unlikely to be correctly represented. 3. Data from in-country sources were used where IUCN data were unavailable.	
Are suitable data available?	Yes. Data are likely to underestimate small, cryptic, rare and undescribed organisms, unless they are obvious or of some human interest (e.g. tourism).	
Sources of data:	• IUCN Red Book 2000 • In-country	
No. countries included in test:	230 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	21 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2 of 3 for age, completeness and quality).	
Basic units:	Density of endangered species expressed as number of species per 1000 sq km land area categorised by IUCN as either critically endangered, endangered or vulnerable.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	0<X≤1
	EVI Score = 3	1<X≤2
	EVI Score = 4	2<X≤3
	EVI Score = 5	3<X≤4
	EVI Score = 6	4<X≤5
	EVI Score = 7	X>5

	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:		

22.2 Description of raw data

The raw data for this indicator are comprised of the total numbers of species in countries considered to be at the most risk of extinction and damage to intraspecific diversity (populations and genetics). The three top categories of IUCN's definitions were used: critically endangered, endangered and vulnerable, which we will collectively term 'endangered' species (IUCN 2000). Of the 235 countries examined, data were available for 230.

The total number of endangered species in countries varied between 1 and almost 1000, with the highest figures being recorded in Indonesia, Malaysia and the USA. No countries recorded zero endangered species. The mean number across the countries examined was 78 species and half of the countries had 32 or more endangered species (the median) (Table 22.1). Variance among countries is moderate, with a standard deviation which is around 1.7 times the mean.

The number of species considered endangered is, as expected from species-area theory, correlated with the size of a country (see significant correlation coefficient in Figure 22.1). This correlation disappears if the data are expressed as density of endangered species, or endangered species per 1000 sq km of land. The risks to biodiversity and the complex ecological processes that could be disrupted as species are lost from ecosystems is expected to be related to the overall diversity in a country, which is in turn related to the diversity of habitat and climate types developed (related to size of the country). This means that this indicator is best expressed as a density function so that risk of loss of species can be evaluated independently of overall size of countries.

The density of endangered species varies between 0.004 and 635 species per sq km, with the highest values being recorded in Bermuda and Norfolk Island. The mean density of endangered species across all countries examined was almost 20 per 1000 sq km, while the median value was 0.58 species per sq km (Table 22.1).

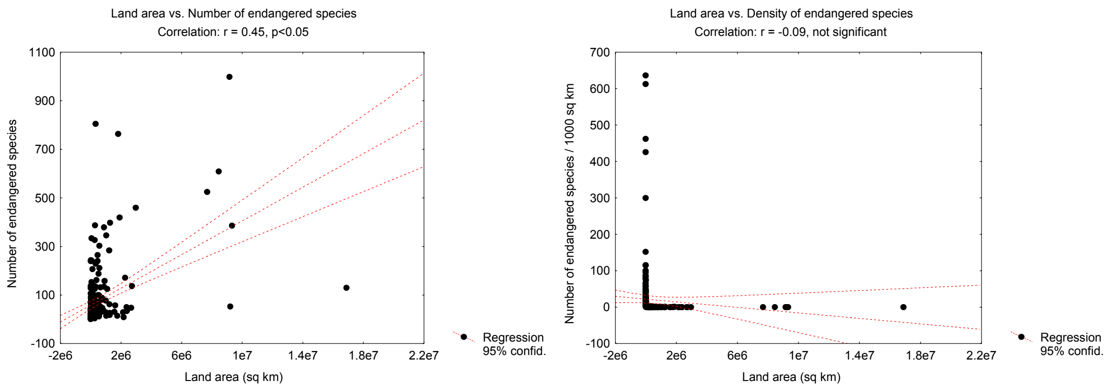
Table 22.1: Basic statistics for total number of endangered species and number of endangered species per 1000 sq km of land. Data are from IUCN 2000.

Statistic	Endangered species spp.	Endangered species / land area spp / 1000 sq km
Mean	78.27	19.79
Median	32.00	0.58
Valid n	230	230
Min	1.00	0.004
Max	998.00	635.84
SD	133.26	75.48
SE	8.79	4.98
Skewness	3.74	6.37
SE Skewness	0.16	0.16
Kurtosis	17.28	43.82
SE Kurtosis	0.32	0.32

Figure 22.1: Graphs of number of endangered species vs. size of countries.

(a) Total number of endangered species vs. size of country (sq km); and (b) Density of endangered species (number per 1000 sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a) (b)



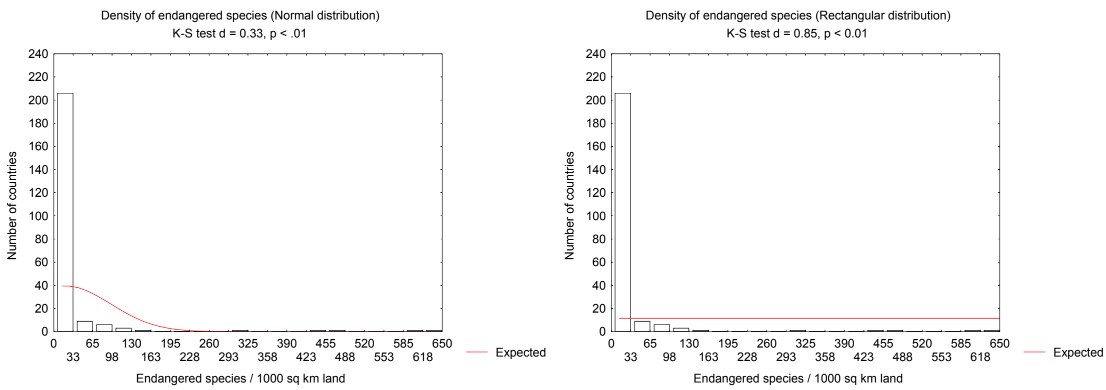
22.3 Distributional characteristics of the indicator data

The density of endangered species was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 22.2). This resulted in a distribution in which most countries were clustered at the lower end of the scale (first category 0-33 species / 1000 sq km) (Figure 22.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

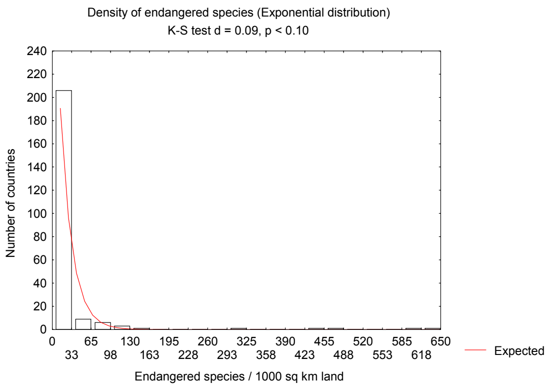
A significant difference between observed and expected values was found in all tests except the lognormal distribution (Figure 22.2). This suggests that the values observed are distributed according to some logarithmic function and that transforming the values to their natural logarithm might provide a better scale for comparison.

Figure 22.2: Kolmogorov-Smirnov goodness-of-fit tests for density of endangered species in countries spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution was the best fit of the observed data.

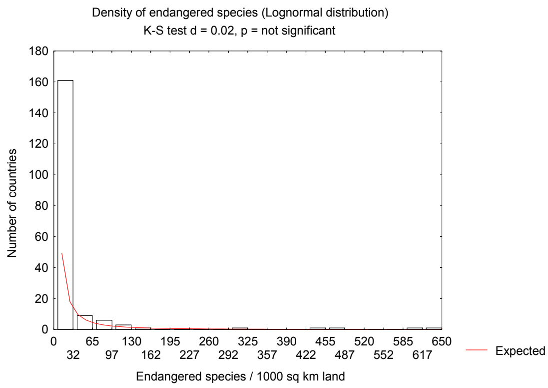
(a) (b)



(c)



(d)

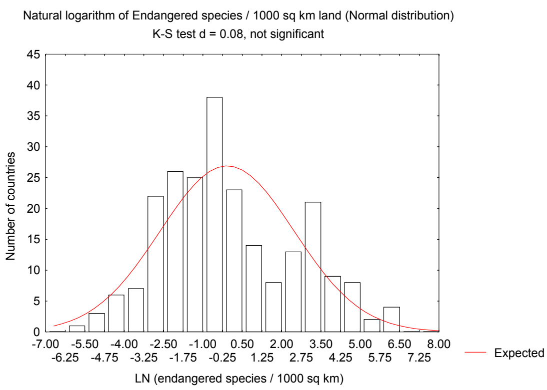


22.4 Proposed EVI scaling and distribution of the data on this scale

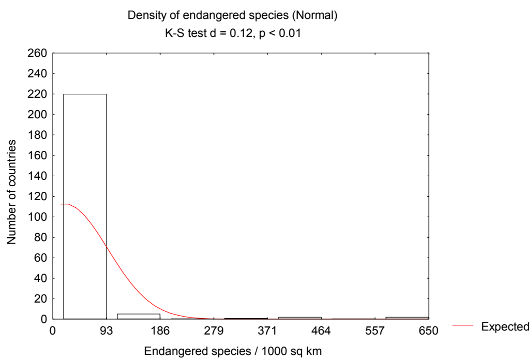
Countries varied in the density of endangered species by five orders of magnitude, and there was a strong clumping of countries at the lower end of the scale (Figure 22.2, Figure 22.3). Although the data were normalised and a better spread among countries at the lower end of the scale was provided by a natural logarithm transformation (Figure 22.3 a), we chose not to apply the transform to this indicator. We considered that countries could and should work towards reducing the number of endangered species to zero (defined as EVI score =1), despite the fact that no country was in this position. All countries with greater than 5 endangered species per 1000 sq km were considered at high risk of ecological damage, and we attributed the highest EVI score (7) to all countries with this level. Values between these two extremes were divided evenly to create the remainder of the EVI scale (Figure 22.3, Table 22.2, 22.3).

Figure 22.3: Frequency distribution of density of endangered species in even and uneven categories and the EVI scale. (a) Frequency distribution of density in 20 even categories for LN(X) transformed data, showing that the transformed data are a good fit to the normal distribution. (b) is the distribution of untransformed data compressed to a 7 category (even) scale. (c) Is the distribution of density of endangered species in seven uneven categories which shows the proposed EVI scale with the 7 categories shown in the graph representing EVI scores from 1-7.

(a)



(b)



(c)

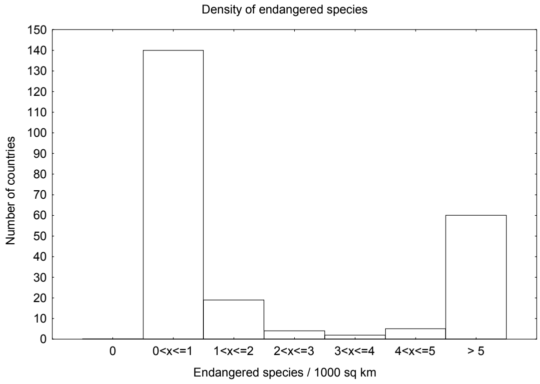


Table 22.2: Proposed EVI scaling for density of endangered species showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Endangered species / 1000 sq km	Observed # countries	Observed % of countries
1	X=0	0	0
2	0<X≤1	140	60.87
3	1<X≤2	19	8.26
4	2<X≤3	4	1.74
5	3<X≤4	2	0.87
6	4<X≤5	5	2.17
7	X>5	60	26.09
No data		5	2.17
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 22.3: Proposed EVI scaling for Indicator 20 on density of endangered species showing examples of countries that fit into each of the EVI scores.

Score	Endangered species / 1000 sq km	Examples
EVI=1	X=0	No countries
EVI=2	0<X≤1	Congo, Ghana, Liberia
EVI=3	1<X≤2	Ecuador, El Salvador, Vanuatu
EVI=4	2<X≤3	Costa Rica, Malaysia, Solomon Is.
EVI=5	3<X≤4	Panama, Taiwan
EVI=6	4<X≤5	Fiji, Luxembourg, Slovenia
EVI=7	X>5	Aruba, Grenada, Sri Lanka

22.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

22.6 Age, completeness and quality of the data

The data obtained for this indicator were from IUCN Red Book 2000 and from in-country sources. In-country data were available for 21 of the 32 collaborating countries, with data being of good age, completeness and quality (all >2 of 3) (Table 22.4).

Table 22.4: Characteristics of age, completeness and quality of the data obtained for endangered species in 230 countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.06	2.05	2.24
Valid n (in-country)	18	20	21
SD (in-country)	0.64	0.94	0.89
SE (in-country)	0.15	0.21	0.19

22.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

22.8 Additional sources & contacts

www.redlist.org/info/tables.html (27/09/01); Cook Islands - Cook Islands Biodiversity & Natural Heritage Database. Natural Heritage Project. Contact - Gerald McCormack (682 20959); Federated States of Micronesia - The Nature Conservancy. Contact - Bill Raynor (691 3204267/ 691 320 7422); Fiji - Draft of Fiji Biodiversity Strategy & Action Plan 1999. (FBSAP). FBSAP Committee; Greece - Contact - Anastasios Legakis, Zoological Museum; Kiribati - A) Wilson, C. 1994. Kiribati State of Environment Report. B) Biodiversity Strategy & Action Plan (BSAP). 2000. BSAP Planning Team; Marshall Islands - Crawford, M. 1992 RMI National Environmental Management Strategy (NEMS) (pp 6); Nauru - A) Thaman, R R and Hassall, D C. 1999; Nauru National Environmental Management Strategy (NEMS). B) InfoNation (from UN Statistics Division); Nepal - Bio-diversity profiles of the high mountains and high Himal, Dept of National Parks; Niue - A) Guide to the Birds of Niue Book, 1998. SPREP. B) Brooke, A. 1997/8. Niue Bat Report. C) Bereteh, Mohammed. UGA/ BIRIGUR LATRO Report; Palau - Freifeld, H and Otobed, D O. 1997. A Preliminary Wildlife Management Plan for the Republic of Palau; Papua New Guinea - Sekhrau, N and Miller, S (eds). PNG Country Study on Biological Diversity, 1991 – 1993; Philippines - Protected Areas and Wildlife Bureau (PAWB) Statistics. Contact - Mr. Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph ; Samoa - A) Tu'u'uleti Taulealo, State of Environment Report: Samoa, Government of Samoa. 1993. (note: data on plants only) B) Government of Samoa National Report to the Convention of Biological Diversity. 1998. Division of Environment & Conservation, Department of Lands, Survey & Environment; Thailand - Office of Environmental Policy and Planning (1996) Thailand's Biodiversity; Tonga - A) Report of the Minister for Fisheries for the year 1997 – Govt. of Tonga. B) Report of the Minister for Fisheries for the year 1998 – Govt. of Tonga C) Biology, Exploitation & Management of Giant Clams D) First Report on a Data Acquisition and Monitoring System for Fanga'uta Lagoon System, Tongatapu, Kingdom of Tonga; Trinidad and Tobago - Cindy Buchoon. Curator of the National Herbarium of Trinidad; Tuvalu - A) IUCN Red Data Book 1990 B) IUCN 1997 Giant Clams: Status, Trade & Mariculture; Vanuatu - Contact - Ernest Bani (678 25302/ 23565) Environment Unit.

23. EXTINCTIONS

23.1 Indicator Summary

Indicator number:	23
Indicator short name:	Extinctions
Sub-index	AVI
Categorisation	Resources & Services
Indicator text:	Number of species known to have become extinct since 1900 per 1000 sq km land area (IUCN definitions).
Signals captured:	This indicator focuses on those species that have become extinct in a country with implied impacts on biodiversity and ecosystem integrity. The loss of these species has resulted in a loss of biodiversity, and may also have resulted in impacts on ecosystem structure and function through complex ecological interactions. The loss of species could negatively affect a country's resilience to future hazards. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.
Notes on this indicator:	1. All known extinctions are included, as categorised by IUCN between the years of 1900 and 2000. 2. Data are likely to be incomplete and biased towards obvious species such as mammals and birds. Insects, marine invertebrates and microorganisms are unlikely to be correctly represented. 3. Undescribed species will not be represented and may be becoming extinct without human knowledge. 4. It is possible for species to become extinct in a country, but not globally extinct. From the perspective of the country concerned, and the environments in it, loss from a country is considered an extinction in that country. If the species are available in other countries, this opens the possibility for a species to become 'unextinct' in the future. 5. We considered using % of known species which have become extinct as the basis of this indicator, but this would tend to hide the real numbers of species that could be lost in very diverse and/or large countries. In terms of environmental vulnerability, countries should aim at ensuring no further species become extinct, not merely gauging their efforts as a percentage of those species available in the country. In a very small, undiverse country, 0.1% extinctions could mean 10 species. In a large or diverse country this percentage could mean the loss of 100 species. Loss per unit area addresses this problem. 6. Countries in which most clearance and species loss occurred pre-1900 (e.g. Europe) have apparently low vulnerabilities in this indicator. This does not represent their true state in terms of extinctions simply because different time frames are being compared. 7. Data from in-country sources were used where IUCN data were unavailable.
Are suitable data available?	Yes. Data are likely to underestimate small, cryptic and rare organisms, unless they are obvious or of some human interest (e.g. tourism).
Sources of data:	• IUCN Red Book 2000

	• In-country	
No. countries included in test:	229 of 235	
Temporary modifications to data or indicator, if applicable:	1. None	
Notes on data age, completeness and quality:	20 of the 32 collaborating countries returned data for this indicator. Age of the in-country data was generally considered good (> value of 2 of 3), while data on completeness and quality were judged of lower reliability (values < 2) by collaborators.	
Basic units:	Density of extinctions expressed as number of known extinct species per 1000 sq km land area.	
Recommended transforms:	2. None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	0<X≤0.25
	EVI Score = 3	0.25<X≤0.5
	EVI Score = 4	0.5<X≤0.75
	EVI Score = 5	0.75<X≤1
	EVI Score = 6	1<X≤1.25
	EVI Score = 7	X>1.25
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	This indicator would be more effective if the period over which extinctions could be lengthened. The timing of development has a large influence on the number of extinctions recorded.	

23.2 Description of raw data

The raw data for this indicator are comprised of the total number of known species that have become extinct in countries since 1900 (IUCN 2000). Of the 235 countries examined, data were available for 229.

The total number of extinct species in countries varied between 0 and 253, with the highest figure being recorded in the USA. The mean number across the countries examined was 3.25, with at least half of the countries examined recording no extinctions (Table 23.1). Variance among countries is moderate to high, with a standard deviation which is around 5.5 times the mean.

The number of species known to have become extinct in a country is, as expected from species-area theory, correlated with the size of a country (see significant correlation coefficient in Figure 23.1). This correlation disappears if the data are expressed as density of extinctions, or extinctions per 1000 sq km of land. The risks to biodiversity and the complex ecological processes that could be disrupted as species are lost from ecosystems is expected to be related to the overall diversity in a country, which is in turn related to the diversity of habitat and climate types developed, and the size of a country. This means that this indicator is best expressed as a density function so that the number of species which have become extinct can be evaluated independently of overall size of countries.

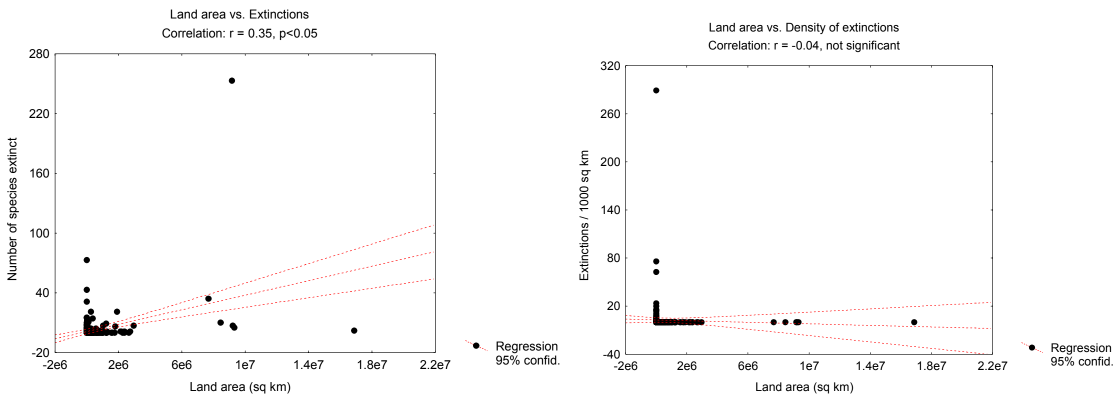
The extinction density in countries varies between 0 and 289 species per sq km, with the highest values being recorded in the Cook Islands, St Helena, Mauritius and Norfolk Island. The mean extinction density across all countries examined was 2.54 species 1000 sq km (Table 23.1).

Table 23.1: Basic statistics for total number of extinct species and number of endangered species per 1000 sq km of land. Data are from IUCN 2000.

Statistic	Extinct species spp.	Extinct species / land area spp / 1000 sq km
Mean	3.25	2.54
Median	0.00	0.00
Valid n	229	229
Min	0	0
Max	253	289.02
SD	17.98	20.27
SE	1.19	1.34
Skewness	12.21	12.83
SE Skewness	0.16	0.16
Kurtosis	165.71	177.84
SE Kurtosis	0.32	0.32

Figure 23.1: Graphs of number of extinct species vs. size of countries. (a) Total number of extinct species vs. size of country (sq km); and (b) Density of extinct species (number per 1000 sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a) (b)

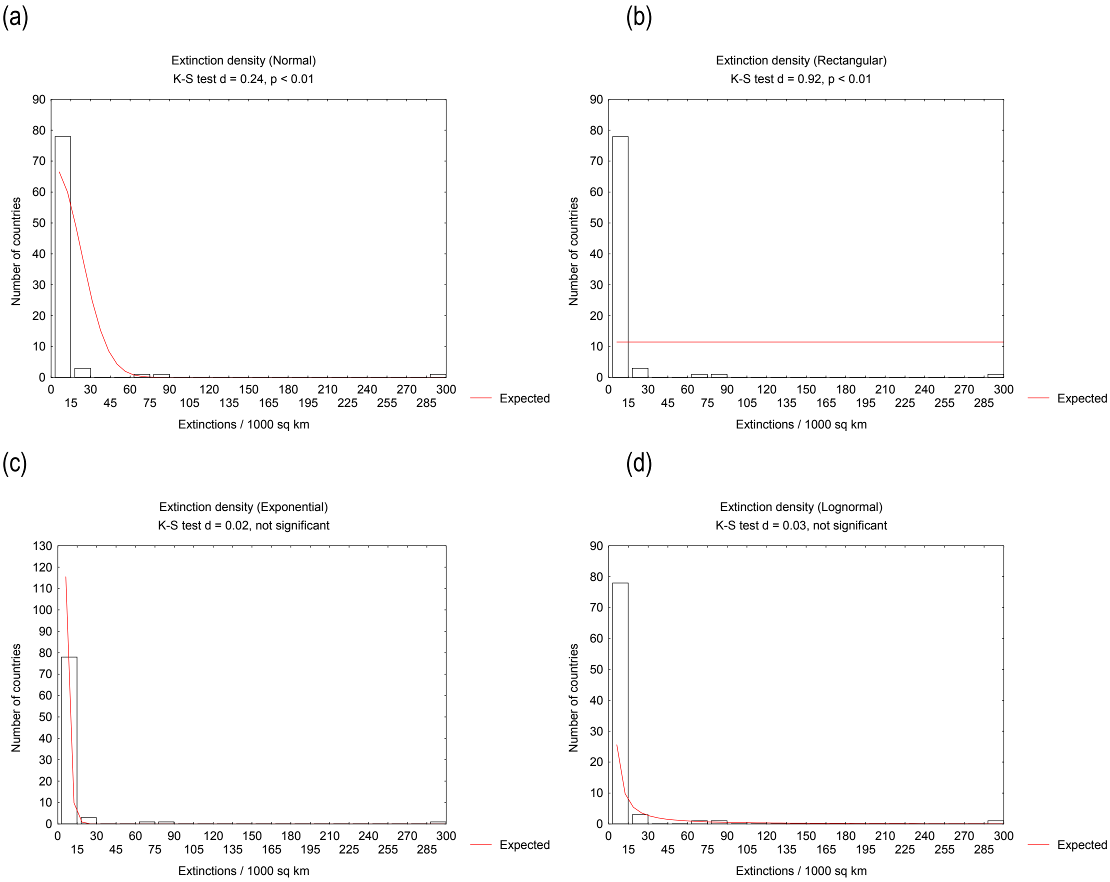


23.3 Distributional characteristics of the indicator data

The density of extinct species was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 23.2). This resulted in a distribution in which most countries were clustered at the lower end of the scale (first category 0-15 species / 1000 sq km) (Figure 23.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal and rectangular distributions, but not in the exponential or lognormal distributions (Figure 23.2). This suggests that the values observed are distributed according to power or logarithmic functions and that if scaling is required to provide better spread among low values, or to linearise the data, a root or logarithmic transform might provide a better scale for comparison.

Figure 23.2: Kolmogorov-Smirnov goodness-of-fit tests for extinction density of countries spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions were the best fit of the observed data.

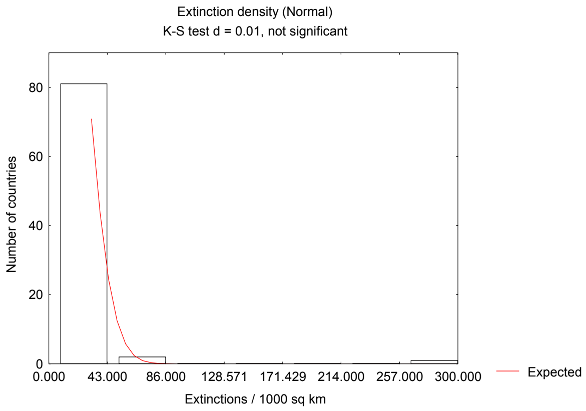


23.4 Proposed EVI scaling and distribution of the data on this scale

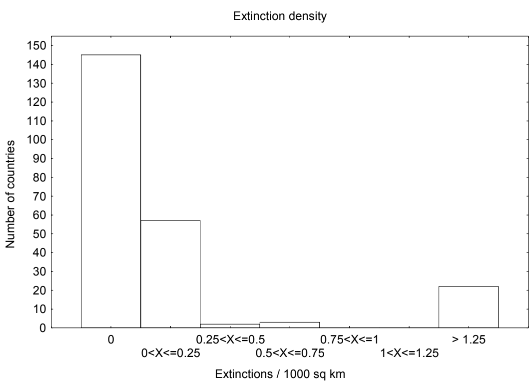
Countries varied in extinction density by three orders of magnitude, and there was a strong clumping of countries at the lower end of the scale (Figure 23.2, 23.3). Although a better spread among countries at the lower end of the scale was provided by a natural logarithm transformation, we chose not to apply the transform to this indicator. We considered that countries could and should work towards preventing any further extinctions, reinstating any species that have become extinct in the country, but are available elsewhere on the globe, and that very low rates of extinction could have far=reaching effects on environmental condition and vulnerability. Those countries with zero extinctions since 1900 were attributed an EVI score =1. All countries with more than 1.25 known extinctions per 1000 sq km were considered at the highest risk of past and future ecological damage, particularly if the rate of loss is sustained. We gave such countries the highest EVI score (7). Values between these two extremes were divided evenly to create the remainder of the EVI scale (Figure 23.3, Table 23.2, 23.3).

Figure 23.3: Frequency distribution of extinction density in even and uneven categories and the EVI scale. (a) Frequency distribution of density in 7 even categories. (b) and (c) is the distribution of extinction density values in seven uneven categories which shows the proposed EVI scale.

(a)



(b)



(c)

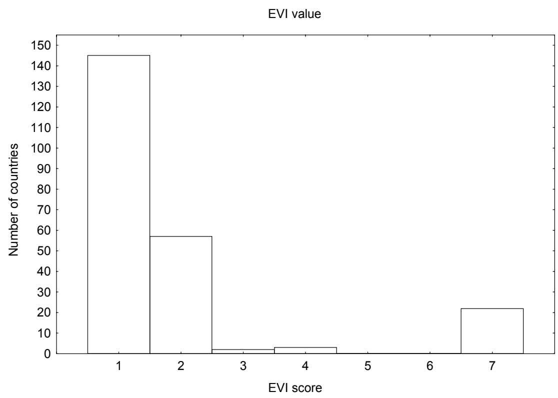


Table 23.2: Proposed EVI scaling for density of extinct species showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Extinct species / 1000 sq km	Observed # countries	Observed % of countries
1	X=0	145	63.32
2	0<X≤0.25	57	24.89
3	0.25<X≤0.5	2	0.87
4	0.5<X≤0.75	3	1.31
5	0.75<X≤1	0	0
6	1<X≤1.25	0	0
7	X>1.25	22	9.61
No data		6	2.62
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 23.3: Proposed EVI scaling for Indicator 23 on density of extinct species showing examples of countries that fit into each of the EVI scores.

Score	Extinct species / 1000 sq km	Examples
EVI=1	X=0	Armenia, Hungary, Lesotho
EVI=2	0<X≤0.25	Brazil, Japan, Malaysia
EVI=3	0.25<X≤0.5	Haiti, New Caledonia
EVI=4	0.5<X≤0.75	Faroe Is., Puerto Rico, Jamaica
EVI=5	0.75<X≤1	None
EVI=6	1<X≤1.25	None
EVI=7	X>1.25	Barbados, Cayman Is., Reunion

23.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

23.6 Age, completeness and quality of the data

The data obtained for this indicator were from IUCN Red Book 2000 and from in-country sources. In-country data were available for 20 of the 32 collaborating countries, with data being of good age, but rated lower in terms of completeness and quality (Table 23.4).

Table 23.4: Characteristics of age, completeness and quality of the data obtained for in-country data.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.06	1.85	1.90
Valid n (in-country)	16	20	20
SD (in-country)	0.77	0.93	0.91
SE (in-country)	0.19	0.21	0.20

23.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

23.8 Additional sources & contacts

www.redlist.org/info/tables.html (27/09/01); Cook Islands - Biodiversity and Natural Heritage Database. Contact - Gerald McCormack (682 20959) Natural Heritage Project; Federated States of Micronesia - The Nature Conservancy. Contact - Bill Raynor (691 3204267/ 691 320 7422); Fiji - Draft of Fiji Biodiversity Strategy & Action Plan (FBSAP). (1991) National Trust of Fiji; Kiribati - Contact - Michael Phillips. Environment & Conservation Division; Marshall Islands - Crawford, M. 1992 RMI National Environmental Management Strategy (NEMS) (pp 6); Nauru - Thaman, R R and Hassall, D C. 1999. Nauru National Environmental Management Strategy (NEMS); Nepal - IUCN (1999), Nepal Country Report on Biological Diversity (pp 44), Kathmandu, Nepal; Niue - A) Niue

SoE Report, 1994. SPREP (pp 15). B) From SPC. Department of Agriculture, Forestry & Fisheries (P O Box 74, Alofi, Niue); Palau - Freifeld, H and Otobed, D O. 1997. A Preliminary Wildlife Management Plan for the Republic of Palau; Papua New Guinea - Sekhrau, N and Miller, S (eds). PNG Country Study on Biological Diversity, 1991 – 1993. Samoa - Schuster, C; Whistler, A and Siuli, T. The Conservation of Biological Diversity in Upland Ecosystems of Samoa; Thailand - Office of Environmental Policy and Planning (1996) Thailand's Biodiversity; Tonga - Watling. D. Wildlife Conservation and Management: pp161; Tuvalu - Contact - Claudia Ludescher Environment Unit; Vanuatu - Contact - Ernest Bani (678 25302/ 23565)Environment Unit.

24. NATURAL VEGETATION COVER REMAINING

24.1 Indicator Summary

Indicator number:	24
Indicator short name:	Natural Vegetation Cover Remaining
Sub-index	AVI
Categorisation	Resources & Services
Indicator text:	Percentage of natural and regrowth vegetation cover remaining (include forests, wetlands, prairies, tundra, desert and alpine associations).
Signals captured:	This indicator focuses on the loss of natural vegetation cover in a country with implied impacts on biodiversity and ecosystem integrity. The loss of natural vegetation has resulted in a loss of biodiversity, and may also have resulted in impacts on ecosystem structure and function through complex ecological interactions. Areas of natural vegetation are viewed as refugia for threatened species, those unknown to science, or those which may act as a future resource (e.g. for biochemical applications). Natural forests and vegetated areas are also likely to be important areas for groundwater intake, soil production, CO_2 – oxygen relationships and attenuating air and water pollution. A country's resilience to future hazards will be related to the rate and total loss of naturally vegetated areas. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.
Notes on this indicator:	1. Amount of natural cover considered here should encompass all ecosystem types, whether forests, grasslands or deserts. 2. Data provided by WRI are expressed as percentage of forests remaining, and may not cover tundra, deserts, alpine and herb areas and grasslands etc. 3. Data from WRI refers to Original forest cover about 8,000 years ago assuming current climatic conditions. 4. Data from in-country sources were used for countries not covered by WRI. 5. The definition of regrowth forest is one in which regrowth is unsupported by human (other than in allowing natural regeneration) and results in a forest community that is self-sustaining indefinitely (not withstanding climatic changes).
Are suitable data available?	Yes.
Sources of data:	1. WRI 2000-2001 2. In-country 3. FAO State of the World's Forests, 1995, 2000.
No. countries included in test:	155 of 235
Temporary modifications to data or indicator, if applicable:	• Data may not include certain types of original cover, such as tundra, deserts, grasslands which are not "forests".
Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data was generally considered good (> value of 2 of 3) by collaborators.
Basic units:	Percentage of original (and regrowth) vegetation cover remaining.
Recommended transforms:	• None
Proposed EVI Scale	EVI Score = 1 : X>80 EVI Score = 2 : 60<X≤80

	EVI Score = 3	40<X≤60
	EVI Score = 4	20<X≤40
	EVI Score = 5	10<X≤20
	EVI Score = 6	0<X≤10
	EVI Score = 7	X=0
	NA (not applicable)	☒ May be used only if original cover is limited to forest (as in the data used for this demonstration EVI), but this indicator specifically targets all forms of original cover. NA would not be usable in the correct form of this indicator.
	ND (no data)	☑ May be used
Future work on this indicator:	This indicator was originally designed to include all original cover, regardless of whether it is forest, desert or tundra. The data used here refer only to original forest cover. All original cover should be investigated.	

24.2 Description of raw data

The raw data for this indicator are comprised of the percentage of original forest cover remaining in a country as compared with the cover about 8,000 years ago, assuming current climatic conditions (WRI 2000-2001). The advantage of using these WRI data is that the percentage of forest remaining theoretically represents the absolute loss since before human intervention. The disadvantage is that the data are limited to the cover of forest, which covers only one type of natural vegetation cover (probably excluding grasslands, savannah, tundra, desert, alpine and herb associations). For the purposes of this demonstration EVI, we consider using loss of the percentage of original forest cover a reasonable proxy for the loss of vegetation. Of the 235 countries examined, data were available for 155, using WRI and some in-country data.

The percentage of original forest remaining in countries covers the complete range of possible values and varies between zero (complete loss of all natural forests) through to 100%. Countries with none of their original forest remaining include Kuwait, Niger and Egypt. These are likely to be incorrect readings because such countries are largely non-forested, and the land area remaining could include large percentages that are natural deserts, grasslands or herbs, so would not result in this low figure if the remaining forms were included. Botswana is a country thought to have 100% of its original forested area remaining. The mean percentage of forests remaining is around 31.5%, with at least half of the countries examined recording 21% or less forests remaining (the median, Table 24.1). Variance among countries is low, with a standard deviation which is around the same size as the mean.

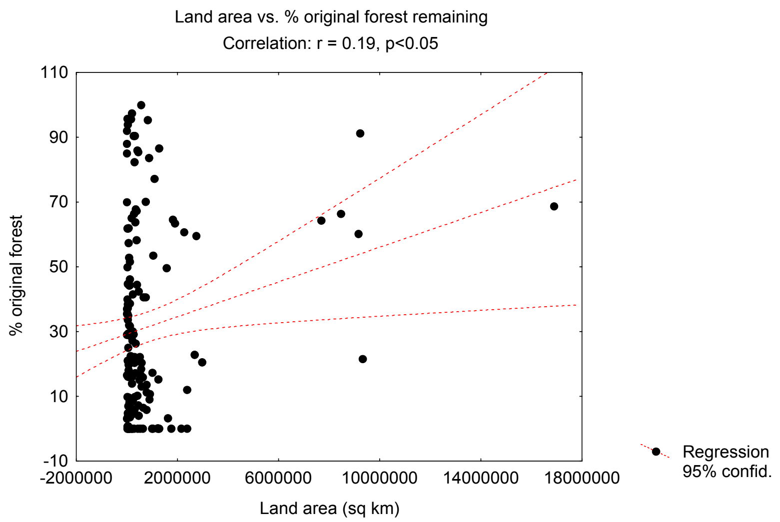
The percentage of forest area remaining is correlated with the size of countries (see significant correlation coefficient in Figure 24.1), but countries may be arranged in two groups. The first group consists of the largest countries which generally tend to have a higher percentage of their original forests intact. Smaller countries (those <2 million sq km) have a variable percentage of their forests remaining, with some close to zero and others ranging up to 100%.

Although the percentage of forest cover remaining does correlate with the size of countries, we chose to use this indicator in its raw state because the figure relates to the absolute loss of forests, regardless of the original cover in relation to land area. We consider that the percentage loss appropriately describes the vulnerability of a country in terms of its future ability to withstand damage from a range of human and natural hazards, without the need to transform the data.

Table 24.1: Basic statistics for percentage of original forest cover remaining. Data are from WRI and in-country sources.

Statistic	Percent of original forest cover remaining
Mean	31.45
Median	21.00
Valid n	155
Min	0
Max	100
SD	29.74
SE	2.39
Skewness	0.78
SE Skewness	0.19
Kurtosis	-0.61
SE Kurtosis	0.39

Figure 24.1: Graph of percentage of original forest cover remaining vs. size of countries.

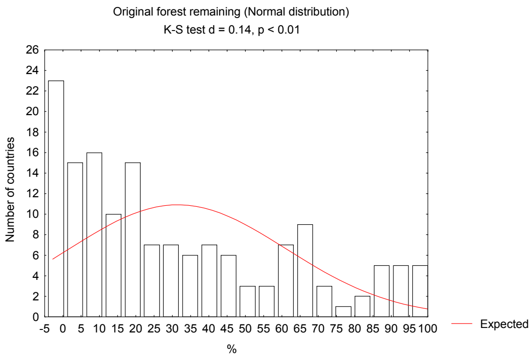


24.3 Distributional characteristics of the indicator data

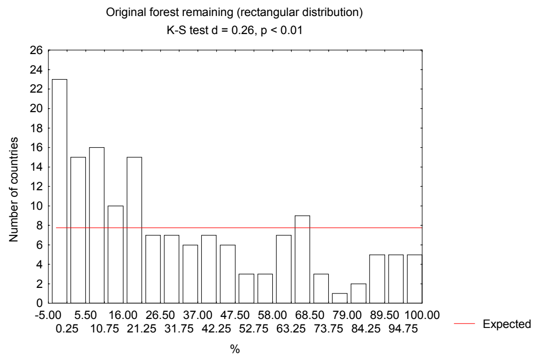
The percentage of forest cover remaining was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 24.2). This resulted in a distribution in which about half of the countries were clustered in the bottom 25% of the range (0-25% of original cover remaining), and the remaining 50% of countries being spread among values of 25-100% (Figure 24.2). The four classes of distributions examined to characterise the observations were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in all of the types of distributions tested (Figure 24.2).

Figure 24.2: Kolmogorov-Smirnov goodness-of-fit tests for percentage of original forest cover remaining of countries spread over 20 even categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. None of the distributions were a good fit of the observed data.

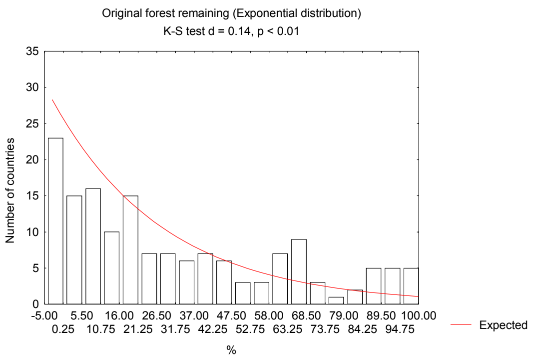
(a)



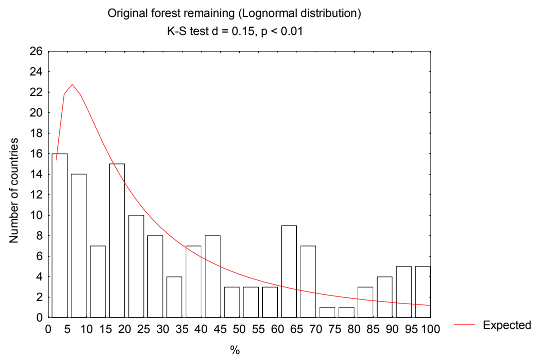
(b)



(c)



(d)

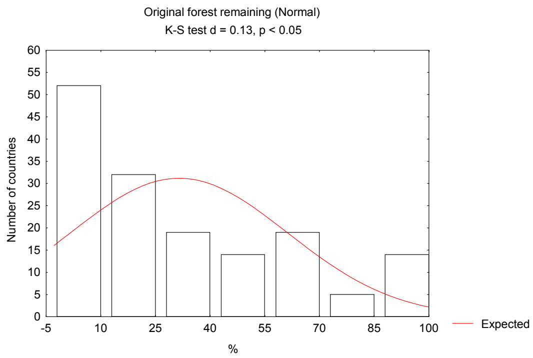


24.4 Proposed EVI scaling and distribution of the data on this scale

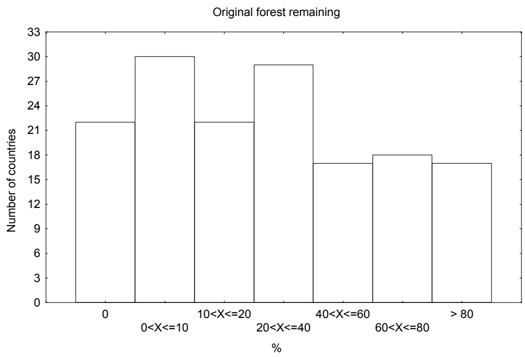
We considered that countries could and should work towards retaining as high a percentage of their original forest cover as possible, while allowing for activities required for human development. In many countries, this might require allowing forests to regenerate. Countries with very low percentages of remaining forest cover are considered more likely to have problems with erosion, flooding, water resources, pollution attenuation, microclimates, protection from extreme climatic events and soil formation and fertility. Those countries with none of their original forests remaining were attributed an EVI score =7; and those with <10% given an EVI score of 6. Countries with greater than 80% of their original forests intact were given an EVI score of 1. The proposed EVI scale is spaced more closely for countries with <20% of their original forests (most vulnerable) and spaced in 20% steps for those with higher values, reflecting the increasing likelihood of better resilience to future events (Figure 24.3, Table 24.2, 24.3).

Figure 24.3: Frequency distribution of percentage of original forest cover remaining in even and uneven categories and the EVI scale. (a) Frequency distribution in 7 even categories. (b) and (c) is the distribution in seven uneven categories which shows the proposed EVI scale.

(a)



(b)



(c)

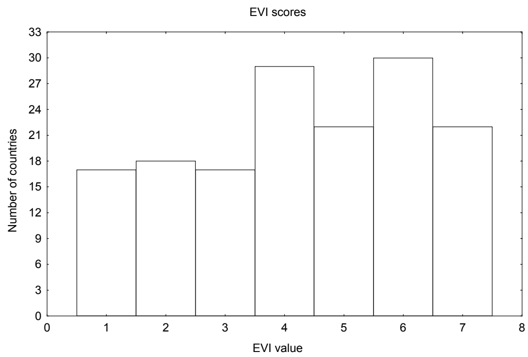


Table 24.2: Proposed EVI scaling for percentage of original forest cover remaining showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Original forest remaining (%)	Observed # countries	Observed % of countries
1	X>80	17	10.97
2	60<X≤80	18	11.61
3	40<X≤60	17	10.97
4	20<X≤40	29	18.71
5	10<X≤20	22	14.19
6	0<X≤10	30	19.35
7	X=0	22	14.19
No data		81	52.26
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 24.3: Proposed EVI scaling for Indicator 24 on percentage of original forest remaining showing examples of countries that fit into each of the EVI scores.

Score	Original forest remaining (%)	Examples
EVI=1	X>80	Belize, Canada, Gabon
EVI=2	60<X≤80	Cambodia, Russia, Zimbabwe
EVI=3	40<X≤60	Chile, Guatemala, Japan
EVI=4	20<X≤40	Italy, Nepal, Poland
EVI=5	10<X≤20	Rwanda, Uzbekistan, Turkey
EVI=6	0<X≤10	UK, Ghana, Portugal
EVI=7	X=0	Burkina Faso, Mali, Malawi

24.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

24.6 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 and from in-country sources. In-country data were available for 17 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 24.4).

Table 24.4: Characteristics of age, completeness and quality of the data obtained for in-country data.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	2.06	2.35
Valid n (in-country)	11	16	17
SD (in-country)	0.63	0.93	0.79
SE (in-country)	0.19	0.23	0.19

24.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

24.8 Additional sources & contacts

www.forest.go.th/stat42/stat.htm (7/6/01) (Thailand); Source 1: FAO - State of the World's Forests 2000, pp 150-153; Source 2: FAO - State of the World's Forests 1995, Table 2: pp 125-130; Source 3: FAO - State of the World's Forests 1995, Table 2: pp 125-130; Source 4: FAO - State of the World's Forests 1995, Table 2: pp 125-131, Table 3: pp 131-135; Botswana - Botswana Rangeland, Inventory and Monitoring Project (BRIMP) Information System. Contact - Mr R. M. Kwerepe267-350511 – Phone; 267-307057 – Fax. rkwerepe@gov.bw ; Costa Rica - Observatorio del desarrollo; Fiji - Contact - Wolf F. SOPAC. Information Technology Unit; Greece - Internal (Greek Embassy, USA), External (CIA World Factbook). Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Barr, J. Ministry of Natural Resources Development (MNRD) 2) Thaman, R. and Whistler, W. FAO; Kyrgyzstan - The National Report on Environment Conditions for 1998-1999; Marshall Islands - Ministry of Resource and Natural Development(MRND). Contact - Frederick Muller; Nauru - Thaman, R R and Hassall, D C. 1999; Nauru National Environmental Management Strategy (NEMS) Nepal - Forest resources of Nepal (1987-1998) Department of forest Research and Survey, Kathmandu, Nepal; Niue - Country Report for UNCED Niue. Government of Niue & SPREP Consultants: Lowry, C and Smith, J.; Palau - Vegetation Survey of the Republic of Palau. Pacific Southwest Forest and Range Experiment Station. Division of Agriculture and Mineral Resources; Papua New Guinea - Papua New Guinea Resource Information System (PNG RIS) (Landuse Section). Contact - Mame Kasalau (675 3214458 or 1046/ 3217813); Philippines - Philippine Forestry Statistics. Contact - Ms Mayumi Ma. Quintos /

Chief, Forest Economics Division / FMB; Samoa - National Environment and Development Management Strategies. 1993. Western Samoa Task Team in association with SPREP; Tuvalu - McLean, R. F. and Hosking, P. C. 1991. Land Resource Survey; Vanuatu - Bellamy, J. Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land Use & Planning Office (LUPO).

25. RATE OF LOSS OF NATURAL VEGETATION COVER

25.1 Indicator Summary

Indicator number:	25	
Indicator short name:	Loss of natural vegetation cover	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	1. Net percentage change in natural vegetation cover over the last five years. 2. Net percentage of land area changed by removal of natural vegetation over the last five years.	
Signals captured:	This measures the rate of loss or gain of natural vegetation cover in countries. It focuses on of biodiversity, ecosystem resilience, the capacity of a country to attenuate pollution, prevention of soil loss, reduction of runoff, recharging of ground waters and soil formation.	
Notes on this indicator:	1. Values may be +ve or –ve, where a positive value indicates net regrowth and a negative value indicates loss. 2. For WRI data, with the exception of South Africa and Australia, forest areas in developed countries are not broken down into the subcategories of natural and plantation because of the difficulty of distinguishing the two in many countries. 3. FAO data were not used for analysis because very large changes between 1995 and 2000 were often spurious, in some countries leading to >-100% change, a result which is clearly not possible. 4. Values are only for forest cover and do not include non-forest forms of natural vegetation (tundra, grasslands, alpine and herb associations)	
Are suitable data available?	Yes, though natural and plantation forests need to be distinguished, and natural vegetation types should include associations other than forests.	
Sources of data:	• WRI 2000-2001 • FAO 1995 and 2001 State of the World's Forests • In-country	
No. countries included in test:	155 of 235	
Temporary modifications to data or indicator, if applicable:	• The data used include natural and plantation forests only. Other forms of natural vegetation should be included and plantations should be excluded. • Data are for the period 1990-1995 and need to be updated.	
Notes on data age, completeness and quality:	13 of the 32 collaborating countries returned data for this indicator. Where they did, the age, completeness and quality of the data were generally considered poor (score of <2 of 3).	
Basic units:	X = Percent change in natural forest cover over last 5 years.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X>0
	EVI Score = 2	No EVI
	EVI Score = 3	No EVI
	EVI Score = 4	X=0
	EVI Score = 5	-1≤X<0

	EVI Score = 6	-2≤X<-1
	EVI Score = 7	X<-2
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Recalculation with updated data which includes all natural vegetation (not just forests) and excludes plantations.	

25.2 Description of raw data

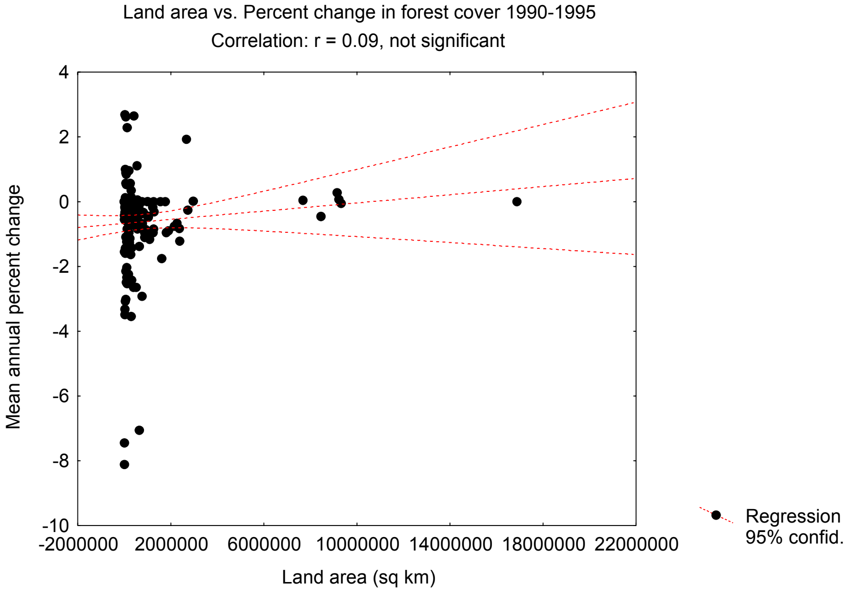
The raw data for this indicator are comprised of the mean annual change (%) in forest cover, including natural and plantation forests during the period 1990-1995 (WRI 2000-2001). A negative value indicates net loss of forest cover and a positive value indicates net gain. These data are not ideal because they are dated (should have been for a 5 years span at least from 1996-2000), are focused only on forests (so exclude other forms of vegetation cover such as grasses), and include plantations which are not natural environments. These deficiencies in the data will be addressed when data collection mechanisms are implemented. For the present study, these data are used as a proxy for the annual rate of change in vegetation cover in countries, and complement Indicator 22 on state of the forest cover in countries. Data for this indicator were available for 155 of the 235 countries examined.

The mean annual change in forest cover 1990-1995 around the globe varied between –8.11% and +2.69% (Table 25.1). The greatest losses in vegetation cover were observed in Lebanon, Jamaica and Afghanistan, and the largest gains were observed in Greece, Iceland, Uzbekistan and Armenia. The global mean change is –0.62%, with half of the world's countries having a value less than –0.26 (the median). The variance among countries is low, with the standard deviation being around 2.3 times the mean. The annual change in forest cover is not correlated with the size of a country (Figure 25.1).

Table 25.1: Basic statistics for annual change in forest cover 1990-1995. Data are from WRI 2000-2001.

Statistic	% Change in forest cover 1990-1995
Mean	-0.62
Median	-0.26
Valid n	155
Min	-8.11
Max	2.69
SD	1.43
SE	0.12
Skewness	-2.22
SE Skewness	0.19
Kurtosis	9.69
SE Kurtosis	0.39

Figure 25.1: Graph of the mean annual change in forest cover vs. size of countries. The correlation is not significant.



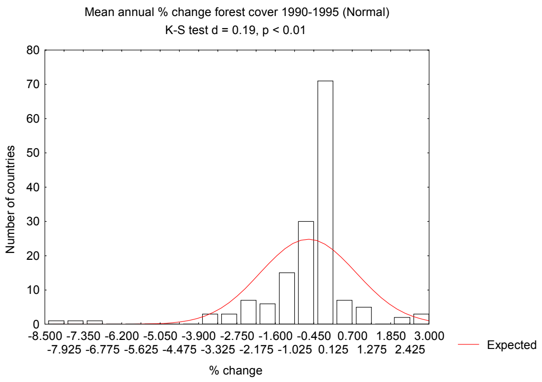
25.3 Distributional characteristics of the indicator data

The annual change in forest cover was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 25.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

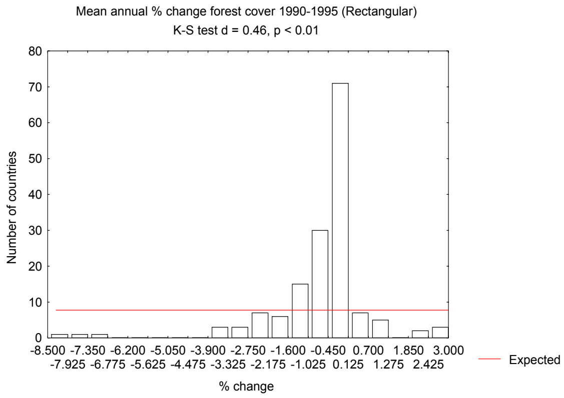
A significant difference between observed and expected values was found in the normal and rectangular models, indicating that the densities of populations of countries around the globe do not approximate some average, and that there are not even numbers of countries with similar rates of change in forest cover. . The distributions could not be directly (without transform) tested against exponential and lognormal distributions because of negative values. The observed distribution was centred near –0.2, with the longest tail extending into the negative range (Figure 25.2).

Figure 25.2: Kolmogorov-Smirnov goodness-of-fit tests for mean annual % change in forest cover of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular. Exponential and Lognormal distributions were not tested for this indicator. Each observed distribution was compared with the expected line using a K-S test for fit.

(a)



(b)



25.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in the rate of change of forest cover between negative and positive values (–8.11% and +2.69%) in close to a normal distribution (test of normality significant for 20 categories in Figure 25.2 a, but not significant in 7 categories in Figure 25.3 a). We chose to maintain a linear scale for this indicator, but make it discontinuous. From a vulnerability perspective, any country with expansion of natural forest areas (of course, not clear in this proxy which includes plantations) is increasing it resilience. These countries were given an EVI score=1. EVI scores 2-3 were not used in this indicator, and EVI=4 was used for all countries with zero gain/loss of forest cover (Table 25.2, 25.3). These are countries that are considered moderately vulnerable because although they are not losing forests, neither are they building their natural forest cover, which for many countries is already in a poor state (this indicator should be used in conjunction with Indicator 22). All countries with negative annual changes in forest cover were scored in EVI=5, 6 and 7 in relation to the rate of loss. The distribution of countries plotted on the proposed EVI scale is shown in Figure 25.3 and Tables 25.2, 25.3.

Figure 25.3: (a) Frequency distribution of mean annual % change in forest cover in 7 even categories; (b) is the frequency distribution over 7 categories and the EVI scale with all positive values in EVI=1, all zero values in EVI=4, and all negative values in the EVI range 5-7.

(a) (b)

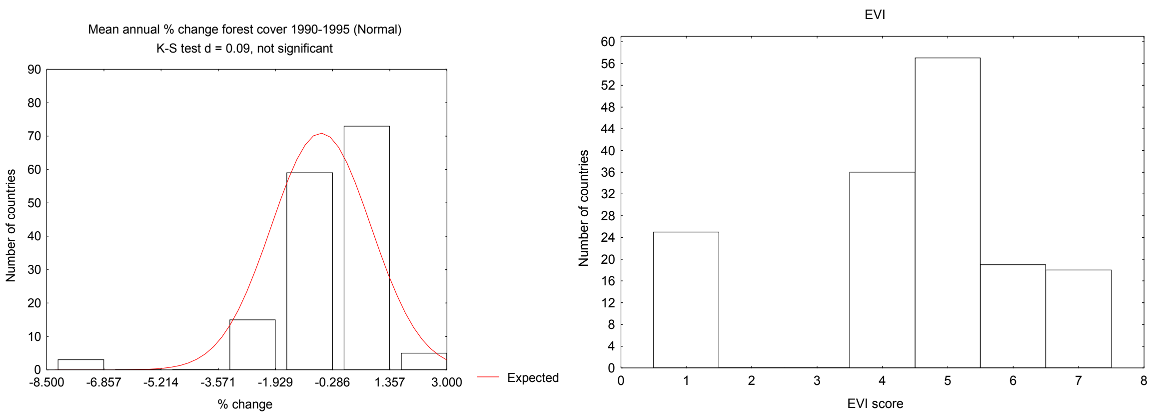


Table 25.2: Proposed EVI scaling for mean annual % change in forest cover showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X>0	25	16.13
2	No EVI		
3	No EVI		
4	X=0	36	23.23
5	-1≤X<0	57	36.77
6	-2≤X<-1	19	12.26
7	X<-2	18	11.61
No data		80	51.61
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 25.3: Proposed EVI scaling for Indicator 25 on mean annual % change in forest cover. Also shown are examples of countries that fit into each of the EVI scores.

Score	Mean annual % change in forest cover	Examples
EVI=1	X>0	Armenia, Norway. Slovakia
EVI=2	No EVI	
EVI=3	No EVI	
EVI=4	X=0	Spain, Mongolia, Turkey
EVI=5	-1≤X<0	Madagascar, Romania, South Africa
EVI=6	-2≤X<-1	Myanmar, Iran, Togo
EVI=7	X<-2	Jordan, Lebanon, Malaysia

25.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

25.6 Age, completeness and quality of the data

The data obtained for this indicator were from two public sources (WRI 2000-2001 and FAO State of the World's Forests 1995, 2001) and from in-country sources (Table 25.4). Of the public sources, WRI data were used despite being dated, because we had difficulties with the FAO data. There were unlikely differences between the separately – published 1995 and 2000 datasets and which led to spurious results. In-country data were available for 13 of the 32 collaborating countries, with data being of poor age, completeness and quality.

Table 25.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	1.85	1.77	1.92
Valid n (in-country)	13	13	12
SD (in-country)	0.55	0.73	0.79
SE (in-country)	0.15	0.20	0.23

25.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

25.8 Additional sources & contacts

UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; FAO - State of the Worlds Forests 2001; FAO - State of the Worlds Forests 1995; Costa Rica - Centro de Investigaciones en Desarrollo Sostenible. (CIDS); Kiribati - A) Thaman & Whistler, UNDP, Suva. B) Barr, J. Ministry of Natural Resources Development (MNRD) Nauru - Thaman. R, Hassall. D 1998 Nauru National Environmental Management Strategy (NEMS), (pp 14); Nepal - State of the Environment, Nepal, 2001. Ministry of population and Environment, Nepal/UNEP/ICIMOD/NOROD/SACEP, Kathmandu Nepal. Niue - Lane, J & SPREP, 1994. Niue SoE Report, 1993; Palau - Environmental Quality Protection Board Permit Files. Contact - Paul Christiansen (680 4881639 or 3600/ 4882963/ EZRA@PALAUNET.COM); Papua New Guinea - Internal data from source. Papua New Guinea Resource Information System (PNGRIS) Contact - Mame Kasalau (675 3214458 or 1046/ 3217813). Technical & Field Services Division, Department of Agriculture & Livestock/ Special Project Officer; Samoa - Department of Lands, Surveys & Environment (DLSE) – Aerial Photos 1990 – 1999. Contact - Leoo Polutea, DLSE; Thailand - www.forest.go.th/stat42/stat/htm (7/6/01); Trinidad & Tobago - Karen Ragoonanan; Tuvalu - Contact - EVI Team (Dr U Kaly); Vanuatu - Land Use and Planning Office (LUPO). Contact – William (LUPO).

26. HABITAT FRAGMENTATION

26.1 Indicator Summary

Indicator number:	26	
Indicator short name:	Fragmented habitats	
Sub-index	AVI	
Categorisation	Resources & Services	
Indicator text:	Total length of all roads in a country (latest data) / land area.	
Signals captured:	This is a proxy measure for pressure on ecosystems resulting from fragmentation into discontinuous pieces. It also relates to habitat disturbance and degradation. Fragmentation is likely to affect biodiversity, affecting species with variability in population numbers, keystones, those susceptible to local extinctions, those that use migration corridors and the persistence of species with large home ranges. For many large mammals and some birds viable fragments of habitat are size-dependent, despite the fact that the overall area available in a country may still sum to a relatively large area. This indicator measures a specific aspect of habitat availability that relates to size and quality of patches. The effects of fragmentation would be particularly important if there are other natural and human stresses operating on susceptible organisms and ecosystems.	
Notes on this indicator:	1. Data were generally unavailable for the original form of this indicator. 2. A proxy of the total length of roads was used. The reasoning behind this is that the length of roads shows not only how dissected and disturbed the land ecosystems may be, but they act as physical barriers for seasonal migrations and normal daily home range movements of animals. Secondarily, roads also lead to direct losses of animals through vehicular accidents.	
Are suitable data available?	Not at present. A proxy of length of roads was used for this evaluation of the EVI. The original form of the indicator would provide a better measure.	
Sources of data:	• World Bank World Development Indicators 2001 http://www.worldbank.org/data/wdi2001/cdrom.htm • In-country	
No. countries included in test:	169 of 235	
Temporary modifications to data or indicator, if applicable:	• A proxy used until required data can be collected	
Notes on data age, completeness and quality:	Only 4 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the age, completeness and quality of the data were generally considered good (score of >2 of 3).	
Basic units:	1. Total length of all roads in a country (km) / land area (sq km) 2. Cumulative area of all fragments of natural cover greater than 1,000 ha in the country as a percent of total land area.	
Recommended transforms:	LN(X+1) for proxy.	
Proposed EVI Scale (Scale is for proxy as LN(X+1)).	EVI Score = 1	X<0.2
	EVI Score = 2	0.2<X≤0.4
	EVI Score = 3	0.4<X≤0.6

	EVI Score = 4	0.6<X≤0.8
	EVI Score = 5	0.8<X≤1.0
	EVI Score = 6	1.0<X≤1.2
	EVI Score = 7	X>1.2
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Sources of data on fragmentation of the land ecosystems of countries needs to be collected and the EVI scale redefined for the original form of the indicator.	

26.2 Description of raw data

The raw data for this proxy indicator are comprised of the total length of the road network in countries. These data were derived from World Bank Development Indicators for between 1990-1999 (but using the latest available value) and from in-country sources. Data for this indicator were available for 169 of the 235 countries examined.

The total length of the national network of roads around the globe varied between 1,040 and more than 6.3 million kilometres (Table 26.1). The lowest values were found in Grenada, Vanuatu and United Arab Emirates, and the highest values in USA, India and Brazil. The world mean length of roads is around 167,086 km (the length of roads found in Iran), with half of the world's countries having less than 30,400 km (the median). The variance among countries is moderate, with the standard deviation being around 3.4 times the mean.

The total length of the road network in a country is correlated with its size (Figure 26.1). Because the fragmentation and disturbance effects of roads depends on their density over the land area, we divided the total length of roads by the total area of land in a country. The resulting density of roads in countries was not significantly correlated with country size (Figure 26.1).

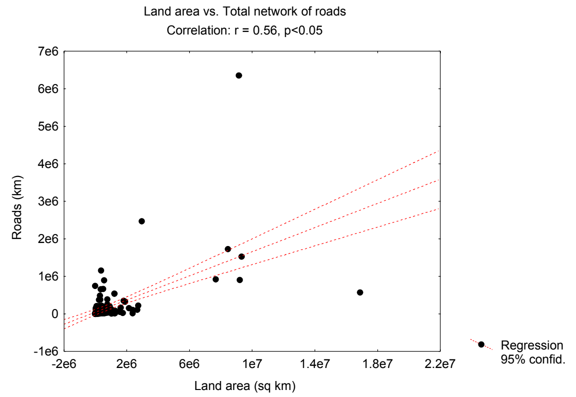
The density of roads in countries varied between 0.001 to 1,210 km/km^2, with a global average of 7.8 km/km^2 and a median of 0.17 km/km^2. The countries with the lowest density of roads per km^2 were Swaziland, Mauritania and Niger and the highest road densities were found in St Lucia, Malta and Bahrain. Malta had a national average of 6.33 km of roads per sq km of land.

Table 26.1: Basic statistics for the road network in countries. Data are from World Bank and in-country sources.

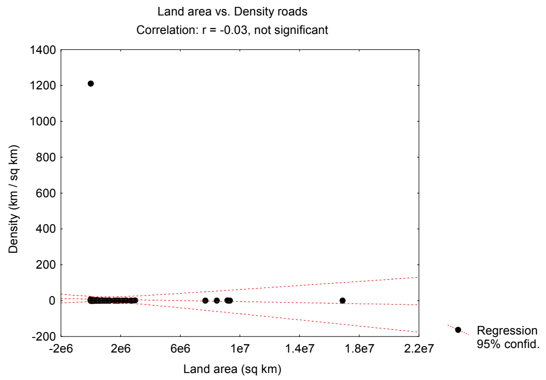
Statistic	Total network of roads (km)	Density roads (km / sq km)	LN(X+1) Density roads
Mean	167,086	7.77	0.40
Median	30,400	0.17	0.16
Valid n	169	169	169
Min	1,040	0.001	0.001
Max	6,348,200	1,210	7.10
SD	569,195	93.04	0.67
SE	43,784.23	7.16	0.05
Skewness	8.39	12.998	6.33
SE Skewness	0.19	0.19	0.19
Kurtosis	85.05	168.96	58.64
SE Kurtosis	0.37	0.37	0.37

Figure 26.1: Graph of the length of road network vs. size of countries, (a) Is the total length of the road network (km) vs. size of country (in km² land area), (b) The density of roads (km/km²) vs. size of country (km²). The correlation is significant in (a) but not in (b).

(a)



(b)



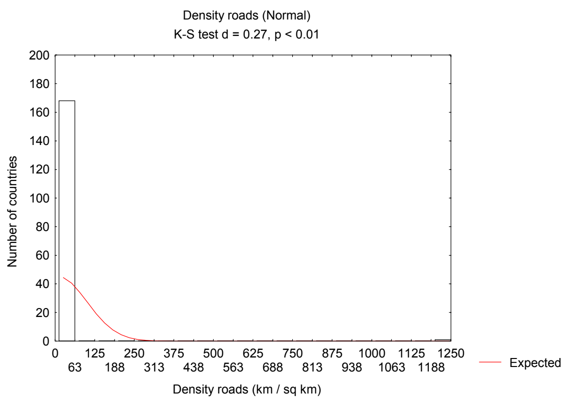
26.3 Distributional characteristics of the indicator data

The density of the road network in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 26.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

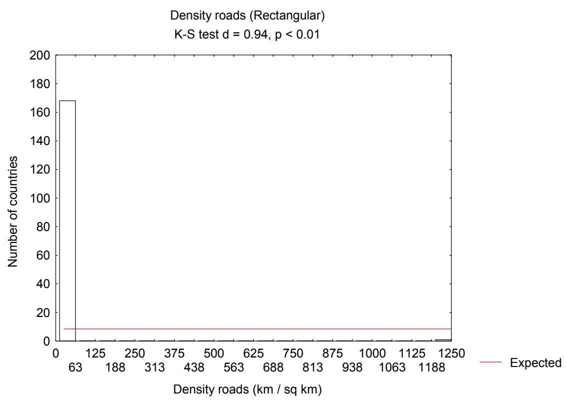
A significant difference between observed and expected values was found in the normal and rectangular models, indicating that the densities of the road network in countries around the globe do not approximate some average, and that there are not even numbers of countries with similar densities. The distribution of road networks was a better fit to the exponential and lognormal functions (both non-significant in the K-S tests). The observed distribution was heavily skewed at the small end of the scale, with few countries at higher values (Figure 26.2).

Figure 26.2: Kolmogorov-Smirnov goodness-of-fit tests for density of road networks spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

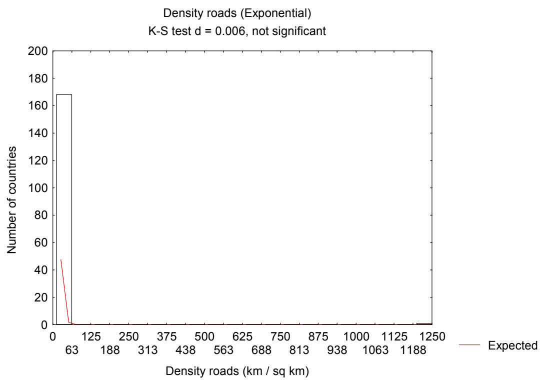
(a)



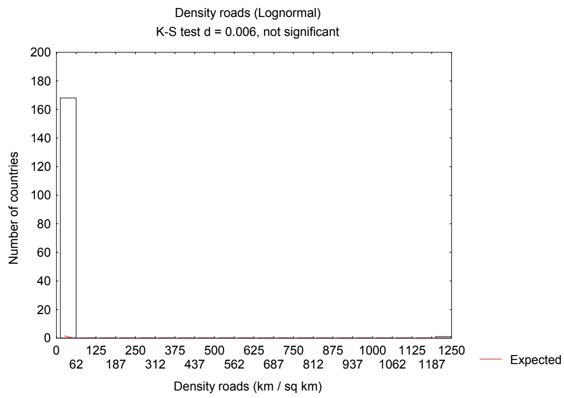
(b)



(c)



(d)

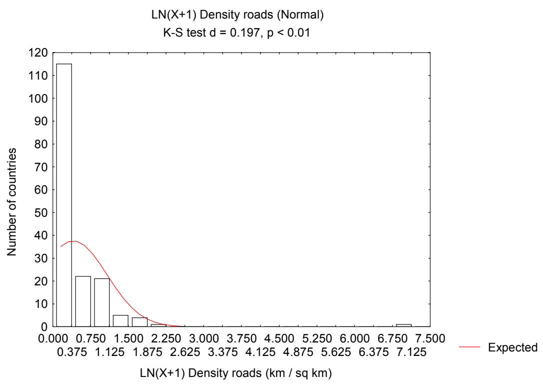


26.4 Proposed EVI scaling and distribution of the data on this scale

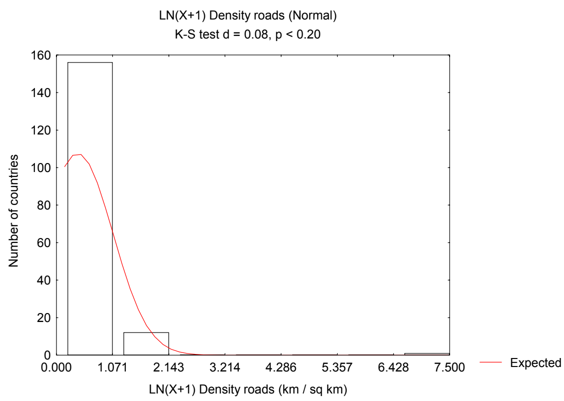
With countries varying in the density of their road networks by 6 orders of magnitude across the globe (Figure 26.2, Figure 26.3), we propose that the raw density values be transformed to a natural log scale to compressed the range of values and provide a better spread among the countries with lower densities. These values would in turn be scaled unevenly to create EVI scores that identify countries with low road densities as being less vulnerable than those with high densities. Countries with less than 0.22 km or road per sq km of land (LN(X+1) value of ≤0.2) were given an EVI score of 1 (this includes uninhabited countries). All countries with a density of >2.32 km of roads per sq km of land and an LN(X+1) value of >1.2 were given an EVI score of 7. The remaining countries were distributed evenly within the remaining EVI scale to indicate increasing vulnerability with increasing density between the above ranges. The distribution of countries plotted on the proposed EVI scale is shown in Figure 26.3, Table 26.2, 26.3.

Figure 26.3: (a) Frequency distribution of LN(X+1) road network density 20 categories; (b) is a the same distribution over 7 even categories; (c) is the frequency distribution over 7 categories with high values grouped; (d) is the 1-7 EVI scale for this indicator.

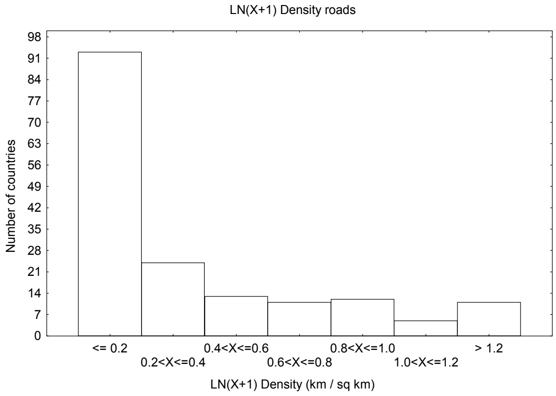
(a)



(b)



(c)



(d)

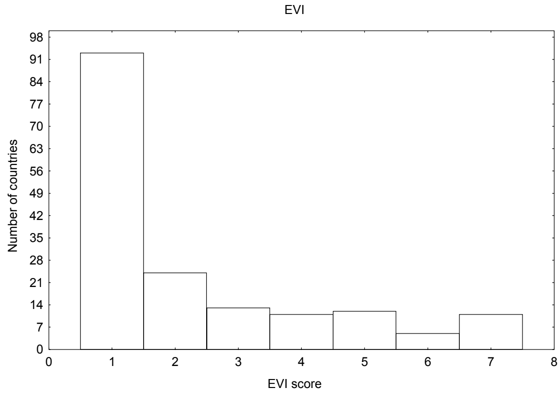


Table 26.2: Proposed EVI scaling for density of roads and the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values LN (X+1)	Observed # countries	Observed % of countries
1	X<0.2	93	55.03
2	0.2<X≤0.4	24	14.20
3	0.4<X≤0.6	13	7.69
4	0.6<X≤0.8	11	6.51
5	0.8<X≤1.0	12	7.10
6	1.0<X≤1.2	5	2.96
7	X>1.2	11	6.51
No data		66	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 26.3: Proposed EVI scaling for Indicator 26 on fragmentation of the land by roads showing the scale as defined on LN(X+1) transformed data and the equivalent values in km / sq km. Also shown are examples of countries that fit into each of the EVI scores. Note that 2.32 km / sq km of roads represents about 4% of the land area covered by the roads themselves. At the upper end of the scale, roads could account for as much as 24% of the land area.

Score	Scale for LN(X+1) density	Scale for raw density	Examples
EVI=1	X<0.2	X<0.22	Bolivia, Algeria, Iceland
EVI=2	0.2<X≤0.4	0.22<X≤0.49	Bahamas, Finland, Moldova
EVI=3	0.4<X≤0.6	0.49<X≤0.82	Costa Rica, Israel, Rwanda
EVI=4	0.6<X≤0.8	0.82<X≤1.23	Estonia, India, Lithuania
EVI=5	0.8<X≤1.0	1.23<X≤1.72	Spain, UK, Ireland
EVI=6	1.0<X≤1.2	1.72<X≤2.32	Jamaica, Hungary, Switzerland
EVI=7	X>1.2	X>2.32	Barbados, Bahrain, Malta

26.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

26.6 Age, completeness and quality of the data

The data obtained for this indicator were from World Bank 2001 and from in-country sources. In-country data were available for 4 of the 32 collaborating countries, with data being of good age, completeness and quality.

Table 26.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	3.00	2.75
Valid n (in-country)	4	2	4
SD (in-country)	0.82	0.00	0.50
SE (in-country)	0.41	0.00	0.25

26.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

26.8 Additional sources & contacts

www.worldbank.org/data/wdi2001/cdrom.htm ; www.forest.go.th/state41/index.htm ; Costa Rica - Ministerio del Ambiente y Energía, Estudio nacional de la biodiversidad, con datos del sistema de información geográfica INBio. Mayo, 1998; Papua New Guinea - Source - Forest Inventory Mapping System (FIMS). Contact - P. Shearman, German Development Service – for the Department of Mines.

27. DEGRADATION

27.1 Indicator Summary

Indicator number:	27	
Indicator short name:	Degradation	
Sub-index	AVI	
Categorisation	Resources & Services	
Indicator text:	Percent of land area that is either severely or very severely degraded (FAO/AGL Terrastat definitions).	
Signals captured:	This indicator captures the status of loss of ecosystems in a country. Degraded land means that which can no longer revert to its natural ecosystem without active and costly rehabilitation by humans to reverse permanent damage, if at all. Types of degradation include water and wind erosion, chemical and physical deterioration, agriculture, deforestation and grazing. These can be associated with salinisation and desertification. This indicator highlights the breakdown of ecosystems which leads to decreasing biodiversity, soil quality, resilience against natural events and the assimilative capacity of the environment.	
Notes on this indicator:	1. Data are percentage of land area that is severely or very severely degraded. Lighter forms of degraded land were not included.	
Are suitable data available?	Yes.	
Sources of data:	• FAO / AGL Terrastat: Severity of human induced degradation. • In-country.	
No. countries included in test:	165 of 235	
Temporary modifications to data or indicator, if applicable:	• None • In future calculations of percentage of degraded land will be calculated using estimates of total land area from WRI 2000-2001 and CIA 2001 (see Indicator 10).	
Notes on data age, completeness and quality:	14 of the 32 collaborating countries returned data for this indicator. Age and quality of the in-country data were generally considered good (> value of 2 of 3 for age and quality), while completeness was considered poor (1.79 of 3).	
Basic units:	Percent of a country's land area considered severely and very severely degraded.	
Recommended transforms:	• None	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	X≤5
	EVI Score = 2	5<X≤10
	EVI Score = 3	10<X≤15
	EVI Score = 4	15<X≤20
	EVI Score = 5	20<X≤25
	EVI Score = 6	25<X≤50
	EVI Score = 7	X>50
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries is needed, but this should not affect the EVI scaling.	

27.2 Description of raw data

The raw data for this indicator are comprised of the total area of severely and very severely degraded land in a country (1000s km^2). Data are the status in 2000 and are derived from FAO/AGL Terrastat. These values were then recalculated as the percentage of the total land area considered severely or very severely degraded. Although there are lighter forms of degradation, these were not included in this indicator. The indicator measures the most severe forms of past degradation in a country as an indicator of poor management in the past, lost resilience and a prognosis if current practices continue. Countries with high levels of degradation have already sustained damage and could be expected to be less resilient to future damage. Of the 235 countries examined, these data were available for 165.

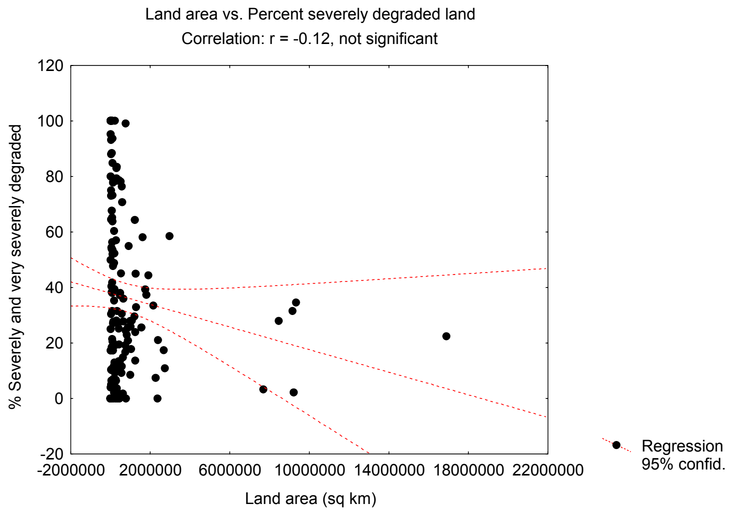
The percentage of severely+ degraded land in countries in 2000 varied between 0 and 100% (Table 27.1). The lowest values were recorded in Switzerland, Djibouti and Fiji, and the highest values were recorded in Trinidad & Tobago, Romania and Puerto Rico. The mean value across the globe was 36%. Half of the countries examined had 28% or more severe or very severe degradation by 2000 (the median) (Table 27.1). Variance among countries was moderately, with a standard deviation which was around 4the same size as the mean.

The percentage of land in countries which is severely or very severely degraded is not correlated with country size (Figure 27.1).

Table 27.1: Basic statistics for severe and very severe degradation. Data are status in 2000.

Statistic	% land severely to very severely degraded
Mean	36.37
Median	27.66
Valid n	165
Min	0
Max	100
SD	32.91
SE	2.56
Skewness	0.68
SE Skewness	0.19
Kurtosis	-0.82
SE Kurtosis	0.38

Figure 27.1: Graph of Percentage of severely+ degraded land vs. size of countries. The correlation is significant.

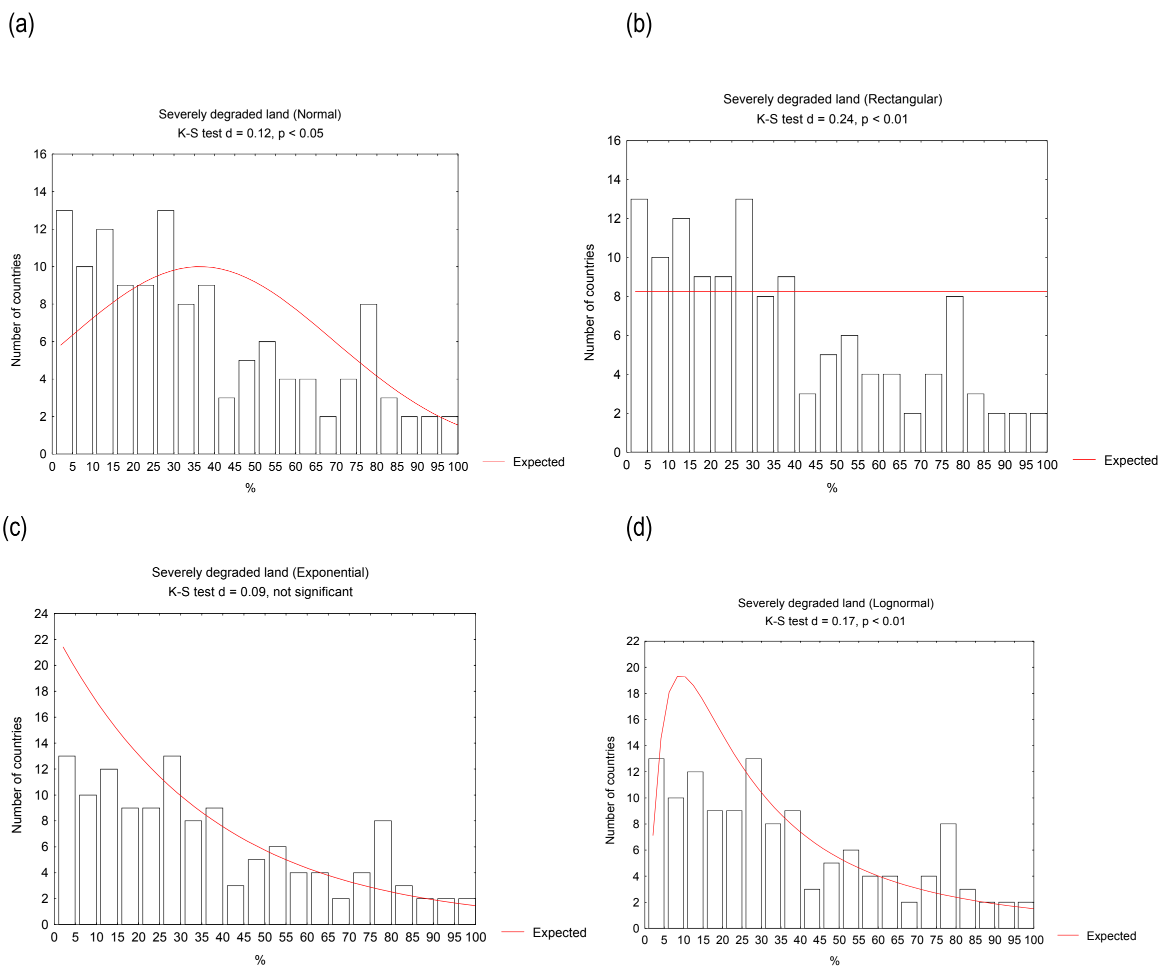


27.3 Distributional characteristics of the indicator data

The percentage of severely+ degraded land in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 27.2). This resulted in one of the more even distributions in the EVI. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal, rectangular and lognormal distributions, but not for the exponential distribution (Figure 27.2). This suggests that the values observed are distributed according to some power function. Transforming the values to a root might provide a better scale for comparison.

Figure 27.2: Kolmogorov-Smirnov goodness-of-fit tests for percentage of severely+ degraded land in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential distribution provided the best fit of the observed data.



27.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in percent of severely+ degraded land from zero to 100%, with a slight clumping of countries towards the lower end of the scale. We propose that the data not be transformed, but used in their raw form. Countries having the greatest percentage of degraded lands are considered more vulnerable and attract a higher EVI score than those low on the scale. However, even relatively low percentages of severely+ degraded land represent major damage to a country's ecosystems, its resilience and ability to recover. We identified all countries with >50% severely degraded land as being at high risk and the most vulnerable, attracting an EVI score of 7. An EVI score of 6 was used for countries with 25-50% severely degraded land. EVI scores or 1 to 5 were spaced evenly to capture countries with between 0 and <25% severely degraded lands (Figure 27.3, Table 27.2, 27.3). This scaling may need to be adjusted to be more critical, with smaller percentages of severely+ degraded land attracting higher EVI scores to accurately reflect the environmental risks involved.

Figure 27.3: Frequency distribution of percentage of severely+ degraded land in even and uneven categories and the EVI scale. (a) Frequency distribution 7 even categories, (b) Is the distribution in seven categories which clump countries with high values, identifying them as being at the highest risk, (c) The proposed EVI scale.

(a) (b)

(c)

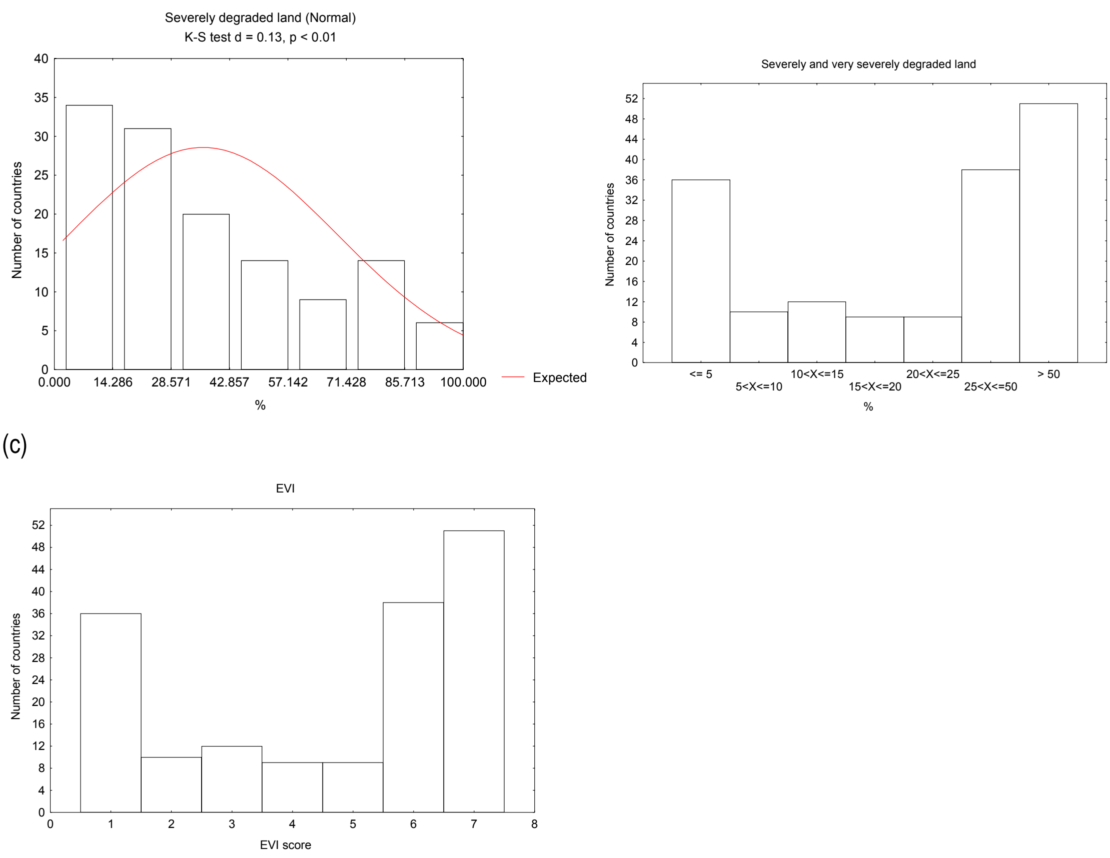


Table 27.2: Proposed EVI scaling for percentage of severely+ degraded land showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for % severe degradation	Observed # countries	Observed % of countries
1	X≤5	36	21.82
2	5<X≤10	10	6.06
3	10<X≤15	12	7.27
4	15<X≤20	9	5.45
5	20<X≤25	9	5.45
6	25<X≤50	38	23.03
7	X>50	51	30.91
No data		70	
NA	☒ May not be used		

ND	☑ May be used (results in no score)

Table 27.3: Proposed EVI scaling for percent severely+ degraded land showing examples of countries that fall into each of the EVI scores.

Score	Scale for % severe degradation	Examples
EVI=1	X≤5	Switzerland, Kuwait, Norway
EVI=2	5<X≤10	Congo, New Zealand, France
EVI=3	10<X≤15	Congo, Georgia, Somalia
EVI=4	15<X≤20	Sudan, UK, Zambia
EVI=5	20<X≤25	Benin, Portugal, Venezuela
EVI=6	25<X≤50	Afghanistan, China, Greece
EVI=7	X>50	Eritrea, Honduras, Jamaica

27.5 Age, completeness and quality of the data

The data obtained for this indicator were from FAO/AGL Terrastat and in-country sources. In-country data were available for 14 of the 32 collaborating countries, with data being considered by collaborators to be of good age and quality (Table 27.4). Completeness of the in-country data was poor.

Table 27.4: Characteristics of age, completeness and quality of the data on degraded land collected by collaborators.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.15	1.79	2.07
Valid n (in-country)	13	14	14
SD (in-country)	0.69	0.80	1.00
SE (in-country)	0.19	0.21	0.27

27.6 Variations among sources of data

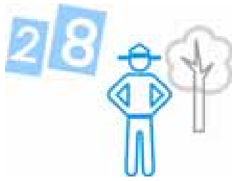
Alternative appropriate sources of data are not at present available for this indicator.

27.7 Additional sources & contacts

www.fao.org/ag/agl/agll/terrastat/wsrout.Asp?wsreport=4&region=2&search=Disp/ (17/01/02); Botswana - Botswana Rangeland, Inventory and Monitoring Project (BRIMP) Information System. Contact - Mr R. M. Kwerepe 267-350511 – Phone; 267-307057 – Fax. Email -rkwerepe@gov.bw; Cook Islands - Contact - Timoti Tangiruaine (682 24484/ 682 21134) Marine Resources. Works, Energy and Physical Planning (MOWEPP)- Lands Department, GIS; Costa Rica - Comisión asesora sobre Degradación de Tierras (CADETI), 2002; Kiribati - Internal information (1969 – 1998 data) Land Management Division. Contact - Riteri Kiboi. Survey Technical Section; Kyrgyzstan - State Agency for Registration of rights on real estate under the Government of the Kyrgyz Republic. Contact - Ms. Goncharova E.; Marshall Islands - Contact - Frederick Muller. Ministry of Resource and Natural Development (MRND); Nauru - RDF Study GIS Maps (provided). Nauru Rehabilitation Corporation (NRC); Nepal - State of Environment, Nepal, 2001,

HMG-N / NORAD / UNEP / ICIMOD / SACEP, Kathmandu, Nepal; Niue - Niue Department of Fisheries, Forestry and Agriculture (DAFF). Contact - Sauni Tongatule (4032/ 4079/ director.agriculture@mail.gov.nu); Palau - Contact - Kashgar Rengulbai (680 4882504/ 4881475/ DAMR@palaunet.com) Environmental Quality Protection Board(EQPB); Philippine - Philippine Asset Accounts, Land and Soil Resource (updates unpublished). National Statistical Coordination Board, Land and Soil Resource; Samoa - Aerial photos 1981, 1987, 1990, 1997. Land, Surveys & Environment; Thailand - GIS. The Pollution Control Department; Tuvalu - Gavin and Hina 5th – 8th March, 1997. Report on Extent of Damage. Damage Assessment Team. Environment Unit; Vanuatu - VANRIS (V3). Contact – William: Land Use Planning Office (LUPO).

28. TERRESTRIAL RESERVES



28.1 Indicator Summary

Indicator number:	28	
Indicator short name:	Terrestrial Reserves	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Percent of terrestrial land area legally set aside as no take reserves.	
Signals captured:	This indicator captures the increase in resilience, function of pollution attenuation, groundwater recharge, limits to losses of biodiversity and refuges afforded by the presence of adequate terrestrial reserves (including aquatic ecosystems located within the land area) in a country. The indicator focuses on areas with the most intact terrestrial environments and the level of environmental management. The benefits of areas set aside as terrestrial reserves increase with increasing area, increasing representation of ecosystem types, increasing degree of protection and period of time of protection. Permanent no-take reserves that are representative of major ecosystem types and occupy 20% of the land area would be considered ideal. Reserves would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts in the country. Reserves may be one of the few ways managers could off-set some other environmental damage and build resilience against natural events that can damage the environmental support system.	
Notes on this indicator:	1. Data refer to area of land especially dedicated to the protection and maintenance of biological diversity, of natural and associated cultural resources, and which are managed through legal or other effective means (see WRI 2000-2001). 2. Reserves includes lakes, rivers, swamps and other aquatic habitats located within the land area of a reserve. 3. See notes in Section 6 on definitions.	
Are suitable data available?	Yes, but only for a limited number of countries.	
Sources of data:	• WRI 2000-2001 • In-country	
No. countries included in test:	161 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	19 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (value of >2 of 3 for age, completeness and quality).	
Basic units:	Percent of the total land area set aside as reserves.	
Recommended transforms:	• None.	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	$20 \le X$
	EVI Score = 2	$15<X<20$
	EVI Score = 3	$10<X\le 15$
	EVI Score = 4	$5<X\le 10$
	EVI Score = 5	$0<X\le 5$
	EVI Score = 6	Not used

	EVI Score = 7	X=0
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries is needed, but this will not affect the EVI scaling.	

28.2 Description of raw data

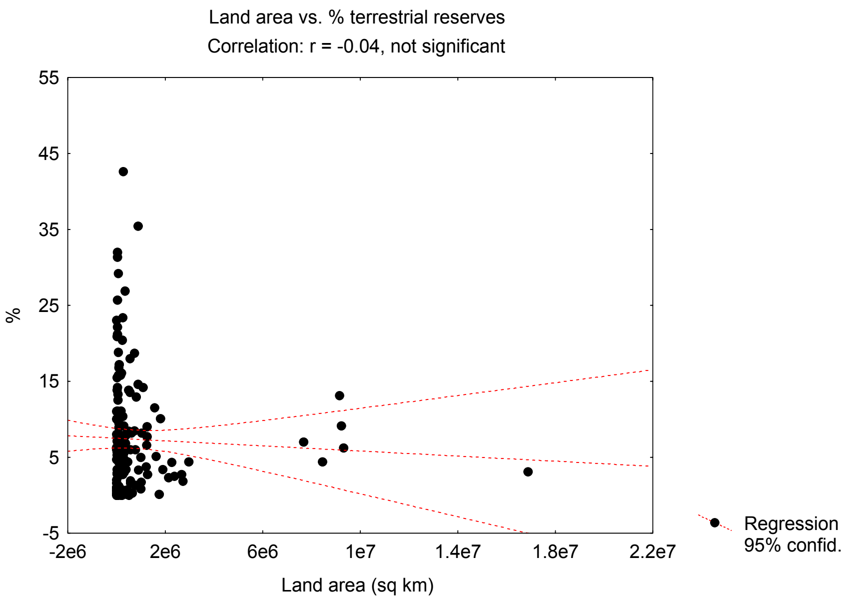
The data for this indicator are comprised of the percentage of the total land area designated as terrestrial reserves, and were obtained from WRI 2000-2001 (originally from WCMC 1999). Data refer to area of land especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed (by categories I-V) through legal or other effective means (see WRI 2000-2001). Of the 235 countries examined, these data were available for 161.

The percent of land set aside as reserves varied between 0 and 42% worldwide (Table 28.1). There are no terrestrial reserves in 8 of the countries examined, including United Arab Emirates, Lao and Nauru. The countries with the greatest areas of terrestrial reserves are Ecuador, Venezuela and Denmark. The mean value across the globe was 7.38%. Half of the countries examined had 5.5% or less of their areas set aside as terrestrial reserves (the median). Variance among countries is relatively low, with a standard deviation that was around the same size as the mean. Percent of land area set aside as reserves was not correlated with the size of countries (Figure 28.1).

Table 28.1: Basic statistics for terrestrial reserves.

Statistic	% Terrestrial reserves
Mean	7.38
Median	5.50
Valid n	161
Min	0
Max	42.60
SD	7.72
SE	0.61
Skewness	1.82
SE Skewness	0.19
Kurtosis	3.91
SE Kurtosis	0.38

Figure 28.1: Graphs of percent land area set aside as reserves vs. size of countries. The correlation is not significant.



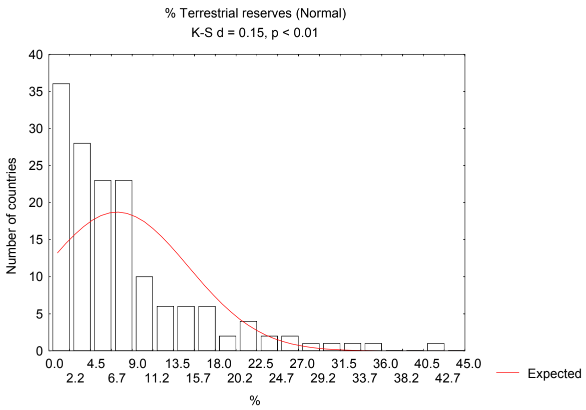
28.3 Distributional characteristics of the indicator data

The percentage of land area as reserves was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 28.2). This resulted in a distribution that was skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

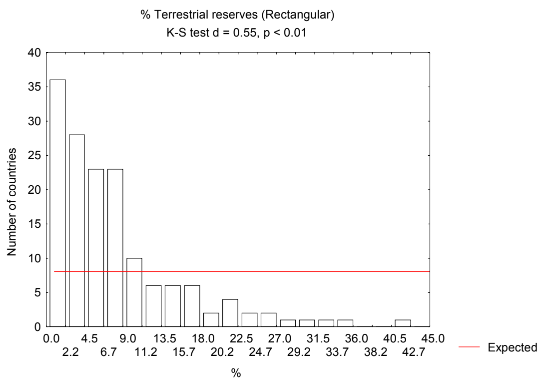
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 28.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 28.2: Kolmogorov-Smirnov goodness-of-fit tests for percentage of terrestrial reserves in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

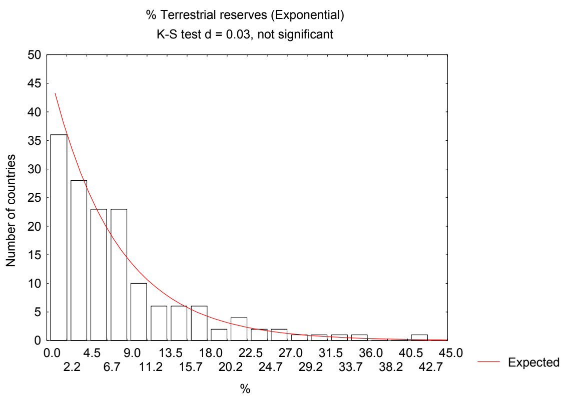
(a)



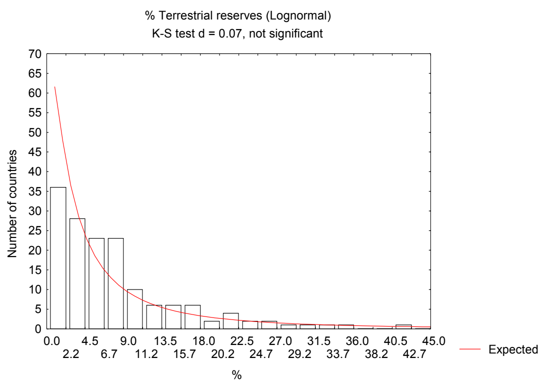
(b)



(c)



(d)



28.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in the percent of their area set aside as reserves by almost 43%. We propose that countries with zero or very little of their area as reserves will be those that have failed to take the opportunity to build their environmental resilience. Countries with 20% of their area set aside as reserves are those that have taken steps to build resilience, maintain biodiversity, refuges and ecosystem functions. For this indicator, the EVI scale is reversed, with high percentages of reserves attracting low EVI scores. We identified those countries with $\geq$ 20% of the total land area as reserves as likely to have actively reduced their risk of environmental damage (EVI=1). Countries with none of their land area in reserves were considered the least resilient / most vulnerable (EVI=7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale, except that we placed a gap at the higher end of the scale at EVI=6 to emphasise a fundamental shift in resilience-building afforded by the presence of reserves (Figure 28.3, Table 28.2, 28.3). The difference between having zero and even a small area of reserves is likely to be of major significance to the resilience of a country.

Figure 28.3: Frequency distribution of percent terrestrial reserves in even categories and the EVI scale. (a) Frequency distribution in 7 even categories, (b) Is the distribution in 6 unevenly-spaced categories design to identify highly vulnerability in countries without reserves, and good resilience in those with 20% or more, (c) is the same a (b) but reversed and given a gap to form the proposed EVI scale.

(a)

(b)

(c)

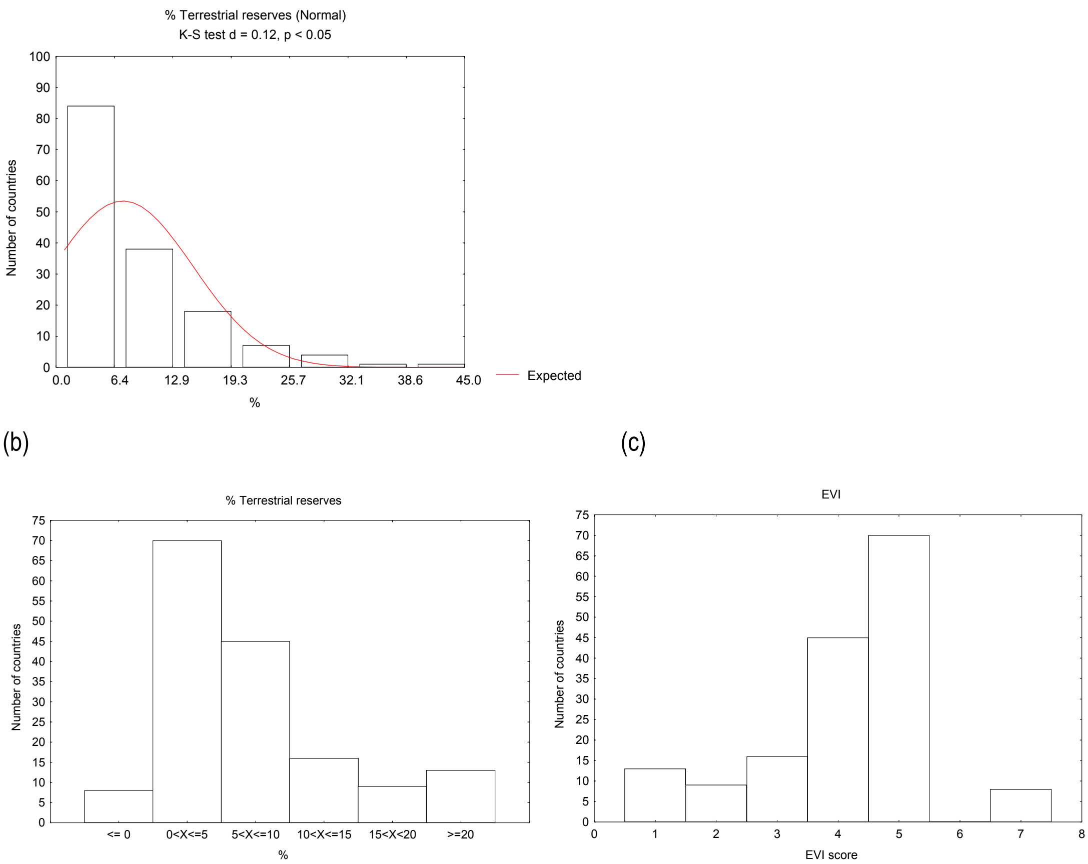


Table 28.2: Proposed EVI scaling for percent of land as reserves showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for % terrestrial reserves	Observed # countries	Observed % of countries
1	20≤X	13	8.07
2	15<X<20	9	5.59
3	10<X≤15	16	9.94
4	5<X≤10	45	27.95
5	0<X≤5	70	43.48
6	Not used		
7	X=0	8	4.97
No data		74	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 28.3: Proposed EVI scaling for percent area as reserves showing examples of countries that fall into each of the EVI scores.

Score	Scale for % terrestrial reserves	Examples
EVI=1	20≤X	Bhutan, Switzerland, Slovakia
EVI=2	15<X<20	Chile, Israel, Cambodia
EVI=3	10<X≤15	Latvia, Mongolia, Rwanda
EVI=4	5<X≤10	Slovenia, Chad, Uganda
EVI=5	0<X≤5	Mauritania, Sierra Leone, Tuvalu
EVI=6	Not used	
EVI=7	X=0	Lao, Nauru, Syria

28.5 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 (and originally from WCMC 1999), as well as in-country sources. In-country data were used to obtain values for 10 of the countries. Information on the characteristics of in-country data was available for 9 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 28.4).

Table 28.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	2.05	2.37
Valid n (in-country)	14	19	19
SD (in-country)	0.68	0.97	0.76
SE (in-country)	0.18	0.22	0.17

28.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

28.7 Additional sources & contacts

www.forest.go.th/stat42/stat.htm (7/6/01) (Thailand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Botswana - A. Government of Botswana, National Report on Measures taken to Implement the Convention of Biological Diversity, 1998 B) The National Conservation Strategy Coordinating Agency, Southern African Biodiversity Support Program, Status of Biodiversity in Botswana, 2002; Cook Islands - Contact - Antoine Nia (682 21256/ 682 22256) Environment Services; Costa Rica - Ministerio del Ambiente y Energía, Sistema Nacional de Áreas de Conservación; Fiji - Mining Tenement Licenses/ Exploration & Minerals Digest. Mineral resource Department; Greece - Zool. Museum, University of Athens. Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Contact - Michael Phillips. Environment &

Conservation Division (E&CD); Kyrgyzstan - Contact - Mr. Myrsaliev N(Unit of Conventions). Department of State Ecological Control and Environment Utilization. Marshall Islands - JACAP, p. 5. Project Prep. Document. SPREP. Republic of Marshall Islands Environmental Protection Agency; Nepal - Annual report, 2000, Department of National Parks. Department of National Parks, Kathmandu; New Zealand - Contact - Hine-Wai Loose. Ministry for the Environment; Niue - Huvalu Information Leaflet. Huvalu Forest Conservation Area Project; Palau - Permit Files - Environmental Quality Protection Board Robert (Bob) Marek (680 4881639 or 3600/ 4882963/ eqpb@palaunet.com); Papua New Guinea - Conserving Biological Diversity. A Strategy for Protected Areas in the Asia – Pacific Region. Braatz, Susan. Office of Environment & Conservation; Samoa - IUCN Directory of Protected Areas in Oceania. World Conservation Monitoring Centre. Lands, Surveys & Environment; Singapore - National parks board (national conservation branch) Contact - Dr Lana Chan: Tel 0065 64719931 / fax 0065 6472 9225 E-Mail: Lena_chan@nparks.gov.sg. Assistant Director; St Lucia - Biodiversity Report, 1998. Statistics Department; Tonga - Thistle, Sheppard, and Prescott. The Kingdom of Tonga, Action Strategy. SPREP. IUCN. Environmental Planning & Conservation Section; Trinidad & Tobago - Contact - Cindy Buchoon; Tuvalu - Mc Lean, R. F. and Hosking, P. C. 1991. Tuvalu Land Resource Survey Report. Country Report. A report prepared for the Food and Agriculture Organisation of the United Nations acting as executing agency for the United Nations Development Programme.; Department of Lands and Survey; Vanuatu - 3rd National Development Plan and Vanuatu Economic Performance, Policy & Reform Issues – Vango & ADB respectively. Environment Unit.

28.8 Definitions

http://earthtrends.wri.org/text/BIO/variables/917notes.htm

An IUCN Management Protected Area is defined by IUCN as “an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means." The World Database on Protected Areas (WDPA) consortium has been working to produce an improved and updated database available in the public domain. Summary information presented in the WDPA, of which UNEP-WCMC is the custodian, includes the legal designation, name, IUCN Management Category, size in hectares, location (latitude and longitude), and the year of establishment for over 100,000 sites. IUCN categorizes protected areas by management objective and has identified six distinct categories of protected areas:

Category Ia. Strict nature reserve: A protected area managed mainly for scientific research and monitoring; an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species.

Category Ib. Wilderness area: A protected area managed mainly for wilderness protection; a large area of unmodified or slightly modified land and/or sea retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.

Category II. National park: A protected area managed mainly for ecosystem protection and recreation; a natural area of land and/or sea designated to: (a) protect the ecological integrity of one or more ecosystems for present and future generations; (b) exclude exploitation or occupation inimical to the purposes of designation of the area; and © provide a foundation for spiritual, scientific, educational, recreational, and visitor opportunities, all of which must be environmentally and culturally compatible.

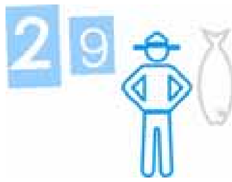
Category III. Natural monument: A protected area managed mainly for conservation of specific natural features; an area containing one or more specific natural or natural/cultural features that is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities, or cultural significance.

Category IV. Habitat/species management area: A protected area managed mainly for conservation through management intervention; an area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

Category V. Protected landscape/seascape: A protected area managed mainly for landscape/seascape conservation and recreation; an area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological, and/or cultural value, and often with high biological diversity.

Category VI, Managed mainly for the sustainable use of natural ecosystems. These areas contain predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while also providing a sustainable flow of natural products and services to meet community needs.

29. MARINE RESERVES



29.1 Indicator Summary

Indicator number:	29
Indicator short name:	Marine Reserves
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	Percentage of continental shelf designated as marine protected areas (MPAs).
Signals captured:	This indicator captures the increase in resilience, function of pollution attenuation and fisheries production, limits to losses of biodiversity and refuges afforded by the presence of adequate marine reserves in a country. The indicator focuses on areas with the most intact marine environments and the level of environmental management. The benefits of areas set aside as marine and coastal reserves increase with increasing area, increasing representation of ecosystem types, increasing degree of protection and period of time of protection. Permanent no-take reserves that are representative of major ecosystem types and occupy 20% of the shelf area would be considered ideal. Reserves would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts in the country. Reserves may be one of the few ways managers could off-set some other environmental damage and build resilience against natural events that can damage the environmental support system.
Notes on this indicator:	1. Landlocked countries are not included in the data and distributions analysed below. They are not given an EVI score for this indicator. Their overall EVI scores are calculated from the remaining indicators. 2. The denominator used for calculating percentage is area of continental shelf from WRI. It is possible for countries to have >100% in this indicator if part of their EEZ is designated. This could lead to misleading results only if countries designate large area of their EEZs as MPAs, or if they designate only oceanic areas from their EEZs as MPAs. 3. Protected areas outside of the continental shelf area need to be omitted from this indicator. 4. See Section 6 below for definitions.
Are suitable data available?	Yes
Sources of data:	• UNEP WCMC 1999 (Using IUCN categories Ia to VI) • WRI 2000-2001 (for area of continental shelf) • In-country
No. countries included in test:	161 of 235, but 41 are landlocked and the indicator not applicable (NA)
Temporary modifications to data or indicator, if applicable:	• The indicator may currently incorporate MPAs beyond the shelf area (leading to >100% for some countries), so at this evaluation of the EVI, form 2 of the indicator text is being used. In future evaluations, only areas within the continental shelf will be included, using form 1 of the indicator text.
Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. Age and quality of the in-country data were generally considered good (value > 2 of 3), but data were considered incomplete.

Basic units:	Percent of the shelf area set aside as marine reserves.	
Recommended transforms:	• None	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	20≤X
	EVI Score = 2	15<X<20
	EVI Score = 3	10<X≤15
	EVI Score = 4	5<X≤10
	EVI Score = 5	0<X≤5
	EVI Score = 6	No score
	EVI Score = 7	X=0
	NA (not applicable)	☑ May be used for landlocked countries, results in no EVI score
	ND (no data)	☑ May be used
Future work on this indicator:	1. Data for a larger number of countries is needed, but this will not affect the EVI scaling. 2. Protected areas outside of the continental shelf area need to be omitted from this indicator, but insufficient data were available to do this during this evaluation. This indicator is only for percent of the shelf area designated as MPAs.	

29.2 Description of raw data

The raw data for this indicator are comprised of the total area of marine reserves (MPAs) established in countries. Data are derived from UNEP WCMC 1999, based on IUCN categories Ia-VI, and from in-country sources. These values were then divided by total area of continental shelf (from WRI 2000-2001) to produce a percentage of shelf area set aside as MPAs. Of the 235 countries examined, these data were available for 120, with a further 41 landlocked countries not included because the indicator is not applicable (NA).

The percentage of shelf area set aside as MPAs in countries varied between 0 and 279% (Table 29.1). This is possible for this evaluation of the EVI because the denominator for the percentage is continental shelf area and the total area of MPAs may exceed this and/or the estimates of continental shelf are imprecise. This could affect our interpretations of the results if countries only designate oceanic parts of their EEZs as MPAs and not the shelf area, and needs to be examined in closer detail.

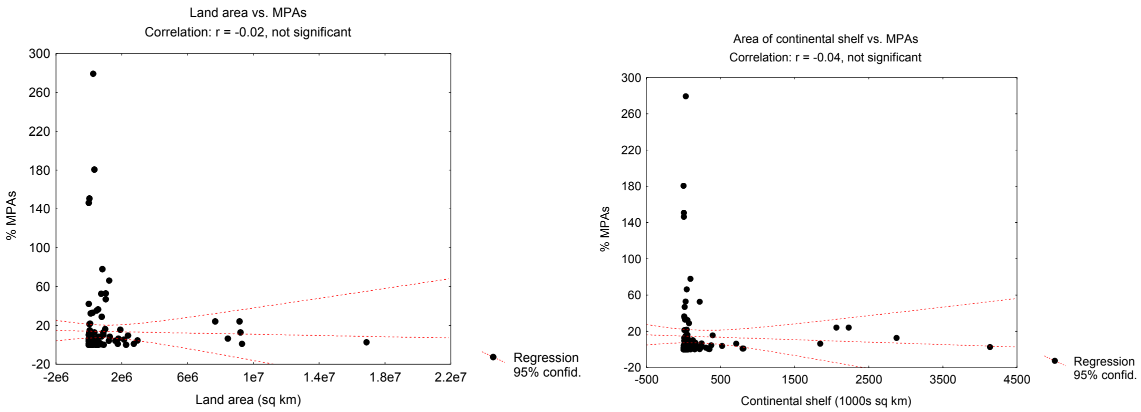
The lowest values, zero, were recorded in 19 countries, including United Arab Emirates, Ghana and Niue, and the highest values were recorded in Ecuador, Republic of Congo and Dominican Republic, which each had >150% of their shelf areas as MPAs. The mean value across the globe was 13.78%. Half of the countries examined had 2.63% or less of their shelf area designated as MPAs (the median). Variance among countries is moderate, with a standard deviation which is around 2.6 times the mean.

The percentage of shelf area as MPAs was correlated neither with size of a country as land area, or the size of the continental shelf (Figure 29.1).

Table 29.1: Basic statistics for marine reserves (MPAs). Data are from a WCMC 1999 and in-country sources.

Statistic	% Marine reserves
Mean	13.78
Median	2.63
Valid n	122
Min	0
Max	279[2]
SD	36.54
SE	3.31
Skewness	4.93
SE Skewness	0.22
Kurtosis	28.16
SE Kurtosis	0.43

Figure 29.1: Graphs of % of shelf as MPAs vs. size of countries. (a) % MPAs vs. size of land area of countries (km^2); and (b) % MPAs vs. size of continental shelf (km^2). Neither correlation is significant.



29.3 Distributional characteristics of the indicator data

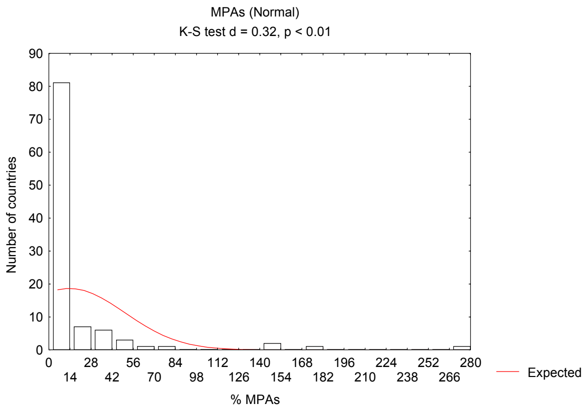
The % of MPAs was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 29.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal, rectangular and exponential distributions, but not for the lognormal distribution (Figure 29.2). This suggests that the values observed are distributed according to some logarithmic function. Transforming the values either to their natural logarithm might provide a better scale for comparison.

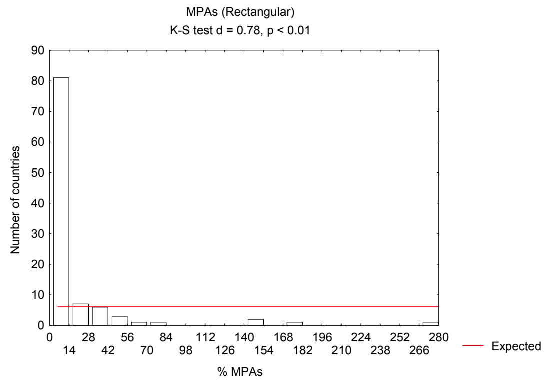
2 Although it is possible for the area of marine reserves to exceed the area of the continental shelf of a country, it is likely that such high figures are in error and due to differences in calculation of the areas involved.

Figure 29.2: Kolmogorov-Smirnov goodness-of-fit tests for % of shelf as MPAs in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

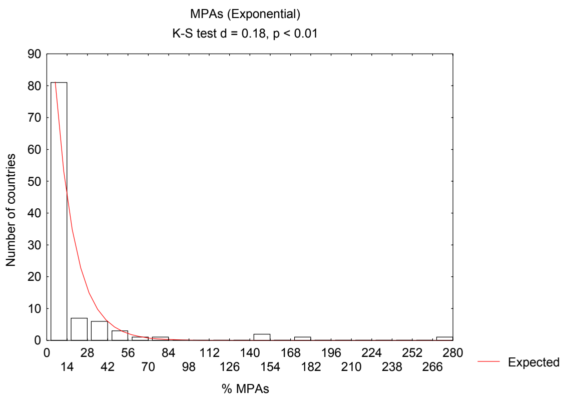
(a)



(b)



(c)



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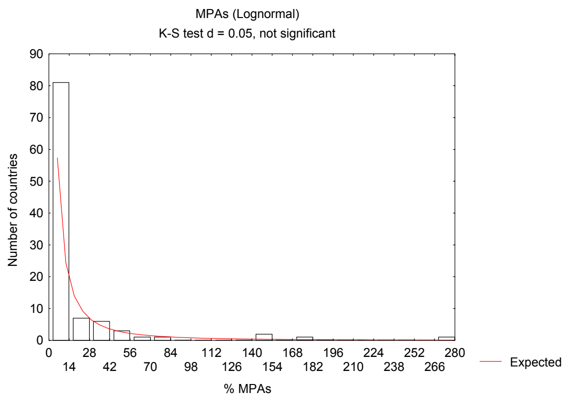
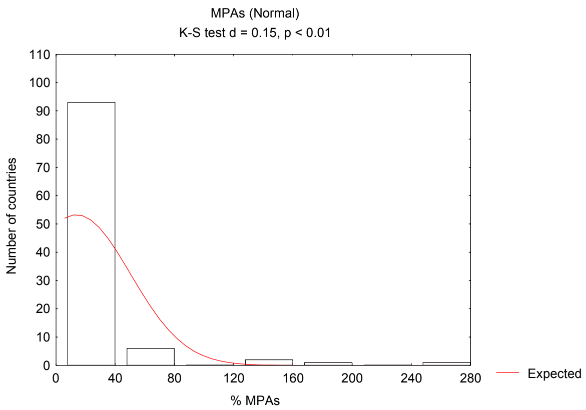


29.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in % of shelf as MPAs by 279%, and there was a strong clumping of countries at the lower end of the scale. We propose that countries with zero or very little of their marine area as reserves will be those that have failed to take the opportunity to build their environmental resilience. Countries with 20% of their area set aside as reserves are those that have taken steps to build resilience, maintain biodiversity, refuges and ecosystem functions. For this indicator, the EVI scale is reversed, with high percentages of reserves attracting low EVI scores. We identified those countries with ≥ 20% of their total shelf area as MPAs as likely to have actively reduced their risk of environmental damage (EVI=1). Countries with none of their marine area in reserves were considered the least resilient / most vulnerable (EVI=7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale, except that we placed a gap at the higher end of the scale at EVI=6 to emphasise a fundamental shift in resilience-building afforded by the presence of reserves (Figure 29.3, Table 29.2, 29.3). The difference between having zero and even a small area of reserves is likely to be of major significance to the resilience of a country.

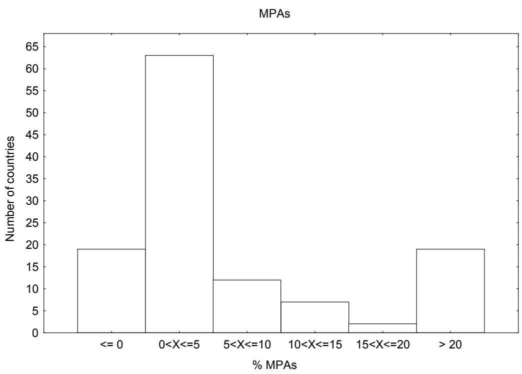
Figure 29.3: Frequency distribution of % MPAs in even categories and the EVI scale. (a) Frequency distribution in 7 even categories, (b) Is the distribution in 6 unevenly-spaced categories design to identify highly vulnerability in countries without reserves, and good resilience in those with 20% or more, (c) is the same a (b) but reversed and given a gap to form the proposed EVI scale.

(a)



(b)

(c)



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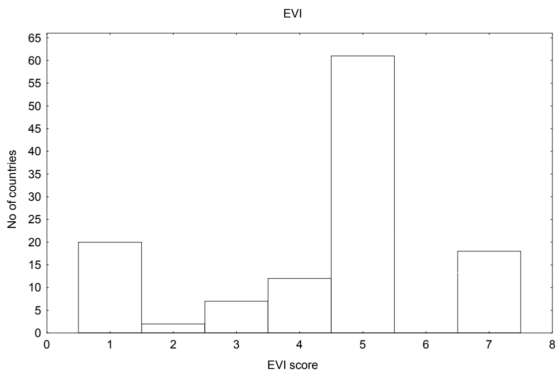


Table 29.2: Proposed EVI scaling for % MPAS showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for % MPAs	Observed # countries	Observed % of countries
1	20≤X	20	16.67
2	15<X<20	2	1.67
3	10<X≤15	7	5.83
4	5<X≤10	12	10.00
5	0<X≤5	61	50.83
6	No score		
7	X=0	18	15.00
No data		74	
NA	☑ May be used	41	
ND	☑ May be used (results in no score)		

Table 29.3: Proposed EVI scaling for % MPAs showing equivalence on the EVI and % scales and examples of countries that fall into each of the EVI scores.

Score	Scale for % MPAs	Examples
EVI=1	20≤X	Australia, Cameroon, Cuba
EVI=2	15<X<20	Egypt, Mexico
EVI=3	10<X≤15	Belize, Germany, Latvia
EVI=4	5<X≤10	Brazil, Algeria, Indonesia
EVI=5	0<X≤5	Gambia, Greece, Lebanon

EVI=6	No score	
EVI=7	X=0	Jordan, Liberia, Niue

29.5 Age, completeness and quality of the data

The data obtained for this indicator were from UNEP WCMC 1999 as well as in-country sources. In-country data were available for 17 of the 32 collaborating countries, with data being considered by collaborators to be of good age and quality, but incomplete (Table 29.4).

Table 29.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.42	1.87	2.88
Valid n (in-country)	12	15	17
SD (in-country)	0.67	0.92	2.47
SE (in-country)	0.19	0.24	0.60

29.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

29.7 Additional sources & contacts

www.forest.go.th/ (Thailand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Cook Islands - Contact - Ian Bertram (682 28722/ 682 29721/ rar@mmr.gov.ck) Director - Research & Economic Development(RED).
Costa Rica - Ministerio del Ambiente y Energía, Sistema Nacional de Áreas de Conservación; Federated States of Micronesia - Action Strategy for the Pacific. 1997. SPREP. The Nature Conservancy; Greece - Zool. Museum, University of Athens. Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Contact - Michael Phillips. Environment & Conservation Division (E&CD); Kyrgyzstan - Contact - Mr. Myrsaliev N(Unit of Conventions). Department of State Ecological Control and Environment Utilization; Marshall Islands - SPREP. Jaluit Atoll Conservation, p.5. Area Project – Project Preparation Document. Earth Moving Department; New Zealand - Contact - Hine-Wai Loose. Ministry for the Environment; Niue - Fisheries Resources Survey of the Island of Niue. Department of Fisheries, Forestry and Agriculture(DAFF); Palau - Palau Conservation Society Fact sheet; Papua New Guinea - Conserving Biological Diversity. A Strategy for Protected Areas in the Asia – Pacific Region. Braatz, Susan. Office of Environment & Conservation; Samoa - IUCN Directory of Protected Areas in Oceania. World Conservation Monitoring Centre. Lands, Surveys & Environment; Tonga - IUCN Directory of Protected Areas in Oceania. Environmental Planning & Conservation Section; Tuvalu - Environment Unit GOT and SPREP, 1995. Department of Lands and Survey; Vanuatu - Contact - Ernest Bani (678 25302/ 23565) Principal Environment Officer/Environment Unit. Contact – Mary Cordiner. Email - Info@wcmc.org.uk. UNEP World Conservation Monitoring Centre (WCMC).

29.8 Definitions

http://earthtrends.wri.org/text/BIO/variables/917notes.htm

An IUCN Management Protected Area is defined by IUCN as “an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means." The World Database on Protected Areas (WDPA) consortium has been working to produce an improved and updated database available in the public domain. Summary information presented in the WDPA, of which UNEP-WCMC is the custodian, includes the legal designation, name, IUCN Management Category, size in hectares, location (latitude and longitude), and the year of establishment for over 100,000 sites. IUCN categorizes protected areas by management objective and has identified six distinct categories of protected areas:

Category Ia. Strict nature reserve: A protected area managed mainly for scientific research and monitoring; an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species.

Category Ib. Wilderness area: A protected area managed mainly for wilderness protection; a large area of unmodified or slightly modified land and/or sea retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.

Category II. National park: A protected area managed mainly for ecosystem protection and recreation; a natural area of land and/or sea designated to: (a) protect the ecological integrity of one or more ecosystems for present and future generations; (b) exclude exploitation or occupation inimical to the purposes of designation of the area; and © provide a foundation for spiritual, scientific, educational, recreational, and visitor opportunities, all of which must be environmentally and culturally compatible.

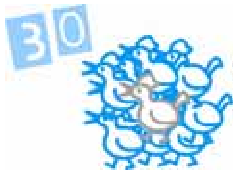
Category III. Natural monument: A protected area managed mainly for conservation of specific natural features; an area containing one or more specific natural or natural/cultural features that is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities, or cultural significance.

Category IV. Habitat/species management area: A protected area managed mainly for conservation through management intervention; an area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

Category V. Protected landscape/seascape: A protected area managed mainly for landscape/seascape conservation and recreation; an area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological, and/or cultural value, and often with high biological diversity.

Category VI, Managed mainly for the sustainable use of natural ecosystems. These areas contain predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while also providing a sustainable flow of natural products and services to meet community needs.

30. INTENSIVE FARMING



30.1 Indicator Summary

Indicator number:	30
Indicator short name:	Intensive farming
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	Average annual tonnage of intensively farmed animal products (includes aquaculture, pigs, chickens, cattle, etc.) produced over the last 5 years per square kilometre land area.
Signals captured:	This indicator captures the risk of pollution, eutrophication, ecosystem loss or damage and the risk of diseases and plagues. It focuses on lands being used for intensive agriculture, which we define as those in which the wastes produced over the land are in excess of the ability of that same land area to attenuate them. Intensive farming includes the farming of poultry, pigs, aquaculture, and some farming of cattle and other animals where kept in feed lots. Intensive farming usually involves clearing of land, feeding, heavy use of pesticides and other medications and a concentrated production of wastes. It concentrates the environmental requirements of farmed animals into a small area, and wastes often find their way into the surrounding water table, waterways and land areas. Countries with a large production through intensive farming methods are also considered more at risk of inadvertent introductions of diseases, species and genetically modified organisms. The effects of intensive farming would be especially important if there are many endangered species, sensitive ecosystems that could be affected by key species, and interactions with on-going human impacts.
Notes on this indicator:	1. We were not able to find a database that focused on quantifying intensive farming. We were able to find FAO data 1996-2000 on total numbers of animal stocks. 2. Numbers on animal stocks were converted to tonnages using average weights for the farmed animals. 3. Tonnages on aquiculture products were available in tonnes from FAO for the years 1995 and 1999.
Are suitable data available?	No. Data are approximate because they focus on species rather than method of production. We determined that poultry, pigs and aquaculture were the most likely to be intensively farmed and were included in this indicator. Cattle, sheep, goats etc were excluded because they are most likely to be extensively farmed.
Sources of data:	• FAO 1996-2000 data • In-country
No. countries included in test:	176 of 235
Temporary modifications to data or indicator, if applicable:	• Data used are head of chickens, ducks, geese, pigs, turkeys and tonnages of all aquaculture products produced in the period 1996-2000. Where necessary, these were converted to tonnes using simple average weights.
Notes on data age, completeness and quality:	12 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).

Basic units:	Intensive farming as X = mean tonnes of intensively farmed animals produced per year per sq km of land.	
Recommended transforms:	• Data transformed to LN(X+1)	
Proposed EVI Scale	EVI Score = 1	X≤2
	EVI Score = 2	2<X≤3
	EVI Score = 3	3<X≤4
	EVI Score = 4	4<X≤5
	EVI Score = 5	5<X≤6
	EVI Score = 6	6<X≤7
	EVI Score = 7	X>7
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Sources of agricultural production data focused on methods of production are needed.	

30.2 Description of raw data

The raw data for this indicator are comprised of the head of poultry and pigs produced in a country converted to tonnes, plus the tonnage of aquaculture products. Data for poultry and pigs is from FAO for the years 1996-2000, and that for aquaculture for the years 1995 and 1999. The conversion to tonnages for poultry and pigs was done using published average weights per animal from a range of sources. The values used were chickens = 2.6 kg, ducks = 2.5 kg, geese = 7.75 kg, pigs = 105 kg, and turkeys = 9.3 kg (references are given on Indicator 23 data table). These values were averaged and summed across species and expressed as mean tonnes per year. These data are not in their ideal form for this indicator. The indicator targets methods of production rather than species, requiring data on tonnages of intensively farmed animal products. These could include all species farmed across the globe, if they are farmed intensively, meaning that animals are usually confined to a small area and fed and/or wastes eliminated from/to sources external to the land or water they occupy. By this definition cattle, sheep or extensively-farmed fish would not be included, because production occurs (almost) exclusively on the land/water they occupy. Conversely, cattle produced in feed lots would qualify as intensively farmed. There is also likely to be error in the data related to the conversion from head of animals to tonnages using the conversion values given above. Data for this indicator will need to be specifically collected in the appropriate form for the future. Of the 235 countries examined, these proxy data were available for 176.

The mean weight of intensively farmed animal products produced in countries between 1996-2000 varied between 0.01 tonnes and almost 43 million tonnes (Table 30.1). The lowest values were recorded in Mauritania, Libya, Eritrea and Sudan, and the highest values were recorded in Spain, Brazil and China. The mean value across the globe was 424,584 tonnes per year. Half of the countries examined produced 12,704 tonnes per year or less of intensively-farmed animals (the median). Variance among countries is high, with a standard deviation which is around 7.6 times the mean.

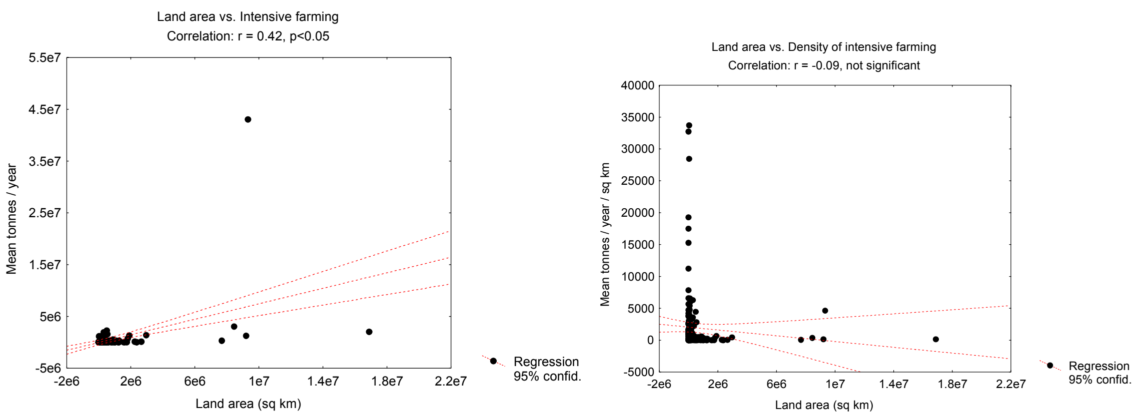
The production of intensively-farmed animals is correlated with the size of a country (see significant correlation coefficient in Figure 30.1). The risks associated with intensive farming are related to the area of land exposed to this form of agriculture and the area over which wastes and pollution can be attenuated. This means that this indicator needs to be divided by total land area in a country to examine the amount of exposure to intensive farming per unit of land area (or density of intensive farming). These data are expressed as tonnes of intensively-farmed animals produced per square kilometre of land area in the country. When the density of intensive farming is, in turn, tested against country size, the correlation with size of country disappears (Figure 30.1 b). The maximum density of intensive farming was observed in Netherlands, with 33,689 tonnes produced per sq km of land in between 1996 and 2000. Note: this extremely high figure is likely to be an artefact of the calculations needed to convert heads to tonnages, but serves as an indicator of the level of exposure. It should not be read as a real measure of the tonnages produced.

Table 30.1: Basic statistics for intensive farming in 176 countries. Data are from FAO and cover years 1996-2000.

Statistic	Intensive farming Mean tonnes / year (1996-2000)	Intensive farming Mean tonnes / year / sq km (1996-2000)	LN (X+1) Intensive farming
Mean	424,584.0	1,902.4	5.2
Median	12,704.05	345.01	5.85
Valid n	176	176	176
Min	0.01	0.01	0.01
Max	42,999,394	33,689	10.42
SD	3,256,138	4,800	3.0
SE	245,440.7	361.8	0.2
Skewness	12.92	4.83	-0.47
SE Skewness	0.18	0.18	0.18
Kurtosis	169.79	26.03	-0.84
SE Kurtosis	0.36	0.36	0.36

Figure 30.1: Graphs of intensive farming vs. size of countries. (a) Tonnes of intensively farmed animals per year vs. size of country (sq km); and (b) Density of intensive farming (tonnes / year / sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a) (b)



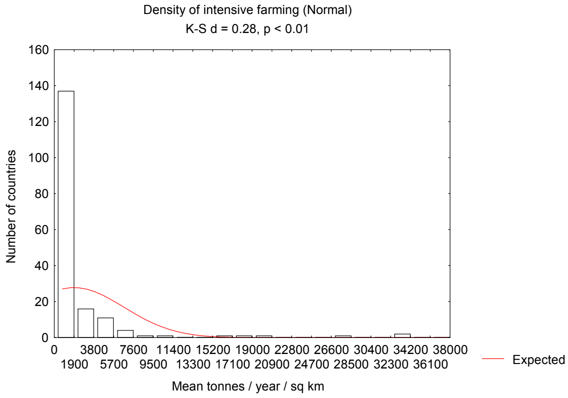
30.3 Distributional characteristics of the indicator data

The density of intensive farming of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 30.2). This resulted in a distribution which was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

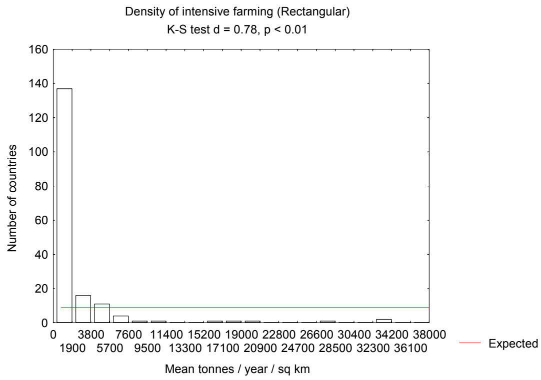
A significant difference between observed and expected values was found in all tests except the lognormal distribution (Figure 30.2). This suggests that the values observed are distributed according to some logarithmic function and that transforming the values to their natural logarithm might provide a better scale for comparison.

Figure 30.2: Kolmogorov-Smirnov goodness-of-fit tests for density of intensive farming in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution was the best fit of the observed data.

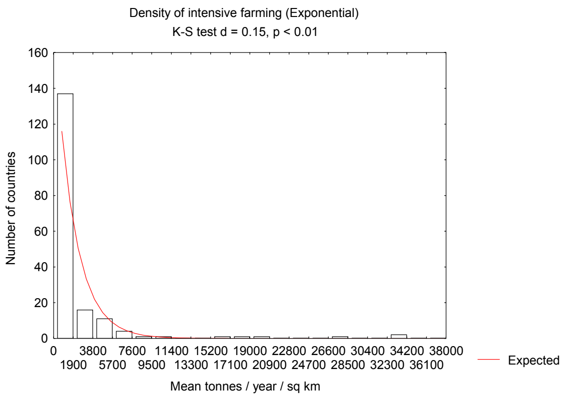
(a)



(b)



(c)



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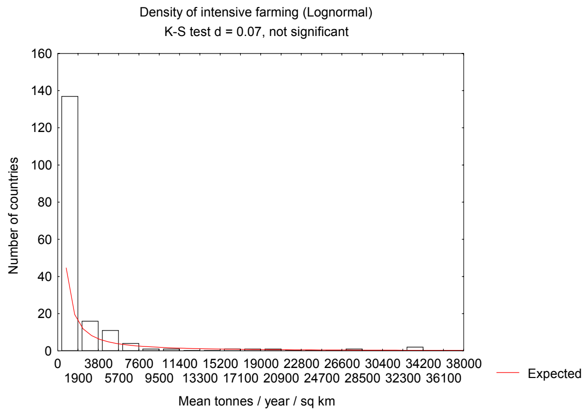
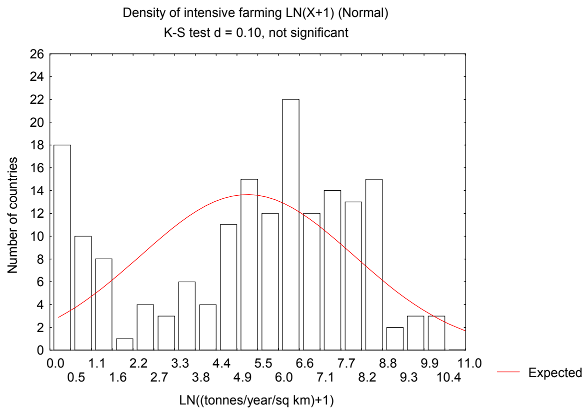


30.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in density of intensive farming by seven orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms (LN(X+1)) for this indicator to provide better spread among the countries and compress the scale to between 0.01 and 10.42, with countries having the greatest levels of intensive farming being considered more vulnerable and attracting a higher EVI score. We identified those countries with ≤ 2 on the transformed (LN freight density) scale as likely to be the least at risk of environmental damage because the amount of intensive farming is small in relation to the area of land available to absorb / attenuate any damage (< 6.39 tonnes / year / sq km land, EVI score = 1). Countries with > 7 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1996-2000 produced more than 109 tonnes of intensively-farmed animal products / year / sq km of their land area. The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 30.3, Table 30.2, 30.3).

Figure 30.3: Frequency distribution of LN(X+1) density of intensive farming in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) intensive farming density in seven uneven categories which clump countries with low and high values, identifying them as being at the lowest and highest risk, respectively. (d) The proposed EVI scale.

(a)



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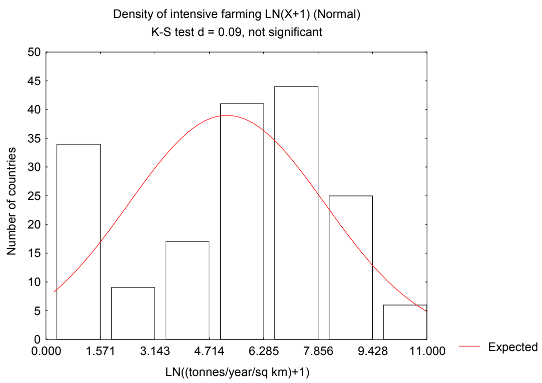

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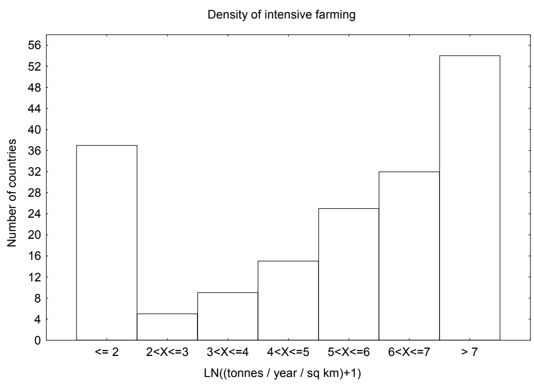

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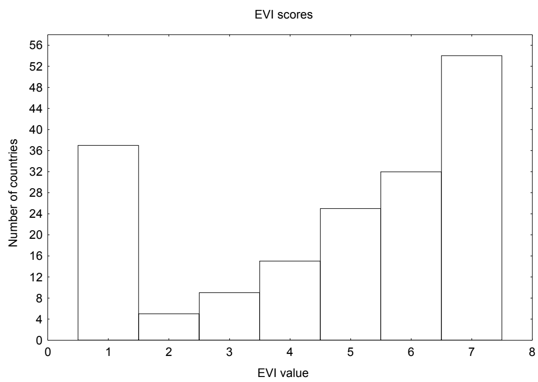


Table 30.2: Proposed EVI scaling for density of intensive farming showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X≤2	37	21.02
2	2<X≤3	5	2.84
3	3<X≤4	9	5.11
4	4<X≤5	15	8.52
5	5<X≤6	25	14.20
6	6<X≤7	32	18.18
7	X>7	53	30.11
No data		58	33.52
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 30.3: Proposed EVI scaling for Indicator 30 on density of intensive farming showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Density of intensive farming	Equivalent scale tonnes / year / sq km	Examples
EVI=1	X≤2	X ≤ 6.39	UAE, Germany, Eritrea
EVI=2	2<X≤3	6.39 < X ≤ 19.09	Congo, French Guiana, Mozambique
EVI=3	3<X≤4	19.09 < X ≤ 53.60	Kenya, Kazakhstan, Iceland
EVI=4	4<X≤5	53.60 < X ≤ 147.41	Angola, Bahamas, Gambia
EVI=5	5<X≤6	147.41 < X ≤ 402.43	Bolivia, Cayman Is. Peru
EVI=6	6<X≤7	402.43 < X ≤ 1095.63	Lebanon, Latvia, Nepal
EVI=7	X>7	X > 1095.63	Italy, Netherlands, Singapore

30.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

30.6 Age, completeness and quality of the data

The data obtained for this indicator were from FAO. The data are not ideal for the purposes of the indicator because they are incomplete in terms of the years covered; provided as head of different animals farmed rather than tonnages; and focus on species rather than farming method (intensive vs. extensive farming). There are likely to be errors created by the conversion of the units of data, and the highest value of 33,600+ tonnes produced per year per square kilometre of a country is an unlikely value. It is clear we will need a better data source for this indicator, and that these data should only be taken as a proxy for the amount of intensive farming occurring in a country.

In-country data were available for 12 of the 32 collaborating countries, with data being of good age, completeness and quality (all >2 of 3) (Table 30.4).

Table 30.4: Characteristics of age, completeness and quality of the data obtained for intensive farming.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	2.17	2.45
Valid n (in-country)	12	12	11
SD (in-country)	0.74	0.72	0.82
SE (in-country)	0.21	0.21	0.25

30.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

30.8 Additional sources & contacts

Costa Rica Observatorio del desarrollo; Greece - Statistical Yearbook of Greece 1998; Marshall Islands - Laura Farm. Agriculture & Quarantine. Contact - Jimmy Josephs; Nepal - Statistical information on Nepalese Agriculture 1999/2000. Ministry of Agriculture and Co-operatives, Kathmandu, Nepal; Palau - Statistical Yearbook, 1999. Planning and Statistics. Agriculture Division; Samoa - 1989 Agriculture Census & Field Surveys. Ministry of Agriculture Forests, Fisheries and Meteorology (MAFFM); Singapore - Agri-Food & Veterinary Authority(AVA). Contact – Koay Sim Huat. Email – koay_sim_huat@ava.gov.sg ; Thailand - National Statistical Coordination Board, Philippine Statistical Yearbook. Bureau of Agricultural Statistics Thailand - www.apps.fao.org/lim500/nph-wrap.pl?Production.Livestock.Stocks&Domain=SUA&servlet=1 A) www.dld.go.th/DLD_web/yearly/stat_dat.html B) www.nso.go.th/thai/stat/shrimp/shrimp.pdf ; Trinidad &Tobago Contact - Cindy Buchoon; Vanuatu - Raw data from source. Samos, A. Vanuatu Agriculture Supplies/ Agriculture Department.

31. FERTILISERS

31.1 Indicator Summary

Indicator number:	31	
Indicator short name:	Fertilisers	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Average annual intensity of fertiliser use over the total land area (kg/yr/km2) over the last 5 years.	
Signals captured:	This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters from the use of chemical NPK fertilisers. This indicator is a measure of damage to ecosystems, water and soil quality, coral reefs and other sensitive organisms through eutrophication, pollution, soil damage and salinisation. The effects of using NPK fertilisers depends on the intensity of application and time and space needed for natural attenuation. The effects of releasing large amounts of fertilisers into the environment would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. WRI: Fertiliser refers to nutrients in terms of nitrogen (N), phosphate (P_2O_5), and potash (K_2O). Fertiliser use is calculated using a trade balance approach. As nations sometimes increase or decrease their stocks of fertiliser in a given year, actual use may be larger or smaller than the figure given. If the sale of fertiliser stocks is particularly large, there is the potential for a negative fertiliser use value. 2. Data are averages for the period 1995-1997.	
Are suitable data available?	Yes, but only for a limited number of countries and years.	
Sources of data:	• WRI 2000-2001 • OECD 1999 • In-country	
No. countries included in test:	164 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	16 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Kilograms of fertilisers used per year per km^2 total land area.	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	X≤2
	EVI Score = 2	2<X≤4
	EVI Score = 3	4<X≤6
	EVI Score = 4	6<X≤7
	EVI Score = 5	7<X≤8
	EVI Score = 6	8<X≤9
	EVI Score = 7	X>9
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries and years is needed, but this should not affect the EVI scaling.	

31.2 Description of raw data

The raw data for this indicator are comprised of the total annual amounts of fertilisers used in a country each year (tonnes/yr). Data are for the years 1995-1997 from WRI 2000-2001 where they were originally expressed as use per ha of croplands. These values were then divided by total land area to produce an average annual amount (in kg) of fertilisers that would need to be attenuated or stored per year per km^2 of the total land area in countries. The greater the average yearly loads, the greater the risk of overload and pollution of land, ground water and waterways. Of the 235 countries examined, these data were available for 164.

The total use of fertilisers in countries varied between 0 and more than 35.8 million tonnes in 1995-1997 (Table 31.1). The lowest values of zero were recorded in 8 countries, including Liberia, Rwanda and Solomon Islands, and the highest values were recorded in China and USA. The mean value across the globe was more than 1 million tonnes in a year. Half of the countries examined used more than 74,000 tonnes per year (the median). Variance among countries was moderate to high, with a standard deviation that was around 4 times the mean.

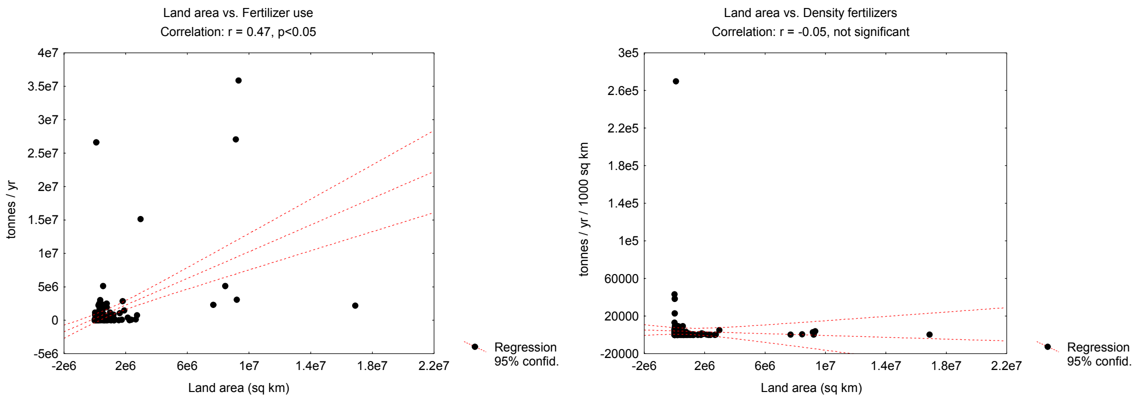
The amount of fertilisers used was correlated with the size of a country (see significant correlation coefficient in Figure 31.1). Since the risks associated with the use of fertilisers are related to the area over which they can be attenuated, we expressed this indicator as an intensity of use, dividing the amounts used each year by total land area in a country. The intensity of fertiliser use did not correlate with country size (Figure 31.1 b). The intensity of fertiliser use varied from 0 to more than 269 tonnes/yr/km^2 land, with the maximum intensities observed in Republic of Korea, Marshall Islands and Belgium.

Table 31.1: Basic statistics for fertiliser use. Data are for the years 1995-1997.

Statistic	Tonnes of fertilisers used per year	Intensity of fertiliser use (kg/yr/km^2)	LN(X+1) (kg/yr/km^2)
Mean	1,050,728	3,846	6
Median	74,835	482.39	6.18
Valid n	164	164	164
Min	0	0	0
Max	35,871,725	269,493	13
SD	4,229,670	21,507	3
SE	330,281.8	1,679.4	0.2
Skewness	6.51	11.77	-0.48
SE Skewness	0.19	0.19	0.19
Kurtosis	44.51	145.21	-0.25
SE Kurtosis	0.38	0.38	0.38

Figure 31.1: Graphs of fertiliser use vs. size of countries. (a) Tonnes of fertilisers used per year vs. size of country (km²); and (b) Intensity of fertiliser use (kg/yr/km² land) vs. size of country (km²). The correlation is significant in (a) and not significant in (b).

(a) (b)



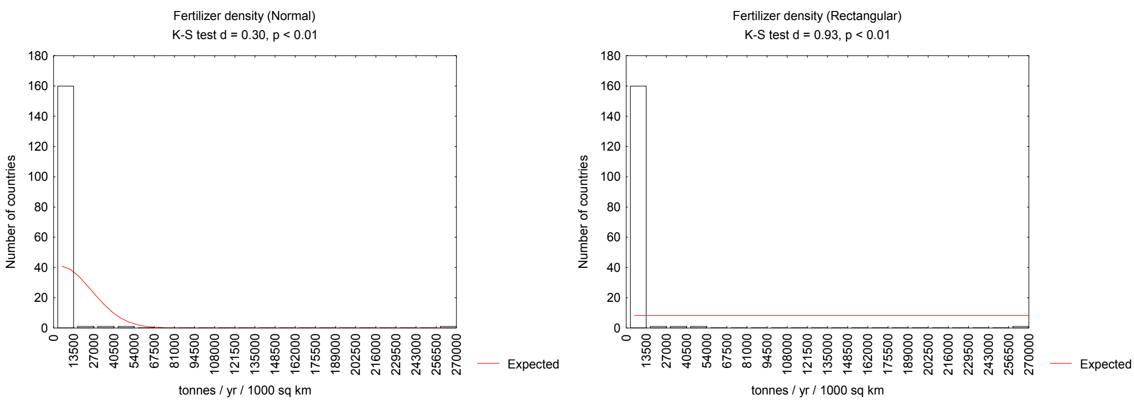
31.3 Distributional characteristics of the indicator data

The intensity of fertiliser use was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 31.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

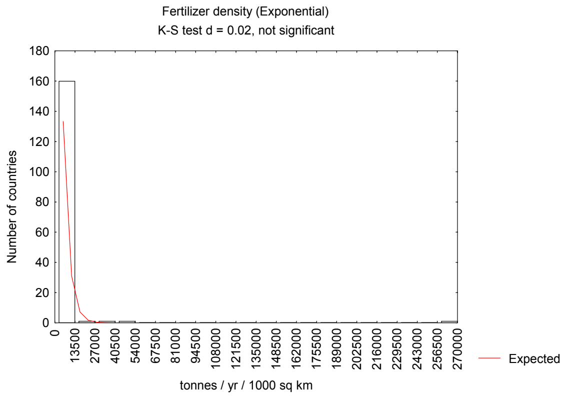
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 31.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values to their root or natural logarithm might provide a better scale for comparison.

Figure 31.2: Kolmogorov-Smirnov goodness-of-fit tests for intensity of fertiliser use in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

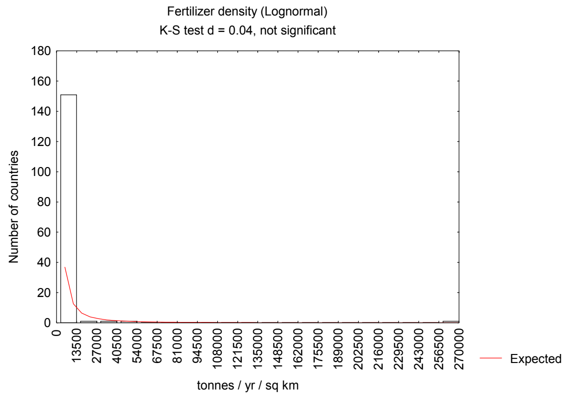
(a) (b)



(c)



(d)

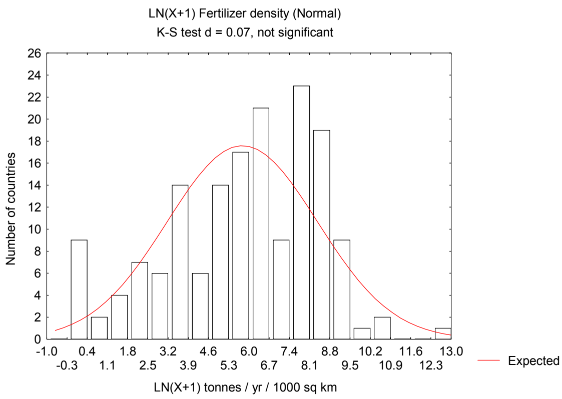


31.4 Proposed EVI scaling and distribution of the data on this scale

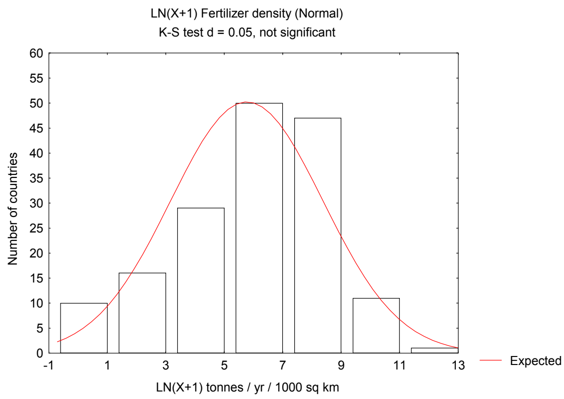
We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries and compress the scale to between 0 and 13, with countries having the highest intensities of fertiliser use being considered more vulnerable and attracting a higher EVI score. We identified those countries with values of <2 on the transformed scale for fertiliser use as likely to be the least at risk of environmental damage, giving them an EVI score=1. Countries with > 9 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1995-1997 used more than 8,000 kg of fertilisers per km^2 of land as a national average (not just across their agricultural lands). The country values between these extremes were spaced unevenly to form the remainder of the EVI scale (Figure 31.3, Table 31.2, 31.3).

Figure 31.3: Frequency distribution of LN(X+1) intensity of fertiliser use in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) transformed data in seven categories which clump countries with high values, identifying them as being at the highest risk. (d) The proposed EVI scale.

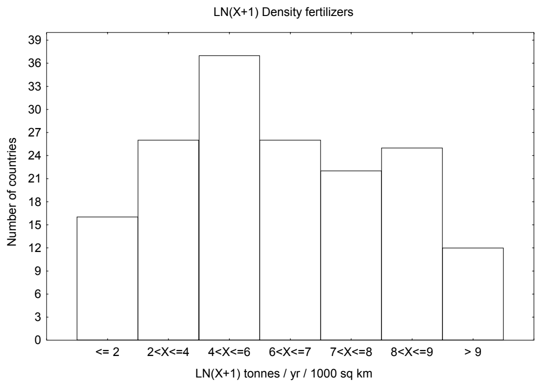
(a)



(b)



(c)



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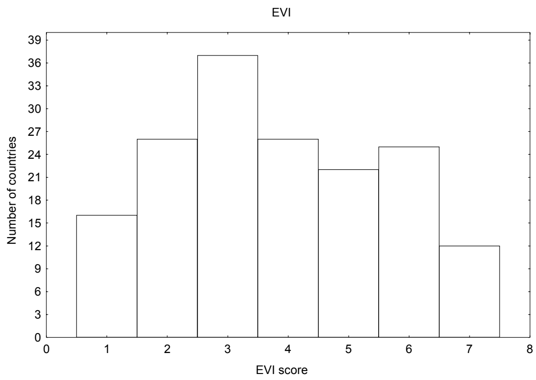


Table 31.2: Proposed EVI scaling for intensity of fertiliser use showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	LN(X+1) Intensity fertiliser use	Observed # countries	Observed % of countries
1	X≤2	16	9.76
2	2<X≤4	26	15.85
3	4<X≤6	37	22.56
4	6<X≤7	26	15.85
5	7<X≤8	22	13.41
6	8<X≤9	25	15.24
7	X>9	12	7.32
No data		71	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 31.3: Proposed EVI scaling for intensity of fertiliser use showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	LN(X+1) Intensity fertiliser use	Equivalent scale in kg/yr/km^2 land	Examples
EVI=1	X≤2	X≤6.39	Botswana, Liberia, Nauru
EVI=2	2<X≤4	6.39<X≤53.60	Eritrea, Cambodia, Oman
EVI=3	4<X≤6	53.60<X≤402.43	Jordan, Senegal, Venezuela
EVI=4	6<X≤7	402.43<X≤1095.63	Estonia, Georgia, Latvia
EVI=5	7<X≤8	1095.63<X≤2979.96	Bulgaria, Guatemala, Macedonia
EVI=6	8<X≤9	2979.96≤8102.08	Belarus, Croatia, Malaysia
EVI=7	X>9	X>8102.08	Cook Islands, France, Ireland

31.5 Age, completeness and quality of the data

The data obtained for this indicator were mostly from WRI 2000-2001, with some additional data from OECD 1999, and in-country sources. In-country data were available for 14 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 31.4).

Table 31.4: Characteristics of age, completeness and quality of the data obtained for fertiliser use.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.13	2.44	2.44
Valid n (in-country)	16	16	16
SD (in-country)	0.62	0.51	0.89
SE (in-country)	0.15	0.13	0.22

31.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

31.7 Additional sources & contacts

www.reports.eea.eu.int/ (2/06/2001) (Greece); OECD 1999, pp 276,279; UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Cook Islands - Cook Islands Customs Import Entries – Extract from database. Cook Islands Statistics Office; Costa Rica - Observatorio del desarrollo / San José, COSTA RICA, 2001; Fiji - Bureau of Statistics/ Department of Agriculture; Kiribati - Internal data (copies of invoices from divisional files). Contact - Manate Tenang (686 28109 or 28108) Agriculture Division; Kyrgyzstan - Department of chemicalixation and plant protection. Contact - Mrs. Malyutina L.V. Mr. Katarov V.M; Marshall Islands - Contact - Laura Farm. Agriculture & Quarantine, Ministry of R & D (Resource & Development); Nauru - Contact - Frank W Davey. Analysis Lab; Palau - Agriculture Monthly Reports. Agriculture Division. Contact - Kashgar Rengulbai (680 4882504/ 4881475/ DAMR@palaunet.com); Philippine - Philippine Statistical Yearbook. Fertilizer and Pesticide Authority.A) 1998 Imports Report B) 1994-1997 Imports Report; Samoa - Agriculture Store Corp. FADINAP, 1998: 41 & 1999: 17 & 10. Ministry of Agriculture; Thailand - State of Environment Report 1998 by Office of Environmental Policy and Planning. Center of Agricultural Statistics, Office of Agricultural Economics, Ministry of Agricultural Cooperatives; Tonga - Annual Trade Report 1995 - 1999. Statistics Department; Trinidad & Tobago - Contact - Karen Ragoonanan; Tuvalu - Department of Agriculture. Contact - Itaia Lausaveve; Vanuatu - Alan Sands. Vanuatu Agricultural Supplies; Ministry of Agriculture, Livestock & Forestry.

32. PESTICIDES

32.1 Indicator Summary

Indicator number:	32	
Indicator short name:	Pesticides	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Average annual pesticides used as kg/km2/year over total land area over last 5 years	
Signals captured:	This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters from heavy use of pesticides. The indicator focuses on damage and pollution of ecosystems, soil damage, damage to reproductive systems of organisms, loss of species, and damage to aquatic organisms including fisheries and coral reefs. Pesticides need time and a suitable area of land or volume of water for their attenuation. High loads of mobile pesticides present risks to all aspects of the environment. The effects of introducing pesticides into the environment where they can accumulate would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. Data for this indicator are from WRI 2000-2001 and were expressed as loads in kg/yr/ha of cropland. We have recalculated them in terms of kg/yr/ha of total land area because this is the area over which they could potentially be attenuated. 2. Data are for 1996 or 1997 only and not an average of the last 5 years 3. Definitions: WRI: Pesticide use (1996) refers to per hectare use or sale to the agriculture sector of substances that reduce or eliminate unwanted plants or animals, especially insects. They include major groups of pesticides such as insecticides, mineral oils, herbicides, plant growth regulators, bacteria and seed treatments, and other active ingredients. OECD: Data include total pesticides, insecticides, fungicides, herbicides, fumigants, rodenticides and anti-coagulants.	
Are suitable data available?	Yes, but only for a limited number of years and countries.	
Sources of data:	• WRI 2000-2001 • OECD 1999 • In-country	
No. countries included in test:	104 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	14 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Kilograms pesticides used per year per km^2 of total land area	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	X=0
	EVI Score = 2	0<X≤0.5
	EVI Score = 3	0.5<X≤1
	EVI Score = 4	1<X≤2

	EVI Score = 5	2<X≤3
	EVI Score = 6	3<X≤4
	EVI Score = 7	X>4
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries and for the last 5 years is needed, but this should not affect the EVI scaling.	

32.2 Description of raw data

The raw data for this indicator are comprised of the total annual amounts of pesticides used in a country each year (kg/yr). Data are only for 1996 for WRI and 1997 for OECD where they were originally expressed as use per ha of croplands. These values were then divided by total land area to produce an average annual amount (kg) of pesticides that would need to be attenuated or stored per year per km^2. The greater the average yearly loads, the greater the risk of overload and pollution of land, ground water and waterways. Of the 235 countries examined, these data were available for 104.

The total use of pesticides in countries varied between 0 and more than 286 million kilograms in 1996 or 1997 (Table 32.1). The lowest values were recorded in Cook Islands and Tuvalu (zero), and the highest values were recorded in USA, Italy and Australia. The mean value across the globe was more than 13.5 million kg in a year. Half of the countries examined used more than 1.5 million kg per year (the median). Variance among countries was moderate, with a standard deviation that was around 2.8 times the mean.

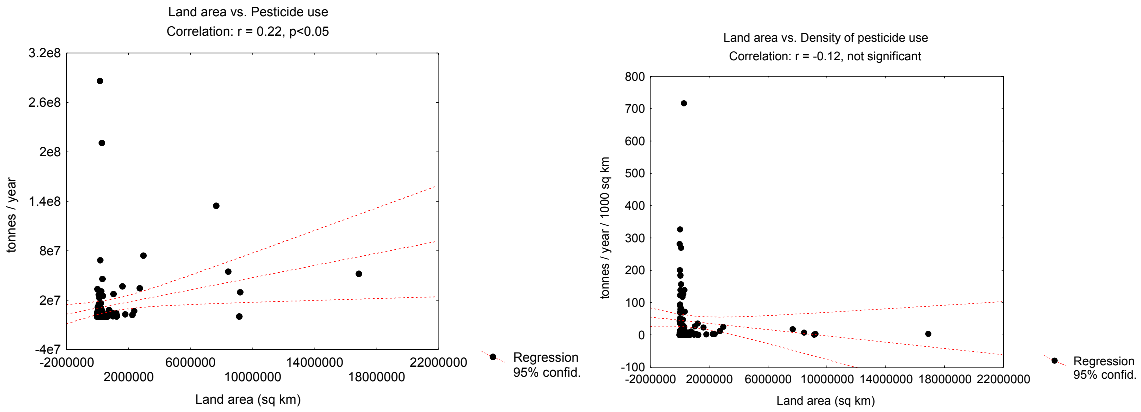
The amount of pesticides used was correlated with the size of a country (see significant correlation coefficient in Figure 32.1). Since the risks associated with the use of pesticides are related to the area over which they can be attenuated, we expressed this indicator as an intensity of use, dividing the amounts used each year by total land area in a country. The intensity of pesticide use did not correlate with country size (Figure 32.1 b). The intensity of pesticide use varied from 0 to 717 kg/yr/km^2 land, with the maximum intensities observed in Italy, Netherlands and Trinidad & Tobago.

Table 32.1: Basic statistics for pesticide use. Data are for 1996 or 1997.

Statistic	Total pesticide use (kg/yr)	Intensity of pesticide use (kg/yr/km^2)	LN(X+1) (kg/yr/km^2)
Mean	13,593,870	41	2
Median	1,552,216	6	2
Valid n	104	104	104
Min	0	0	0
Max	286,221,000	717	7
SD	38,524,667	92	2
SE	3,777,654	9	0
Skewness	5.22	4.64	0.44
SE Skewness	0.24	0.24	0.24
Kurtosis	30.93	28.56	-0.997
SE Kurtosis	0.47	0.47	0.47

Figure 32.1: Graphs of pesticide use vs. size of countries. (a) Kilograms of pesticides in 1996 or 1997 (kg/yr) vs. size of country (sq km); and (b) Intensity of pesticide use (kg/yr/km^2 land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a) (b)



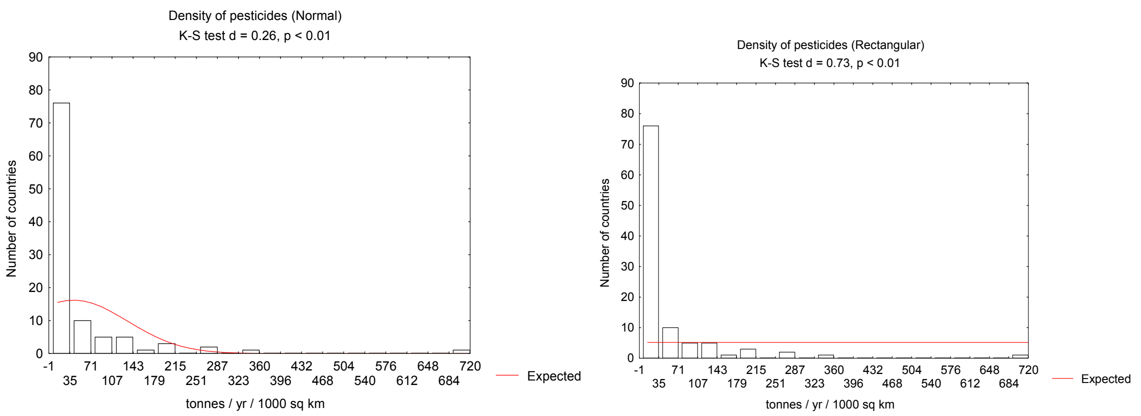
32.3 Distributional characteristics of the indicator data

The intensity of pesticide use was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 32.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal, rectangular and exponential distributions, but not for the lognormal distribution (Figure 32.2). This suggests that the values observed are distributed according to some logarithmic function. Transforming the values to their natural logarithm might provide a better scale for comparison.

Figure 32.2: Kolmogorov-Smirnov goodness-of-fit tests for intensity of pesticide use in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution provided the best fit of the observed data.

(a) (b)



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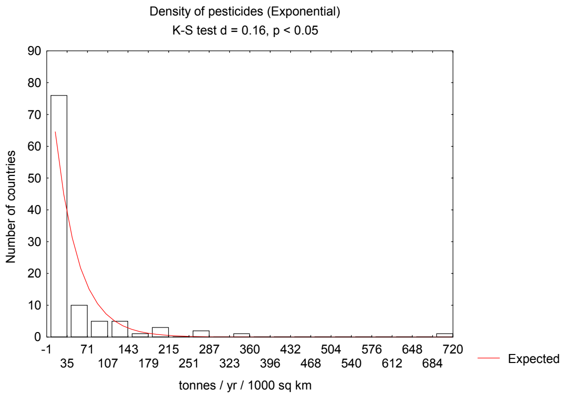

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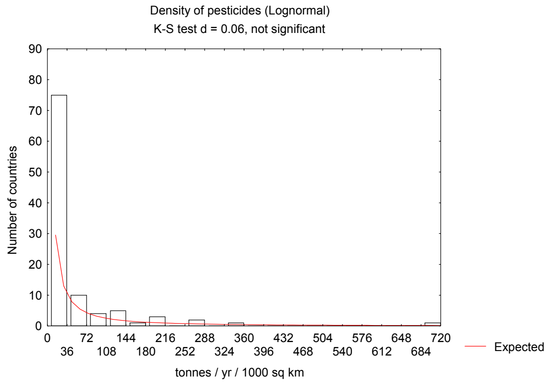
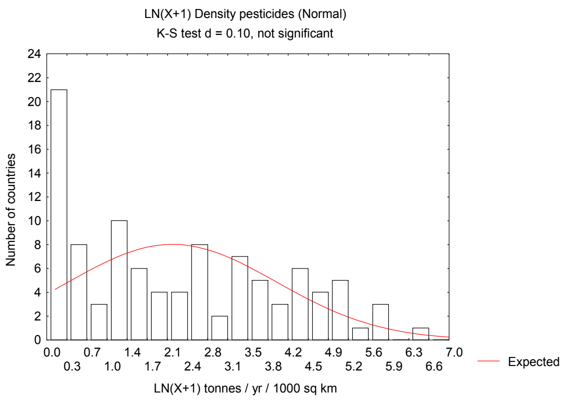


32.4 Proposed EVI scaling and distribution of the data on this scale

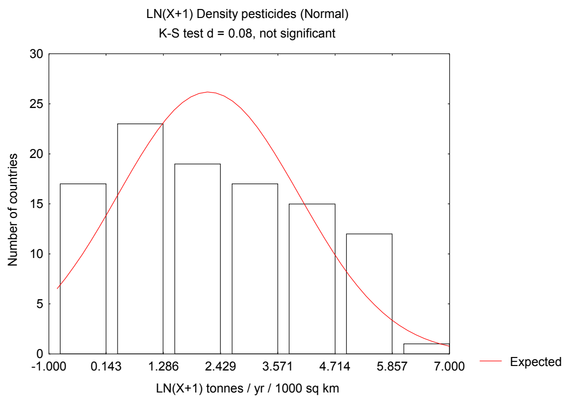
We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries and compress the scale to between 0 and 7, with countries having the highest intensities of pesticide use being considered more vulnerable and attracting a higher EVI score. We identified those countries with zero reported pesticide use in 1996 or 1997 as likely to be the least at risk of environmental damage, giving them an EVI score=1. Note however, that zero reported use in those years does not mean that use has been zero in the past or that it will continue to be so in the future. Countries with > 4 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1996 or 1997 used more than 53 kg of pesticides per km^2 of land as a national average (not just across their agricultural lands). The country values between these extremes were spaced unevenly to form the remainder of the EVI scale (Figure 32.3, Table 32.2, 32.3).

Figure 32.3: Frequency distribution of LN(X+1) intensity of pesticide use in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) transformed intensities in seven categories which spread countries with low values and clump those countries with high values, identifying them as being at the highest risk. (d) The proposed EVI scale.

(a)



(b)



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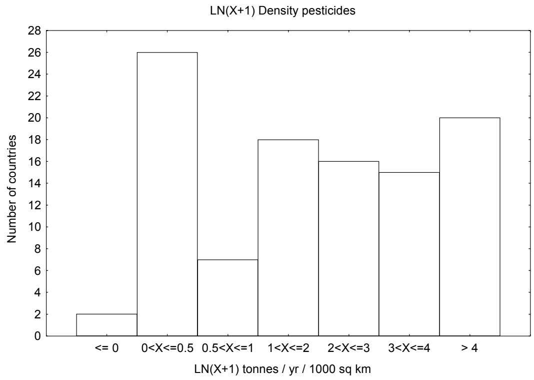

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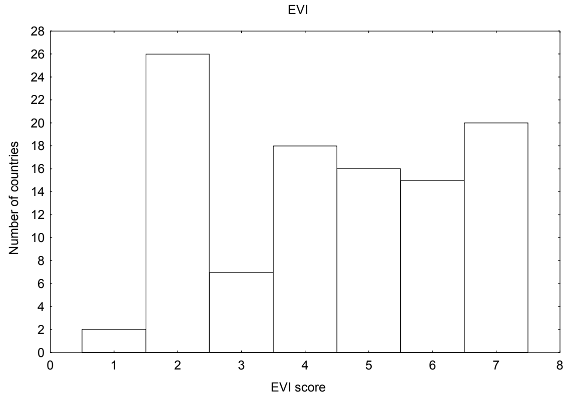


Table 32.2: Proposed EVI scaling for intensity of pesticide use showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for LN(X+1) intensity	Observed # countries	Observed % of countries
1	X=0	2	1.92
2	0<X≤0.5	26	25.00
3	0.5<X≤1	7	6.73
4	1<X≤2	18	17.31
5	2<X≤3	16	15.38
6	3<X≤4	15	14.42
7	X>4	20	19.23
No data		131	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 32.3: Proposed EVI scaling for intensity of pesticide use showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) intensity	Equivalent scale in $kg/yr/km^2$	Examples
EVI=1	X=0	X=0	Cook Is., Tuvalu
EVI=2	0<X≤0.5	0<X≤0.65	Angola, Ethiopia, Nepal
EVI=3	0.5<X≤1	0.65<X≤1.72	Gambia, Indonesia, Sudan
EVI=4	1<X≤2	1.72<X≤6.39	Egypt, Norway, Suriname
EVI=5	2<X≤3	6.39<X≤19.09	Brazil, Pakistan, Oman
EVI=6	3<X≤4	19.09≤53.60	Austria, Colombia, India
EVI=7	X>4	X>53.60	Italy, Sri Lanka, Romania

32.5 Age, completeness and quality of the data

The data obtained for this indicator were mostly from WRI 2000-2001, with some additional data from OECD 1999, and in-country sources. In-country data were available for 14 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 32.4).

Table 32.4: Characteristics of age, completeness and quality of the data obtained for pesticide use.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.21	2.43	2.50
Valid n (in-country)	14	14	14
SD (in-country)	0.58	0.76	0.76
SE (in-country)	0.15	0.20	0.20

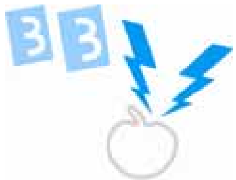
32.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

32.7 Additional sources & contacts

www.reports.eea.eu.int/ (2/06/2001) (Greece); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; OECD 1999, pp 280-281; Cook Islands - Cook Islands Customs Imports Entries. Extract from Trade Database – Imports. Cook Islands Statistics Office; Costa Rica - Observatorio del desarrollo / San José, COSTA RICA, 2001; Fiji - Bureau of Statistics. Contact - Jone Feresi (384233)- Department of Agriculture; Kiribati - Internal data (copies of invoices from divisional files). Contact - Manate Tenang (686 28109 or 28108) Agriculture Division; Kyrgyzstan - Department of chemicalixation and plant protection. Contact - Mrs. Malyutina L.V. Mr. Katarov V.M.; Marshall Islands - Contact - Laura Farm. Agriculture & Quarantine; Nepal - Office records. Ministry of Agriculture and Co operatives. Assistant Agro-Economist, Pradhyumna Rej Pandey, Phone +1 223441; Niue - Niue Department of Fisheries, Forestry and Agriculture (DAFF). Contact - Sauni Tongatule (4032/ 4079/ director.agriculture@mail.gov.nu); Palau - Environmental Quality Protection Board (EQPB) Kashgar Rengulbai (680 4882504/ 4881475/ DAMR@palaunet.com) – Agriculture; Samoa - Agriculture Store Corp. & Farm Supplies Ltd. FAO Questionnaire; Pesticides Technical Committee, 1999. Agriculture; St Lucia - Compendium of Environmental statistics. Road transport division, ministry of communications, works, transport and pub. Utilities; Thailand - State of Environment Report 1998 by Office of Environmental Policy and Planning. Center of Agricultural Statistics, Office of Agricultural Economics, Ministry of Agricultural Cooperatives; Tuvalu - Contact - Itaia Lausaveve - Agriculture Department; Vanuatu - Alan Sands - Vanuatu Agricultural Supplies.

33. BIOTECHNOLOGY



33.1 Indicator Summary

Indicator number:	33
Indicator short name:	Biotechnology
Sub-index	REI
Categorisation	Resources & services
Indicator text:	Cumulative number of deliberate field trials of genetically modified organisms conducted in the country since 1986.
Signals captured:	This indicator captures the risk to genetic diversity, genetic pollution and unpredictable ecosystem effects of introducing incompletely tested and/or unpredictable bioengineered organisms into the environment. This includes new toxin-producing organisms, terminators (the use of deliberately sterile organisms is often used as a biological control method for pests) or organisms with new ecological behaviours. This indicator operates under the precautionary principle. The effects of releasing organisms developed under laboratory conditions into the environment are unknown until they are tested in the environment. We have used data on deliberate field trials of GMOs for this indicator. It is likely that the risks of GMOs are less dependent on the *area* used, and more dependent on the *different types* of GMOs being either tested or grown. That is, we see risk increasing more with exposure to increasing numbers of GMOs, rather than the number of instances of any one type because of the capacity to spread once a gene 'escapes'. Although operating at the genetic rather than species level, we see some of the risks of GMOs to ecosystems as being similar to those associated with introduced species.
Notes on this indicator:	1. Although the number of deliberate field trials of GMOs does correlate with the size of countries, we did not convert this indicator to a density over the land area of a country. GMOs are considered capable of spreading once released into the field and we considered that the number of trials, particularly of different organisms would be a better measure of the risks involved in introducing new genetic materials into the environment. 2. ISAAA data show most countries with a zero value, while the remaining data sources show many of these with no data. For this evaluation of the EVI we have used the zero values provided by ISAAA. 3. Field trials can include several instances of a single GMO type. 4. Any kind of GMO is included.
Are suitable data available?	Yes, but only for a limited number of countries.
Sources of data:	• OECD Sept 2000 database http://www1.oecd.org/ehs/table.htm • ISAAA International Services for the acquisition of agribiotech applications, 1997, 2002 http://www.isaaa.org/kc/ • BINAS http://binas.unido.org/binas/trials.php3 • BIOTECH 1991-1999 http://biotech.jrc.it/ • Information Systems for Biotechnology (ISB), 2002; http://www.nbiap.vt.edu/ • In-country
No. countries included in test:	235 of 235

Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	4 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were considered good (value of 3 of 3).	
Basic units:	Cumulative number of deliberate field trials of GMOs in countries 1996-2000.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	Not used
	EVI Score = 3	Not used
	EVI Score = 4	Not used
	EVI Score = 5	0<X≤20
	EVI Score = 6	20<X≤50
	EVI Score = 7	X>50
	NA (not applicable)	☒ May not be used.
	ND (no data)	☑ May be used
Future work on this indicator:	Data need to be updated and expanded to cover all countries.	

33.2 Description of raw data

The raw data for this indicator are comprised of the cumulative total number of deliberate GM field trials in countries between 1986 and 2002. Data cover a range of organisms, including plants, bacteria, fungi, viruses (but is not limited to them should any new types be introduced) and are derived from a range of sources (see listing above). The greater the cumulative number of trials of GMOs in a country, the greater is the risk of genetic escape and unpredictable effects on ecosystems. Of the 235 countries examined, these data were available for all, with most countries having zero by 2002.

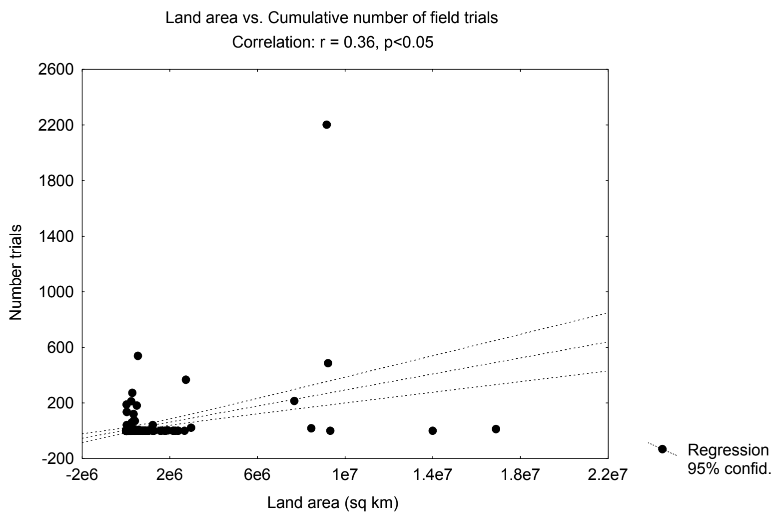
The cumulative number of field trials of GMOs in countries between 1986-2002 varied between 0 and more than 2,200 (Table 33.1). Fifteen of the countries for which we have data have not had any field trials, including Kiribati, Luxembourg and Singapore. The greatest numbers of cumulative trials of GMOs were recorded in USA, France and Canada. The mean value across the globe was a total of 111 trials per country. Half of the countries examined carried out 5.5 trails between 1986-2000, or less (the median). Variance among countries was moderately high, with a standard deviation that is around 3 times the mean.

The cumulative number of deliberate GMO field trials is correlated with the size of a country (Figure 33.1). Since the risks associated with GMOs are more related to the number of new types that could result in ecological impacts, rather than the density of trials, we did not express this indicator as a density function.

Table 33.1: Basic statistics for biotechnology - GMO trials. Data are from a range of sources and are cumulative totals for years 1986-2000.

Statistic	Deliberate field trials
Mean	22.74
Median	0.00
Valid n	235
Min	0
Max	2202
SD	155.70
SE	10.15
Skewness	12.17
SE Skewness	0.16
Kurtosis	166.26
SE Kurtosis	0.32

Figure 33.1: Graph of cumulative number of GMO field trials vs. size of countries (km^2). The correlation is significant at p=0.05.



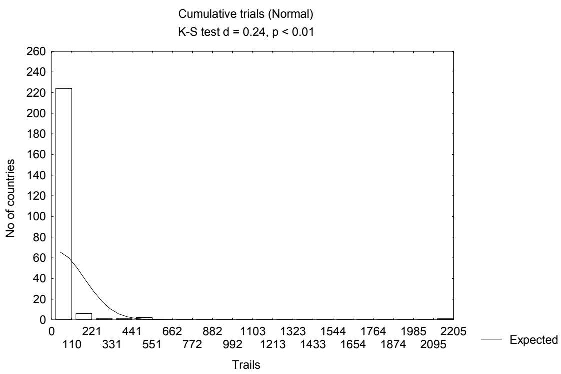
33.3 Distributional characteristics of the indicator data

The number of GMO field trials in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 33.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

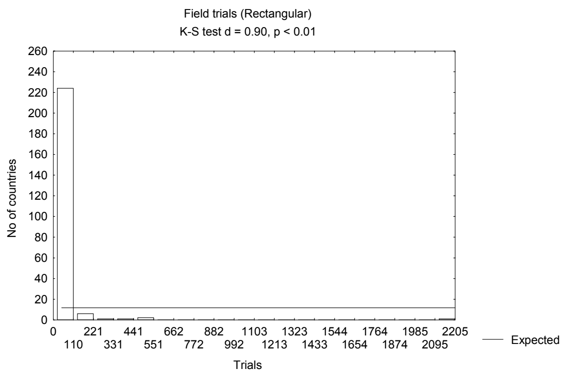
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 33.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 33.2: Kolmogorov-Smirnov goodness-of-fit tests for GMO field trials in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

(a)



(b)



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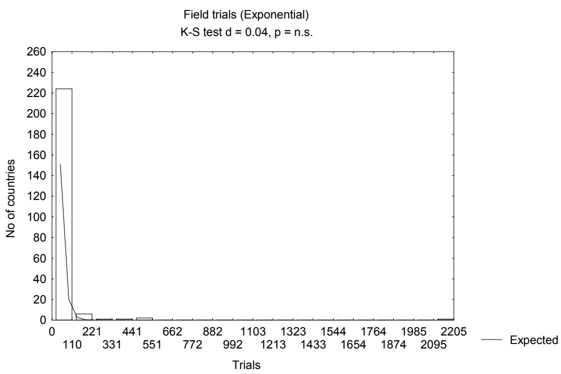

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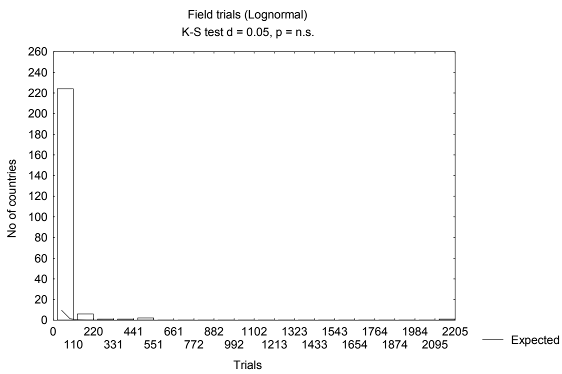


33.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in cumulative total number of GMO field trials by three orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be used in their raw form, with countries having the highest cumulative exposure to novel organisms being considered more vulnerable and attracting a higher EVI score. We identified those countries with no GMO field trials as the ones likely to be at low risk of environmental damage (but not zero because of transboundary and/or accidental releases) (EVI=1). Countries with between 0 and ≤ 20 GMO field trials between 1986 and 2002 were given an EVI score of 5, with the EVI scores of 2-4 not being used for this indicator. We consider the uncontrolled and unknown risks of releasing GMOs into the environment great enough that even low levels of exposure should attract an EVI score that indicates high environmental vulnerability. Countries with greater than 20, but ≤ 50 GMO trials were given an EVI score of 6, and greater cumulative totals an EVI score of 7 (Figure 33.3, Table 33.2, 33.3). We propose that in future evaluations of the EVI, this same scaling should be used, with increasing cumulative total GMO field trials being tested against these same criteria.

Figure 33.3: Frequency distribution of GMO field trials in (a) 7 even categories and (b) the EVI scale.

(a) (b)

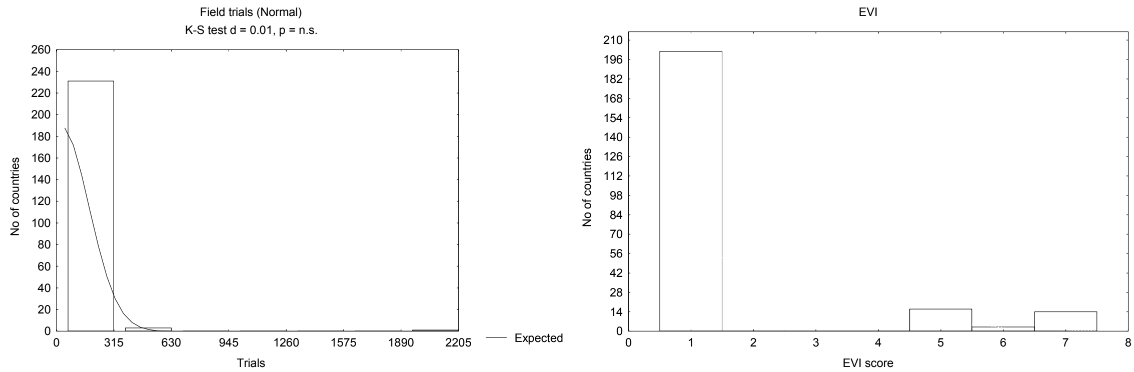


Table 33.2: Proposed EVI scaling for GMO field trials showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	No of GMO field trials	Observed # countries	Observed % of countries
1	X=0	202	85.96
2	Not used		
3	Not used		
4	Not used		
5	0<X≤20	16	6.81
6	20<X≤50	3	1.28
7	X>50	14	5.96
No data		0	0
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 33.3: Proposed EVI scaling for GMO field trials showing examples of countries that fell into each of the EVI scores.

Score	No of GMO field trials	Examples
EVI=1	X=0	Cook Islands, Singapore, Tonga
EVI=2	Not used	
EVI=3	Not used	
EVI=4	Not used	
EVI=5	0<X≤20	Austria, Brazil, Norway
EVI=6	20<X≤50	Denmark, India, South Africa
EVI=7	X>50	Netherlands, Sweden, USA

33.5 Age, completeness and quality of the data

The data obtained for this indicator were from a range of sources and need to be updated for all countries. Estimates of the quality of in-country data were available for only 3 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 33.4).

Table 33.4: Characteristics of age, completeness and quality of the in-country data.

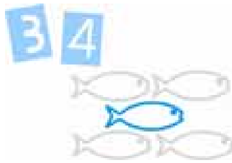
Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	3	3	3
Valid n (in-country)	4	4	4
SD (in-country)	0	0	0
SE (in-country)	0	0	0

33.6 Variations among sources of data

Data for this indicator are patchy and derived from several sources. Alternative appropriate sources of data are not at present available for this indicator.

33.7 Additional sources & contacts

www1.oecd.org/ehs/table.htm (Sept 2000); www.isaac.org/kc/Global_Status/global/Europe/trialist.htm (International Services for the acquisition of Agribiotech Applications) (09/01/03); www.binas.unido.org/binas/trials.php3 (08/01/03); BIOTECH 1991-1999 http://biotech.jrc.it/ (08/01/03); Information Systems for Biotechnology (ISB), 2002; http://www.nbiap.vt.edu/ (29/01/03); Costa Rica - Consejo Asesor de Degradación de Tierras (CADETI), 2002; Kyrgyzstan - Resolution of the Govt. #364; Singapore - Source - Agri-Food & Veterinary Authority of Singapore. Contact - Koay Sim Huat, Head International Affairs Division (63257638 /62206068 / koay_sim_huat@ava.gov.sg); St Lucia - Compendium of Environmental statistics. Road transport division, ministry of communications, works, transport and pub. Utilities.



34. PRODUCTIVITY OVERFISHING

34.1 Indicator Summary

Indicator number:	34
Indicator short name:	Productivity overfishing
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	Average Ratio of Productivity : Fisheries Catch (tonnes Carbon/sqkm of EEZ/year) : (tonnes/sqkm Shelf area/year) over the last 5 years
Signals captured:	This indicator captures the risk of damage to fisheries stocks by examining rates of extraction in relation to the potential for the environment to replenish those stocks (productivity). We term this "ecological overfishing" or fishing beyond the capacity of the environment to replenish stocks through primary production and biomass transfer. If the catch is high and productivity low, there is a higher risk that overall fisheries stocks can be depleted (all other factors being equal) than if the converse were the case. This indicator should be read in combination with Indicator 39 which focuses on catch per human effort. The effects of ecological overfishing would be especially important if there are interactions with other on-going human and natural impacts. A small P:C ratio means greater vulnerability of fisheries.
Notes on this indicator:	1. This indicator does not measure overfishing of individual stocks in a country. Individual stocks may be highly vulnerable even where the overall biomass extracted is not high in relation to productivity. A low EVI score coupled with the loss of certain stocks may suggest that effort is too focused in a country and suggests investigations. 2. This indicator has been revised to better capture the rate of catch in relation to the ability of the environment to replenish the catch. 3. The previous text for this indicator was: "Percent of fisheries stocks over-fished (FAO definitions)". Although there are some FAO references to the state of the world's fisheries, which discuss the state of stocks, these data are not generally available for individual countries. 4. Tonnages on fisheries catch production were available from FAO for the years 1993 and 1998. We averaged the most recent 5 years (1994-1998). 5. Data on productivity were obtained from University of British Colombia (UBC). http://saup.fisheries.ubc.ca/eez/eez.aspx 6. Area of shelf was used as the density denominator for fisheries catches, but excludes lakes and other freshwater fisheries. These should be added. 7. Data on catches needs to consider whether they arise from within the country's EEZ, or outside.
Are suitable data available?	Yes. Data on productivity and catches should be expanded to include freshwaters. Landlocked countries are currently excluded as a result. Catches need clarification on what is caught within a country's waters, in contrast to what the fleet may catch outside.
Sources of data:	• FAO 1993-1998 data (fisheries) • UBC (productivity)

	• In-country (not used)
No. countries included in test:	171 of 235
Temporary modifications to data or indicator, if applicable:	• None.
Notes on data age, completeness and quality:	14 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).
Basic units:	Fisheries catch in relation to productivity as the Productivity : Catch ratio. The greater the catch (t/sqkm EEZ/yr) in relation to productivity (t/sqkm shelf/yr) the more vulnerable the country to overfishing.
Recommended transforms:	• Data transformed to LN(X)

Proposed EVI Scale	EVI Score = 1	X>15
	EVI Score = 2	14<X≤15
	EVI Score = 3	13<X≤14
	EVI Score = 4	12<X≤13
	EVI Score = 5	11<X≤12
	EVI Score = 6	10<X≤11
	EVI Score = 7	X≤10
	NA (not applicable)	☑ May be used for countries which do not have fisheries
	ND (no data)	☑ May be used
Future work on this indicator:	Data on productivity of fishing waters is required for this indicator. Catches from outside a country's EEZ need to be removed from the data and added to the statistics for the nations used as fishing grounds.	

34.2 Description of raw data

The raw data for this indicator are comprised of the annual fisheries catches in a country (tonnes) from FAO for the years 1994-1998, which are averaged over years and divided by the shelf area (km^2) (tonnes/km^2/year). Values of productivity provided as grams of Carbon fixed / m^2 / day from UBC were converted to tonnes/km^2/year and divided by catch to create a dimensionless Productivity : Catch ratio (P:C). The indicator targets the amount of fisheries catches in relation to the ability of the aquatic ecosystems to replenish them, attempting to identify countries which may be engaging in ecological overfishing. If the catches are large in relation to productivity, it is expected that countries will tend to be more vulnerable to overfishing than those with a higher P:C ratio. We have used this indicator because data on maximum sustainable yields and status of stocks are generally unavailable. Of the 235 countries examined, these proxy data were available for 171.

The mean annual fisheries catch production between 1994 and 1998 varied between 3 tonnes and 31.2 million tonnes (Table 34.1). The lowest values were recorded in Monaco, Pitcairn and Lesotho, and the highest values were recorded in Japan, Peru and China. The mean value across the globe was 548,857 tonnes per year, and half of the countries examined caught 21,903 per year or less (the median) (Table 34.1). Variance among countries is high, with a standard deviation that is around 4.4 times the mean.

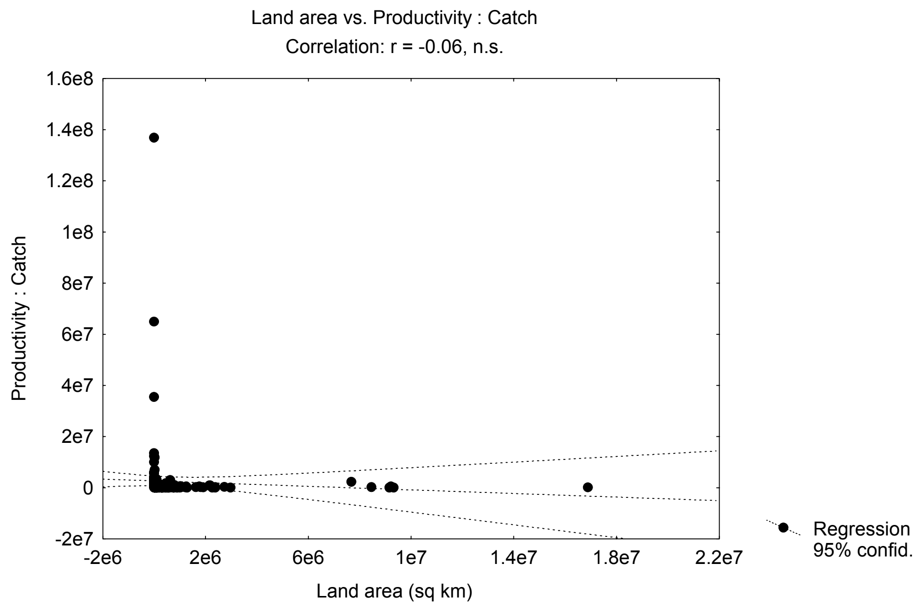
The fisheries catch production is correlated with the size of a country. The risks associated with overfishing from an ecological perspective are related to the amount of fisheries catch and the ability of the environment to produce them, either as area of fisheries-supporting ecosystems or productivity. From the utilisation side, overfishing also relates to the amount of effort being expended by humans (but see Indicator 39) and a range of other ecological and biological factors. We chose to use shelf are (UBC data) as the denominator required to make rates of catch comparable among countries as catch density. These data are expressed as tonnes of fisheries catches per year per square kilometre of shelf area around the country, despite the fact that catches includes oceanic, coastal and freshwater fisheries. Catches may also include or exclude tonnages collected by or from other countries. In future collections of data for this indicator, we will include catches by distant water nations and exclude catches collected from other countries from these data.

The P:C ratio varied between 350 and 136.8 million (Table 34.1). A small P:C ratio indicates that overall catches are large in relation to the amount of biomass primary production, and that such countries are vulnerable to ecological overfishing. The country with the lowest P:C ratio, and therefore highest catches in relation to productivity (and greatest vulnerability) is Slovenia, followed by Peru and Iraq. The highest P:C ratios were recorded in Monaco, Pitcairn and Marshall Islands. The P:C ratio was not significantly correlated with country size (Figure 34.1).

Table 34.1: Basic statistics for fisheries catch production and Productivity:Catch ratio. Data are from FAO and cover years 1994-1998.

Statistic	Fisheries catch Mean tonnes / year (1994-1998)	Productivity: Catch Ratio	LN (X) P:C
Mean	548,857	2,419,068	12.66
Median	21,903	290,728	12.58
Valid n	211	171	171
Min	3	349.26	5.86
Max	31,276,470	136,845,800	18.73
SD	2,418,075	11,909,973	1.87
SE	166,467	910,778.4	0.14
Skewness	10.31	9.56	0.15
SE Skewness	0.17	0.19	0.19
Kurtosis	125.92	100.85	0.79
SE Kurtosis	0.33	0.37	0.37

Figure 34.1: Productivity : Catch ratio vs. size of countries.



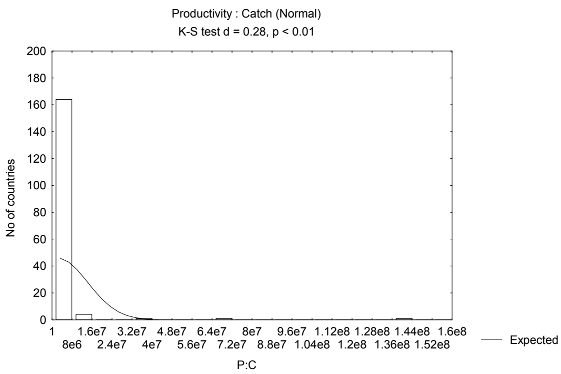
34.3 Distributional characteristics of the indicator data

The P:C ratios were plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 34.2). This resulted in a distribution that was heavily skewed at the lower end of the linear scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

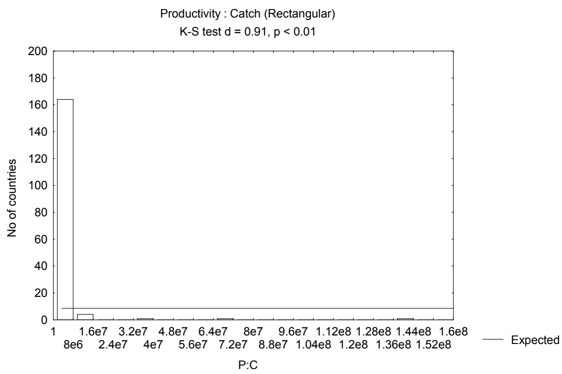
A significant difference between observed and expected values was found in the normal and rectangular distributions, while the exponential and lognormal distributions did not differ significantly from the observed data (Figure 34.2). This suggests that transforming the values to their root or natural logarithm might provide a better scale for comparison and provide better spread among countries.

Figure 34.2: Kolmogorov-Smirnov goodness-of-fit tests for P:C ratios in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions were the best fit of the observed data.

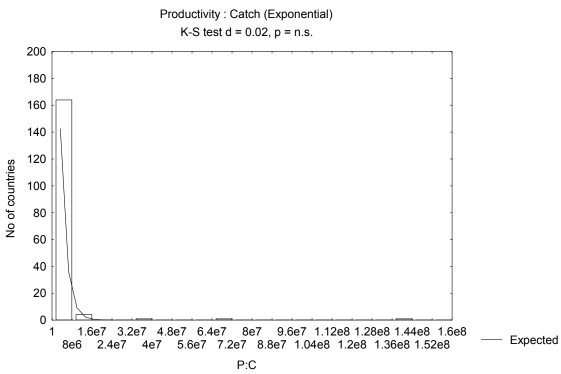
(a)



(b)



(c)



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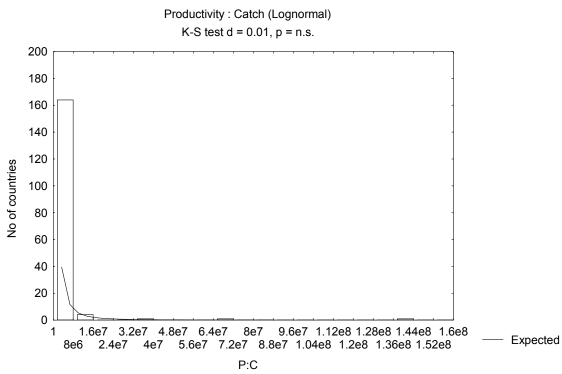


34.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in P:C ratios by six orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms, LN(X), for this indicator to provide better spread among the countries and compress the scale to values of between 5 and 20. Countries having the lowest P:C ratios would be considered more vulnerable to overfishing and would attract a higher EVI score. We identified those countries with >15 on the transformed LN(X) scale as likely to be the least at risk of environmental damage because the tonnages caught are small in relation to the area available for fishing and the primary production in surrounding waters (EVI score = 1). We suggest that at least a four-orders-of-magnitude greater primary production of biomass is needed to support each tonne of biomass extracted in fisheries to allow for biomass transfer to at least 3 trophic levels. Countries with ≤10 on the transformed scale were considered the most vulnerable (EVI score =7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 34.3, Table 34.2, 34.3).

Figure 34.3: Frequency distribution of LN(X) P:C ratios in even categories and the proposed EVI scale. (a) Frequency distribution of LN(X) P:C ratios in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the proposed EVI scale.

(a) (b)

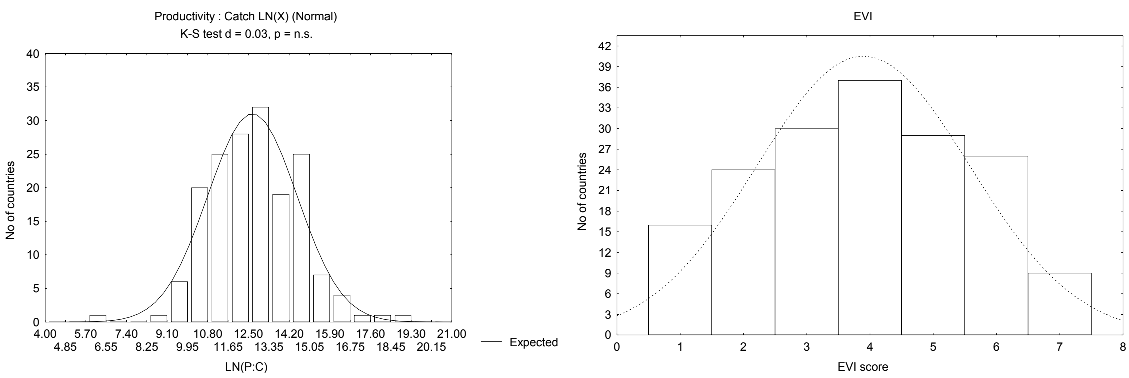


Table 34.2: Proposed EVI scaling for P:C ratios showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X>15	16	9.36
2	14<X≤15	24	14.04
3	13<X≤14	30	17.54
4	12<X≤13	37	21.64
5	11<X≤12	29	16.96
6	10<X≤11	26	15.20
7	X≤10	9	5.26
No data		64	37.43
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 34.3: Proposed EVI scaling for Indicator 24 on ecological overfishing showing equivalence on the LN(X) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X) Productivity: Catch	Equivalent scale P:C	Examples
EVI=1	X>15	X>3,269,017	Cayman Is., Marshall Is., Pitcairn
EVI=2	14<X≤15	1,202,604<X≤3,269,017	Seychelles, Somalia, Tonga
EVI=3	13<X≤14	442,413<X≤1,202,604	Albania, Haiti, Jamaica
EVI=4	12<X≤13	162,754<X≤442,413	Argentina, Croatia, St, Lucia
EVI=5	11<X≤12	59,874<X≤162,754	Guadeloupe, Pakistan, Singapore
EVI=6	10<X≤11	22,026<X≤ 59,874	Denmark, Poland, Togo
EVI=7	X≤10	X≤22,026	Chile, Iraq, Thailand

34.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

34.6 Age, completeness and quality of the data

The data obtained for this indicator were from FAO for the years 1994-1998. The data are not ideal for the purposes of the indicator because they are dated (it would be better to cover the most recent 5 years). The productivity measures cover the entire EEZ and do not cover freshwater areas, part of the fisheries of many countries. This particularly omits landlocked countries that do not have EEZs and therefore could not be evaluated here.

In-country data were available for 14 of the 32 collaborating countries, with data being of good age, completeness and quality (all >2 of 3) (Table 34.4). These were not used for the purposes of this demonstration EVI because they covered different year ranges.

Table 34.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.29	2.23	2.14
Valid n (in-country)	14	13	14
SD (in-country)	0.73	0.60	0.95
SE (in-country)	0.19	0.17	0.25

34.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

34.8 Additional sources & contacts

www.oae.go.th/statistic/yearbook/1998-99/ (Thailand); Cook Islands - Research & Economic Development (RED), Ministry of Marine Resources (MMR). Contact - Ian Bertram. MMR; Federated States of Micronesia - Department of Marine Development, Pohnpei State. Contact - Donald David. Department of Marine Development/ Head of Department; Fiji - 1994 Cabinet Paper “Fisheries Annual Report”. Fisheries Department; Kiribati - Internal information from Fisheries Division Tanaea. Fisheries Statistics Unit. Contact - T Tebaitongo. Fisheries Division Tanaea; Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Contact - Mr. Anarbekov Ruslan. Marine environment division / Deputy Director; Nauru - Nauru Fisheries and Marine Resources Authority(NFMRA). Contact - Peter Jacob (674 4443733/ 4443812/ peterjacob_nfmra@hotmail.com); Nepal - Country profile – Nepal 1999/2000. Directorate of Fisheries development, Balaju, Kathmandu; New Zealand - Fisheries assessment plenary’s, research reports (various), returns from fisheries, electronic databases. Contact - Daniel Druce, Policy analyst, fisheries planning and co-ordination, ministry of fisheries, P O Box 1020, Wellington, New Zealand: E.Mail druced@fish.govt.nz ; Niue - A)

Fisheries Resources Survey of the island of Niue, 1993. SPC. B)Niue 1999 Pelagic Fisheries Assessment; Palau - Contact - Theo Isamu (680 4885722/ 4883125/ theodmr@palaunet.com) Division of Marine Resources; Papua New Guinea - Status of Coral Reef Fisheries – Statistics, Fishing-gears and Impacts. Chapter 4. Anas, A; Kumoru, L. and Lokani, P. (Live Reef Fish Section); Samoa - A) Annual Report 1997/1998. Fisheries Division. B) An Assessment of the Subsistence and Artisanal Inshore Fisheries on Savaii, Western Samoa. 1997. Based on the Households Interview Questionnaire and Fishers Creel Surveys undertaken in 1990-91 and 1996-97. M. App. Sc. Thesis. Mulipola, A. P.; Thailand - Amnual Kongprom et al. (2000) Draft the Status of Demesal Fishery Resources of the Gulf of Thailand; Tonga - A) Report of the Minister for Fisheries for the Year 1997. Government of Tonga. B) Report of the Minister for Fisheries for the Year 1998. Government of Tonga. C) Summary of Activities and Recommendations of SPC/ Tonga Ministry of Fisheries aquarium-fish management project (May 6-24, 1996). D) Biological Survey and Management of Mullet Resource in Tonga. 1995. Res. Bull. Tonga; Tuvalu - Sautia Maluofenua. Fisheries Department.

35. FISHING EFFORT

35.1 Indicator Summary

Indicator number:	35
Indicator short name:	Fishing effort
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	Average annual number of fishers per kilometre of coastline over the last 5 years.
Signals captured:	This indicator captures the risk of damage to fisheries stocks through overcapacity of human effort. In this indicator we have tried to capture all fishers, not just the commercial fleet. Countries with large densities of fishers working their coastlines, including freshwater coasts such as lakes, are more likely to overfish their resources than those with lower densities. This indicator should be read in combination with Indicator 24, which focuses on ecological overfishing. The effects of overfishing would be especially important if there are interactions with other on-going human and natural impacts.
Notes on this indicator:	1. This indicator has been revised to better capture the fishing pressure in a country. 2. Data on changes in catch per unit of effort (CPUE) over time, say percent change over 5 years, would be ideal for this indicator, but we were unable to find appropriate data to detect changes in CPUE. 3. Data on number of fishers is from WRI 2000-2001 but only incompletely covers years 1994-1996 (i.e. some years missing for most countries). 4. Numbers of fishers are available for landlocked countries, where the length of coastline is sometimes recorded as zero (see Indicator 11). In the future, lengths of lake coastlines and length of rivers may need to be added where this has been omitted for some countries, to allow for the calculation of values for this indicator.
Are suitable data available?	Yes, but not for all years and countries. The lengths of non-marine coastlines are not complete.
Sources of data:	• WRI 2000-2001 • In-country (not used)
No. countries included in test:	97 of 235
Temporary modifications to data or indicator, if applicable:	• Some landlocked countries have been omitted because no estimates of their non-maritime coastlines are available. Non-maritime coasts are also missing for countries that have marine coastlines.
Notes on data age, completeness and quality:	15 of the 32 collaborating countries returned data for this indicator, but only for the discarded form of the indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).
Basic units:	Density of fishers as mean annual number of fishers per km of coastline (last 5 years).
Recommended transforms:	• Data transformed to LN(X+1)

Proposed EVI Scale	EVI Score = 1	X≤2
	EVI Score = 2	2<X≤2.5
	EVI Score = 3	2.5<X≤3
	EVI Score = 4	3<X≤3.5
	EVI Score = 5	3.5<X≤4
	EVI Score = 6	4<X≤4.5
	EVI Score = 7	X>4.5
	NA (not applicable)	☑ May be used for (rare) countries which do not have fisheries
	ND (no data)	☑ May be used
Future work on this indicator:	More recent and complete data are needed. Investigations on the use of area of territorial waters and area of lakes as denominator may be needed.	

35.2 Description of raw data

The raw data for this indicator are comprised of the mean number of fishers operating in a country from WRI 2000-2001 for the years 1994-1996. These values are averaged over the three years and divided by the total length of shorelines (maritime + lake coasts, where available) in kilometres. The indicator targets the pressure on fisheries resources in terms of numbers of people accessing them, including commercial and non-commercial operators. This indicator focuses on the human side of overfishing and complements the information in Indicator 24 on ecological overfishing (capacity of the environment to replenish stocks). If the density of fishers operating in a country is large, it is expected that countries will be vulnerable to overfishing and any downstream effects of habitat-disruption and loss of key ecosystem determinants. We have used the number of fishers rather than fleet size because we acknowledge that in many countries it is informal fishing that may be dominant. Of the 235 countries examined, these data were available for 97.

The mean annual number of fishers operating in countries between 1994 and 1996 varied between 154 and over 12 million (Table 35.1). The lowest values were recorded in Kyrgyzstan, Slovenia and Switzerland, and the highest values were recorded in Indonesia, India and China. The mean value across the globe was 298,944 fishers, and half of the countries examined have 16,722 fishers operating in their waters, or less (the median). Variance among countries is high, with a standard deviation which is around 4.5 times the mean.

The number of fishers operating is correlated with the size of a country, but not the total length of its shorelines (Figure 35.1 a & c). The risks associated with overfishing is related to the amount of effort being expended by humans and a range of other ecological and biological factors (see also Indicator 34). To make an estimate of the human effort comparable among countries, we chose to calculate the density of fishers operating in a country using length of coastlines as the denominator. These data are expressed as mean number of fishers operating per kilometre of coasts in the country (averaged over years).

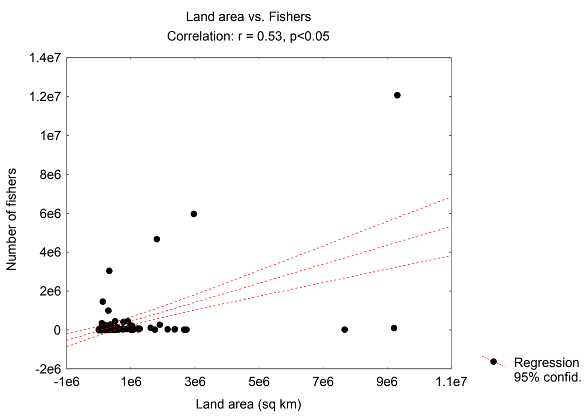
The density of fishers is correlated with the size of a country, but not with the length of its coastlines (Figure 35.1 b & d). The maximum density of fishers was observed in Bangladesh, China and India, with over 400 fishers operating / year / km coastline between 1994 and 1996. The minimum densities of fishers were recorded in Sweden, New Zealand and Finland.

Table 35.1: Basic statistics for number and density of fishers. Data are from WRI 2000-2001 1994-1996.

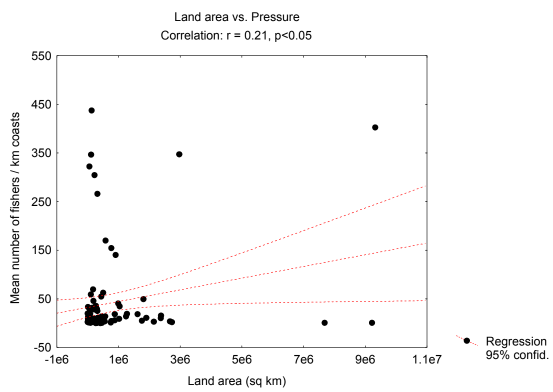
Statistic	Mean number of fishers (average of 94-96)	Density of fishers Mean number of fishers / km coast	LN(X+1) Density of fishers
Mean	298,944	41.46	2.45
Median	16,722	8.89	2.29
Valid n	113	97	97
Min	154	0.12	0.12
Max	12,076,192	437.07	6.08
SD	1,357,803	91.35	1.49
SE	127,731	9.27	0.15
Skewness	6.97	3.05	0.70
SE Skewness	0.23	0.24	0.24
Kurtosis	54.25	8.52	0.04
SE Kurtosis	0.45	0.49	0.49

Figure 35.1: Graphs of number and density of fishers vs. size of countries. (a) Number of fishers vs. size of country (km²); and (b) Density of fishers (number / year / km coasts) vs. size of country (km²); (c) Number of fishers vs. length of coastline; and (d) Density of fishers vs. length of coastline. The correlation is significant in (a) and (b) and not significant in (c) and (d).

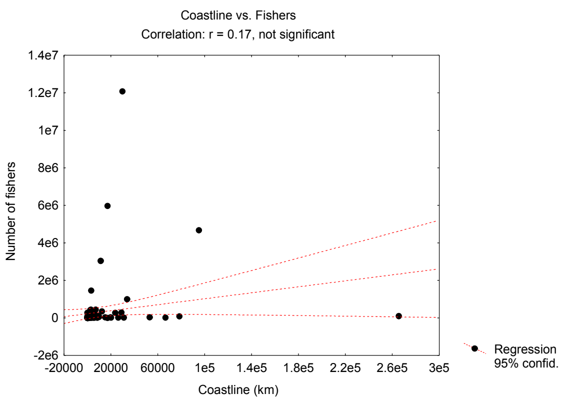
(a)



(b)



(c)



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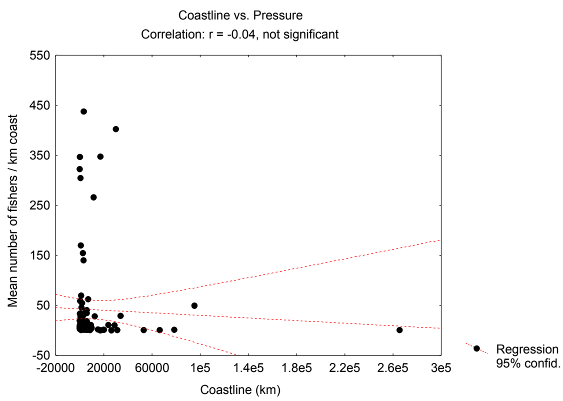


35.3 Distributional characteristics of the indicator data

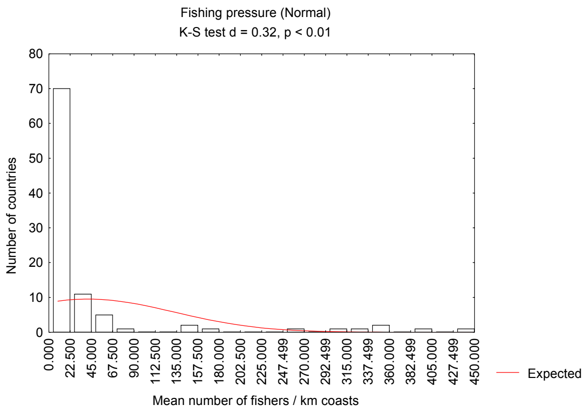
The density of fishers operating in a country was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 35.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function).

Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

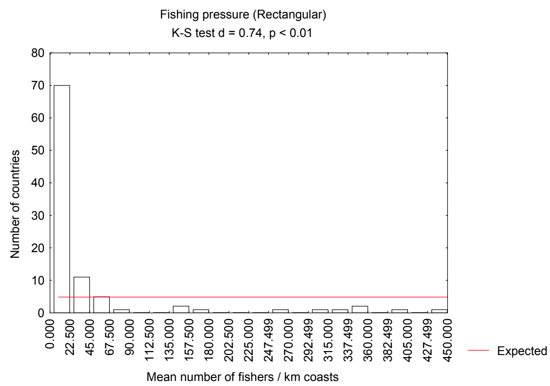
A significant difference between observed and expected values was found in all distributions except the lognormal (Figure 35.2). This suggests that transforming the values to their natural logarithm might provide a better scale for comparison, allowing for better differentiation among countries at the lower end of the scale.

Figure 35.2: Kolmogorov-Smirnov goodness-of-fit tests for density of fishers in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution was the best fit of the observed data.

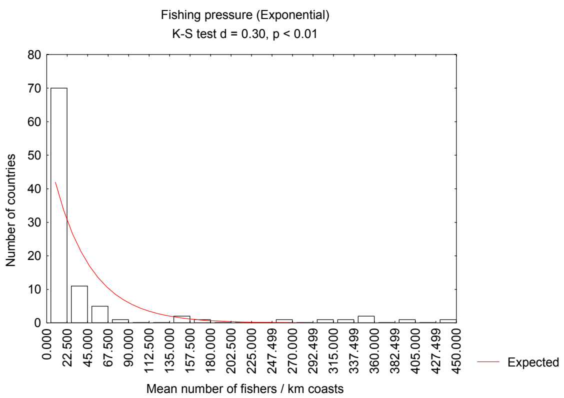
(a)



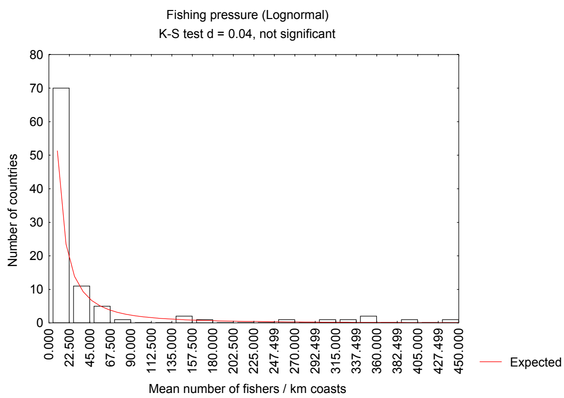
(b)



(c)



(d)



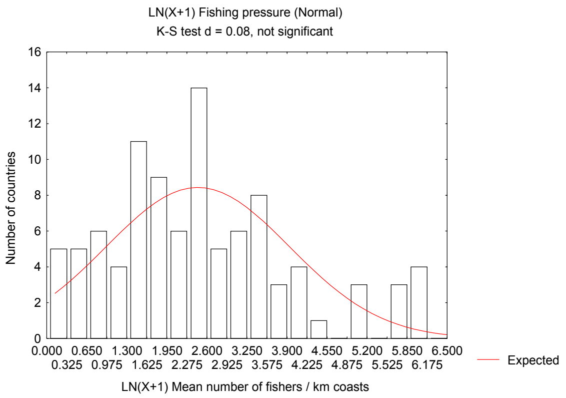
35.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in the density of fishers by five orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries and compress the scale to between 0.12 and 6.08. Countries with the greatest number of fishers per km of coastline would be considered more vulnerable to overfishing and would attract a higher EVI score. We identified those countries with a value of ≤ 2 on the transformed LN(X+1) scale as likely to be the least at risk of environmental damage because the number of people fishing is small in relation to the length of coastlines, and hence ecosystems available to support the fisheries (< 6.39

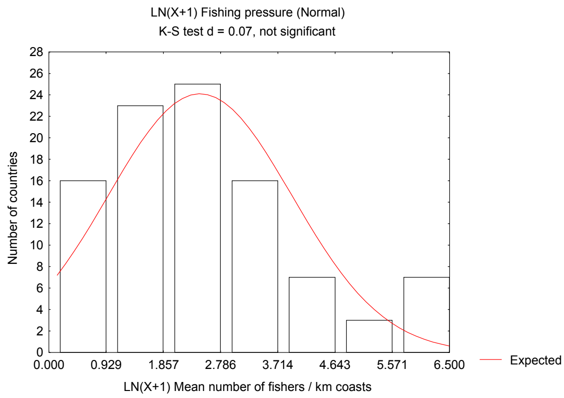
fishers / year / km coast, EVI score = 1). Countries with > 4.5 on the transformed scale (>89 fishers / year / km coast) were considered the most vulnerable (EVI score =7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 35.3, Table 35.2, 35.3).

Figure 35.3: Frequency distribution of LN(X+1) density of fishers in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) The same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) density of fishers in seven uneven categories which clump countries with higher values, identifying them as being at the highest risk. (d) The proposed EVI scale.

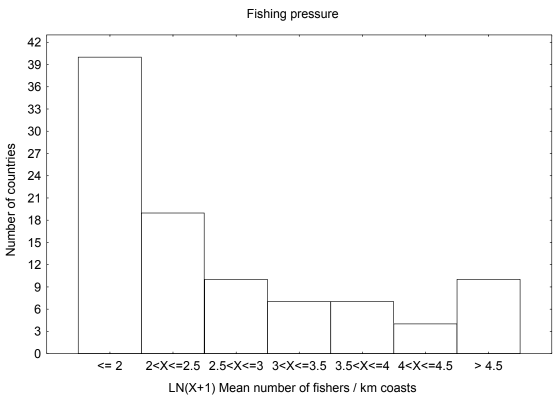
(a)



(b)



(c)



(d)

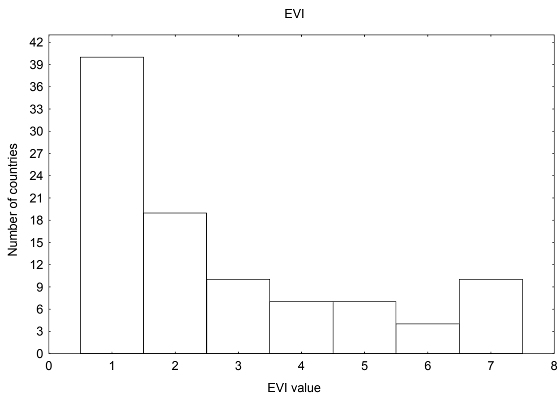


Table 35.2: Proposed EVI scaling for density of fishers showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X≤2	40	41.24
2	2<X≤2.5	19	19.59
3	2.5<X≤3	10	10.31
4	3<X≤3.5	7	7.22
5	3.5<X≤4	7	7.22
6	4<X≤4.5	4	4.12
7	X>4.5	10	10.31
No data		138	142.27
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 35.3: Proposed EVI scaling for Indicator 35 on fishing pressure showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Density of intensive farming	Equivalent scale tonnes / year / sq km	Examples
EVI=1	X≤2	X ≤ 6.39	Albania, Australia, Panama
EVI=2	2<X≤2.5	6.39 < X ≤ 11.18	Croatia, Mexico, Yugoslavia
EVI=3	2.5<X≤3	11.18 < X ≤ 19.09	Cameroon, Spain, Kenya
EVI=4	3<X≤3.5	19.09 < X ≤ 32.12	Sri Lanka, Romania, Trinidad & Tobago
EVI=5	3.5<X≤4	32.12 < X ≤ 53.60	Indonesia, Senegal, Egypt
EVI=6	4<X≤4.5	53.60 < X ≤ 89.02	Cambodia, Macedonia, Morocco
EVI=7	X>4.5	X > 89.02	Bangladesh, Benin, India

35.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

35.6 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 for the years 1994-1996. The data are dated, incomplete and do not cover the 5 year span required (last 5 years).

In-country data were available for 15 of the 32 collaborating countries, with data being of good age, completeness and quality (all ≥2 of 3) (Table 35.4). These were not used in these calculations because they were collected for the old form of the indicator.

Table 35.4: Characteristics of age, completeness and quality of the data obtained for fishing effort.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	2.29	2.27
Valid n (in-country)	14	14	15
SD (in-country)	0.39	0.61	0.88
SE (in-country)	0.10	0.16	0.23

35.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

35.8 Additional sources & contacts

www.apps.fao.org/fishery/fprod1-e.htm, www.apps.fao.org/page/form?collection=Fishery.Primary&Domain=Fishery&servlet=1&language=EN (Greece); Cook Islands - Contact - Ian Bertram, Director - Research & Economic Development(RED); Ministry of Marine Resources(MMR); Federated States of Micronesia - Contact - Donald Davis, Office of Economic Affairs/ Marine Development; Kiribati - Fisheries Statistics Unit. Contact - T. Tebaitongo. Fisheries Division; Marshall

Islands - Marshall Islands Marine Resources Authority (MIMRA). Contact - Glen Joseph (Terry Keju's contact: 8262/ 5447/ MIMRA@ntamar.com); Nauru - Contact - Peter Jacob (674 4443733/ 4443812/ peterjacob_nfmra@hotmail.com). Nauru Fisheries and Marine Resources Authority (NFMRA)/ Acting CEO, Fisheries Division; New Zealand - Contact - Daniel Druce, Policy Analyst, Fisheries Planning and coordination, Ministry of fisheries, P O Box 1020, Wellington, New Zealand druced@fish.govt.nz; Niue - Niue 1999 Pelagic Fisheries Assessment. Department of Fisheries, Forestry and Agriculture(DAFF); Palau - Contact - Theo Isamu (680 4885722/ 4883125/ theodmr@palaunet.com). Department of Marine Resources; Papua New Guinea - Anas, A, Kumoru, L, and Lokano, P. Status of Coral Reef Fisheries – Statistics, Fishing-Gears and Impacts (Chapter 4, pp 24). (Live Reef Fish Section). PNG National Fisheries Authority; Philippines - National Statistical Coordination Board(NSCD), Philippine Asset Accounts. NSCD; Samoa - Contact - Anne Trevor. Fisheries Division, Ministry of Agriculture, Forests, Fisheries & Meteorology (MAFFM); Tonga - A) Annual Reports – Inshore Fisheries Statistics B) Report of the Minister for Fisheries 1997 & 1998 C) Results of the Field Surveys on Giant Clam Stock in the Tongatapu Island Group. 995. Tu'avao, T., Loto'ahea, T., Udagawa, K., and Sone, S. Fish. Res. Bull. Tonga, 3: 1-10. D) Open Culture of Giant Clam in Tonga: An Aspect of Managing Giant Clam Resources. 1995. Loto'ahea, T. and Sone, S. Fish Res. Bull. Tonga, 4: 25-30. E) Preliminary Report on the Biomass Study of Sea Cucumber in Ha'apai. Lokani, P., Matoto, S. V., and Ledua, E. F) Pilot Study of the Biology of the Sandfish in Tonga. 1993. Bobko, S., US Peace Corps Volunteer. Submitted to the Ministry of Lands, Survey and Natural Resources. (Ministry of Fisheries); Vanuatu - Contact - Kalo Pakoa (Moses Amos: 678 23119/ 23621; Wesley Obed: fax- 23641/ fishery@vanuatu.com.vu) Fisheries Department.

36. RENEWABLE WATER

36.1 Indicator Summary

Indicator number:	36
Indicator short name:	Renewable water
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	1. Average annual water usage as percentage of renewable water resources over the last 5 years 2. Average annual percentage of water usage per year met from renewable and non-declining sources over the last 5 years
Signals captured:	This indicator captures the risk to terrestrial environments, aquatic ecosystems and ground waters from over-extraction of freshwater resources. It focuses on sustainable use of surface free water and groundwater and damage through salinisation, extraction of functionally non-renewable groundwater, and damage to rivers, lakes and other habitats. Renewable water is that which is caught in rain tanks and reservoirs, or collected from streams, rivers, lakes, ice or groundwater sources that are not being diminished or salinised as a result of the extraction. The effects of over-extraction would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.
Notes on this indicator:	1. This proxy indicator does not show whether the water actually used by countries comes from renewable sources or whether it is mined. It shows only whether overall withdrawals exceed the available supply of renewable water. Countries may still be making the choice to mine their water from non-renewable sources. 2. Kuwait has no renewable water resources. It therefore has no value for the water use as % of renewable (would be ∞) and does not appear in the distributional analyses below. It was assigned an EVI=7 score. 3. The original form of the indicator, shown as 2 above, would be a better measure because it encompasses the choice of whether needs are being met from the available renewable resources.
Are suitable data available?	Yes
Sources of data:	• WRI 2000-2001 for a single year between 1980 and 1995 • Worldwater.org 2000 • In-country
No. countries included in test:	144 of 235
Temporary modifications to data or indicator, if applicable:	• None
Notes on data age, completeness and quality:	16 of the 32 collaborating countries returned data for this indicator. Age and quality of the in-country data were generally considered good (> value of 2/3), but data were considered incomplete (value of 1.88 of 3).
Basic units:	Water use as a percent of total renewable water (note this does not imply that any water used actually comes from renewable sources).

	Original units are in km^3/yr.	
Recommended transforms:	• None	
Proposed EVI Scale (For untransformed % values)	EVI Score = 1	X≤10
	EVI Score = 2	10<X≤20
	EVI Score = 3	20<X≤40
	EVI Score = 4	40<X≤60
	EVI Score = 5	60<X≤80
	EVI Score = 6	80<X≤100
	EVI Score = 7	X>100
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	1. Data for a larger number of countries is needed, but this should not affect the EVI scaling 2. The indicator should be able to determine the amount of water used that is actually from renewable sources 3. Data need to be updated, and calculated as an average of the last 5 years.	

36.2 Description of raw data

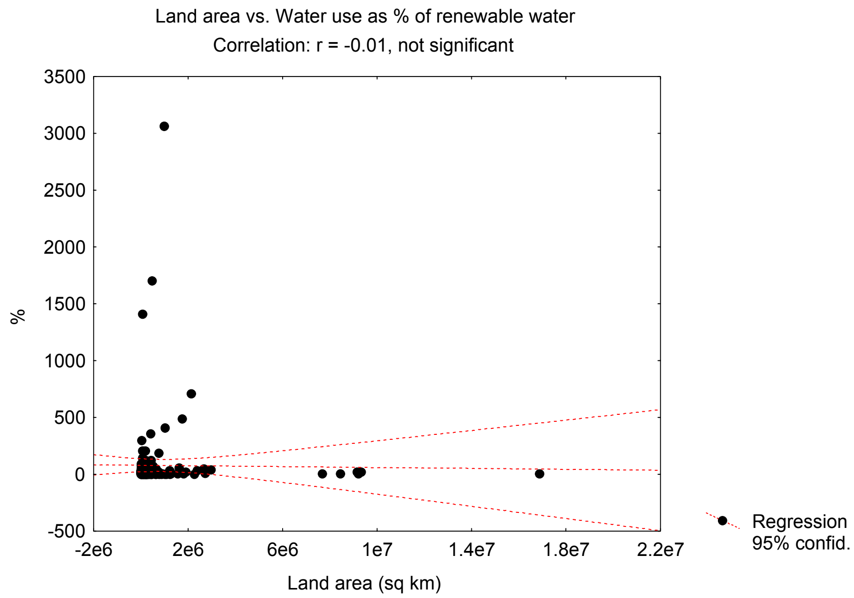
The raw data for this indicator are estimates of (1) total annual withdrawals of water (km^3) and (2) total average annual internal renewable water resources (km^3). Data are for a single year for each country collected in the period from 1980 to 1995 and are derived from WRI 2000-2001. The value for (1) was then divided by (2) to create a measure of the demand for water in relation to available renewable sources. The resulting figure in no way indicates whether the renewable sources are being utilized, or whether functionally non-renewable ones are. It merely indicates whether countries needs/use of water is within the environment's capacity to supply it renewably. The original form of the indicator "*Mean percentage of water usage per year met from renewable and non-declining sources*" would have been a better measure for this indicator, but data were unavailable. The greater the average yearly use of water in relation to renewable resources available, the greater is the risk of extraction of non-renewable resources and damage to ecosystems, ground water and waterways. Of the 235 countries examined, these data were available for 144.

The percent water use varied between 0.01 and over 3,000% of the available renewable water (Table 36.1). The lowest values were recorded in Papua New Guinea, Bhutan and Equatorial Guinea, and the highest values were recorded in Kuwait, Egypt and Turkmenistan. The mean value across the globe was 77.78%. Half of the countries examined used 5.91% of the amount of available renewable resources per year or less (the median). Variance among countries is moderately high, with a standard deviation that is around 4.1 times the mean. The water use as a percentage of renewable water is not correlated with the size of a country (Figure 36.1), so there was no need to express this indicator as a density measure.

Table 36.1: Basic statistics for water use as % of renewable available. Data are for a single year between 1980 and 1995.

Statistic	Water use as % of renewable water	LN(X+1) Water use % renewable
Mean	77.78	2.24
Median	5.91	1.93
Valid n	144	144
Min	0.01	0.01
Max	3,061.11	8.03
SD	320.94	1.79
SE	26.75	0.15
Skewness	7.19	0.87
SE Skewness	0.20	0.20
Kurtosis	58.42	0.35
SE Kurtosis	0.40	0.40

Figure 36.1: Graph of Water use as % of renewable water vs. size of countries. The correlation is not significant.



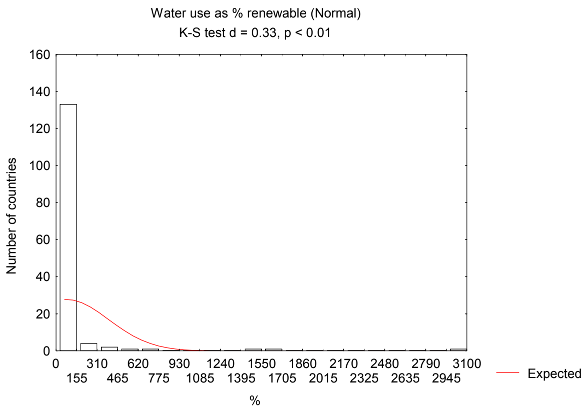
36.3 Distributional characteristics of the indicator data

The water use as % of renewable water in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 36.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

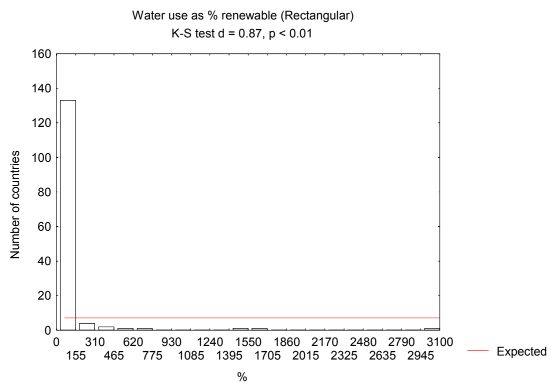
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 36.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 36.2: Kolmogorov-Smirnov goodness-of-fit tests for water use as a % of renewable water in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

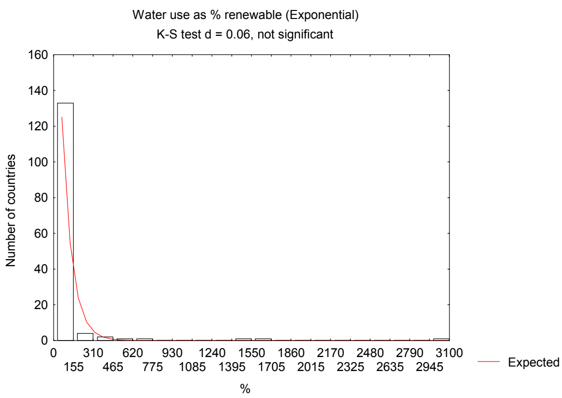
(a)



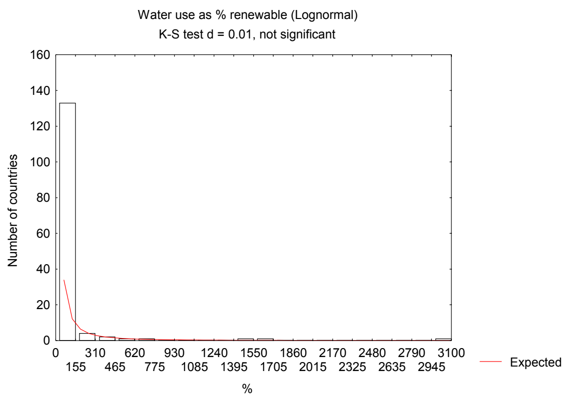
(b)



(c)



(d)

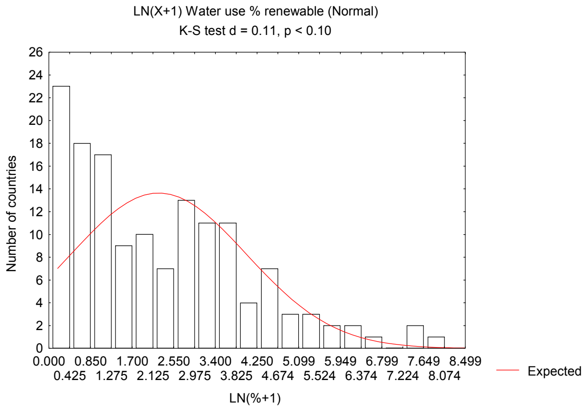


36.4 Proposed EVI scaling and distribution of the data on this scale

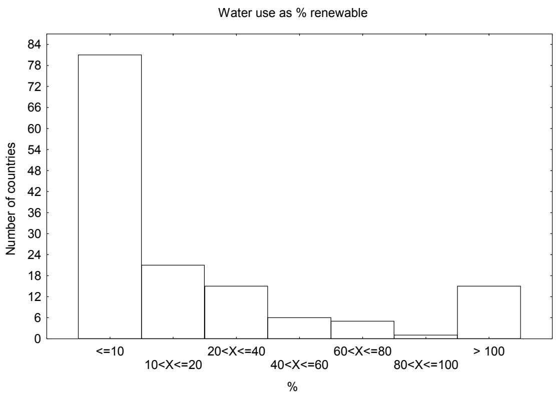
Countries varied in water use as a % or renewable water resources by five orders of magnitude, and there was a strong clumping of countries at the lower end of the scale (Figure 36.2). Although a transform to natural logarithms LN(X+1) for this indicator did provide better spread among the countries and compress the scale (Figure 36.3 a), we decided to use the raw percentages to scale the EVI. Countries with the greatest use of water in relation to their renewable resources are considered more vulnerable and attract a higher EVI score than those using only a fraction of their renewable capacity. We identified those countries with ≤ 10% water use in relation to their renewable resources as likely to be the least at risk of environmental damage (EVI score = 1). Countries with > 100% use in relation to resources were considered the most vulnerable (EVI score =7). These are the countries that would be exceeding their resources, even if as much as possible of their needs were being met from renewable sources. Even this figure may need to be scaled down. 100% use of renewable water resources would still mean renewable waters extracted from rivers, lakes etc that could still sustain permanent indirect ecological damage from extraction, even if the water would be replaced, particularly if there is a defined dry season. The country values between these extremes were spaced unevenly to form the remainder of the EVI scale, with a slight emphasis on higher levels of usage (Figure 36.3, Table 36.2, 36.3).

Figure 36.3: Frequency distribution of LN(X+1) Water use as % of renewable water in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) % water use as renewable water in 20 even categories. (b) is the same distribution compressed to a 7 category (even) scale. (c) The proposed EVI scale.

(a)



(b)



(c)

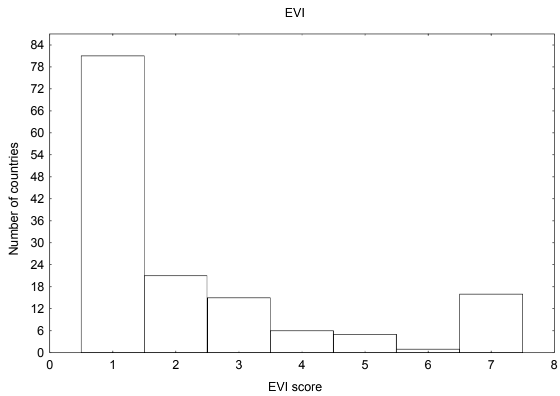


Table 36.2: Proposed EVI scaling for water use as % renewable showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available. Note Kuwait does appear in these counts.

EVI Scale	Scale for water use as % renewable	Observed # countries	Observed % of countries
1	X≤10	81	55.86
2	10<X≤20	21	14.48
3	20<X≤40	15	10.34
4	40<X≤60	6	4.14
5	60<X≤80	5	3.45
6	80<X≤100	1	0.69
7	X>100	16	11.03
No data		90	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 36.3: Proposed EVI scaling for Indicator 36 water use as % of renewable water and examples of countries that fit into each of the EVI scores.

Score	Scale for water use as % renewable	Examples
EVI=1	X≤10	Albania, Botswana, Finland
EVI=2	10<X≤20	Cuba, Greece, Sri Lanka
EVI=3	20<X≤40	Spain, Italy, South Africa
EVI=4	40<X≤60	Germany, Iran, Sudan
EVI=5	60<X≤80	Belgium, Bulgaria, Yemen
EVI=6	80<X≤100	Israel (only country)
EVI=7	X>100	Egypt, Kuwait, UAE

36.5 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 and Worldwater.org 2000, as well as in-country sources. In-country data were available for 16 of the 32 collaborating countries, with data being considered by collaborators to be of good age and quality, but incomplete (Table 36.4).

Table 36.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.57	1.88	2.19
Valid n (in-country)	14	16	16
SD (in-country)	0.65	0.89	0.83
SE (in-country)	0.17	0.22	0.21

36.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

36.7 Additional sources & contacts

www.mwa.or.th/~mevadept/stdata.html; UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Botswana - Botswana Rangeland, Inventory and Monitoring Project (BRIMP) Information System; Cook Islands - Second Water Utilities Databook, 1997. ADB. Waterworks, Marine Resources. Works, Energy and Physical Planning (MOWEPP); Costa Rica - Instituto Meteorológico Nacional, Departamentos de Aguas, 2002; Federated States of Micronesia - Contact - Robert Hadley, Department of TCLI; Fiji - Contact - Sadeesh Chand Maharaj (306177) Ministry of Health; Kiribati - Issues, Traditions and Conflicts in Groundwater Use and Management. Groundwater Recharge in Low Coral Islands Bonriki, South Tarawa, Republic of Kiribati. 1999. UNESCO-IHP Humid Tropics Programme. Water Research Foundation of Australia. Public Works Department (PWD); Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Contact - Mrs. Neronova T.I, Unit of Water Resources and Air

Protection; Marshall Islands - ADB TA # 1946 – RMI. Parson Engineering Science. Marshalls Water & Sanitation Conservation (MWSC); Nepal - State of Environment, Nepal, 2001, HMG-N / NORAD / UNEP / ICIMOD / SACEP, Kathmandu, Nepal; Niue - VIC GREEN. The Pacific Technical Assistance Facility (PACTAF) Contact - Andre' Siohane (683 4297/ 4223/ waterworks@mail.gov.nu) Public Works Department; Palau - Contact - Ann Kitalong (680 4886095/ ercpalau@hotmail.com) Office of Environmental Response and Coordination (OERC); Papua New Guinea - Contact - Maino Virobo (3250198/ 3250182). Hydrologist - Office of Environment & Conservation (OE & C); Samoa - Dorsch Consult. 1999. Apia Water Consolidation Project. Leak Detection Report. Samoa Water Authority; Singapore - Water department/ public utilities board; Thailand - www.pwa.thaigov.net/statistic.htm ; Tonga - Tonga Water Board's Records (Engineering Division). Contact - Lesieli Niu (676 23299/ 23518/ Lniutwb@kalianet.to) Chief Engineer; Vanuatu - Contact - John Chaniel (678 22211), BP 26, Port Vila. UNELCO Vanuatu Limited.

37. SULPHUR DIOXIDE EMISSIONS

37.1 Indicator Summary

Indicator number:	37	
Indicator short name:	Sulphur dioxide (SO_2) emissions	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Average annual SO2 emissions (tonnes / sq km / yr) over the last 5 years	
Signals captured:	This indicator captures the risk to ecosystem health from air pollution, including its downstream effects. High rates of emissions of gases from industry present risks to all aspects of the environment through diffuse pathways, including deposition by rain. The effects of air pollution (of which SO_2 is only one indicator and only one of the gases of concern) into the environment and beyond its capacity to attenuate them would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. This indicator was originally designed to measure ambient concentrations of SO_2 in the country or in its largest city, but data were difficult to obtain. 2. We redefined the indicator to focus on emissions for which data are available for most countries. This proxy may not measure the conditions acting on a country if emissions tend to be exported and do not primarily act on the country producing the gases. Issues of the transboundary export of pollution and the resulting effects on countries receiving air pollution would be better assessed using the original form of the indicator, though the sources may not be readily identifiable. 3. Data are for 1995 only.	
Are suitable data available?	Yes.	
Sources of data:	• GEO-3 Data Compendium 2002 • OECD 1999 • WRI 2000-2001 • HDR 1999 • WDI 2001 • In-country	
No. countries included in test:	223 of 235	
Temporary modifications to data or indicator, if applicable:	• None, the new form of the indicator is an acceptable proxy until sufficient data on ambient conditions can be collected.	
Notes on data age, completeness and quality:	7 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Sulphur dioxide emissions as tonnes/km^2/year	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	$X \leq 0.25$
	EVI Score = 2	$0.25 < X \leq 0.5$
	EVI Score = 3	$0.5 < X \leq 0.75$
	EVI Score = 4	$0.75 < X \leq 1$
	EVI Score = 5	$1 < X \leq 1.5$
	EVI Score = 6	$1.5 < X \leq 2$

	EVI Score = 7	X>2
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	1. Updated data for the last 5 years are needed. 2. The ability of the EVI to measure vulnerability of the environment to air pollution would be better measured by the original form of the indicator on ambient concentrations of SO_2. 3. An agreement for climate stations in countries to measure ambient SO_2 concentrations should be investigated.	

37.2 Description of raw data

The raw data for this indicator are comprised of the total amount of SO_2 emitted in 1995 in countries (tonnes). The mean amount emitted across all countries in 1995 was more than 633,600 tonnes and varied between zero and 34.5 million tonnes (Table 37.1). The lowest values were recorded in Albania, Norfolk Island, Svalbard and Tokelau, and the highest values were recorded in China, USA and Russia. Half of the countries examined emitted 35,000 tonnes of SO_2 in 1995, or less (the median) (Table 37.1). Variance among countries is moderately high, with a standard deviation which is around 4.4 times the mean.

The amount of SO_2 emitted is correlated with the size of a country (see significant correlation coefficient in Figure 37.1). Since the risks associated with pollution are related to the area over which the wastes and pollution can be attenuated, we expressed this indicator as a density function, dividing the emission amount by total land area in a country. This way of expressing the data also puts them on a common scale for comparison among countries with the units of tonnes/km^2/year (in this case only 1995). When the density of SO_2 emissions is, in turn, tested against country size, there is no correlation with size of country (Figure 37.1 b).

Density of SO_2 emissions varied from zero to 686 tonnes/km^2/yr. The minimum values remain the same as those seen for raw SO_2 emissions (zero values) and the maximum values were observed in Singapore, Gibraltar and Macau.

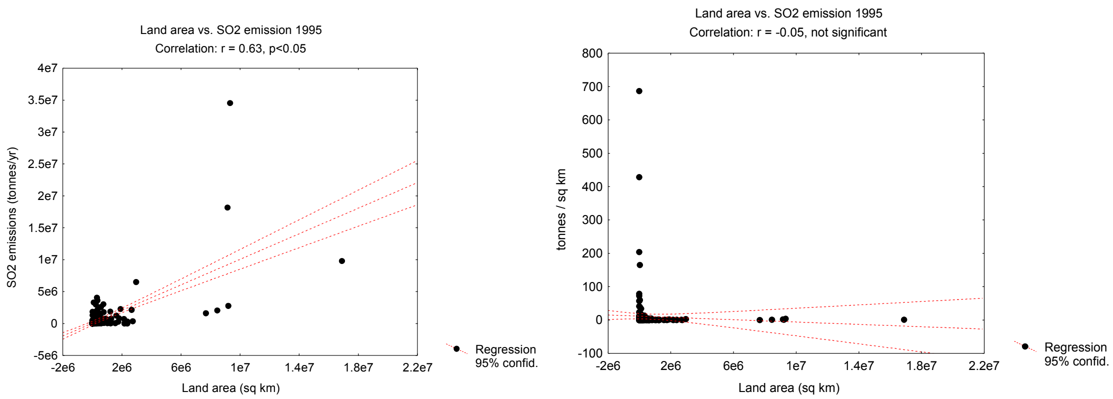
The greater the average yearly emissions of SO_2 per km^2 of land, the greater is the risk of overload of pollution of air, land, ground water and waterways. Of the 235 countries examined, these data were available for 223.

Table 37.1: Basic statistics for SO_2 emissions. Data are from a range of sources for 1995.

Statistic	Total SO_2 emissions 1995 (tonnes/yr)	Density of SO_2 emission 1995 (tonnes/yr/km^2)	LN(X+1) (tonnes/yr/km^2)
Mean	633,602	10.5	0.9
Median	35,010	0.50	0.41
Valid n	223	223	223
Min	0.00	0.00	0.00
Max	34,544,140	686	7
SD	2,768,963	57	1
SE	185,423.5	3.8	0.1
Skewness	9.73	9.52	2.13
SE Skewness	0.16	0.16	0.16
Kurtosis	109.13	100.79	5.11
SE Kurtosis	0.32	0.32	0.32

Figure 37.1: Graphs of SO_2 emissions vs. size of countries. (a) SO_2 emissions (tonnes) in 1995 vs. size of country (km^2); and (b) Density of SO_2 emissions (tonnes/year/km^2 land) vs. size of country (km^2). The correlation is significant in (a) and not significant in (b).

(a) (b)



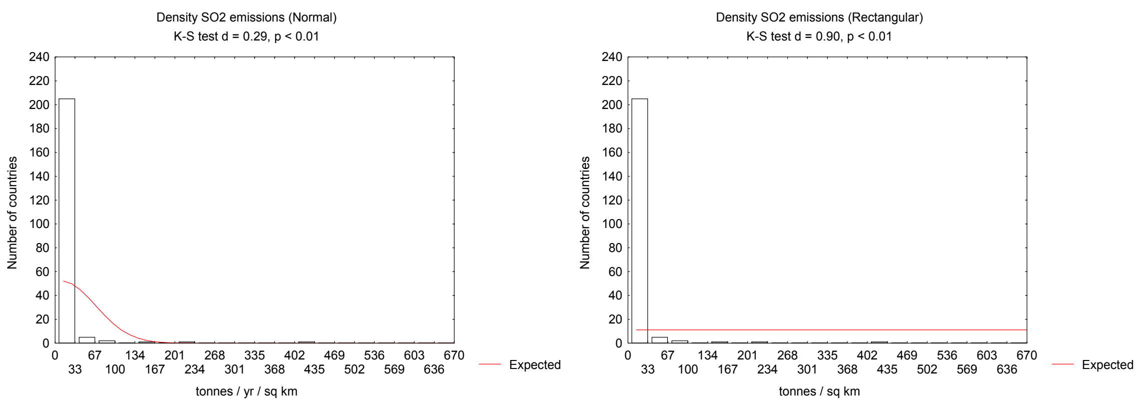
37.3 Distributional characteristics of the indicator data

The density of SO_2 emissions in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 37.2). This resulted in a distribution which was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

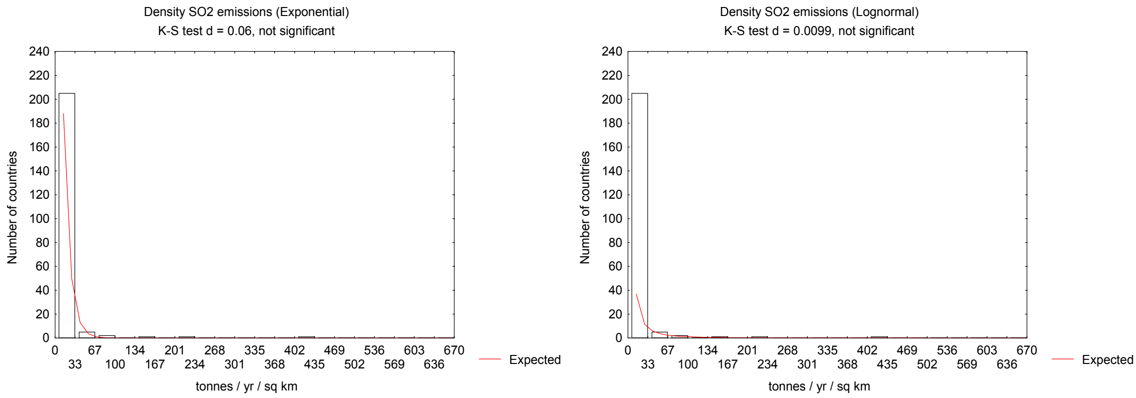
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 37.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison and provide a better spread among countries.

Figure 37.2: Kolmogorov-Smirnov goodness-of-fit tests for density of SO_2 emissions in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

(a) (b)



(c) (d)

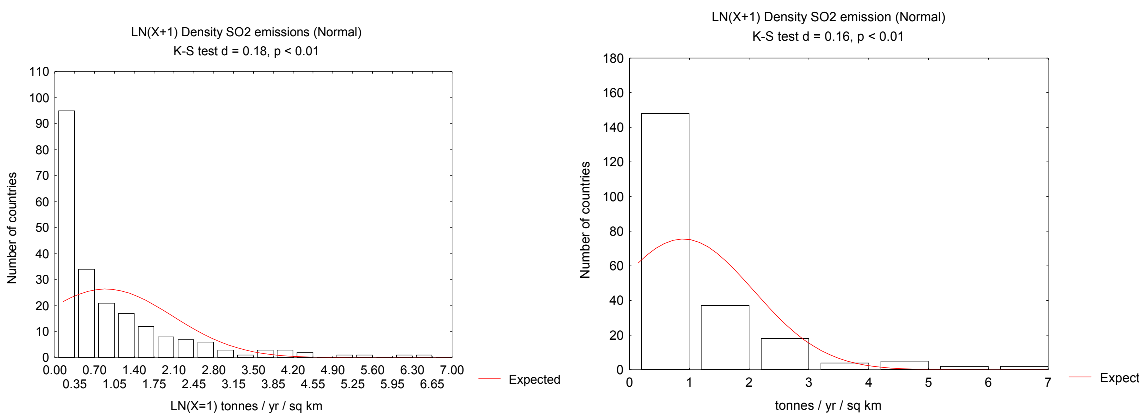


37.4 Proposed EVI scaling and distribution of the data on this scale

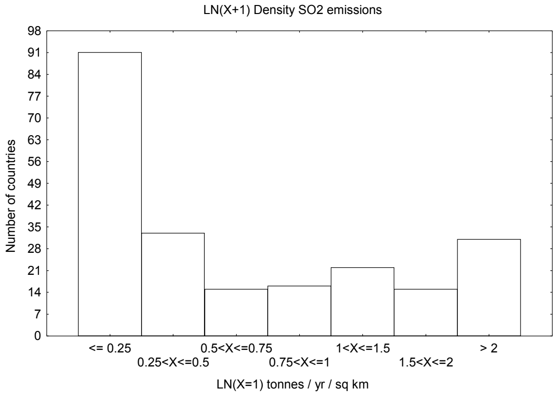
Countries varied in density of SO_2 emissions on a scale between 0 and 686, with a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries at the lower end of the scale and compress it to between 0 and 7. Countries having the greatest SO_2 emissions per km^2 are considered more vulnerable and would attract a higher EVI score. We identified those countries with ≤ 0.25 on the transformed LN(X+1) scale as likely to be the least at risk of environmental damage related to SO_2 emissions because the amount emitted is small in relation to the area of land available to absorb / attenuate it (< 0.28 tonnes / km^2 land / year, EVI score = 1). Countries with > 2 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1995 emitted more than 6.39 tonnes of SO_2 for every km^2 of their national land area. The country values between these extremes were spaced unevenly to form the remainder of the EVI scale (Figure 37.3, Table 37.2, 37.3). An uneven spacing was used to reinforce the increasing environmental risks associated with loads of several tonnes of SO_2 emitted for every km^2 of land.

Figure 37.3: Frequency distribution of LN(X+1) density of SO_2 emissions in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) transformed density in seven categories which puts more focus on countries with high values, identifying them as being at the highest risk. (d) The proposed EVI scale.

(a) (b)



(b)



(c)

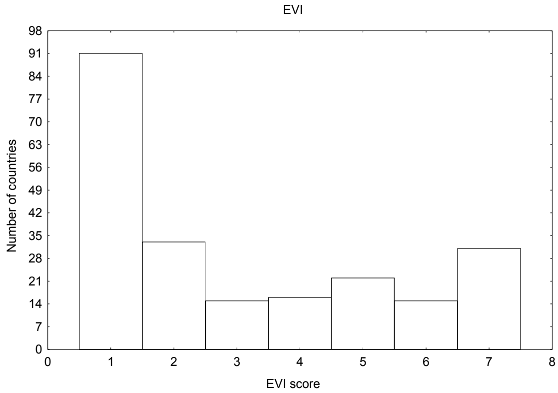


Table 37.2: Proposed EVI scaling for density of SO_2 emissions showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale LN(X+1)	Observed # countries	Observed % of countries
1	X≤0.25	91	40.81
2	0.25<X≤0.5	33	14.80
3	0.5<X≤0.75	15	6.73
4	0.75<X≤1	16	7.17
5	1<X≤1.5	22	9.87
6	1.5<X≤2	15	6.73
7	X>2	31	13.90
No data		12	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 37.3: Proposed EVI scaling for SO_2 emissions/km^2/year showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fall into each of the EVI scores.

Score	Scale LN(X+1)	Equivalent scale density of SO_2 emissions/km^2/yr	Examples
EVI=1	X≤0.25	X≤0.28	Argentina, Cameroon, Marshall Is.
EVI=2	0.25<X≤0.5	0.28<X≤0.65	Canada, Indonesia, St. Lucia
EVI=3	0.5<X≤0.75	0.65<X≤1.12	Finland, Iran, Nigeria
EVI=4	0.75<X≤1	1.12<X≤1.72	Moldova, Seychelles, El Salvador
EVI=5	1<X≤1.5	1.72<X≤3.48	Martinique, Reunion, USA
EVI=6	1.5<X≤2	3.48<X≤6.39	Slovenia, Ukraine, Mauritius
EVI=7	X>2	X>6.39	Malta, Singapore, Taiwan

37.5 Age, completeness and quality of the data

The data obtained for this indicator were mostly from GEO-3 Data Compendium 2002, as well as in-country sources. In-country data were available for 7 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 37.4).

Table 37.4: Characteristics of age, completeness and quality of the data obtained for SO_2 emissions from in-country sources.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.71	2.71	2.86
Valid n (in-country)	7	7	7
SD (in-country)	0.76	0.76	0.38
SE (in-country)	0.29	0.29	0.14

37.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator. Data on ambient levels of SO_2 in countries would be more suitable for this indicator. An agreement for climate stations in countries to measure ambient SO_2 concentrations should be investigated.

37.7 Additional sources & contacts

www.geocompendium.grid.unep.ch/data_sets/atmosphere/data/emissions_so2_total_rivm.htm (17/01/03); OECD 1999, pp 19; UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; United Nations Development Programme. 1999. Human Development Report. (pp 205 – 208) UNDP; World Development Indicators, 2001. (pp 174-175); Botswana - A) Annual Air pollution Reports B) Lankopane et al, 2002 Dispersion Model Calculations for BCL Limited Smelter in Selebi-Phikwe. C) Tshukudu. T and Knudsen. S, 1997 Dispersion calculations for BCL Limited Smelter in Selebi-Phikwe; Costa Rica - Resumen de Monitorie de Aire. Alfaro, M. del R., PECAires-Una,2002; Greece - Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Contact - Mrs. Neronova T.I. Unit of Water Resources and Air Control, Chief; Niue - Niue Initial National Communication Report. Niue Meteorology Services; Singapore - Strategic planning and research department. Contact - Mr Adrian Tan, engineer (strategic planning) tel: 0065 67319710 E-Mail Adrian_tan@env.gov.sg; Thailand - Pollution Control Depratment, Thailand. Tel 66 2 2982253 Fax 66 2 2982240 E-mail: marinepollution_pcd@yahoo.com.

38. WASTE PRODUCTION

38.1 Indicator Summary

Indicator number:	38	
Indicator short name:	Waste production	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Average annual net amount of generated and imported toxic, hazardous and municipal wastes per square kilometre land area over the last 5 years (t/km^2/yr).	
Signals captured:	This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters from toxic and municipal wastes. All such wastes need a suitable area of land or volume of water for their eventual attenuation. High waste loads present risks to all aspects of the environment. The effects of dumping large amounts of wastes into the environment and beyond its capacity to attenuate them would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. Data include wastes generated in each country in addition to those imported for storage or attenuation. 2. Wastes exported to other countries are specifically not included as a deduction in this indicator, so there will be double-accounting of wastes because where they appear in one country as generated, they may also appear in another as imported. We believe this a better measure of vulnerability. 3. Data from in-country sources were difficult to obtain.	
Are suitable data available?	Yes, but only for a limited number of countries.	
Sources of data:	• EEA 2001 European Environment Agency http://themes.eea.eu.int/Environmental_issues/waste/indicators/generation/w1_total_waste.pdf • UNEP 1998 http://www.unep.ch/basel/pub/table1.pdf • EPA http://www.zerowasteamerica.org/WasteTrade.htm • MZPSR Ministry of Environment of Slovak Republic 2000 http://www.sazp.sk/slovak/periodika/sprava/psreng/waste/waste_b_5.html • In-country	
No. countries included in test:	51 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	9 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Wastes produced and imported (including toxic, hazardous and municipal wastes) as X = mean tonnes per year per sq km of land.	
Recommended transforms:	• Data transformed to LN(X+1)	
Proposed EVI Scale	EVI Score = 1	X≤1
	EVI Score = 2	1<X≤2
	EVI Score = 3	2<X≤3
	EVI Score = 4	3<X≤4
	EVI Score = 5	4<X≤5

	EVI Score = 6	5<X≤6
	EVI Score = 7	X>6
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries is needed, but this should not affect the EVI scaling.	

38.2 Description of raw data

The raw data for this indicator are comprised of the total annual amounts of generated and imported wastes in a country each year (in 1000s tonnes). Data are means for the years 1996-2000 and are derived from a range of sources (see data sheet and summary above). These values were then divided by total land area to produce an average annual tonnage of wastes that would need to be attenuated or stored per year per sq km. The greater the average yearly load of wastes, the greater is the risk of overload and pollution of land, ground water and waterways. Of the 235 countries examined, these data were available for only 51.

The mean annual total tonnage of wastes produced and imported into countries between 1996-2000 varied between 30 tonnes and more than 380 million tonnes (Table 38.1). The lowest values were recorded in Cook Islands, Uganda and Yugoslavia, and the highest values were recorded in Romania, Russia and USA. The mean value across the globe was 11.8 million tonnes per year. Half of the countries examined produced/imported 251,000 tonnes of wastes per year or less (the median). Variance among countries is moderately high, with a standard deviation which is around 4.5 times the mean.

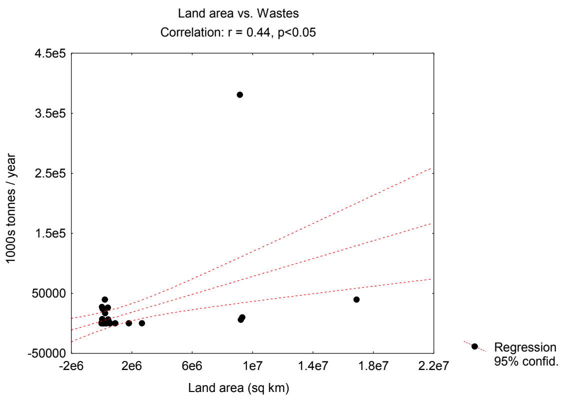
The amount of wastes generated and imported is correlated with the size of a country (see significant correlation coefficient in Figure 38.1). Since the risks associated with wastes are related to the area over which the wastes and pollution can be attenuated, we expressed this indicator as a density function, dividing the amounts produced/imported each year by total land area in a country. When the density of wastes generated/imported is, in turn, tested against country size, the correlation with size of country disappears (Figure 38.1 b). Waste density varied from 0.000192 to 22,789 tonnes per year per sq km land. The maximum waste density was observed in Monaco.

Table 38.1: Basic statistics for wastes generated and imported. Data are from a range of sources and cover years 1996-2000.

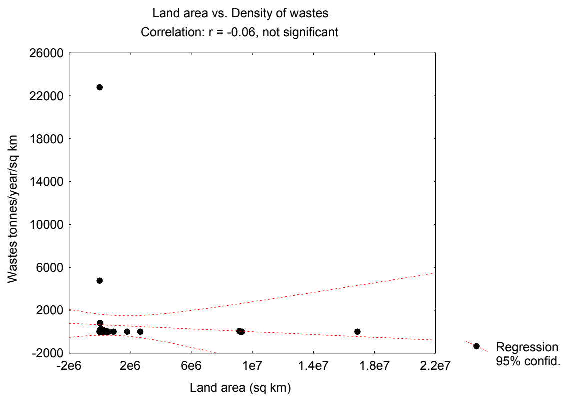
Statistic	Wastes (generated + imported) 1000s tonnes / year (1996-2000)	Density of wastes Mean tonnes / year / sq km (1996-2000)	LN(X+1) Density of wastes
Mean	11,860.74	578.09	1.96
Median	251.24	2.06	1.12
Valid n	51	51	51
Min	0.03	0.000192	0.000192
Max	380,625.2	22,789.5	10.03410
SD	53,554.56	3,243.15	2.32
SE	7,499.14	454.13	0.32
Skewness	6.79	6.73	1.61
SE Skewness	0.33	.333464	0.33
Kurtosis	47.51	46.48870	2.51
SE Kurtosis	0.66	.655920	0.66

Figure 38.1: Graphs of wastes generated/imported vs. size of countries. (a) Tonnes of wastes generated/imported (in 1000s tonnes) per year vs. size of country (sq km); and (b) Density of wastes (tonnes / year / sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a)



(b)



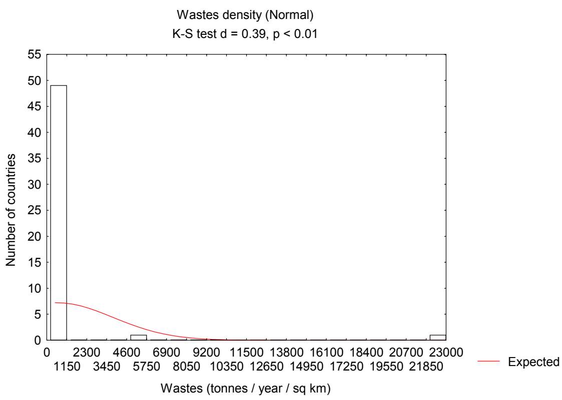
38.3 Distributional characteristics of the indicator data

The density of wastes generated/imported into countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 38.2). This resulted in a distribution which was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

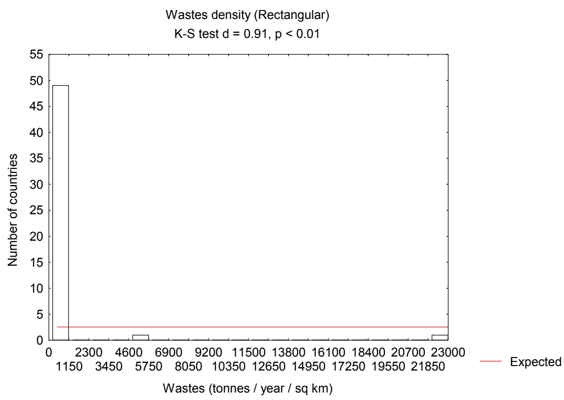
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 38.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 38.2: Kolmogorov-Smirnov goodness-of-fit tests for density of wastes in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

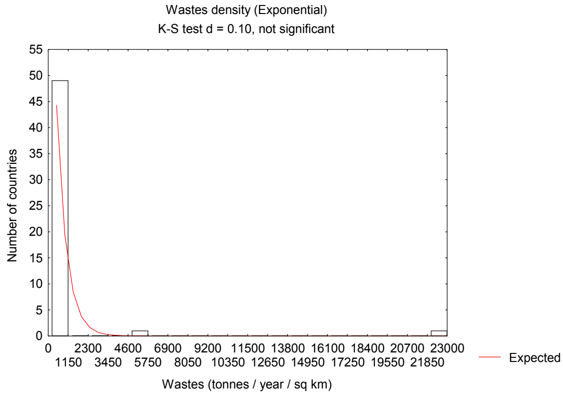
(a)



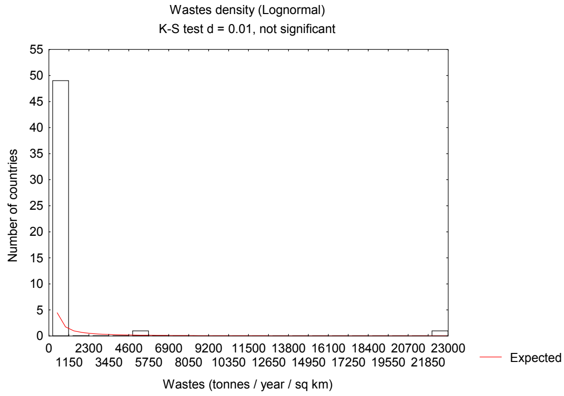
(b)



(c)



(d)

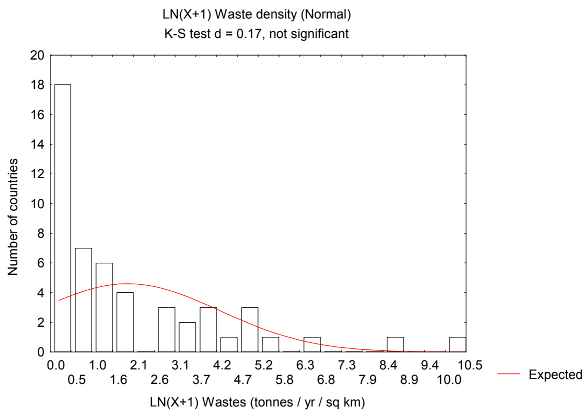


38.4 Proposed EVI scaling and distribution of the data on this scale

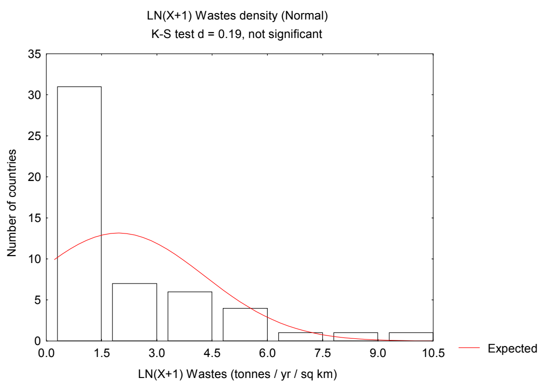
Countries varied in density of waste production by eight orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms (LN(X+1)) for this indicator to provide better spread among the countries and compress the scale to between 0 and 10, with countries having the greatest waste loads per sq km being considered more vulnerable and attracting a higher EVI score. We identified those countries with ≤ 1 on the transformed (LN(X+1)) scale as likely to be the least at risk of environmental damage because the amount of wastes generated/imported is small in relation to the area of land available to absorb / attenuate them (< 1.72 tonnes / year / sq km land, EVI score = 1). Countries with > 6 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1996-2000 produced and/or imported more than 402 tonnes of wastes / year / sq km of their land area. The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 38.3, Table 38.2, 38.3).

Figure 38.3: Frequency distribution of LN(X+1) density of wastes produced/imported in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, showing that the transformed data are a good fit to the normal distribution. (b) is the same distribution compressed to a 7 category (even) scale. (c) Is the distribution of LN(X+1) transformed waste density in seven categories which clump countries with high values, identifying them as being at the highest risk. (d) The proposed EVI scale.

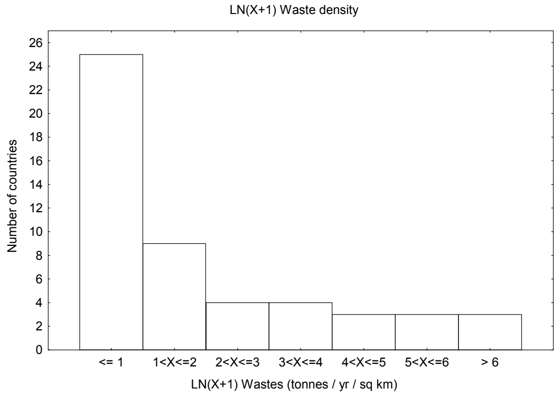
(a)



(b)



(c)



(d)

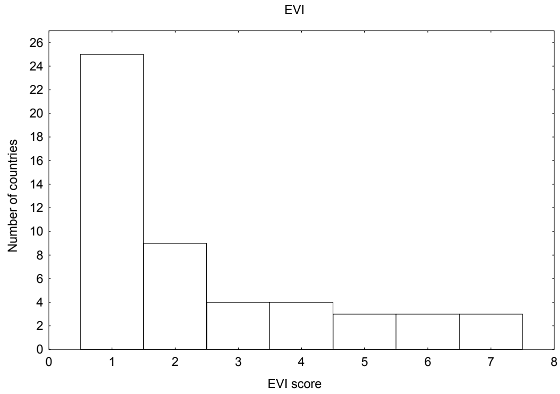


Table 38.2: Proposed EVI scaling for density of wastes generated/imported showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values LN(X+1)	Observed # countries	Observed % of countries
1	X≤1	25	49.02
2	1<X≤2	9	17.65
3	2<X≤3	4	7.84
4	3<X≤4	4	7.84
5	4<X≤5	3	5.88
6	5<X≤6	3	5.88
7	X>6	3	5.88
No data		184	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 38.3: Proposed EVI scaling for Indicator 38 on density of wastes showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Waste density	Equivalent scale tonnes / year / sq km	Examples
EVI=1	X≤1	X ≤ 1.72	Austria, Cyprus, Italy
EVI=2	1<X≤2	1.72 < X ≤ 6.39	Bulgaria, Ireland, Norway
EVI=3	2<X≤3	6.39 < X ≤ 19.09	Cuba, Morocco, Palau
EVI=4	3<X≤4	19.09 < X ≤ 53.60	Hungary, Slovakia, USA
EVI=5	4<X≤5	53.60 < X ≤ 147.41	Estonia, UK, Uzbekistan
EVI=6	5<X≤6	147.41 < X ≤ 402.43	Denmark, Romania, Portugal
EVI=7	X>6	X > 402.43	Monaco, Netherlands, St. Pierre & Miquelon

38.5 Age, completeness and quality of the data

The data obtained for this indicator were from European Environment Agency, UNEP, USA EPA and Ministry of the environment of the Slovak Republic, as well as in-country sources. In-country data were available for 9 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 38.4).

Table 38.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.25	2.33	2.38
Valid n (in-country)	8	9	8
SD (in-country)	0.71	0.71	0.74
SE (in-country)	0.25	0.24	0.26

38.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

38.7 Additional sources & contacts

www.themes.eea.eu.int/Environmental_isses/waste/indicators/generation/w1_total_waste.pdf (28/01/03); www.unep.ch/basel/pub/table1.pdf ; www.zerowasteamerica.org/WasteTrade.htm (29/01/2003); www.sazp.sk/slovak/periodika/sprava/psreng/waste/waste_b_5.html (28/01/03); Cook Islands Environment Service. Contact - Antoine Nia (682 21256/ 682 22256); Costa Rica - Municipalidad de San José, 2002; Federated States of Micronesia - Solid Waste Management Plan. WHO RS/ 91/ 0110/ OGAWA. Pohnpei State Environmental Protection Agency; Greece - Ministry of Environment and EU Stats; Kiribati - Waste Characterization Survey & Solid Waste Management Plan. Sinclair K Mertz. Suva, Fiji. Environment & Conservation Division (E&CD); Palau - Internal Solid Waste Management Plan. Golder Associates Ltd. Environmental Quality Protection Board (EQPB); Philippines - Metro Manila's Toxic and Hazardous Wastes, 1996. Environmental Management Bureau, Department of Environment and Natural Resources; Singapore - Lim Siak Heng: Tel 6731 9782 Fax : 67319651. Executive engineer Pollution Control Department (PCD); Thailand - Municipal solid waste management questionnaires/ Pollution Control Status Report. Pollution Control Dept. Ministry of Science, Technology and Environment; Trinidad &Tobago - Contact - June Ragbiringh-Chang; Tuvalu - Mertz, S K. 1999. Tuvalu National Environmental Management Strategy (NEMS). Environment Department.

39. WASTE TREATMENT

39.1 Indicator Summary

Indicator number:	39	
Indicator short name:	Waste treatment	
Sub-index	Hazards	
Categorisation	Resources & Services	
Indicator text:	Mean annual percent of hazardous, toxic and municipal waste effectively managed and treated over the past 5 years.	
Signals captured:	Proportion of wastes rendered less harmful. This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters from toxic and municipal wastes and how they are treated. All wastes need a suitable area of land or volume of water for their eventual attenuation, but treatment and recycling are effective means of reducing the overall waste load in a country. High waste loads present risks to all aspects of the environment. The effects of dumping large amounts of wastes into the environment and beyond its capacity to attenuate them would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. Effectively managed wastes are composted, reused, recycled, subjected to controlled incineration (including temperature control, retention time control and control of emissions), and/or placed in controlled landfill (involving treatment of leachate, containment, gas management, aftercare and rehabilitation i.e. recovery, planting and post management).	
Are suitable data available?	Data are very limited, covering mostly Europe. Most data cover only one year between 1992 and 1998.	
Sources of data:	• Eurostat http://www.waste.eionet.eu.int • In-country	
No. countries included in test:	41 of 235	
Temporary modifications to data or indicator, if applicable:	• Percentage of wastes treated was >100% for some countries. This is attributed to the combination of data from different years for municipal and toxic wastes. Countries for which % treated was >100 were reduced to 100% for the analysis. Better data are required.	
Notes on data age, completeness and quality:	11 of the 32 collaborating countries returned valid data for this indicator. Age, completeness and quality of the data were considered good (value of around 2/3).	
Basic units:	Average annual percentage of wastes produced that undergo treatment that limits negative effects on the environment.	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=100
	EVI Score = 2	80≤X<100
	EVI Score = 3	60≤X<80
	EVI Score = 4	50≤X<60
	EVI Score = 5	40≤X<50
	EVI Score = 6	30≤X<40
	EVI Score = 7	X<30
	NA (not applicable)	☒ May not be used

	ND (no data)	☑ May be used
Future work on this indicator:	World data on how municipal and hazardous wastes are treated are generally lacking. This is an important environmental indicator that needs to be monitored as part of sustainable development. Data is urgently needed, but this will not affect the EVI scaling.	

39.2 Description of raw data

The raw data for this indicator are comprised of the average (last 5 years) annual percentage of municipal and toxic wastes that are generated in the country and which are treated. This figure is calculated from reported amounts of municipal and toxic wastes generated (in 1000s tonnes) and the amount subject to treatment (also in 1000s tonnes). For this indicator, effectively managed wastes are those that are composted, reused, recycled, subjected to controlled incineration (including temperature control, retention time control and control of emissions), and/or placed in controlled landfill (involving treatment of leachate, containment, gas management, aftercare and rehabilitation i.e. recovery, planting and post management). Data are usually from the years between 1992 and 1998, for any one country are usually for only one year, with municipal data and hazardous waste data often for different years. These data were difficult to obtain, with some derived from Eurostat, and others from in-country sources. Nevertheless, this is a key indicator and data on this issue are likely to be available in the next few years.

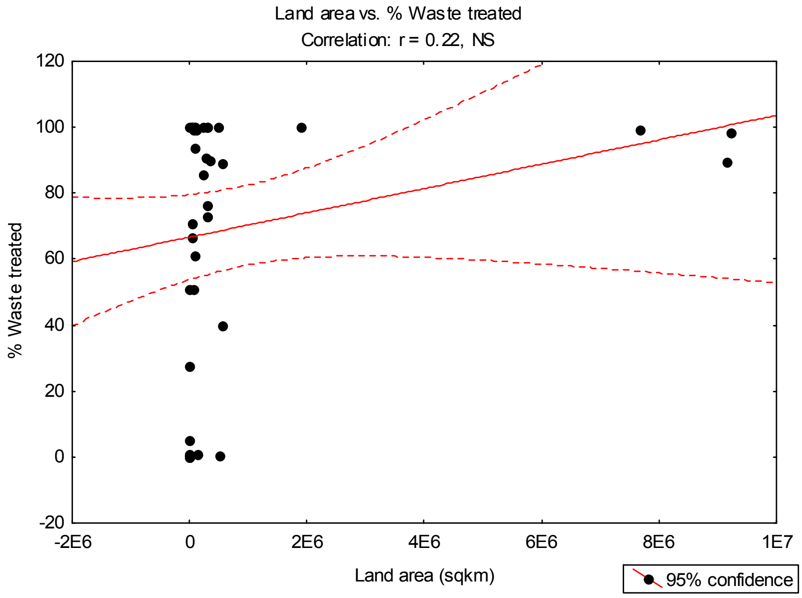
This indicator is complementary to 38 on waste production. Poorly handled wastes are likely to affect greater areas of the country and result in significant ecosystem damage than those that have been contained and attenuated before release into the environment. The countries with lowest environmental vulnerability to damage by the wastes they generate will be those that effectively manage 100% of the wastes they produce. Of the 235 countries examined, these data were available for only 41.

The percentage of wastes treated in countries varied between 0 and 100% (Table 39.1). The lowest values were recorded in Tuvalu, Palau and Federated States of Micronesia and the highest values in many European countries, Mexico and Singapore. The mean value across the globe was 70% and half of the countries examined treated 90% of their wastes per year (the median). Variation among countries is low, with a standard deviation which is around half of the mean. The amount of wastes generated and imported is not correlated with the size of a country (Figure 39.1).

Table 39.1: Basic statistics for wastes generated and imported. Data are from a range of sources and cover years 1996-2000.

Statistic	% of wastes treated
Mean	69.7
Median	89.8
Valid n	41
Min	0
Max	100
SD	38.8
SE	6.1
Skewness	-0.99
SE Skewness	0.37
Kurtosis	-0.67
SE Kurtosis	0.72

Figure 39.1: Graph of percentage of wastes treated vs. size of countries (km^2). The correlation is not significant.



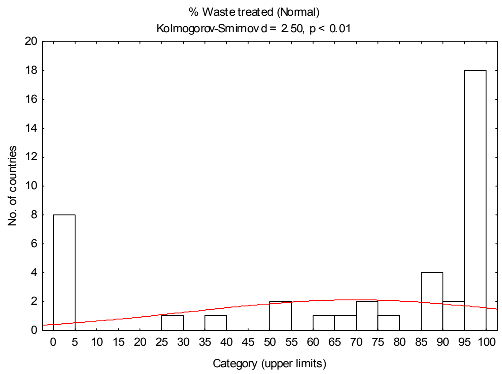
39.3 Distributional characteristics of the indicator data

The percentage of wastes generated that undergo treatment was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 39.2). This resulted in a distribution which was heavily populated at the upper end of the scale, with smaller numbers of countries spread over the rest of the range. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) or Chi-squared tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

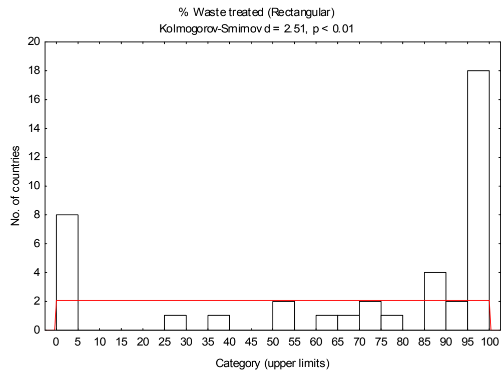
A significant difference between observed and expected values was found in all of the distributions tested (Figure 39.2). This suggests that the values observed are not distributed according to any of the major distributional types. No transform was applied to these data.

Figure 39.1: Kolmogorov-Smirnov goodness-of-fit tests for % waste treatment in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S or Chi-squared test for goodness of fit. The observed distribution was not a good fit to any of these distributional types.

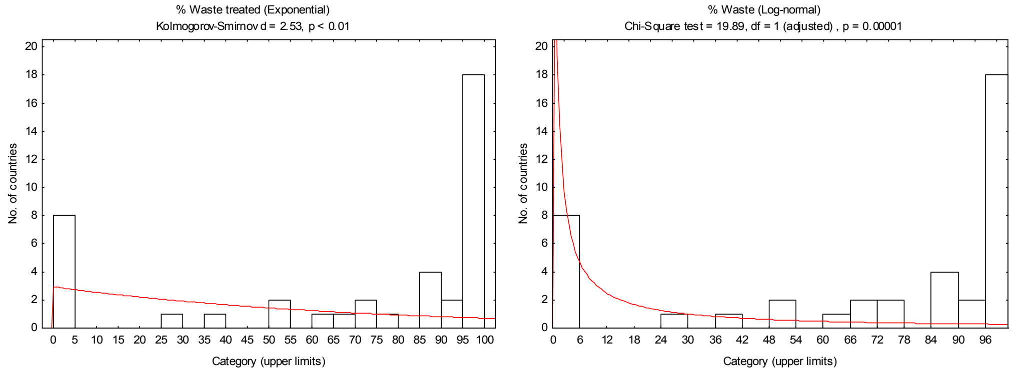
(a)



(b)



(c) (d)



39.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in the percentage of their wastes that they treated from zero to 100%, with a clumping of countries at the upper end of the scale. We propose that the percentage data be used in their raw form, and that countries with the greatest levels of waste treatment be considered less vulnerable, attracting a lower EVI score. We identified those countries with 100% waste treatment as those least risk of environmental damage (regardless of the total amount generated which is covered in Indicator 38). Countries with <30% of their wastes effectively managed were considered the most vulnerable (EVI score =7). The values between these extremes were spaced unevenly to form the remainder of the EVI scale with differences being measured more critically towards the lower end of the percentage treated scale (Figure 39.3, Tables 39.2, 39.3).

Figure 39.2: Frequency distribution of global EVI scores generated for % wastes treated.

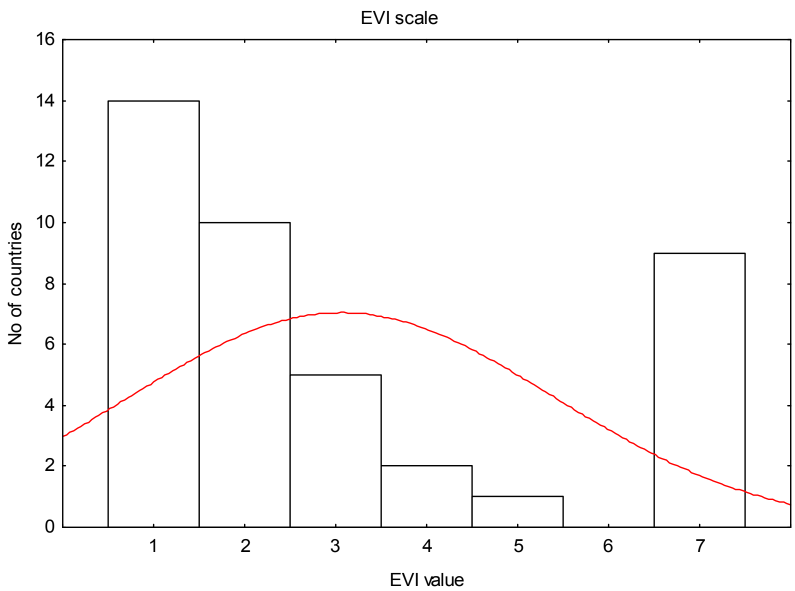


Table 39.2: Proposed EVI scaling for % of wastes treated showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	X=100	14	5.96
2	80≤X<100	10	4.26
3	60≤X<80	5	2.13
4	50≤X<60	2	0.85
5	40≤X<50	1	0.43
6	30≤X<40	0	0
7	X<30	9	3.83
No data		194	82.56
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 39.3: Proposed EVI scaling for Indicator 39 on % of wastes treated showing examples of countries that fit into each of the EVI scores.

Score	% waste treated	Examples
EVI=1	X=100	Belgium, Switzerland, Singapore
EVI=2	80≤X<100	Australia, Iceland, France
EVI=3	60≤X<80	Poland, Finland, Slovakia
EVI=4	50≤X<60	Czechoslovakia, Luxembourg
EVI=5	40≤X<50	Botswana
EVI=6	30≤X<40	None
EVI=7	X<30	Cook Islands, Thailand, Tuvalu

39.5 Age, completeness and quality of the data

The data obtained for this indicator were from Eurostat and in-country sources. In-country data were available for 11 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 39.4).

Table 39.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.7	2.1	2.3
Valid n (in-country)	6	10	11
SD (in-country)	0.5	0.6	0.5
SE (in-country)	0.2	0.2	0.1

39.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

39.7 Additional sources & contacts

www.waste.eionet.eu.i/results_html?country=all&dataset=2&sector=All%20sectors&year=a (21/1/03); Botswana - Department of Sanitation and Waste Management. Contact - Mr S. Pathmanathan. Phone: 3900076. Fax: 3909953. spathmanathan@gov.bw ; Cook Islands - Contact - Antoine Nia (682 21256/ 682 22256). Environment Services; Federated States of Micronesia - Solid Waste Management Plan. WHO RS/ 91/ 0110/ OGAWA. Pohnpei State Environmental Protection Agency; Kiribati - Waste Characterization Survey & Solid Waste Management Plan. Sinclair K Mertz. Suva, Fiji. Environment & Conservation Division (E&CD); Marshall Islands - Crawford, M. 1992 RMI National Environmental Management Strategy (NEMS) Part A, (pp 51); Niue - Waste Management Plan – Niue. Draft, 2000. Community Affairs; Palau - Internal Solid Waste Management Plan. Golder Associates Ltd. Environmental Quality Protection Board (EQPB); Papua New Guinea - Solid Waste Characterisation Study and Management Plan for Port Moresby, PNG Country Report. Office of Environment & Conservation (OE & C); Singapore - Lim Siak Heng: Tel 6731 9782 Fax : 67319651. Executive engineer Pollution Control Department (PCD); Thailand - Pollution Control Department. Thailand. Tel 66 2 2982253 Fax 66 2 2982240 e-mail: marinepollution_pcd@yahoo.com; Tuvalu - Environment Department. Contact – Mataio. Environment Dept; Vanuatu - Mertz, S. K. Solid Waste Characterization & Management Plan Study. Port Vila Municipality.

40. INDUSTRY

40.1 Indicator Summary

Indicator number:	40	
Indicator short name:	Industry	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Average annual use of electricity for industry over the last 5 years per square kilometre of land.	
Signals captured:	This indicator captures all major potential chemical and other industrial polluters that could cause significant environmental damage from accidents and diffuse pollution, including acid rain, not normally recorded as part of waste streams. It also captures electricity generation and/or use specifically for purposes of industry, which in itself has ecological consequences. This indicator is used to take into account accidents such as the Bhopal chemical explosion in India, as well as incidents such as the Chernobyl and more recently the Japanese nuclear disaster. The effects of industrial accidents and diffuse pollution would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. The new form of this indicator uses the proxy of electricity use for industry because information on numbers of relevant industries was difficult to obtain for a large number of countries.	
Are suitable data available?	Yes, but only for less than half of the countries. Data are available only for 1997 and need to be updated to include the past 5 years.	
Sources of data:	• WRI 2000-2001 • In-country	
No. countries included in test:	117 of 235	
Temporary modifications to data or indicator, if applicable:	• None. The new form of the indicator is considered an acceptable alternative form and can be retained.	
Notes on data age, completeness and quality:	16 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Tonnes of oil equivalent (toe) per year per sq km of land.	
Recommended transforms:	• Data untransformed	
Proposed EVI Scale	EVI Score = 1	X≤5
	EVI Score = 2	5<X≤10
	EVI Score = 3	10<X≤20
	EVI Score = 4	20<X≤50
	EVI Score = 5	50<X≤100
	EVI Score = 6	100<X≤200
	EVI Score = 7	X>200
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries is needed, but this should not affect the EVI scaling. Data also need to be updated.	

40.2 Description of raw data

The raw data for this indicator are comprised of the electricity consumption for industry in countries during 1997 in 1000s tonnes oil equivalent (1000s toe) derived from WRI 2000-2001. The electricity used for industry in 1997 varied between 20,000 toe and almost 453.5 million toe (Table 40.1). The lowest values were recorded in Moldova, Jordan and Bosnia Herzegovina, and the highest values were recorded in China, USA and Russian Federation. The mean value across the globe was over 24 million toe in 1997. Half of the countries examined used 3.6 million toe of electricity in 1997 (the median). Variance among countries is moderate, with a standard deviation which is around 2.7 times the mean. Of the 235 countries examined, these data were available for 117.

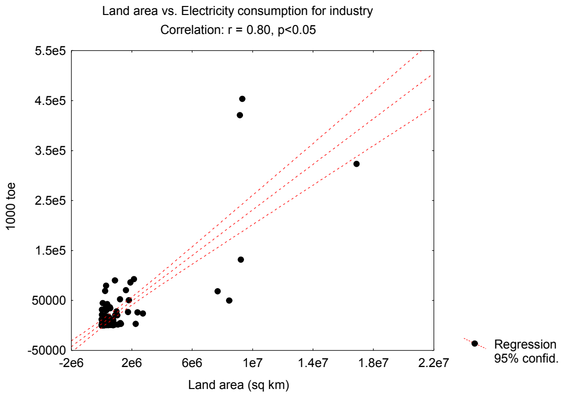
The amount of electricity used for industry is correlated with the size of a country (see significant correlation coefficient in Figure 40.1). Since the environmental risks associated with industry are related to the area over which accidental events, wastes and pollution can be attenuated, we expressed this indicator as a density function, dividing the amount of electricity used by total land area in a country and expressing the resulting values in toe/km^2 (instead of 1000s toe/km^2). When the density of electricity used for industry is in turn tested against country size, the correlation with size of country disappears (Figure 40.1 b). Electricity for industry per sq km varied from 0.42 to 2,266 toe/km^2 of land. The minimum Electricity/km2 was observed in Jordan, and the highest values in Trinidad & Tobago, Kuwait and Netherlands.

Table 40.1: Basic statistics for electricity used for industries and electricity for industry per sq km of land. Data are from WRI 2000-2001 for the year 1997.

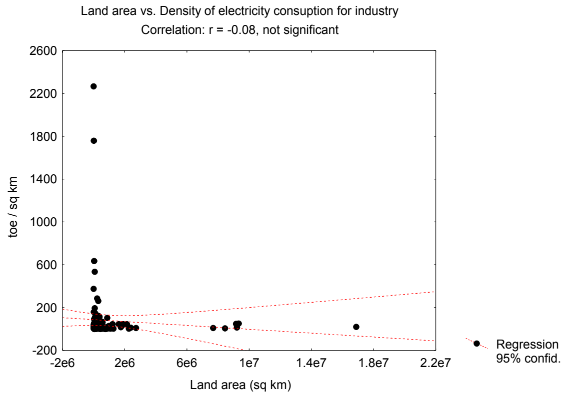
Statistic	Electricity used for industries 1997 (1000 toe)	Electricity used for industry / sq km (toe / sq km)
Mean	24,116.34	79.19
Median	3,607.401	18.41
Valid n	117	117
Min	19.89	0.42
Max	453,543.0	2,265.8
SD	66,162.27	273.95
SE	6,116.70	25.33
Skewness	5.16	6.60
SE Skewness	0.22	0.22
Kurtosis	28.70	46.84
SE Kurtosis	0.44	0.44

Figure 40.1: Graphs of electricity used for industry vs. size of countries for 1997. (a) Electricity use (in 1000s toe) in 1997 vs. size of country (sq km); and (b) Density of electricity used for industry (toe / sq km land) vs. size of country (sq km). The correlation is significant in (a) and not significant in (b).

(a)



(b)



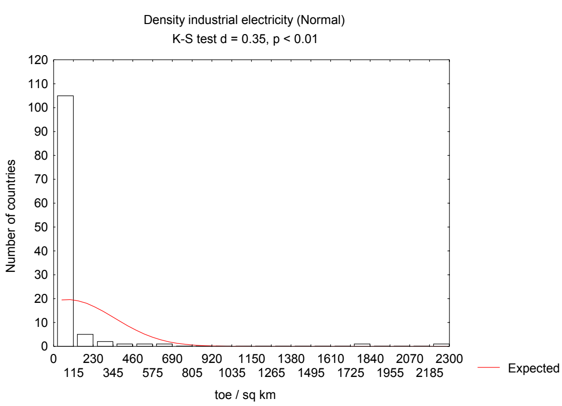
40.3 Distributional characteristics of the indicator data

The electricity used for industry / km^2 in countries in 1997 was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 40.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

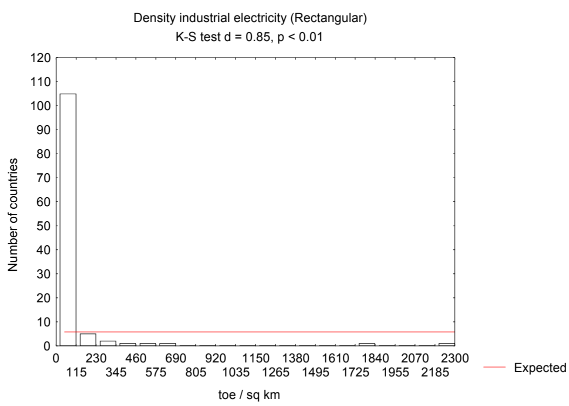
A significant difference between observed and expected values was found in the normal, rectangular and exponential distributions, but not for the lognormal distribution (Figure 40.2). This suggests that the values observed are distributed according to a logarithmic function. Transforming the values to their natural logarithms might provide a better scale for comparison.

Figure 40.2: Kolmogorov-Smirnov goodness-of-fit tests for electricity used for industry per km^2 in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The lognormal distribution provided the best fits of the observed data.

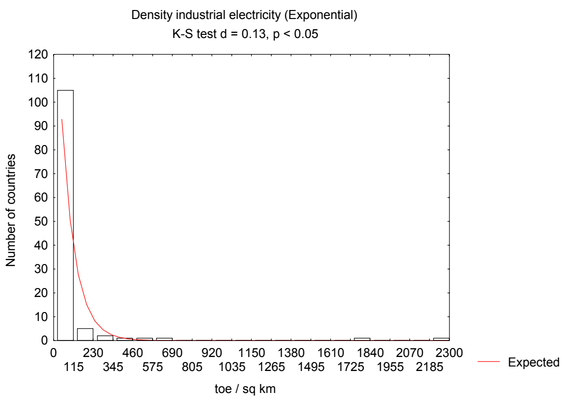
(a)



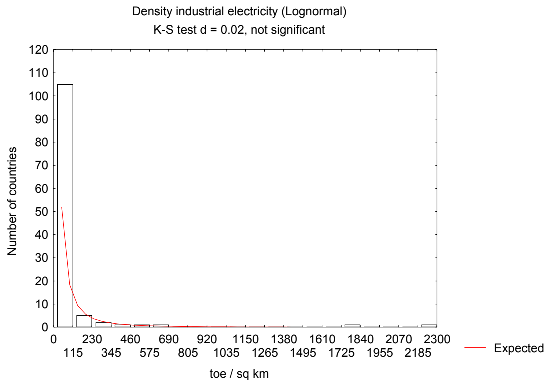
(b)



(c)



(d)



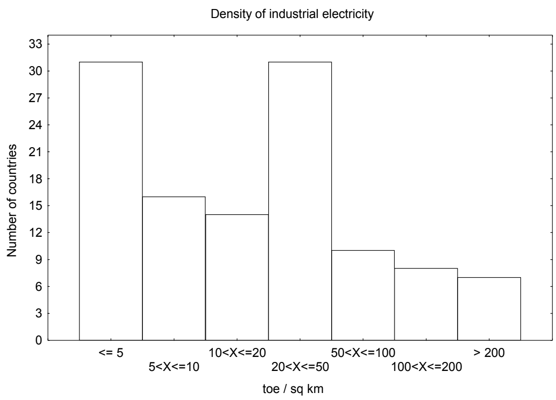
40.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in their electricity use for industry per km^2 by six orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We did not transform these data, but used them on their untransformed density scale (toe/km^2). Countries with the greatest loads per km^2 of industrial electricity use were considered more vulnerable and attracted a higher EVI score.

We identified those countries with ≤ 5 toe/km^2 as likely to be the least at risk of environmental damage related to toxic industries because the amount of electricity use for industry is small in relation to the area of land available (EVI score = 1). Countries with > 200 toe/km^2 were considered the most vulnerable (EVI score =7). These are the countries that in 1997 used more than 200 and up to 2,265 electricity for industry (toe) for every km^2 of their national land area. The country values between these extremes were spaced unevenly, with an increasing focus on higher levels of usage to form the remainder of the EVI scale (Figure 40.3, Table 40.2, 40.3).

Figure 40.3: Frequency distribution of density of electricity use for industry (toe/km^2) in even and uneven categories and the EVI scale. (a) Frequency distribution of density in 20 even categories, and (b) The proposed EVI scale.

(a)



(b)

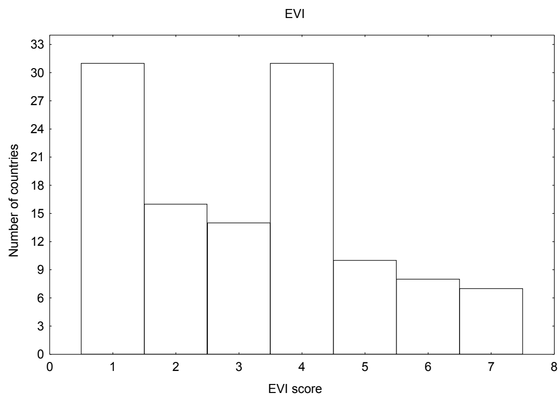


Table 40.2: Proposed EVI scaling for electricity use for industry / km² showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Electricity use for industry (toe/km²)	Observed # countries	Observed % of countries
1	X≤5	31	26.50
2	5<X≤10	16	13.68
3	10<X≤20	14	11.97
4	20<X≤50	31	26.50
5	50<X≤100	10	8.55
6	100<X≤200	8	6.84
7	X>200	7	5.98
No data		118	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 40.3: Proposed EVI scaling for electricity use / km² showing examples of countries that fell into each of the EVI scores.

Score	Electricity use for industry (toe/km²)	Examples
EVI=1	X≤5	Angola, Chile, Jordan
EVI=2	5<X≤10	Australia, Belarus, Lebanon
EVI=3	10<X≤20	Gabon, Lithuania, Pakistan
EVI=4	20<X≤50	Iran, Nigeria, El Salvador
EVI=5	50<X≤100	Denmark, Malaysia, Oman
EVI=6	100<X≤200	Belgium, Germany, Venezuela
EVI=7	X>200	Norway, Netherlands, Trinidad & Tobago

40.5 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 and in-country sources. In-country data were available for 15 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 40.4).

Table 40.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.79	2.27	2.07
Valid n (in-country)	14	15	15
SD (in-country)	0.43	0.96	0.96
SE (in-country)	0.11	0.25	0.25

40.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

40.7 Additional sources & contacts

www.world-nuclear.org (16/7/02); www.diw.go.th/ Report on Control of Waste Discharged from Oil and Gas Exploration and Production in the Gulf of Thailand, Pollution Control Dept (2001) (Thailand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Cook Island - Bureau of Statistics Information – Census 1998. Environment Services; Federated States of Micronesia - FSM DEA, and Department of Health, Education and Social Affairs (DHESA). Contact - Eneriko Suldan , and Moses Petrick (691 3202619/ 691 3205263/ Fsmhealth@mail.fm). FSM DEA/ Assistant Secretary; DHESA/ Environmental Health Specialist; Fiji - Vandana Naidu (311 699). Department of Environment (DoE); Greece - Various sources. Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Contact - Michael Phillips. Environment & Conservation Division (E&CD); Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Conatct - Mr Myrsaliev. Unit of Conventions; Nauru - Nauru Rehabilitation Corporation (NRC) Contact - Dempsey Detenamo (674 4443220/ 4443272/ detenamo@yahoo.com); Palau - Permit Files. Environmental Quality Protection Board (EQPB). Contact - Robert (Bob) Marek (680 4881639 or 3600/ 4882963/ eqpb@palaunet.com); Papua New Guinea - Data provided by: Katrina Solien (674 3250194, 3250113). Assistant Manager, Office of Environment & Conservation (OE & C); Republic of Marshall Islands - Republic of Marshall Islands Environmental Protection Agency (RMI EPA) Employees. Contact - Deborah Barker (Yumie Crisostomo's contact: 3035/ 5203/ EPARMI@ntamar.com/ Yumic@hotmail.com) Samoa - Lands, Surveys & Environment. Contact - Vainuupo Jungblut (685 22481 or 22486/ 23176/ envdlse@samoa.net); Singapore - Lim Siak Heng: Tel 6731 9782 Fax : 67319651. Executive engineer Pollution Control Department (PCD); St Lucia - Sustainable development and environment department. Contact - Christopher Corbin Tel: 7584685041 Fax – 7854516958 E-Mail ccorbin@planning.gove.lc. Senior sustainable development + Environment officer; Tonga - Environmental Planning & Conservation Section (EPACS) Contact - Lupe Matoto (676 23611/ 23216/ imepacs@candw.to, Vailala@candw.to) EPACS; Tuvalu - Environment Department. Contact – Mataio. Environment Dept; Vanuatu - Contact - Ernest Bani (678 25302/ 23565). Environment Unit/ Principal Environment Officer.

41. SPILLS

41.1 Indicator Summary

Indicator number:	41	
Indicator short name:	Spills	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Total number of spills of oil and hazardous substances greater than 1000 litres on land, in rivers or within territorial waters per million km maritime coast during the last five years	
Signals captured:	This indicator captures the risk to marine, estuarine, riverine, lake, ground water and terrestrial ecosystems from spills of hydrocarbons and other toxic fluids. Only spills greater than 1,000 litres are included. The effects of spills of toxic chemicals are of special significance for endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. Two countries, Kyrgyzstan and Kazakhstan recorded spills during the period 1996-2000 but do not have maritime coasts.	
Are suitable data available?	Yes, but only for a limited number of countries. Data were obtained for 152 countries, but many recorded zero spills between 1996-2000. It is likely that many of these zero values result from a failure to report.	
Sources of data:	• ITOPF 2002 International Tanker Owners Federation - Refers to oil spills at sea only • SPILLS 2000 www.etcentre.org/spills. The source of the spill must be a vessel, generally a tanker or barge on which a petroleum product was cargo, and must involve at least 1000 barrels (42,000 gallons). • CRED 2000 The OFDA/CRED International disaster database: data source derived from LLOYDS CAS • In-country	
No. countries included in test:	152 of 235 (127 with zero values)	
Temporary modifications to data or indicator, if applicable:	• Length of coastlines should include lakes and rivers.	
Notes on data age, completeness and quality:	9 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Number of spills greater than 1,000 litres between 1996-2000.	
Recommended transforms:	• Data untransformed	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	0<X≤50
	EVI Score = 3	50<X≤100
	EVI Score = 4	100<X≤150
	EVI Score = 5	150<X≤200
	EVI Score = 6	200<X≤250
	EVI Score = 7	X>250
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	1. Data for a larger number of countries is needed, but this should	

	not affect the EVI scaling 2. An accurate estimate of total length of rivers and length of lake coastlines is needed for all countries and would make a better denominator of this indicator 3. The method of estimating length of coastlines and rivers needs to be done at the same measurement scale for all countries.

41.2 Description of raw data

The raw data for this indicator are comprised of the total number of spills greater than 1,000 litres recorded between 1996 and 2000 anywhere on land or in aquatic environments and divided by the total length of coasts. For this evaluation we have only used the length of maritime coasts. River lengths and lake coasts will be included when appropriate data are available. Data are means for the years 1996-2000 and are derived from a range of sources (see data sheet and summary above). Of the 235 countries examined, data were available for 152, but are likely to be underestimated. It is likely that many of the countries that recorded zero spills of over 1,000 litres did have them, but that they were not recorded.

The total number of recorded spills (1996-2000) varied between 0 and 58 (Table 41.1). Zero values were recorded in 127 countries, with only 25 countries recording any spills in that period. The largest number of spills was recorded in Costa Rica (58), with a large gap between it and the next highest countries, Greece (3) and Australia (2). The mean value across the globe was 0.61 spills per country between 1996-2000, with most countries recording no spills (Table 41.1).

The number of spills is not correlated with the size of a country (Figure 41.1), but because the risks associated with spills are related to the area of land and water over which they are accidentally spilled and the rate at which they can be attenuated, we expressed this indicator as a density function, dividing the total number of spills over the 5 year period by the total length of maritime coasts in a country. We used length of coasts rather than land area for this indicator because most spills either occur in coastal waters or are mobilised by waters. Aquatic ecosystems are those most likely to be damaged by spills because it is harder to contain them. Spills to land are usually contained in bunds and recollected, or can be quickly limited, so detrimental effects are likely to be less. These arguments do however apply to rivers, lakes and groundwater, and there is a need to include these ecosystems in the indicator.

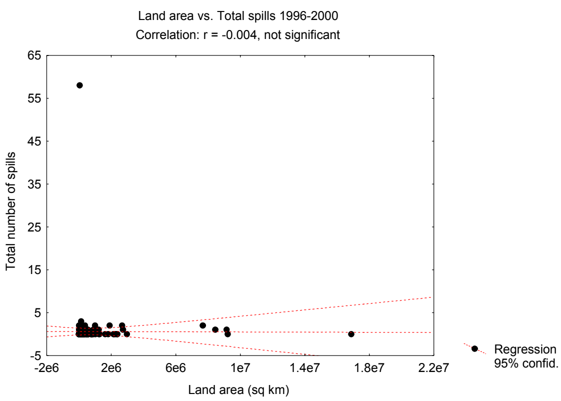
The total number of spills is not correlated with country size (as km^2 land area) nor length of maritime coastline (km) (Figure 41.1). The density of spills (spills per 1 million km of coast) varied between 0 and over 28,000, with the maximum density of spills being in Costa Rica, followed by Marshall Islands and Singapore.

Table 41.1: Basic statistics for total spills and density of spills. Data are from a range of sources and cover years 1996-2000.

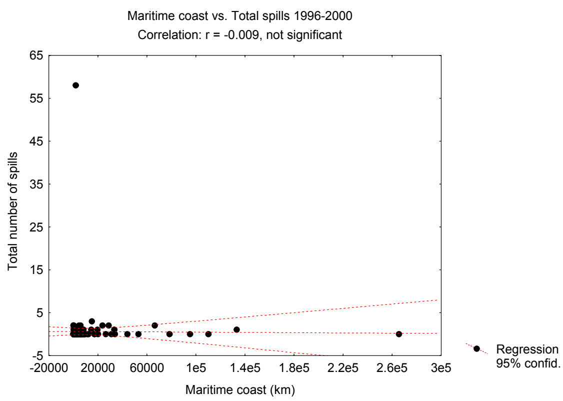
Statistic	Total spills 1996-2000	Density of spills Spills / million km coast (total 1996-2000)
Mean	0.61	278.67
Median	0.00	0.00
Valid n	152	150
Min	0	0.00
Max	58	28,032.87
SD	4.72	2,345.06
SE	0.38	191.47
Skewness	12.07	11.37
SE Skewness	0.20	0.20
Kurtosis	147.58	134.22
SE Kurtosis	0.39	0.39

Figure 41.1: Graphs of spills between 1996-2000 vs. size of countries. (a) Total spills vs. size of country (sq km); and (b) Total spills vs. length of maritime coastline (km). The correlation is not significant in (a) or (b).

(a)



(b)



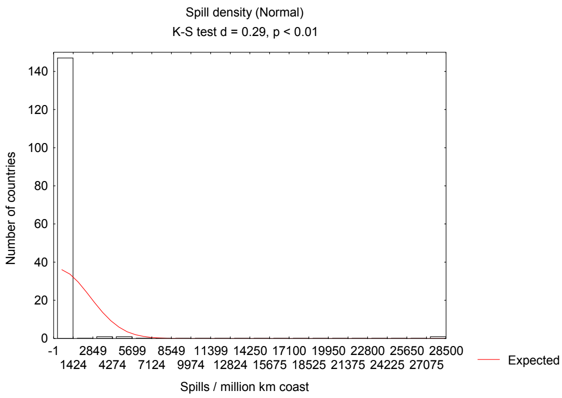
41.3 Distributional characteristics of the indicator data

The density of spills was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 41.2). This resulted in a distribution heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 41.2). This suggests that the values observed are distributed most closely to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 41.2: Kolmogorov-Smirnov goodness-of-fit tests for density of spills in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

(a)



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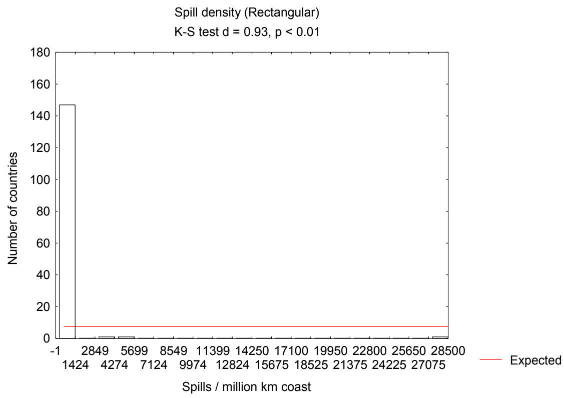
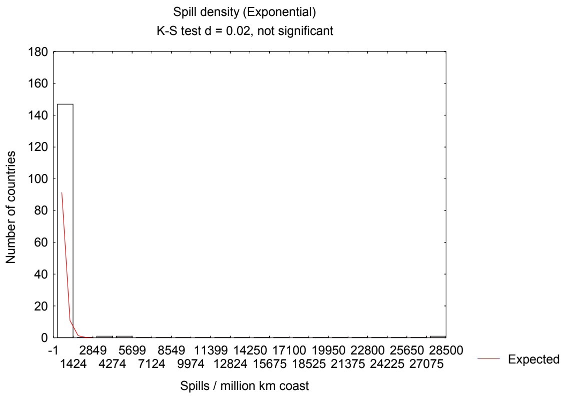
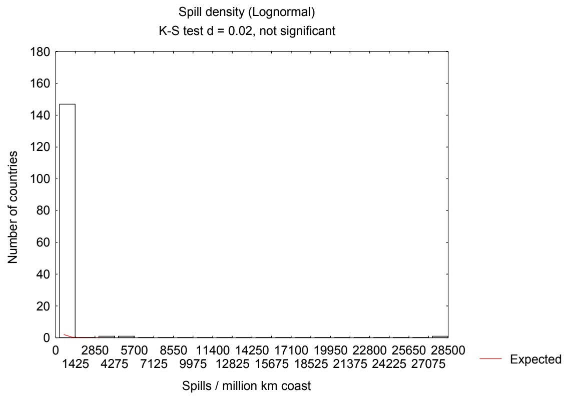


(c)



(d)

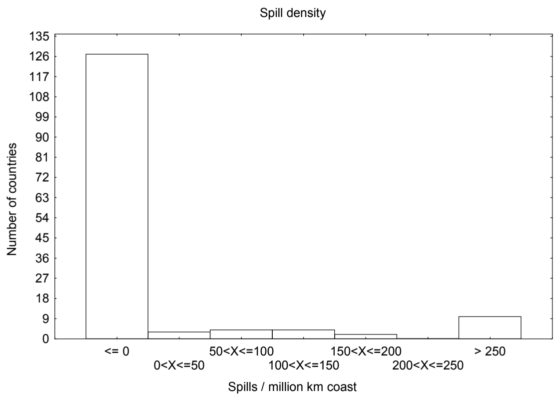


41.4 Proposed EVI scaling and distribution of the data on this scale

Countries varied in density of spills by three orders of magnitude, with a strong clumping of countries at the lower end of the scale at zero. We propose that the data not be transformed, and that countries with the greatest spill densities per million km of coastline being considered more vulnerable and attracting a higher EVI score. We identified those countries with 0 spills, followed by those with ≤50 spills per million km of coast to be the least at risk of environmental damage because the amount of materials spilled is small in relation to the area of land and sea available to absorb / attenuate them (EVI scores = 1 and 2, respectively). Countries with > 250 spills per million km of coast were considered the most vulnerable (EVI score =7). The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 41.3, Table 41.2, 41.3).

Figure 41.3: Frequency distribution of density of spills in even and uneven categories and the EVI scale. (a) Frequency distribution of density in 7 even categories. (b) is proposed EVI scale.

(a)



(b)

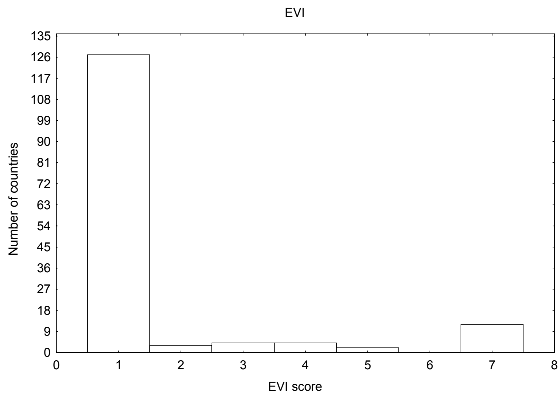


Table 41.2: Proposed EVI scaling for density of spills showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for Spill density	Observed # countries	Observed % of countries
1	X=0	127	83.55
2	0<X≤50	3	1.97
3	50<X≤100	4	2.63
4	100<X≤150	4	2.63
5	150<X≤200	2	1.32
6	200<X≤250	0	0
7	X>250	12	7.89
No data		83	54.61
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 41.3: Proposed EVI scaling for Indicator 41 on density of spills showing examples of countries that fell within each of the EVI scores.

Score	Scale for Spill density	Examples
EVI=1	X=0	Anguilla, Bahrain. Latvia
EVI=2	0<X≤50	Australia, Brazil, USA
EVI=3	50<X≤100	Cuba, Japan, UK
EVI=4	100<X≤150	Thailand, France, Venezuela
EVI=5	150<X≤200	Colombia, Greece
EVI=6	200<X≤250	None
EVI=7	X>250	Costa Rica, Singapore, South Africa

41.5 Age, completeness and quality of the data

The data obtained for this indicator were from ITOPF 2002, SPILLS 2000, CRED 2000 and in-country sources. In-country data were available for 17 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 41.4).

Table 41.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.29	2.06	2.00
Valid n (in-country)	17	17	17
SD (in-country)	0.59	0.97	0.94
SE (in-country)	0.14	0.23	0.23

41.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

41.7 Additional sources & contacts

www.itopf.com/country_profiles/profiles/view.html (16/01/03); www.cred.be/emdat/guide.htm (19/03/2002), www.etcentre.org/spills ; Cook Islands - Contact - Antoine Nia (682 21256/ 682 22256). Environment Services; Costa Rica - Direccion saniamiento ambiental. Municipalidad de San Jose; Federated States of Micronesia - Gawel, M. 1993. FSM SoE. (pp 34-35). SPREP; Fiji - Fiji National Oil Spill Committee. National Fire Authority (NFA) Sher Bahadur - NFA/ Secretary; Kiribati - Contact - Yale Carden. Environment & Conservation Division (E&CD); Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Contact - Mr Myrsaliev. Unit of Conventions; Marshall Islands - A) Crawford, M. 1992. RMI National Environmental Management Strategy (NEMS), B) Republic of Marshall Islands Environmental Protection Agency (RMI EPA) Employees; Nauru - Nauru Phosphate Corporation (NPC). Contact - David De-Luckner (NPC); Nepal - Office Records. Nepal Oil Corporation, Kathmandu; Niue - Country Report for UNCED – Niue, 1991. Government of Niue & SPREP (Consultants – Lowry, C & Smith, J). pp 53. EVI Team; Niue - Data based on first-hand knowledge and experience. Bulk Fuel Corporation(BFC). Contact - Berry Sofaea (fax: 683 4362/ bulkfuel@mail.gov.nu). BFC Terminal Supervisor; Palau - Conversation with Emil Edesomel, Pollution Prevention Officer. Environmental Quality Protection Board (EQPB); Samoa - Report on Oil Spill (July 1999) based on observation and investigation. Lands, Surveys & Environment; Singapore - Lim Siak Heng: Tel 6731 9782 Fax : 67319651. Executive engineer Pollution Control Department(PCD); Thailand - Pollution Control Department. Thailand. Tel 66 2 2982253 Fax 66 2 2982240 e-mail: marinepollution_pcd@yahoo.com; Tonga - 1994 – 1999 Annual Report. Ministry of Marine & Ports (MMP); Tuvalu - Environment Department. Contact – Mataio. Environment Dept.

42. MINING

42.1 Indicator Summary

Indicator number:	42
Indicator short name:	Mining
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	1. Average annual mining production over the past 5 years (includes all surface and subsurface mining and quarrying) (tonnes/km^2/yr). 2. Tonnes of mining material (ore + tailings) extracted from sub-surface mines per square kilometre per land area per year average last five years. Include all metals, oil, coal and any other non-renewables extracted through sub-surface mining.
Signals captured:	This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters from the effects of ecosystem disturbance, accidents, oil spills and toxic leachates, and processing from mining of all kinds. All disturbance can lead to vulnerability to other processes, human and natural, and wastes need a suitable area of land or volume of water for their eventual attenuation or long term deposition. High levels of mining activity present risks to all aspects of the environment. The effects of mining would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.
Notes on this indicator:	1. Data are on average annual production between 1996-2000 for most products, except Uranium for which data for only the year 2000 were available. 2. Data includes 81 types of mining, including clays, gravels, cement, gems, radioactive materials, metals, petroleum and gas. 3. Production is not the best measure for this indicator. We designed the indicator to measure the total amount of ores extracted, not just the much smaller amounts of final products taken from them. Ore extraction is considered a better measure of environmental disturbance for two reasons. First, it measures the level of general physical disturbance of the environment, regardless of the value or volume/weight of the final product of interest. Second, the amount of ore extracted may be self-weighting. That is, for large volume/weight materials such as stone, cement, gravels etc, the amount of material extracted is approximately equal to the final product (except for overburden) and therefore represents mostly the physical disturbance. For heavy metals, the amount of ore extracted is much larger than the weight of the final product. In this case, using the value for ore builds-in a stronger signal than just final production figures, the difference representing some measure of the effects of processing the ore to the final concentrate. 4. Data from in-country sources were difficult to obtain.
Are suitable data available?	Yes

Sources of data:	• USGS - US Geological Survey and are mean annual production 1996-2000 • World Nuclear Association 2003 web site - http://www.world-nuclear.org/info/inf23.htm • Diamond Registry 2002 -- http://www.diamondregistry.com/News/2002/production.htm • Salt Institute 2002 - http://www.salt.org.il/frame_prod.html (data from USGS Mineral Commodity Summaries 2002) • Uranium is only from 2000 • In-country	
No. countries included in test:	235 of 235	
Temporary modifications to data or indicator, if applicable:	• Data are currently for production. Full extractions of all ores would be a better method of evaluation of this vulnerability.	
Notes on data age, completeness and quality:	12 of the 32 collaborating countries returned data for this indicator. Age and completeness of the in-country data were generally considered good (> value of 2 of 3), while the quality of the data was considered low (1.83).	
Basic units:	Average total mining production 1996-2000 in tonnes. This was divided by land area.	
Recommended transforms:	• Data transformed to LN(X+1)	
Proposed EVI Scale LN(X+1) scale	EVI Score = 1	X≤1
	EVI Score = 2	1<X≤2
	EVI Score = 3	2<X≤3
	EVI Score = 4	3<X≤4
	EVI Score = 5	4<X≤5
	EVI Score = 6	5<X≤6
	EVI Score = 7	X>6
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	1. Data for total materials extracted would be a better measure for this indicator. 2. It would be better if non-toxic mining that largely causes disturbance were separated from mining that requires heavy processing and is associated with heavy leachates. 3. 129 countries are recorded as having no mining production. For at least some of these, such as Papua New Guinea and Kyrgyzstan, this is clearly incorrect. Data need to be updated and checked.	

42.2 Description of raw data

The raw data for this indicator are comprised of the total annual tonnage of mining production across all mined species. Data are means for the years 1996-2000 and are derived from a range of sources (see listing above). The mean annual mining production in countries between 1996-2000 varied between 0 and more than 773 million tonnes (Table 42.1). There was no recorded mining production during that period in 126 countries. This is unlikely to be accurate, since even those countries without significant industrial mining will usually meet their own needs for quarried materials such as gravels and cement locally. The in-country data were not used as they were not comparable with the data we obtained from public sources, but do show that significant mining is occurring in these countries. For example, Greece reported 1.03 tonnes/ore extracted/year between 1996-2000 and Kyrgyzstan 8,753 tonnes in 1998 (it is not clear whether this is a total for the country in tonnes or a per km^2 values: units were intended to be tonnes/km^2/yr). Marshall Islands, Papua New Guinea and Philippines all returned values for ore extracted that do not appear in the public data sets. For this evaluation of the EVI, they have EVI scores of 1, which is at least for some of the countries in error. On this basis, we are also cautious of the remaining data, as this may also underestimate the amount of mining occurring in a country. All countries need to be re-evaluated with updated, appropriate data.

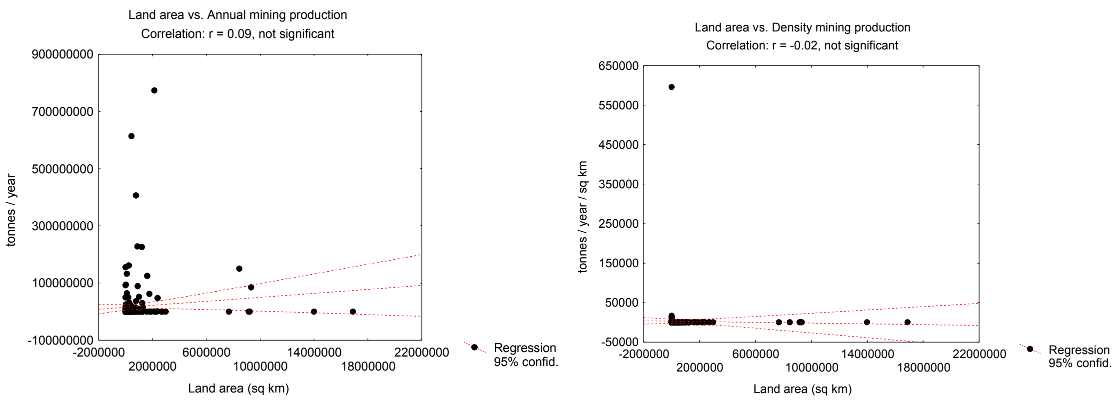
The lowest values for mining production (that were non-zero) were recorded in Central African Republic, Liberia and Burkina Faso, and the highest values in Saudi Arabia, Iraq and Turkey. The mean value across the globe was 17.3 million tonnes per year (Table 42.1). Variance among countries is moderately high, with a standard deviation which is around 4.3 times the mean. Data were theoretically available for all of the 235 countries examined (though see comments above).

Mining production is not correlated with the size of a country (Figure 42.1), but since the risks associated with habitat disturbance and effects of wastes are related to the area over which they can be recolonised, attenuated or deposited, we expressed this indicator as a density function (intensity), dividing the annual production by total land area in a country. The intensity of mining production was also not correlated with the size of a country. The intensity of mining production varied from 0 to 595,771 tonnes/km2/year as a national average. The greatest mining intensities were recorded in St Kitts & Nevis, Bahrain and Nauru.

Table 42.1: Basic statistics for mining. Data are from a range of sources and cover years 1996-2000.

Statistic	Mean annual mining production tonnes / year (1996-2000)	Intensity mining production Mean tonnes / year / sq km (1996-2000)	LN(X+1) Intensity of mining production
Mean	17,370,077	2,866	1.47
Median	0	0	0.00
Valid n	235	235	235
Min	0	0	0.00
Max	773,061,009	595,771	13.30
SD	75,541,781	38,879	2.56
SE	4,927,802	2,536	0.17
Skewness	7.32	15.29	1.82
SE Skewness	0.16	0.16	0.16
Kurtosis	61.71	234.09	2.78
SE Kurtosis	0.32	0.32	0.32

Figure 42.1: Graphs of mean annual mining production vs. size of countries. (a) Mining production (tonnes) per year vs. size of country (km^2); and (b) Intensity of mining (tonnes / km^2/yr) vs. size of country (km^2). Neither correlation is significant.



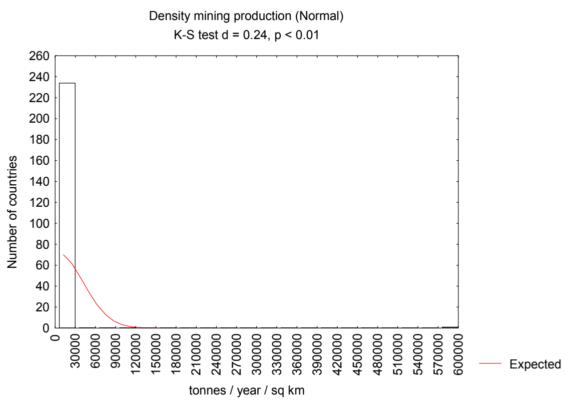
42.3 Distributional characteristics of the indicator data

Intensity of mining production in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 42.2). This resulted in a distribution which was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

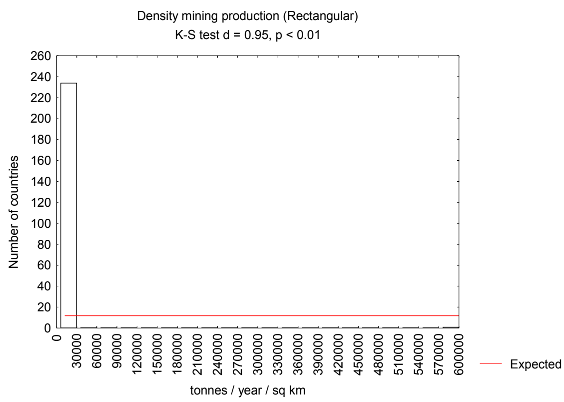
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 42.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 42.2: Kolmogorov-Smirnov goodness-of-fit tests for intensity of mining production in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

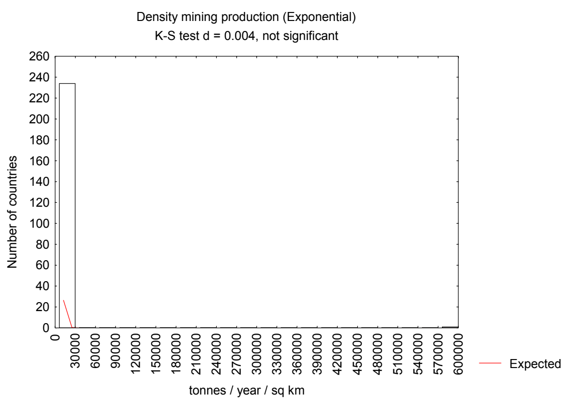
(a)



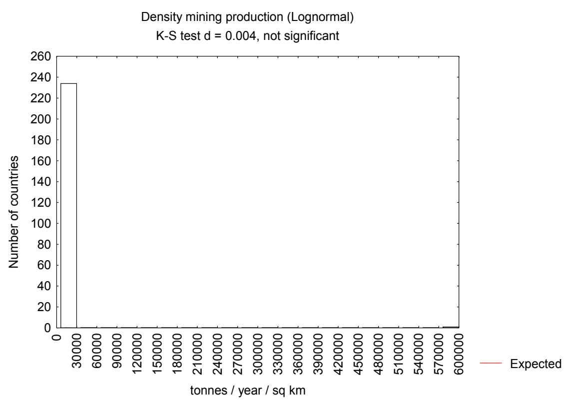
(b)



(c)



(d)

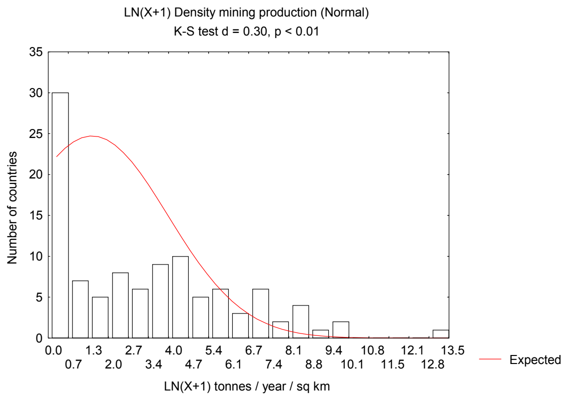


42.4 Proposed EVI scaling and distribution of the data on this scale

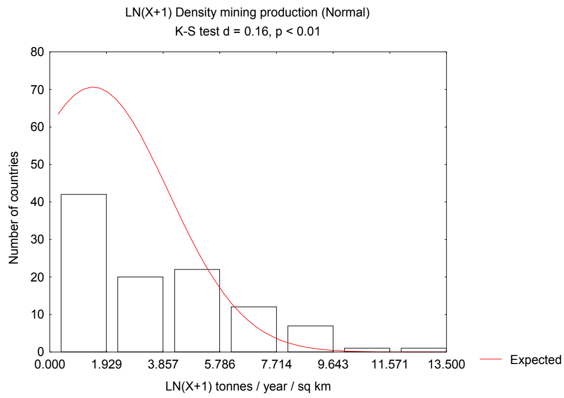
Countries varied in density of intensive farming by at least five orders of magnitude, and there was a strong clumping of countries at the lower end of the scale, caused primarily by the zero values recorded for many countries. Nevertheless there are many countries with low levels of mining, so the scaling of the EVI can be set for this indicator using the values obtained. We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries and compress the scale, with countries having the greatest amount of mining production per km^2 being considered more vulnerable and attracting a higher EVI score. We identified those countries with ≤1 on the transformed scale (≤ 1.72 tonnes/km^2/year) as being at low risk of environmental damage due to mining, giving them an EVI score of 1. Countries with > 6 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that in 1996-2000 produced more than 402 tonnes of mined materials / year / km^2 of land as a national average. The values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 42.3, Table 42.2, 42.3).

Figure 42.3: Frequency distribution of LN(X+1) intensity of mining production in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) intensity in 20 even categories, (b) is the same distribution compressed to a 7 category (even) scale, (c) the proposed EVI scale.

(a)



(b)



(c)

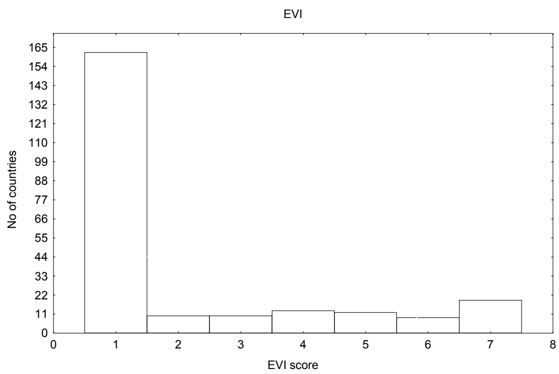


Table 42.2: Proposed EVI scaling for intensity of mining production showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LNX+1)	Observed # countries	Observed % of countries
1	X≤1	162	68.94
2	1<X≤2	10	4.26
3	2<X≤3	10	4.26
4	3<X≤4	13	5.53
5	4<X≤5	12	5.12
6	5<X≤6	9	3.83
7	X>6	19	8.09
No data		0	0
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 42.3: Proposed EVI scaling for intensity of mining production showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fall within each of the EVI scores.

Score	Scale for LN(X+1) Intensity of mining production	Equivalent scale tonnes / year / km^2	Examples
EVI=1	X≤1	X≤1.72	Belgium, Estonia, Japan
EVI=2	1<X≤2	1.72<X≤6.39	Afghanistan, Djibouti, Fiji
EVI=3	2<X≤3	6.39<X≤19.09	Mauritania, Peru, Senegal
EVI=4	3<X≤4	19.09<X≤53.60	Algeria, Egypt, Morocco
EVI=5	4<X≤5	53.60<X≤147.41	Austria, Cuba, Nigeria
EVI=6	5<X≤6	147.41<X≤402.43	Croatia, Lebanon, Oman
EVI=7	X>6	X>402.43	Cyprus, Iraq, Qatar

42.5 Age, completeness and quality of the data

The data obtained for this indicator were from a range of industry, observer and in-country sources. In-country data were available for 12 of the 32 collaborating countries, with data being considered by collaborators to be of good age and completeness, but low quality (Table 42.4). In-country data could not be incorporated in this evaluation because they were on ores extracted and not mining production.

Table 42.4: Characteristics of age, completeness and quality of the data obtained from collaborators.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.00	2.27	1.83
Valid n (in-country)	12	11	12
SD (in-country)	0.60	1.01	0.72
SE (in-country)	0.17	0.30	0.21

42.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

42.7 Additional sources & contacts

www.diamondregistry.com/News/2002/production.htm; www.world-nuclear.org/info/inf23.htm; www.salt.org.il/frame_prod.html; www4.btwebworld.com/mineralsuk/britmin/AMS1995-99.pdf (29/01/03); www.minerals.er.usgs.gov/minerals/pubs/country/2001/; Botswana - Contact - Mr. N.C MmolawaTel: 365 7000 Fax: 352141 nmmolawa@gov.bw Department of Mines Senior Mining Engineer; Federated States of Micronesia - Contact - Eneriko Suldan. FSM Department of Economic Affairs (FSMDEA); Fiji - SML (B) Files: Form 13 & 14 Monthly Reports. Minerals Resources Department (MRD); Kiribati - Contact - Naomi Atauea (686 21099/ 686 21120) Ministry of Natural Resources Development (MNRD); Kyrgyzstan - Department of State Ecological Control and Environment Utilization. Contact - Mr. Myrsaliev N, Unit Of Conventions; Marshall Islands - Contact - J. Kramer (Kenneth Kramer's contact: 3560/ 3348/ Kkramer@ite.net) Pacific International (Construction) Inc.; Nauru - Shipment data; Niue - Contact - DeveTalagi (Fax: 4223). Public Works Department/ Director; Papua New Guinea - Annual Mining Estimates. Mining Division; Philippines - Environmental Degradation due to Selected Economic Activities. Minerals and Mining Sector, PEENRA; Samoa - Contact - Vainuupo Jungblut. Lands, Surveys & Environment; Thailand - Mineral Statistic of Thailand 1996-2000. Department of Mineral Resource; Tuvalu - Mc Lean, R. F. and Hosking, P. C. 1991. Tuvalu Land Resource Survey Report. Country Report. A report prepared for the Food and Agriculture Organisation of the United Nations acting as executing agency for the United Nations Development Programme.

43. SANITATION

43.1 Indicator Summary

Indicator number:	43
Indicator short name:	Sanitation
Sub-index	REI
Categorisation	Resources & Services
Indicator text:	1. Density of population without access to safe sanitation (WHO definitions). 2. Density of population without access to secondary or higher levels of sewage treatment.
Signals captured:	'Safe sanitation' is normally an issue seen from a human perspective. It deals with hygiene, disease control and direct quality of life for humans. We are using this information for the EVI from and environmental perspective. This indicator (text 1 above) is a proxy measure for how human waste is treated before it enters the environment. We are taking safe sanitation as an indication of at least some pre-treatment of sewage before it enters stream, groundwater recharge, coastal and land areas. If sanitation is of a low standard, ecosystems downstream have a higher risk of being polluted with sewage that has not been broken down and which will contain high levels of urea, ammonia, nitrites, pharmaceuticals and pathogens. The WHO definition of safe sanitation used here is the percentage of the human population with sewage disposal facilities that can effectively prevent human, animal, and insect contact. This includes connections to public sewers, household systems such as pit and pour-flush latrines, septic tanks, communal toilets, and other such facilities.
Notes on this indicator:	1. The original indicator text was converted to a density function and reversed from a focus part of the population *with* sanitation (text 3), to focus on part *without* sanitation for a more relevant and intuitive EVI scale. 2. This scale is set more critically than that on population density because it focuses on populations without access to safe sanitation and which may therefore be more likely to release untreated pollutants into the surrounding environment. 3. A better form of this indicator would be the population without access to at least secondary sewage treatment (text 2 above). That is, at least partial bacterial breakdown of sewage before it is released into the environment.
Are suitable data available?	Yes, approximate data only – the definition of 'safe sanitation' is from a human perspective and is not sufficiently focused on quality of the discharge from an environmental perspective. This is however a reasonable proxy because and delay in release of sewage (even in pit latrines) will tend to allow time for bacterial decomposition.
Sources of data:	• WRI 2000-2001 (using WHO definitions) • In-country
No. countries included in test:	108 of 235
Temporary modifications to data or indicator, if applicable:	• Indicator uses data on 'safe sanitation'. This indicator should use data on level of sewage treatment.

Notes on data age, completeness and quality:	17 of the 32 collaborating countries returned data for this indicator. The age, completeness and quality of the data were generally considered good (score of >2 of 3).	
Basic units:	Percent of human population *with* access to safe sanitation, converted to percent *without* access and then a density of population per km^2.	
Recommended transforms:	LN(X+1)	
Proposed EVI Scale LN(X+1) data	EVI Score = 1	X<1.5
	EVI Score = 2	1.5<X≤2
	EVI Score = 3	2<X≤2.5
	EVI Score = 4	2.5<X≤3
	EVI Score = 5	3<X≤3.5
	EVI Score = 6	3.5<X≤4
	EVI Score = 7	X>4
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	A source of data which focuses on levels of treatment of sewage is needed. This indicator should focus on percent of population with access to at least secondary sewage treatment (Indicator text 2 above).	

43.2 Description of raw data

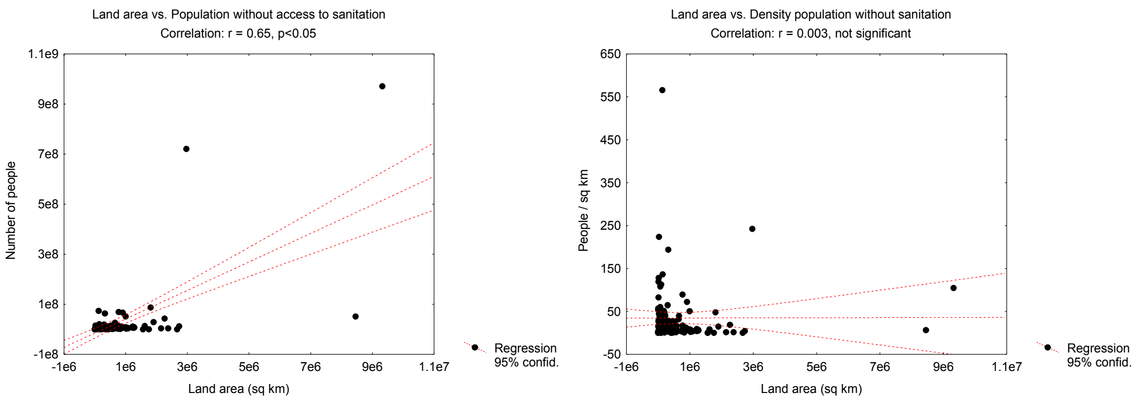
The raw data for this indicator are comprised of the percentage of the human population in countries with access to safe sanitation (WHO definitions), are derived from WRI 2000-2001and in-country sources and mostly refer to the years 1990-1997. These data were reversed to focus on that part of the population *without* access to safe sanitation and recalculated as a population density to focus on environmental load. Data for this indicator were available for 108 of the 235 countries examined.

The total world human population by 1997 without access to safe sanitation was approximately 2.67 billion. In terms of density over land area, the global average was almost 35 / km^2. Densities varied between 0 (in uninhabited territories such as Antarctica and in countries such as Uzbekistan and Singapore) and 566 people/km^2 without access to safe sanitation per km^2 (Table 43.1). The maximum densities were found in Bangladesh, India and Haiti. Half of the world's countries have less than 14.01 people / km^2 without access to safe sanitation (the median). The variance among countries is low to moderate, with the standard deviation being around twice the mean. The density of human populations without access to safe sanitation is not correlated with the size of a country (Figure 43.1).

Table 43.1: Basic statistics for density of population without access to safe sanitation. Data are from WRI 2000-2001 and in-country sources.

Statistic	Population without access to safe sanitation	Density of population without access to safe sanitation (population / km^2)	LN(X+1) Population density
Mean	24,744,643	34.73	2.63
Median	3,323,950	14.01	2.71
Valid n	108	108	108
Min	0	0	0
Max	970,944,080	565.56	6.34
SD	115,728,738	67.82	1.41
SE	11,136,003	6.53	0.14
Skewness	7.26	5.24	0.04
SE Skewness	0.23	0.23	0.23
Kurtosis	53.94	35.96	-0.49
SE Kurtosis	0.46	0.46	0.46

Figure 43.1: Graphs of human populations without access to safe sanitation vs. size of countries. (a) Size of the population without access to safe sanitation, (b) Density of population without access to safe sanitation. The size of population without access to safe sanitation does correlate with the size of countries, but density does not.



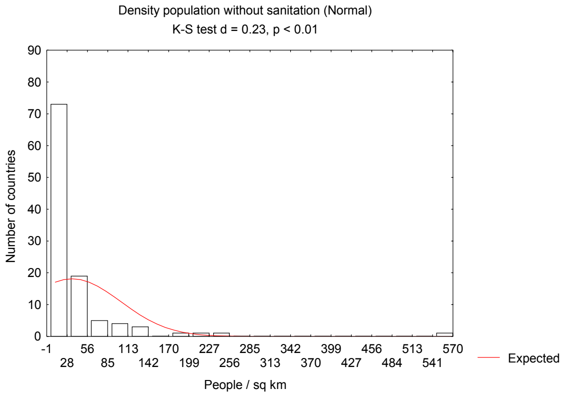
43.3 Distributional characteristics of the indicator data

The density of people without access to safe sanitation was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 43.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

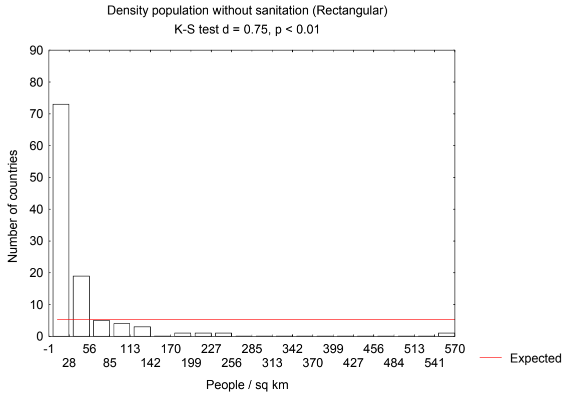
A significant difference between observed and expected values was found in the normal, rectangular and exponential models, indicating that the densities of populations without access to safe sanitation around the globe do not approximate these types of distributions. The distribution for densities of populations without access to safe sanitation was a better fit to the lognormal functions (Figure 43.2). The observed distribution was heavily skewed at the low end of the scale, with few countries at higher values.

Figure 43.2: Kolmogorov-Smirnov goodness-of-fit tests for population density without access to safe sanitation spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

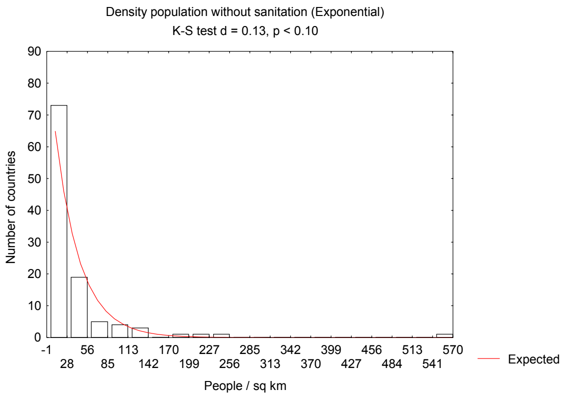
(a)



(b)



(c)



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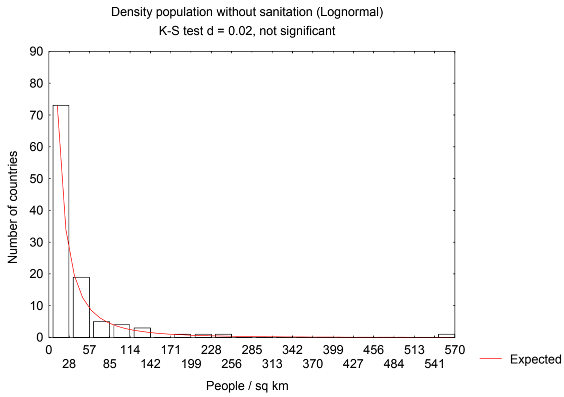


43.4 Proposed EVI scaling and distribution of the data on this scale

We propose that the raw values for density of human population without access to safe sanitation be transformed to a natural log scale to give a more compressed range between 0 and 6.3 and to provide better spread among the countries with lower densities. These values would be scaled evenly to create EVI scores that group and highlight countries with large densities of people without access to safe sanitation as a national average. Ideally, countries should have none of their population discharging untreated sewage into the environment for lowest vulnerability, and the proposed EVI scale highlights this focus. We set an upper limit of around 50 people per km^2 beyond which countries would be highly vulnerable to environmental damage from untreated sewage (LN(X+1) value of >4 equating to an EVI=7). Countries with less than 3.48 people per km^2 without access to safe sanitation and an LN(X+1) value of <1.5 were given an EVI score of 1 (including uninhabited countries). The remaining countries were distributed evenly within the remaining LN(X+1) scale to indicate increasing vulnerability with increasing population density between the above ranges. The distribution of countries plotted on the proposed EVI scale is shown in Figure 43.3, Table 43.2, 43.3).

Figure 43.3: (a) Frequency distribution of LN(X+1) density of populations without access to safe sanitation in 20 categories; (b) is a the same distribution over 7 even categories; (c) is the frequency distribution over 7 categories with values ≤1.5 and >4 grouped; (d) is the 1-7 EVI scale for this indicator.

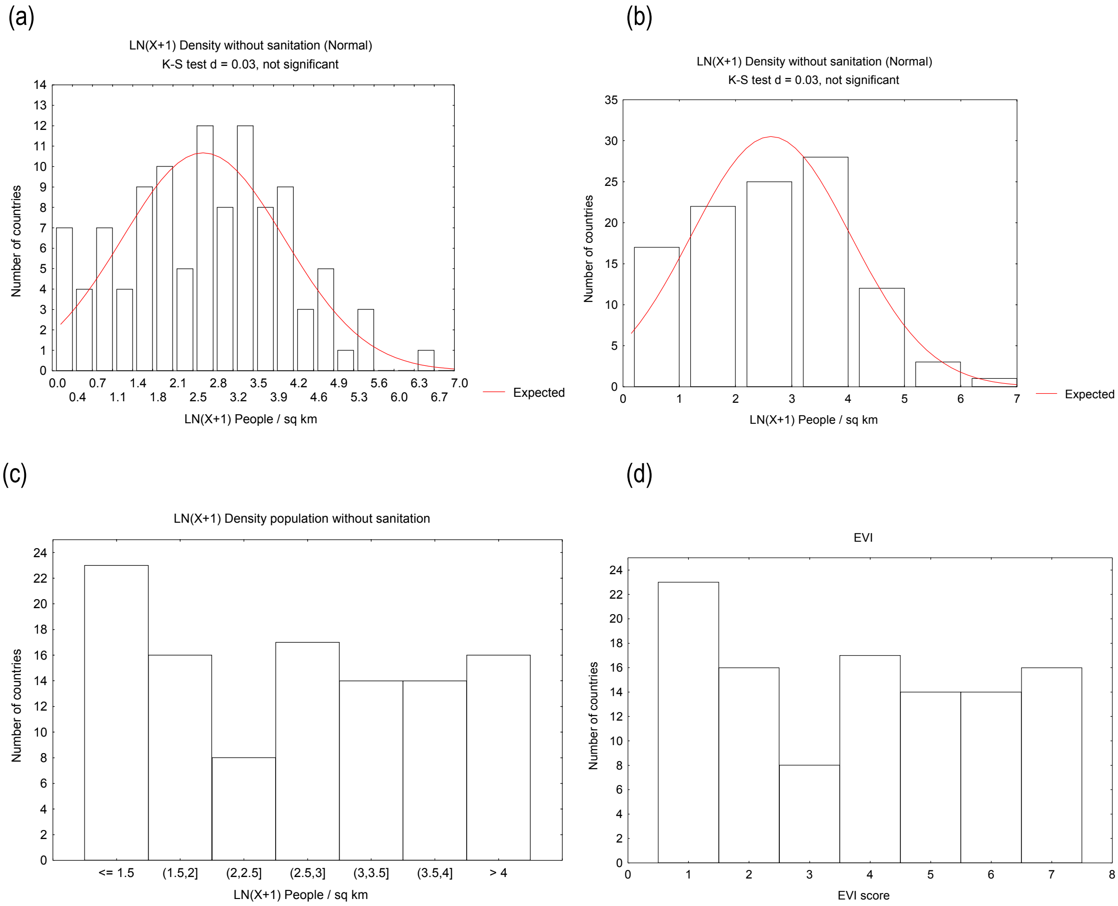


Table 43.2: Proposed EVI scaling for density of people without access to safe sanitation and the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X<1.5	23	21.30
2	1.5<X≤2	16	14.81
3	2<X≤2.5	8	7.41
4	2.5<X≤3	17	15.74
5	3<X≤3.5	14	12.96
6	3.5<X≤4	14	12.96
7	X>4	16	14.81
No data		127	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 43.3: Proposed EVI scaling for density of people without access to safe sanitation showing the scale as defined on LN(X+1) transformed data and the equivalent values in population / square kilometre. Also shown are examples of countries that fall into each of the EVI scores.

Score	Scale for LN(X+1) Population density without access to safe sanitation	Scale for Population density without access to safe sanitation	Examples
EVI=1	X<1.5	X<3.48	UAE, Algeria, Libya
EVI=2	1.5<X≤2	3.48<X≤6.39	Fiji, New Zealand, Chad
EVI=3	2<X≤2.5	6.39<X≤11.18	Equatorial Guinea, Panama, Paraguay
EVI=4	2.5<X≤3	11.18<X≤19.09	Palau, Venezuela, Zimbabwe
EVI=5	3<X≤3.5	19.09<X≤32.12	Guinea, Morocco, Nicaragua
EVI=6	3.5<X≤4	32.12<X≤53.60	Dominican Rep, Ghana, Lesotho
EVI=7	X>4	X>53.60	Kiribati, Sri Lanka, Nepal

43.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

43.6 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001 and from in-country sources. In-country data were available for 16 of the 32 collaborating countries, with data being of good age, completeness and quality (Table 43.4).

Table 43.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.79	2.20	2.50
Valid n (in-country)	14	15	16
SD (in-country)	0.43	0.94	0.82
SE (in-country)	0.11	0.24	0.20

43.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

43.8 Additional sources & contacts

www.nso.go.th/pop2000/table/tadv_tab13.xls (Thailand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Botswana - CSO, 2001 Population Census. Department of Sanitation, National Master Plan; Cook Islands - A) Water and Sanitation in the South Pacific. 1998 Report. B) Pacific Human Development Report, 1999. SP Epidemiological Implementation. (Statistics Office); Costa Rica - Instituto Nacional de

Estadística y Censos, Encuesta de Hogares de Propósitos Múltiples. Módulo de Vivienda; Kiribati - A) Environmental Health Staff. B) National Statistics Office. Ministry of Health and Family Planning; Kyrgyzstan - Source - Inspectorate of Sanitation and Epidemiological Control. Contact - Mrs. Vashneva N.S. Leading Specialist; Marshall Islands - Marshalls Water & Sanitation Conservation (MWSC) Billing; Nauru - Contact - Dempsey Detenamo (674 4443220/ 4443272/ detenamo@yahoo.com) Nauru Rehabilitation Corporation; Nepal - State of the Environment, Nepal, 2001 (p-46) Ministry of Population and Environment, Kathmandu; New Zealand - Community sewerage survey- Prepared for the ministry of health, February 2001, by Beca Steven in association with the institute of Environmental Science and research Ltd. Ministry of Health; Niue - Contact - Water Division, PWD. Andre Siohane (683 4297/ 4223/ waterworks@mail.gov.nu); Palau - Census of Population & Housing. Office of Planning & Statistics; Papua New Guinea - Source - Department of Health, Community Health, Water Supply & Sanitation. Contact - Maino Virobo (3250198/ 3250182). OE & C/ Hydrologist; Philippines - Source - Modified Field Health Service Information System. Contact - Mr. Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph Statistical Coordination Officer. Environmental Health Service, Department of Health; Singapore - Source – Sewerage department. Contact - Sandra Joy Vaz, Tel: 7313110 : Fax 7313020 E-Mail Sandra_Vaz@pub.gov.sg. Director, corporate management department; Trinidad & Tobago - Contact - Cindy Buchoon.

44. VEHICLES

44.1 Indicator Summary

Indicator number:	44	
Indicator short name:	Vehicles	
Sub-index	REI	
Categorisation	Resources & Services	
Indicator text:	Number of vehicles per square kilometre of land area (most recent data)	
Signals captured:	This indicator captures the risk to terrestrial ecosystems in the form of habitat damage, habitat fragmentation, loss of biodiversity, pollution hazardous wastes and industries, including air and lead pollution on land and in waterways. Of particular concern is fragmentation of the countryside which can interfere with normal movements and/or migration of terrestrial mammals. The definition of *vehicles* used here is from the World Bank. The effects would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.	
Notes on this indicator:	1. Data from WRI only cover 1996	
Are suitable data available?	Yes.	
Sources of data:	• WRI 2000-2001 • OECD 1999 • In-country	
No. countries included in test:	156 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	20 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (> value of 2/3 for age, completeness and quality).	
Basic units:	Vehicles in a country per sq km of land.	
Recommended transforms:	• LN(X+1)	
Proposed EVI Scale (For LN(X+1) transformed values)	EVI Score = 1	X≤1
	EVI Score = 2	1<X≤1.5
	EVI Score = 3	1.5<X≤2
	EVI Score = 4	2<X≤2.5
	EVI Score = 5	2.5<X≤3
	EVI Score = 6	3<X≤3.5
	EVI Score = 7	X>3.5
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Data for a larger number of countries is needed, but this should not affect the EVI scaling.	

44.2 Description of raw data

The raw data for this indicator are comprised of the total number of vehicles in a country. Data are mostly from WRI 2000-2001, with some derived from in-country sources through our collaborators. The total number of vehicles in countries varied between 335 and more than 161.4 million (Table 44.1). The lowest values were recorded in Tuvalu, Nauru and Niue, and the highest values in Brazil, Japan and Germany. The mean value across the globe was almost 3.4 million vehicles, with half of the countries examined having less than 300,000 vehicles (the median was 291,240) (Table 44.1). Variance among countries is moderately high, with a standard deviation which is around 4.3 times the mean.

The number of vehicles being used in a country is significantly correlated with its size (see significant correlation coefficient in Figure 44.1). Since the risks associated with vehicles are related to the area over which they are used, the amount of roading needed, the degree of fragmentation of the landscape and the area over which pollution can be attenuated, we expressed this indicator as a density function, dividing the number of vehicles by total land area in a country. This puts the indicator on a common scale for large and small countries. When the density of vehicles is, in turn, tested against country size, the correlation with size of country disappears (Figure 44.1 b).

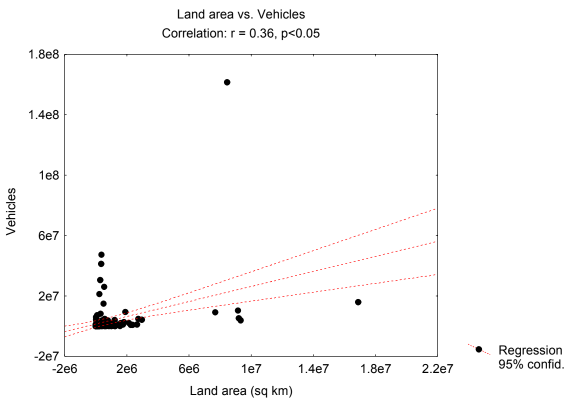
The density of vehicles in countries varied from 0.01 to 2,789 per km^2. The smallest density of vehicles was found in Chad, Mongolia and Mauritania, and the maximum densities in Macau, Singapore and Netherlands. The global mean density of vehicles was 36 per km^2, with a median value of 1.8 vehicles per km^2 (Table 44.1).

Table 44.1: Basic statistics for vehicles in countries. Data are from WRI 2000-2001 and In-country sources.

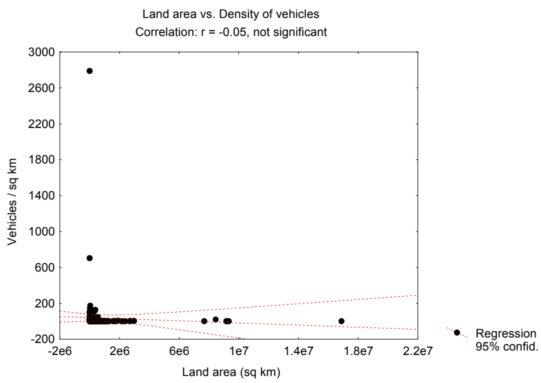
Statistic	Vehicles	Density of vehicles Vehicles / sq km	LN(X+1) Vehicles / sq km
Mean	3,352,598	36	2
Median	291,240.0	1.8	1.0
Valid n	156	156	156
Min	335	0.01	0.01
Max	161,439,135	2,789	8
SD	14,249,791	230	2
SE	1,140,896	18	0
Skewness	9.32	11.31	1.26
SE Skewness	0.19	0.19	0.19
Kurtosis	99.62	134.13	1.50
SE Kurtosis	0.39	0.39	0.39

Figure 44.1: Graphs of number of vehicles vs. size of countries. (a) Total number of vehicles vs. size of country (km^2); and (b) Density of vehicles (number / km^2 land) vs. size of country (km^2). The correlation is significant in (a) and not significant in (b).

(a)



(b)



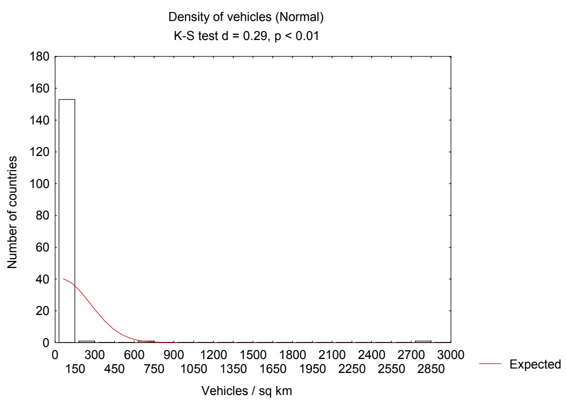
44.3 Distributional characteristics of the indicator data

The density of vehicles in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 44.2). This resulted in a distribution that was heavily skewed at the lower end of the scale, that is, most countries have low densities of vehicles, and a few have very large densities. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

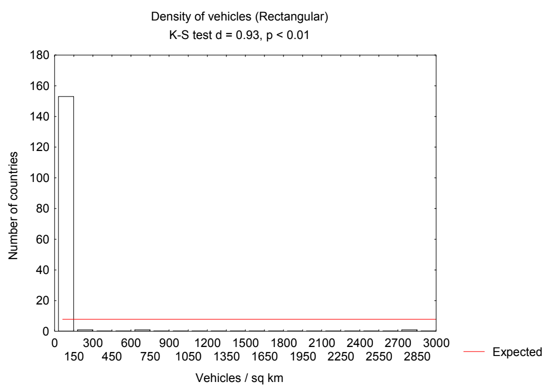
A significant difference between observed and expected values was found in the normal and rectangular distributions, but not for the exponential and lognormal distributions (Figure 44.2). This suggests that the values observed are distributed according to some power or logarithmic function. Transforming the values either to a root or natural logarithm might provide a better scale for comparison.

Figure 44.2: Kolmogorov-Smirnov goodness-of-fit tests for density of vehicles in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. The exponential and lognormal distributions provided the best fits of the observed data.

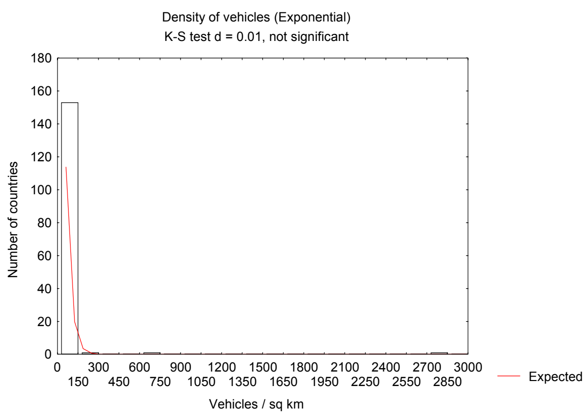
(a)



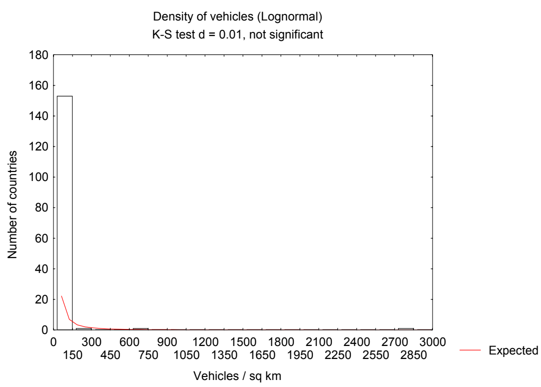
(b)



(c)



(d)

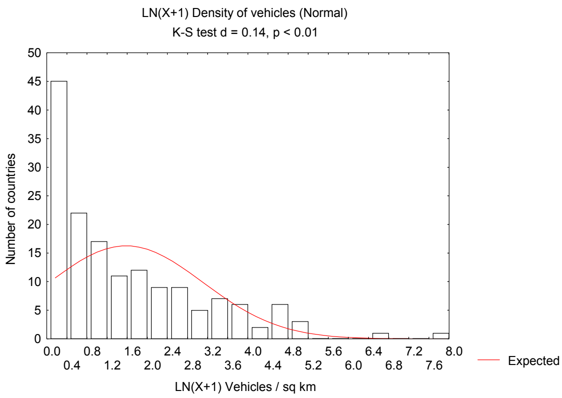


44.4 Proposed EVI scaling and distribution of the data on this scale

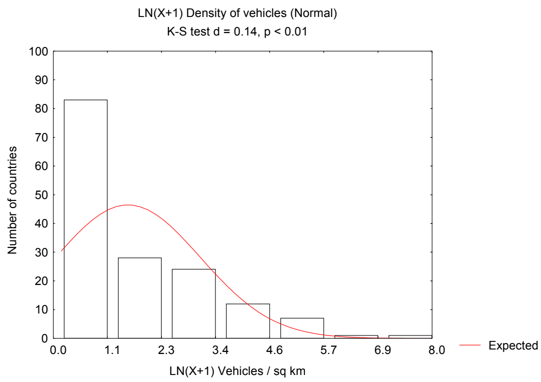
Countries varied in density of vehicles by five orders of magnitude, and there was a strong clumping of countries at the lower end of the scale. We propose that the data be transformed to their natural logarithms LN(X+1) for this indicator to provide better spread among the countries at the lower end of the scale and to compress it. Countries with the greatest density of vehicles per km^2 are considered more vulnerable and attract a higher EVI score than those with low densities. We identified those countries with ≤ 1 on the transformed LN(X+1) scale as likely to be the least at risk of environmental damage from vehicle use and its associated effects because the effects are likely to be small in relation to the area of land available to absorb / attenuate them (< 1.72 vehicles / km^2 land, EVI score = 1). Countries with > 3.5 on the transformed scale were considered the most vulnerable (EVI score =7). These are the countries that had more than 32.12 vehicles per km^2 of their entire land area. The country values between these extremes were spaced evenly on the transformed scale (unevenly on the raw scale) to form the remainder of the EVI scoring (Figure 44.3, Table 44.2, 44.3).

Figure 44.3: Frequency distribution of LN(X+1) density of vehicles in even and uneven categories and the EVI scale. (a) Frequency distribution of LN(X+1) density in 20 even categories, (b) is the same distribution compressed to a 7 category (even) scale (c) Distribution of countries on the proposed EVI scale.

(a)



(b)



(c)

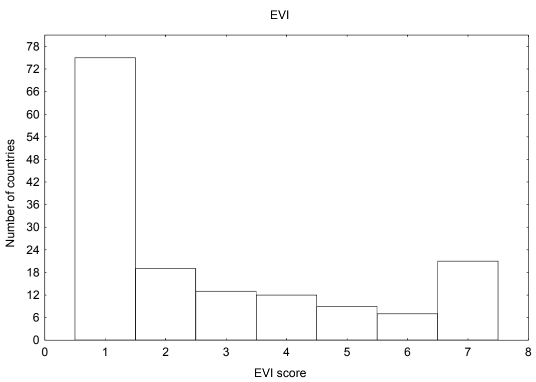


Table 44.2: Proposed EVI scaling for density of vehicles showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for LN(X+1) density of vehicles	Observed # countries	Observed % of countries
1	X≤1	75	48.08
2	1<X≤1.5	19	12.18
3	1.5<X≤2	13	8.33
4	2<X≤2.5	12	7.69
5	2.5<X≤3	9	5.77
6	3<X≤3.5	7	4.49
7	X>3.5	21	13.46
No data		79	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 44.3: Proposed EVI scaling for density of vehicles showing equivalence on the LN(X+1) and untransformed scales and examples of countries that fall into each of the EVI scores.

Score	Scale for LN(X+1) density of vehicles	Equivalent scale in Density of vehicles (Vehicles / sq km)	Examples
EVI=1	X≤1	X≤1.72	Australia, Haiti, Algeria
EVI=2	1<X≤1.5	1.72<X≤3.48	Burundi, Ecuador, Sri Lanka
EVI=3	1.5<X≤2	3.48<X≤6.39	Costa Rica, Georgia, Kiribati
EVI=4	2<X≤2.5	6.39<X≤11.18	Bangladesh, Estonia, Jamaica
EVI=5	2.5<X≤3	11.18<X≤19.09	Bulgaria, Croatia, Lithuania
EVI=6	3<X≤3.5	19.09<X≤32.12	Brazil, Hungary, Trinidad & Tobago
EVI=7	X>3.5	X>32.12	France, Nauru, Singapore

44.5 Age, completeness and quality of the data

The data obtained for this indicator were from WRI 2000-2001, OECD 1999 and In-country sources. In-country data were available for 20 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (all >2 of 3) (Table 44.4).

Table 44.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.32	2.70	3.00
Valid n (in-country)	19	20	20
SD (in-country)	0.58	0.66	0.00
SE (in-country)	0.13	0.15	0.00

44.6 Variations among sources of data

Sufficient (in terms of number of countries for which data area available) alternative sources of data are not at present available for this indicator.

44.7 Additional sources & contacts

UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.
WRI 1998-1999.; OECD 1999; Botswana - Transport and communications Statistics, 2000. Central statistics Office; Cook Islands - 1996 Census of Population & Dwelling. Statistics Office, Ministry of Finance and Economic Management (MFEM); Costa Rica - Ministerio de Obras Públicas y Transportes; Federated States of Micronesia - FSM 1999 Statistical Yearbook. FSM Department of Economic Affairs (FSMDEA); Fiji - Fiji Bureau of Statistics; Greece - Greek Monthly Statistics Bulletin, June 2001. Greek Government Statistics; Kiribati - Statistics Office. Contact - Reeiti Takaria (686 21816/ 686 21272); Kyrgyzstan - The National Report on Environment Conditions for 1998-1999; Marshall Islands - RMI Statistical Abstract. Contact - Jefferson Butuna's contact: 3802/ 3805/ planning@ntamar.com. - Office of Planning and Statistics(OPS)/ Director; Nauru - Climate Change – Response. Republic pf Nauru Response, 1999 (pp 2). Adapted from Nauru Census, 1992). SOPAC (Energy Unit); Nepal - Statistical pocket book, Nepal, 2000. Department of Central Bureau of Statistics, Kathmandu, Nepal; Niue - Niue Police Station. Contact - Margaret Siosikefu (683 4219/ 4143/ stats.epdsu@mail.gov.nu), Niue Statistics; Palau - Department of Motor Vehicles/ Ministry of Justice; Philippines - National Statistical Coordination Board, Philippine Statistical Yearbook. Land Transportation Office; Samoa - Annual Statistics Abstract, 1998. Statistics Department; Singapore - Land Transport authority, management services Dept, CPI's. Contact - Ong Eng Chin (Mc) Policy officer DID 63757088 E-Mail: eng_chin_oya@lta.gov.sg. Policy / policy officer; St Lucia - Compendium of Environmental statistics. Road transport division, ministry of communications, works, transport and pub. Utilities; Thailand - www.motc.go.th/ (6/6/01); Tonga - Annual Trade Report 1995 - 1999. Statistics Department; Trinidad & Tobago - Contact - Karen Ragoonanan; Tuvalu - Town Council Vehicle Register. Funafuti Town Council.

45. HUMAN POPULATION DENSITY

45.1 Indicator Summary

Indicator number:	45	
Indicator short name:	Population density	
Sub-index	AVI	
Categorisation	Human Populations	
Indicator text:	Total human population density (number per km^2 land area).	
Signals captured:	This is a proxy measure for pressure on the environment resulting from the number of humans being supported per unit of land. The greater numbers of people increases pressure on the environment for resources, for the attenuation of wastes and physical disturbance of the environment.	
Notes on this indicator:	1. None	
Are suitable data available?	Yes	
Sources of data:	• WRI 2000-2001 • CIA Fact sheets 2001 • In-country	
No. countries included in test:	232 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	23 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the age, completeness and quality of the data were generally considered good (score of >2 of 3). We complied a composite using data from WRI, CIA and in-country sources in that order of preference.	
Basic units:	X = total human population divided by area of land (sq km).	
Recommended transforms:	LN(X+1)	
Proposed EVI Scale (Scale refers to the natural logarithm of population density).	EVI Score = 1	X<3
	EVI Score = 2	3<X≤3.5
	EVI Score = 3	3.5<X≤4
	EVI Score = 4	4<X≤4.5
	EVI Score = 5	4.5<X≤5
	EVI Score = 6	5<X≤5.5
	EVI Score = 7	X>5.5
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	None.	

45.2 Description of raw data

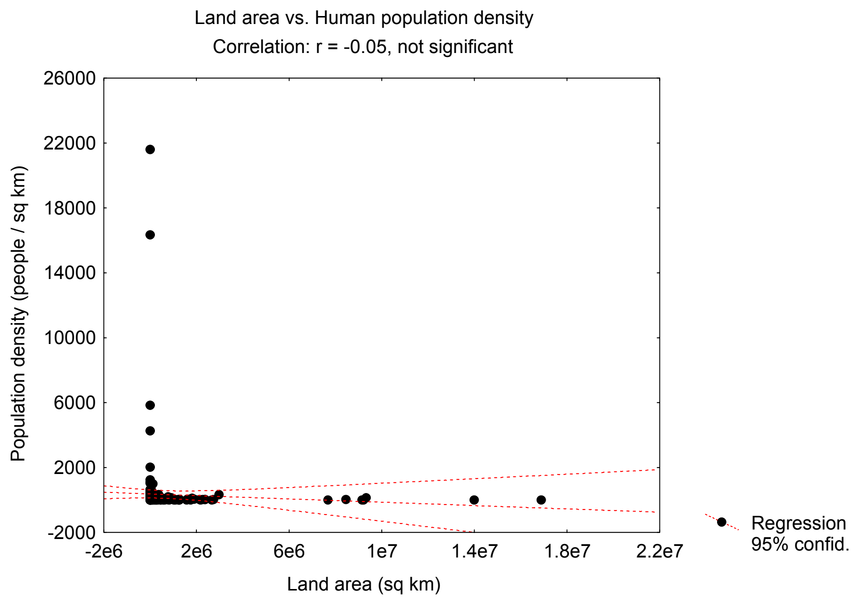
The raw data for this indicator are comprised of the total human population density of countries, regardless of whether the population is largely clumped in cities, spread over the available land area, or concentrated in particular types of land. Data for this indicator were available for 232 of the 235 countries examined.

The total human population density around the globe varied between 0 (in uninhabited territories such as Antarctica) and 21,606 people per square kilometre (Singapore, Macau and Monaco) (Table 45.1). The mean density of coastal populations is around 343 people per sq km (the density found in India and Japan), with half of the world's countries have less than 68 people per sq km (the median). The variance among countries is moderate to high, with the standard deviation being around 5.3 times the mean. The density of human populations is not correlated with the size of a country (Figure 45.1).

Table 45.1: Basic statistics for population density. Data are from WRI 2000-2001, CIA 2001 and in-country sources.

Statistic	Human population density (population / sq km)	LN(X+1) Population density
Mean	343.78	4.09
Median	68.28	4.24
Valid n	232	232
Min	0.00	0.00
Max	21606.33	9.98
SD	1831.19	1.70
SE	120.22	0.11
Skewness	9.90	-0.09
SE Skewness	0.16	0.16
Kurtosis	103.98	0.96
SE Kurtosis	0.32	0.32

Figure 45.1: Graph of the population density vs. size of countries. The correlation is not significant.



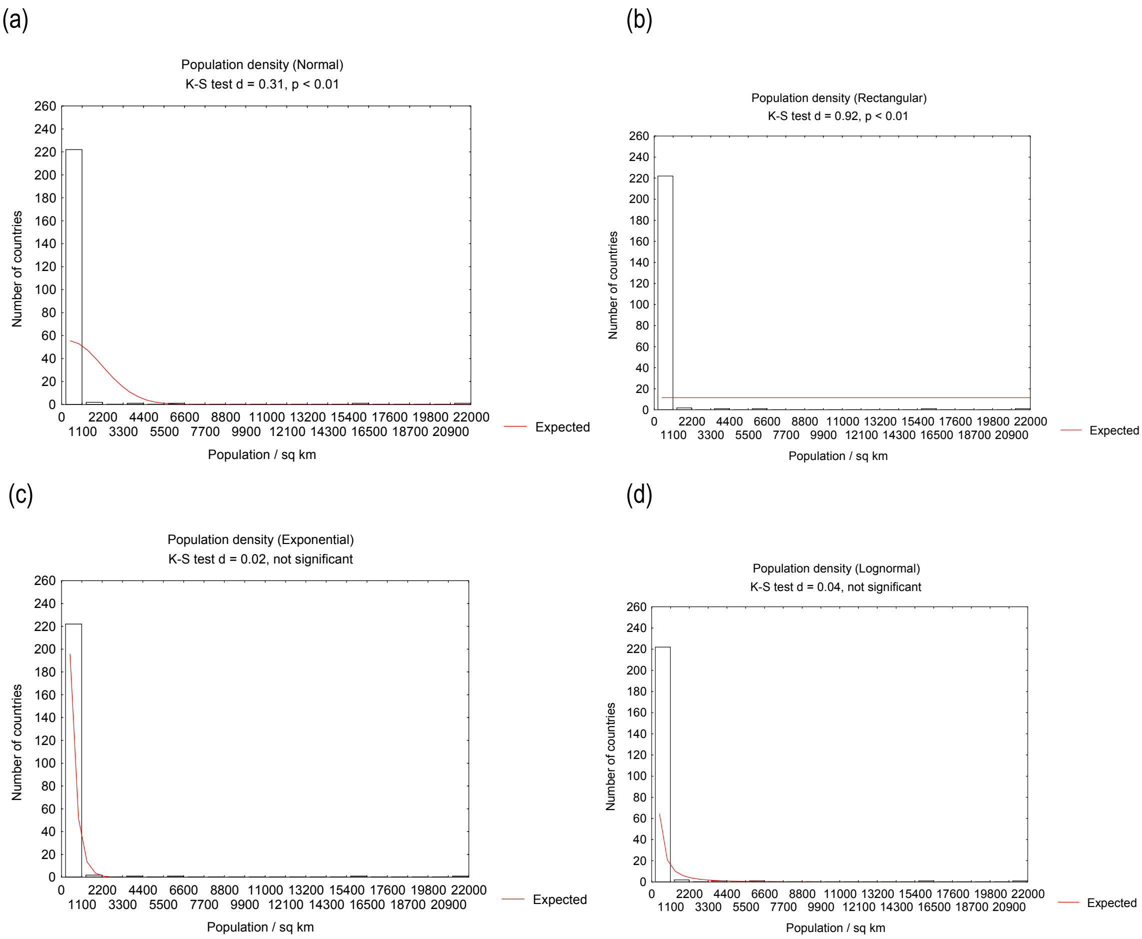
45.3 Distributional characteristics of the indicator data

The density of the human population of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 45.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

A significant difference between observed and expected values was found in the normal and rectangular models, indicating that the densities of populations of countries around the globe do not approximate some average, and that there are not even numbers of countries with similar population densities. The distribution of population densities was a better fit to the exponential and lognormal functions (both non-significant in the K-S tests).

The observed distribution was heavily skewed at the small end of the scale, with few countries at higher values (Figure 45.2).

Figure 45.2: Kolmogorov-Smirnov goodness-of-fit tests for population density of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

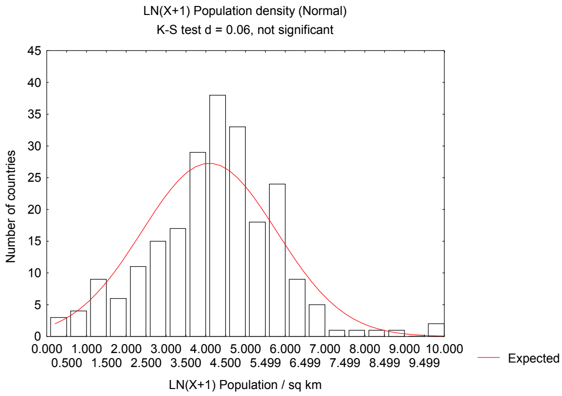


45.4 Proposed EVI scaling and distribution of the data on this scale

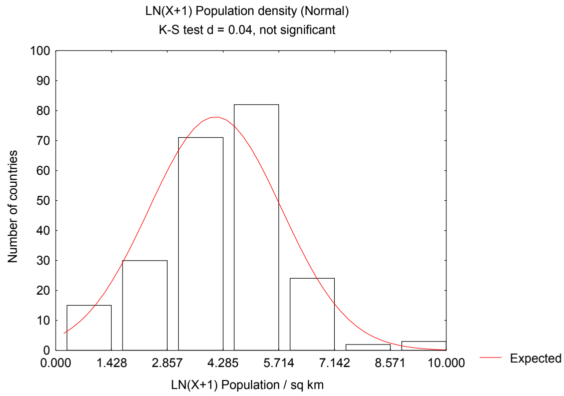
With countries varying in the density of their human populations by 5 orders of magnitude across the globe (Figure 45.2, 45.3), we propose that the raw values be transformed to a natural log scale to give a more compressed range between 0 and 10 and to provide better spread among the countries with lower densities. These values would in turn be scaled unevenly to create EVI scores that group countries of small and large population densities. Countries with less than 19 people per sq km and an LN(X+1) value of ≤3 were given an EVI score of 1 (including uninhabited countries). All countries with an average population density of >243 people per sq km and an LN(X+1) value of >5.5 were given an EVI score of 7. The remaining countries were distributed evenly within the remaining EVI scale to indicate increasing vulnerability with increasing population density between the above ranges. The distribution of countries plotted on the proposed EVI scale is shown in Figure 45.3, Table, 45.2, 45.3).

Figure 45.3: (a) Frequency distribution of LN(X+1) density of populations in 20 categories; (b) is a the same distribution over 7 even categories; (c) is the frequency distribution over 7 categories with values ≤3 and >5.5 grouped; (d) is the 1-7 EVI scale for this indicator.

(a)



(b)



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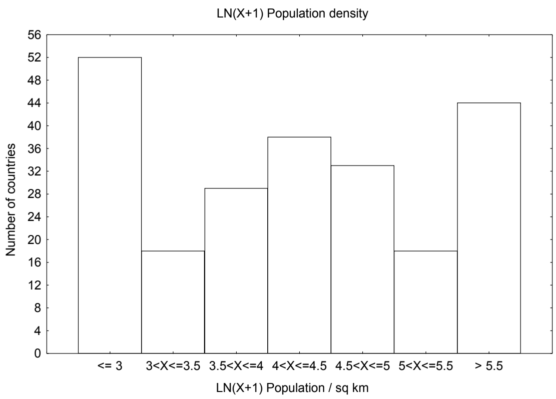

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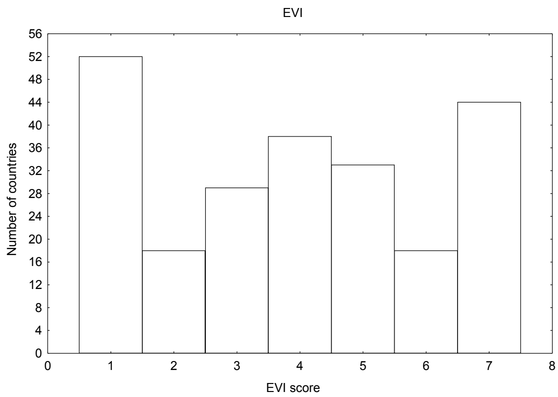


Table 45.2: Proposed EVI scaling for population density the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X<3	52	22.41
2	3<X≤3.5	18	7.76
3	3.5<X≤4	29	12.50
4	4<X≤4.5	38	16.38
5	4.5<X≤5	33	14.22
6	5<X≤5.5	18	7.76
7	X>5.5	44	18.97
No data		3	1.29
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 45.3: Proposed EVI scaling for Indicator 45 on population density showing the scale as defined on LN(X+1) transformed data and the equivalent values in population / square kilometre. Also shown are examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Population density	Scale for Population density	Examples
EVI=1	X<3	X<19.09	Argentina, Congo, Kazakhstan
EVI=2	3<X≤3.5	19.09<X≤32.12	Guinea, Lao, Sweden
EVI=3	3.5<X≤4	32.12<X≤53.60	Eritrea, Nicaragua, Senegal
EVI=4	4<X≤4.5	53.60<X≤89.02	Georgia, Lithuania, French Polynesia

EVI=5	4.5<X≤5	89.02<X≤147.41	Cuba, Gambia, Slovakia
EVI=6	5<X≤5.5	147.41<X≤243.69	Jamaica, Seychelles, Liechtenstein
EVI=7	X>5.5	X>243.69	Aruba, Gibraltar, Mauritius

45.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

45.6 Age, completeness and quality of the data

The data obtained for this indicator were from two public sources (WRI 2000-2001 and CIA 2001) and from in-country sources. Of the public sources, WRI data were used in preference to CIA data, with the latter being used where data were not given by WRI. In-country data were available for 23 of the 32 collaborating countries, with data being of good age, completeness and quality (Table 45.4).

Table 45.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.17	2.74	2.87
Valid n (in-country)	23	23	23
SD (in-country)	0.83	0.54	0.34
SE (in-country)	0.17	0.11	0.07

45.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

45.8 Additional sources & contacts

www.stats.govt.nz (New Zealand); www.nso.go.th/pop2000/summary.htm (20/7/01) (Thailand); www.bartleby.com/151/a21.html (CIA The World Fact Book.) (20/02/2002); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Botswana - Miss Minkie Pheto, 352200 Phone, 352201 Fax, mmpheto@gov.bw Statistician, Environment Statistics Unit; Cook Islands - Annual Statistical Bulletin, June 2000. Statistics Office; Costa Rica - Observatorio del desarrollo; Federated States of Micronesia - FSM 1994 Census Report/ FSM 1999 Statistical Yearbook. FSM Department of Economic Affairs; Fiji - 1996 Population & Housing Census (General tables) Bureau of Statistics; Greece - Greek Government Statistics; Kiribati - Report on the 1995 Census of Population, Volume 1: Basic Information & Tables. Bureau of Statistics; Kyrgyzstan - National Statistics Committee; Nauru - Nauru Census, 1992. Bureau of Statistics; Nepal - Department of Central Bureau of Statistics, Kathmandu, Nepal; Niue - Niue Household Listing Report 9 –10 October 1999. Niue Statistics; Palau - Census of Population & Housing, 2000. Office of Planning and Statistics; Papua New Guinea - Report on 1990 National Population and Housing Census in PNG. National

Statistics Office; Philippines - Contact - Mr. Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph. Statistical Coordination Officer. National Statistics Office; Republic of the Marshall Islands - Republic of the Marshall Islands(RMI) Statistical Abstract. Contact - Jefferson Butuna: 3802/ 3805/ planning@ntamar.com Office of Planning and Statistics; Samoa - Population Census 1991. (pp 16) Statistics Department; Tonga - Population Census 1996: A) Administrative and General Tables B) Household Analyses. Statistics Department, Tonga; Tuvalu - Tuvalu Population & Housing Census, 1991. Central Statistics Division.

46. HUMAN POPULATION GROWTH

46.1 Indicator Summary

Indicator number:	46	
Indicator short name:	Population Growth	
Sub-index	REI	
Categorisation	Human Populations	
Indicator text:	Annual human population growth rate over the last 5 years	
Signals captured:	Potential for future damage caused by all human activities	
Notes on this indicator:	This indicator focuses on the potential for damage relating to expanding human populations. It signals increasing rates of habitat damage, exploitation of natural resources and disposal of wastes that will need to be assimilated into the environment. It also captures the risk of infrastructure not being able to keep up with demand for issues such as waste treatment.	
Are suitable data available?	Yes	
Sources of data:	• WRI 2000-2001 • U.S. Bureau of Census - International Data Base • In-country	
No. countries included in test:	182 (165 for correlation with land area)	
Temporary modifications to data or indicator, if applicable:	The value [0] in the original datasets "indicates a value less than 0 and greater than negative one-half". This was given for Italy and Slovenia, but was reinterpreted as 0 for this analysis.	
Notes on data age, completeness and quality:	Where multiple values for these measures were reported, these were reduced to the lowest given value for use in the analysis. That is, if 2 and 3 were returned for a measure, the value 2 was used in the analysis. If no value given, 0 was used.	
Basic units:	Average percent yearly change in population (1996-2001)	
Recommended transforms:	None	
Proposed EVI Scale	EVI Score = 1	$X<0$
	EVI Score = 2	$X=0$
	EVI Score = 3	$0 \leq X<0.5$
	EVI Score = 4	$0.5 \leq X<1$
	EVI Score = 5	$1 \leq X<1.5$
	EVI Score = 6	$1.5 \leq X<2$
	EVI Score = 7	$2 \leq X$
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	None.	

46.2 Description of raw data

The raw data for this indicator are averages of 5 years of change in human population size as a percentage of starting population size for each year. For the 182 countries examined, values varied between –4.5% and 8.2%, where a negative value indicates an average shrinkage of the human population size of the country. The average value across all countries was 1.53% positive growth, a rate seen in countries such as New Caledonia, Tajikistan, South Africa, and Marshall Islands. The standard deviation (SD) was 1.37, slightly smaller than the mean (Table 46.1). The standard error (SE) (standard deviation of means) was 0.10, which was around 7% of the mean.

The frequency distribution of the average % human population growth values showed that most countries (a total of 103 of the 182, 57%) had between 1% and 3% annual positive growth in their human populations. Forty-six countries (25%) had between zero and 1% average growth over the 5 year time frame, and a further 21 (12%) had and average of between 0 and 4.5% *negative* population growth over the period. The lowest population growth rate was recorded at Niue (-4.5%). Twelve countries had extremely high rates of average annual growth, which in the case of Liberia reached the value of 8.2% (Figure 46.1).

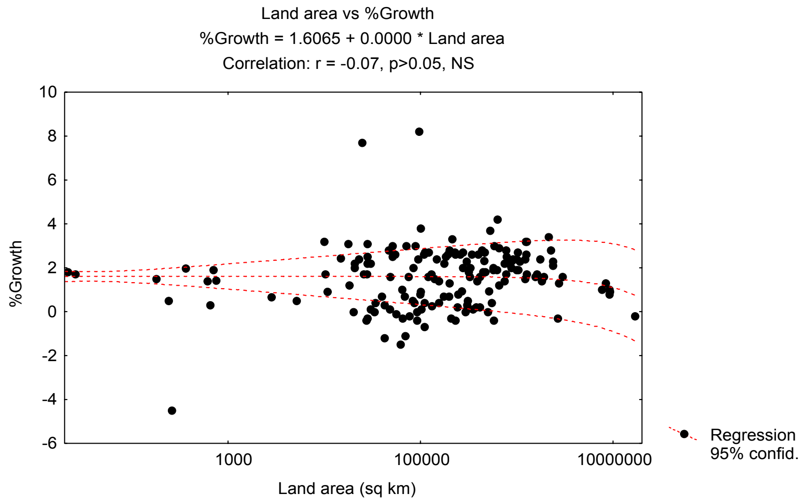
Human population growth rate, whether negative or positive did not correlate significantly with the size of a country, as measured by its land area (km^2) (Figure 46.1). This result suggests that adjustments to this indicator to remove any signal of country size are unnecessary.

Table 46.1: Basic statistics for % human population growth in 182 countries.

Statistic	Value
Mean	1.53
Median	1.60
Min	-4.50
Max	8.20
SD	1.37
SE	0.10
Skewness	0.50
SE Skewness	0.18
Kurtosis	5.78
SE Kurtosis	0.36

Figure 46.1: Graph of land area versus average % human population growth in 165 test countries.

The results show that population growth is not correlated with the size of country as indicated by its land area.

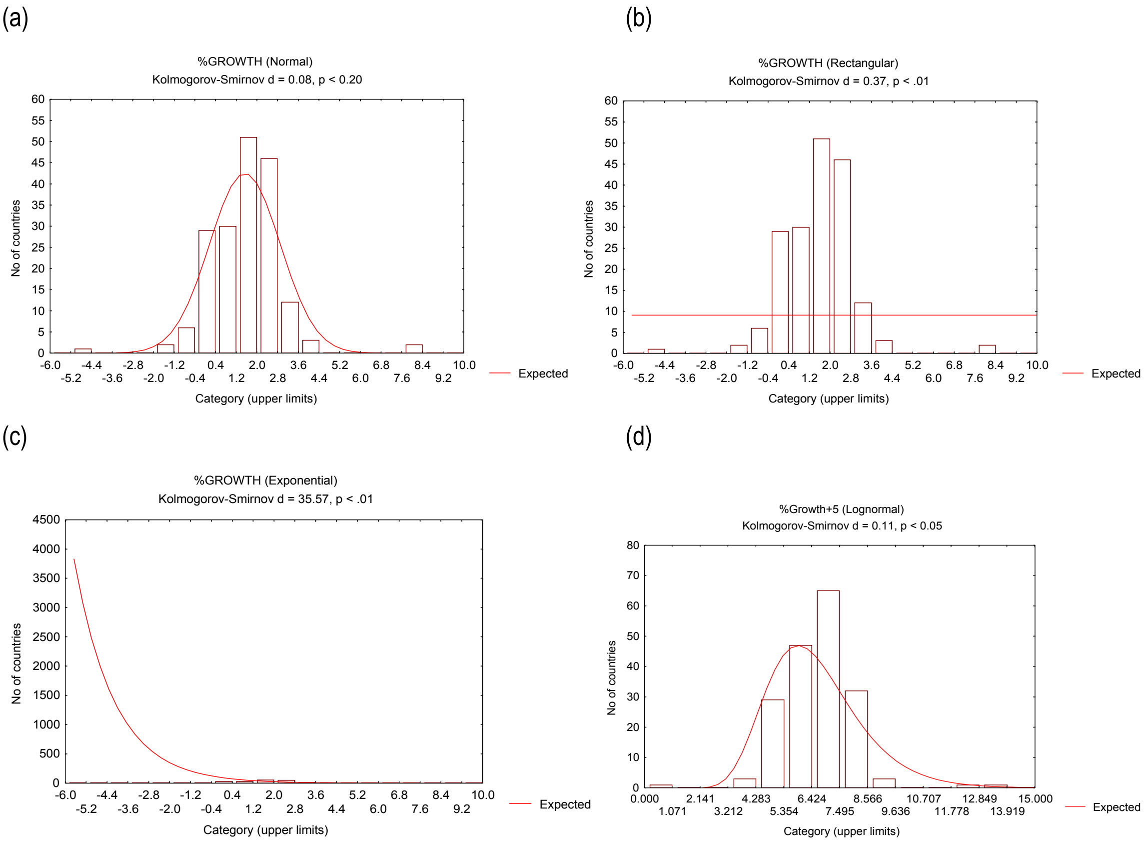


46.3 Characteristics of the indicator data

The average human population growth rate data were plotted as frequency distributions in 20 categories to identify any underlying distributions (Figure 46.2). The four classes of distributions examined were normal (linear), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). The K-S tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. For the rectangular, exponential and lognormal distributions, a significant difference between observed and expected values was found, indicating that the fit was not good (Figure 46.2). The normal distribution was found to be the best fit for the observed distribution of average % population growth. The data for this indicator were as a result used without transformation.

Figure 46.2: Frequency distribution of density of endemic species in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines).

Each comparison was made using a K-S test for fit. All comparisons resulted in significant K-S tests, except for the lognormal distribution, suggesting that a logarithmic transform may be useful for mapping these data on the EVI scale.



46.4 Proposed EVI scaling and distribution of the data on this scale

We propose that the EVI scale be a simple one based on a linear distribution, but with slightly varying intervals. Negative human population growth rates are likely to lead to lower environmental vulnerability, while strongly positive growth rates, some as high as 8% p.a. are likely to be associated with very high environmental vulnerability because there is expected to be an expansion in the use of resources and degradation of ecosystems, which will be at its worst when the rate of expansion is high. That is, we propose that the ability of countries to develop sustainably will be low when they have to accommodate increasingly larger numbers of new citizens each year. We set a benchmark with average growth rates of between –1% and +1% p.a. returning a vulnerability score of 3 (Table 46.2). The more strongly negative average human population growth rates were set at EVI scores of 1 and 2 and strongly positive rates of growth were spread over EVI scores 4-7.

The data were plotted as a frequency distribution with 7 categories to correspond with the proposed EVI scale. The majority of countries (102, 56%) fell on this scale at EVI value 4 (Table 46.2, Figure 46.3). About 33% of countries were either very weakly positive or negative, indicating that their situation was not changing significantly; these scored an EVI value of 3. Only one country (Niue) had strongly negative growth, while 14 countries (8%) had strongly positive growth of between 3% and 5% and scored an EVI value of 5. Two countries plotted with an EVI score of 7, having strongly positive growth rates of 7% or more (Table 46.3).

Table 46.2: Proposed EVI scaling for Indicator 27 on average % human population growth rate.

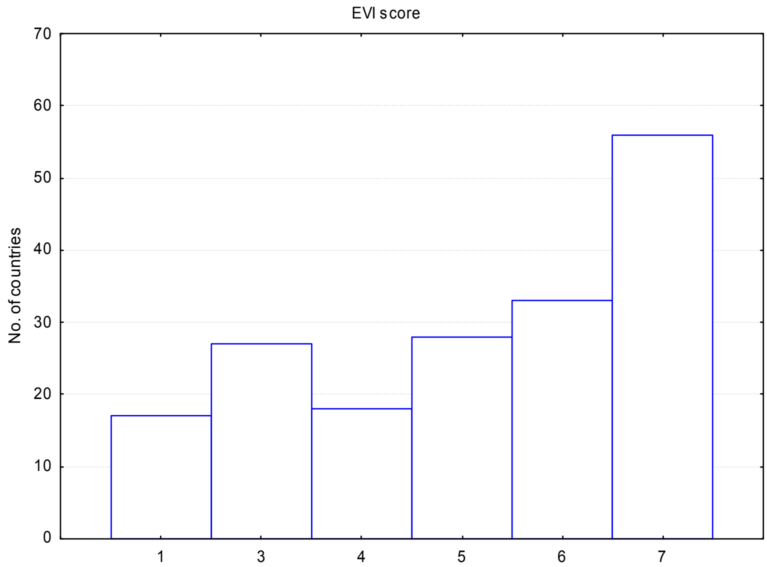
NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values	Observed # countries	Observed % of countries
1	X<0	17	9.5
2	X=0	None	None
3	0≤X<0.5	27	15.1
4	0.5≤X<1	18	10.1
5	1≤X<1.5	28	15.6
6	1.5≤X<2	33	18.4
7	2≤X	56	31.2
	Missing	56	
NA	☒ May not be used		
ND	☑ May be used		

Table 46.3: Proposed EVI scaling for Indicator 46 on population growth showing examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Population density	Examples
EVI=1	X<0	Estonia, Armenia, Ukraine
EVI=2	X=0	None
EVI=3	0≤X<0.5	Jamaica, Greece, Japan
EVI=4	0.5≤X<1	Iceland, Thailand, Malta
EVI=5	1≤X<1.5	Albania, Kenya, St Lucia
EVI=6	1.5≤X<2	Costa Rica, Zambia, Venezuela
EVI=7	2≤X	Belize, Bhutan, Burundi

Figure 46.3: Plot of the frequency distribution of country data on average % growth of the human population on the proposed EVI scale. The seven bars shown represent EVI categories 1-7 from left to right.



46.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later stage when scales have been set for all indicators.

46.6 Age, completeness and quality of the data

The age of the data for this indicator was generally low, with the average score across all countries being 2.77 of a possible best of 3.00 (i.e. latest data<2 years old) (Table 46.4). There was a problem with completeness and the quality of data from in-country sources, with average scores across all countries of 1.03 and 1.96, respectively (also of a possible best of 3.00). For most of the countries we had to use external sources based on estimates and in some cases, extrapolations.

Table 46.4: Characteristics of age, completeness and quality of the data obtained for 166 countries on the number of endemic species.

Characteristic	Age	Completeness	Quality
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Mean value across countries:	2.77	1.03	1.96
SD	0.70	0.41	0.47
SE	0.05	0.03	0.03

46.7 Variations among sources of data

Alternative public sources of data exist for this indicator and will be tested in the future to evaluate the size of differences among sources and any effect on the EVI calculations.

46.8 Additional sources & contacts

www.stats.govt.nz (New Zealand); www.forest.go.th/stat42/stat.htm (7/6/01)(Thailand); www.bartleby.com/151/a23.html (CIA: The World Fact Book, 2001)(26/02/2002); www.census.gov/ipc/www/idbrank.html (US Census Bureau); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Botswana - Source - Central statistics Office. Contact - Ms Sarah Kabaija Phone - 352200; Fax - 352201; Email - skabaija@gov.bw ; Cook Islands - Annual Statistics Bulletin, 2000. Statistics Office; Costa Rica - GEO, Estadísticas Ambientales de América Latina y del Caribe, Observatorio del Desarrollo 2001; Federated States of Micronesia - 1994 FSM Census Report. FSM Department of Economic Affairs; Fiji - A) 1996 Census B) other estimations. Bureau Of Statistics; Greece - Greek Government Statistics; Kiribati - Report on the 1995 Census of Population, Volume 1: Basic Information & Tables. Bureau of Statistics; Kyrgyzstan - Department of Statistics; Nauru - Year 2000 Pocket Statistical Summary, South Pacific Commission. EVI Team; Nauru - Year 2000 Pocket Statistical Summary, South Pacific Commission; Nepal - Statistical Year book, Various Issues, Nepal. Department of Central Bureau of Statistics, Nepal; Niue - 1999 Census. Niue Statistics; Palau - 1999 Statistical Yearbook, 1995 & 2000 Census; Papua New Guinea - Report on 1990 National Population and Housing Census in PNG. National Statistics Office; Philippines - National Statistics Office/National Statistical Coordination Board. Contact - Mr. Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph ; Republic of the Marshall Islands - Republic of the Marshall Islands(RMI) Statistical Abstract. Contact - Jefferson Butuna: 3802/ 3805/ planning@ntamar.com Office of Planning and Statistics; Samoa - Annual Statistics Abstract 1998 (pp 4). Statistics Department; Singapore - Yearbook of statistics, Singapore 2001 Census of population 2000, advance data releaseCensus of population 2000, statistical release 1-5. Singapore department of statistics; Tonga - Population Census (1996) Demographic Analysis. Statistics Department; Tuvalu - Tuvalu Population & Housing Census, 1991. Central Statistics Division.

47. TOURISTS

47.1 Indicator Summary

Indicator number:	47	
Indicator short name:	Tourists	
Sub-index	REI	
Categorisation	Human Populations	
Indicator text:	1. Average annual number of international tourists per km^2 land over the past 5 years 2. Average annual number of international tourist-days per km^2 of land over the last five years.	
Signals captured:	This is a measure for the additional load of all human impacts associated with international visitors and not reported in human population statistics. Tourists place additional pressure on the environment through increasing demands on local resources and through creation of pollution as well as physical disturbances of the environment. It is possible that their environmental burden is greater than that of residents	
Notes on this indicator:	1. Although data on number of international tourists is generally available through WTO and in-country tourist boards (for 169 countries), the number of days stayed is generally not available (only 32 countries). 2. A proxy for this indicator using only the mean annual number of tourists / land area was used.	
Are suitable data available?	Yes, partially. Data on number of days stayed are generally not available and form an important part of this indicator.	
Sources of data:	• WTO (World Trade Organisation) web site • In-country tourist boards and EVI collaborators	
No. countries included in test:	169 of 235	
Temporary modifications to data or indicator, if applicable:	• Data were intended to be # international tourists x # of days stayed / land area. Data on days stayed were not generally available and have been omitted for this demonstration EVI.	
Notes on data age, completeness and quality:	21 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the age, completeness and quality of the data were generally very (score of >2.5 of 3). We complied a composite using data from WTO and in-country sources in that order of preference.	
Basic units:	X = mean number of international tourists x number of days stayed divided by area of land (sq km).	
Recommended transforms:	LN(X+1)	
Proposed EVI Scale	EVI Score = 1	X<3
	EVI Score = 2	3<X≤3.5
	EVI Score = 3	3.5<X≤4
	EVI Score = 4	4<X≤4.5
	EVI Score = 5	4.5<X≤5
	EVI Score = 6	5<X≤5.5
	EVI Score = 7	X>5.5
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	Obtain data on number of days stayed by international tourists and	

	recalculate scores.

47.2 Description of raw data

The raw data for this indicator should be comprised of the mean annual number of tourist-days (tourists x number of days stay) divided by area of land to produce a density measure of tourist-days per sq km in a country. As we were unable to obtain sufficient data on the days stayed, for the purposes of this demonstration EVI we have used the proxy of mean annual number of tourists (1996-2000) divided by land area. Data on days stayed were available for 32 countries (not all collaborators) and averaged 9.4 days, but ranged between 1.8 and 34 days. These figures show how important including a signal of days stayed are likely to be for this indicator. A single tourist could stay 18 times longer in some countries than in others, making a simple measure of tourist density insufficient for this indicator. Proxy data for this indicator were available for 169 of the 235 countries examined.

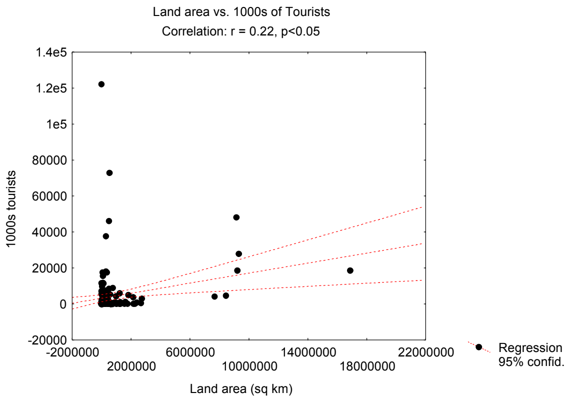
The average annual number of international tourists visiting countries around the globe varied between around 1000 (Tuvalu) and 122 million (Mauritius), with an average of 4 million and a median of 455,000 (i.e. half of the countries had 455,000 or less) (Table 47.1). The mean density of tourists visiting countries per annum varied between 0.002 (Chile) and almost 258,000 per sq km of land area (Macau), with an average of around 3,000 (similar to Malta) and a median of 5.38. The average number of tourists visiting a country per year does correlate with its size (Figure 47.1), but this relationship disappears for density of tourists.

Table 47.1: Basic statistics for mean annual number and density of tourists. Data are from WTO and in-country sources.

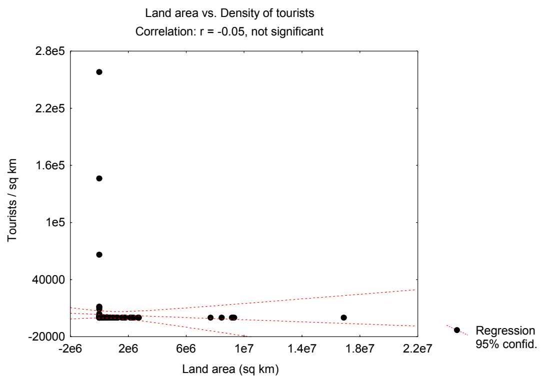
Statistic	Mean annual international tourists (1000s people)	Mean density of international tourists (people / sq km)	LN(X+1) Mean density of international tourists LN(people/sq km + 1)
Mean	4,228.56	3,057.27	2.51
Median	455.67	5.38	1.85
Valid n	169	169	169
Min	1.00	0.002	0.002
Max	122,164.80	257,920.60	12.46
SD	12,762.33	23,282.83	2.48
SE	981.72	1,790.99	0.19
Skewness	6.33	9.42	1.50
SE Skewness	0.19	0.19	0.19
Kurtosis	49.08	94.69	2.68
SE Kurtosis	0.37	0.37	0.37

Figure 47.1: Graphs of the (a) number and (b) density of tourists vs. size of countries. The correlation is significant in (a) and not significant in (b).

(a)



(b)



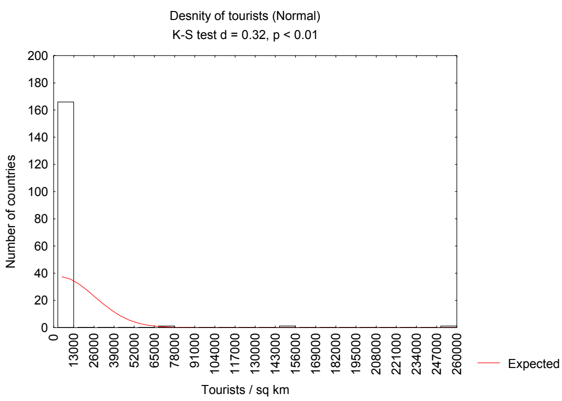
47.3 Distributional characteristics of the indicator data

The density of the annual tourist population of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 47.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

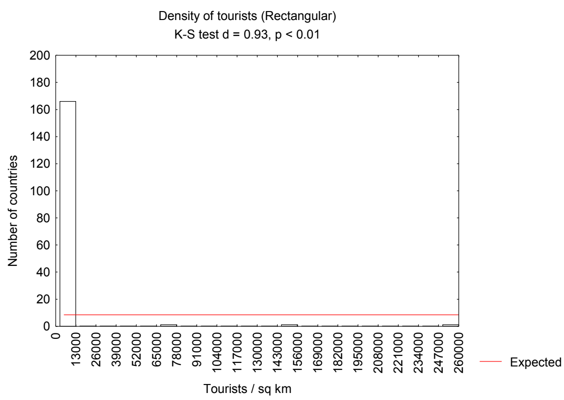
A significant difference between observed and expected values was found in the normal and rectangular models, indicating that the densities of tourists in countries around the globe do not approximate some average, and that there are not even numbers of countries with similar tourist densities. The distribution of tourist densities was a better fit to the exponential and lognormal functions (both non-significant in the K-S tests). The observed distribution was heavily skewed at the low end of the scale, with few countries at higher values (Figure 47.2).

Figure 47.2: Kolmogorov-Smirnov goodness-of-fit tests for population density of countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

(a)



(b)



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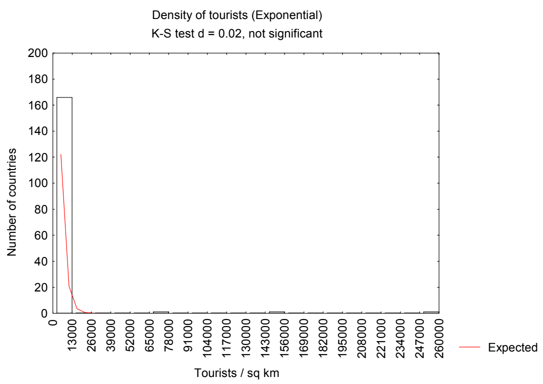

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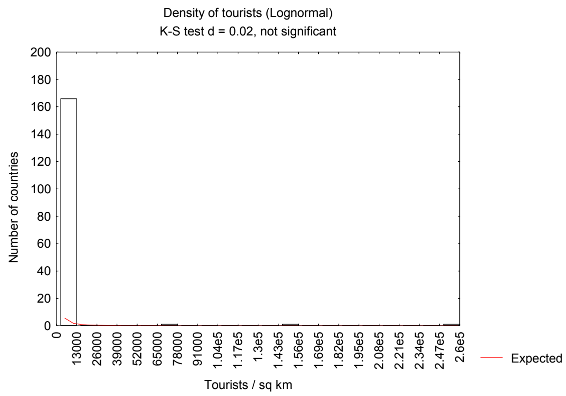
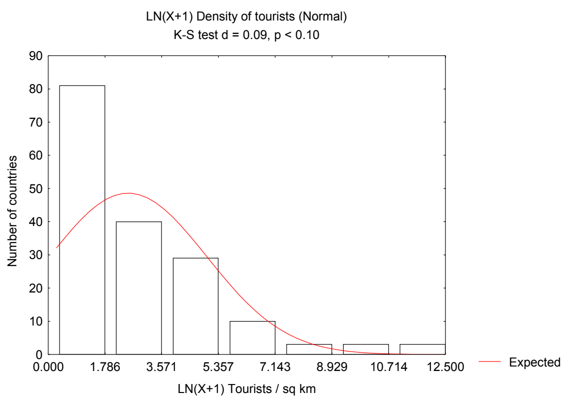


47.4 Proposed EVI scaling and distribution of the data on this scale

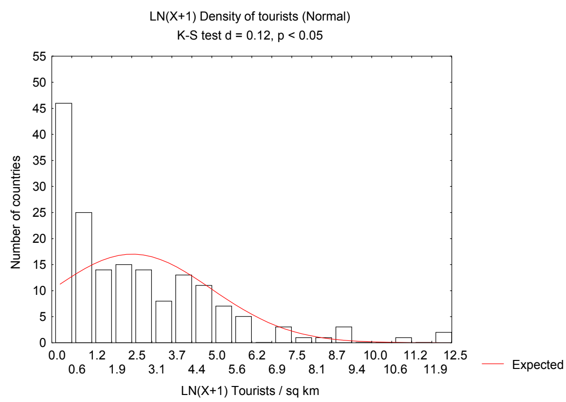
With countries varying in the density of their annual tourist populations by 8 orders of magnitude across the globe (Table 47.1 and Figure 47.2), we propose that the raw values be transformed to a natural log scale to give a more compressed range between 0 and 12.5 and to provide better spread among the countries with lower densities. These values would in turn be scaled unevenly to create EVI scores that group countries of small and large tourist densities. Countries with less than 19 tourists annually per sq km and an LN(X+1) value of ≤3 were given an EVI score of 1. All countries with an average annual tourist density of >243 people per sq km and an LN(X+1) value of >5.5 were given an EVI score of 7. The remaining countries were distributed evenly within the remaining EVI scale to indicate increasing vulnerability with increasing tourist density between the above ranges. The distribution of countries plotted on the proposed EVI scale is shown in Figure 47.3, Table 47.2, 47.3).

Figure 47.3: (a) Frequency distribution of LN(X+1) density of tourists in 20 categories; (b) is a the same distribution over 7 even categories; (c) is the frequency distribution over 7 categories with values ≤3 and >5.5 grouped; (d) is the 1-7 EVI scale for this indicator.

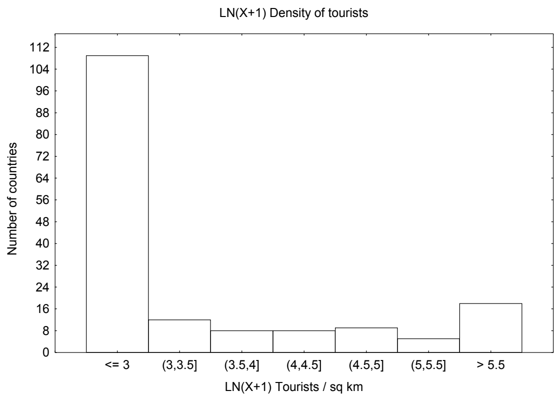
(a)



(b)



(c)



(d)

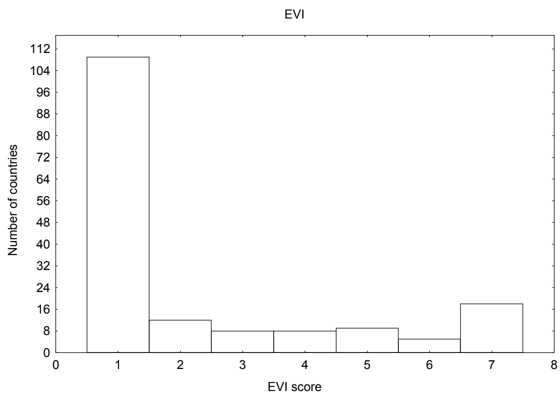


Table 47.2: Proposed EVI scaling for density of tourists, giving the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X<3	109	64.50
2	3<X≤3.5	12	7.10
3	3.5<X≤4	8	4.73
4	4<X≤4.5	8	4.73
5	4.5<X≤5	9	5.33
6	5<X≤5.5	5	2.96
7	X>5.5	18	10.65
No data		66	39.05
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 47.3: Proposed EVI scaling for Indicator 47 on density of tourists showing the scale as defined on LN(X+1) transformed data and the equivalent values in average annual tourists visiting / square kilometre. Also shown are examples of countries that fit into each of the EVI scores.

Score	Scale for LN(X+1) Density of tourists	Scale for Density of tourists	Examples
EVI=1	X<3	X<19.09	Colombia, Lao, Nigeria
EVI=2	3<X≤3.5	19.09<X≤32.12	Costa Rica, Slovakia, Tunisia
EVI=3	3.5<X≤4	32.12<X≤53.60	Germany, Slovenia, Tuvalu
EVI=4	4<X≤4.5	53.60<X≤89.02	UK, Greece, Lithuania
EVI=5	4.5<X≤5	89.02<X≤147.41	Spain, Italy, Palau
EVI=6	5<X≤5.5	147.41<X≤243.69	Austria, Hungary, Belgium
EVI=7	X>5.5	X>243.69	Barbados, Cook Is. Liechtenstein

47.5 Age, completeness and quality of the data

The data obtained for this indicator were from the World Tourist Organisation (WTO web page) and from in-country sources, including information posted on Tourist Bureau web sites and that collected by collaborators. In-country data were available for 21 of the 32 collaborating countries, with data being of very good age, completeness and quality (>2.5 scoring out of 3 by collaborators) (Table 47.4).

Table 47.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.67	2.71	3.00
Valid n (in-country)	21	21	20
SD (in-country)	0.48	0.46	0.00
SE (in-country)	0.11	0.10	0.00

47.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

47.7 Additional sources & contacts

www.world- tourism.org/market_research/facts&figures/statistics/t_ita00country.pdf (13/12/02); www.czso.cz/eng/figures (28/11/02) (Brunei Darussalam); www.brazil.org.uk/page.php?cid=1189 (29/11/02) (Brazil); www.cnta.com/lyen/2fact/annual.htm (13/12/02) (China); www.embassy.org/cambodia/tourism/tour.htm (13/12/02)(Cambodia); www.stat.gov.tw (Taiwan); www.bps.go.id/sector/tourism/table25.shtml (29/11/02) (Indonesia); Barbados - Digest of Tourism Statistics. Barbados Statistical Service; Botswana - Contact - Mrs Joyce Morontshe. 353024 – phone 308675 – fax. tourism@botsnet.bw. Tourism/Tourism Officer II. Department of Tourism; Cook Islands - Annual Statistical Bulletin, June 2000. Cook Islands Statistics Office; Costa Rica - Estadisticas. Estadísticas, Instituto Costarricense del Turismo (ICT), 2002; Federated States of Micronesia - FSM Department of Economic Affairs (FSMDEA) Data Collection. Contact - Edgar Santos (691 3202646/ 691 3205854/ Fsmrd@mail.fm) DEA/ Tourism Development Officer; Fiji - A) Fiji Visitors Bureau (FVB) Market Overview 1994, 1995, 1996 B) FVB Statistical Report on visitor Arrivals into Fiji 1994-1998. Aswal, c/- Alasdairs McIntyre, PO Box 38-201, Auckland, NZ; Greece - Greek National Tourisms Office Statistics. Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Vuti, L. Survey Report No. 15. Kiribati Visitor Survey. Commerce Department; Marshall Islands - Arrival cards & internal information (Office of Planning and Statistics (OPS): 1994 – 1998, Marshall Islands Visitors Authority(MIVA): 1999); Nepal - Nepal Tourist statistics, 1999. Ministry of Culture, Tourism and Civil Aviation; New Zealand - International Visitor arrivals – Published monthly by Statistics New Zealand. Contact - Anthony Sturrock email anthonys@nztb.govt.nz. Marketing research division, tourism New Zealand, New Zealand; Niue - Niue Statistics. Contact - Esther Pavihi (683 4224/ 4225/ esther.niuetourism@mail.gov.nu) Niue Tourism Office; Palau - Internal data from Palau Visitors Authority. Office of Planning & Statistics(OPS) Contact - Bernard Pullon (680 4885627/ brpullon@palaunet.com); Papua New Guinea - National Statistics Office (NSO) Contact - Catherine Aisoli (675 3011226/ 3251869/ caisoli@nso.gov.pg); Philippines - National Statistical Coordination Board, Philippine Statistical Yearbook. Department of Tourism; Samoa - A) Tourism Economic Impact Study. Vaai, A. K (Kolone Vaai & Associates); Tuinabua, L (TCSP); Ngau-Chuu, T (TCSP); and Riddout, P (Project Manager). B) Vuti, L. and Muagututia, R./ Petelo Kavesi.1994. Samoa Visitor Survey/

Annual Update. 1994; Singapore - Singapore tourist board (STB) Contact - Cindy Tay, 68313590 / Fax 67349217 E-Mail cindytay@stb.iom.sg ; Tonga - Tonga Visitors Bureau (TVB) Contact - Falati Papani (676 25334/ 23507); Trinidad & Tobago - Karen Ragoonanan; Tuvalu - Tuvalu Tourism Statistics Records. Tourism, Trade & Commerce (TTC). Contact - Mr Uatimani Maaloo. Tourism Officer; Vanuatu - National Tourism Development Office of Vanuatu (NTDO). Contact - Peris Kalopong (678 22515 or 22685 or 22813/ 23889/ tourism@vanuatu.com.vu). NTDO/ General Manager.

48. COASTAL SETTLEMENTS

48.1 Indicator Summary

Indicator number:	48	
Indicator short name:	Human Populations	
Sub-index	AVI	
Categorisation	Anthropogenic	
Indicator text:	Density of people living in coastal settlements (i.e. with a city centre within 100km of any maritime or lake* coast). (* To be included, lakes must have an area of at least 100 sq km).	
Signals captured:	This indicator captures the focus of stress on coastal ecosystems, often the most productive living areas in a country, through pollution, eutrophication, resource depletion and habitat degradation. The adjacent water areas are capable of spreading pollution widely in aquatic habitats and will not tend to allow for attenuation over upland areas. Countries with heavy densities of human populations living on their coastal areas are likely to be damaging some of their most productive and diverse areas and negatively affecting the resilience of the country to natural disasters such as cyclones, tsunamis etc.	
Notes on this indicator:	1. Area of coastal lands is calculated by multiplying length of all coastlines (maritime + lake) by 100km. Where this figure exceeds the total area of land in a country (from WRI 2000-2001 and CIA 2002, Indicator 11), the figure used is total land area. This situation can occur because of overlap of the 100km band where coasts are close together or very convoluted. 2. Landlocked countries for which this indicator is not applicable are given the value of zero (and the lowest EVI score).	
Are suitable data available?	Yes	
Sources of data:	WRI 2000-2001 CIA Fact sheets 2001 In-country	
No. countries included in test:	182 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	16 of the 32 collaborating countries returned data for this indicator. Where they did so, most relied on external sources. For in-country sources, the completeness and quality of the data were generally considered good (score of >2 of 3), while the age of data scored an average of 1.94 of 3. We compiled a composite using data from WRI, CIA and in-country sources in that order of preference.	
Basic units:	X = population living with 100 km of a coast divided by the area of coastal lands (sq km).	
Recommended transforms:	LN(X+1)	
Proposed EVI Scale	EVI Score = 1	X<3
	EVI Score = 2	3<X≤3.5
	EVI Score = 3	3.5<X≤4
	EVI Score = 4	4<X≤4.5
	EVI Score = 5	4.5<X≤5
	EVI Score = 6	5<X≤5.5
	EVI Score = 7	X>5.5

	NA (not applicable)	☑ May be used
	ND (no data)	☑ May be used
Future work on this indicator:	Better estimates of the area of coastal lands are needed. These should include all lands within 100 km of maritime and lake coasts.	

48.2 Description of raw data

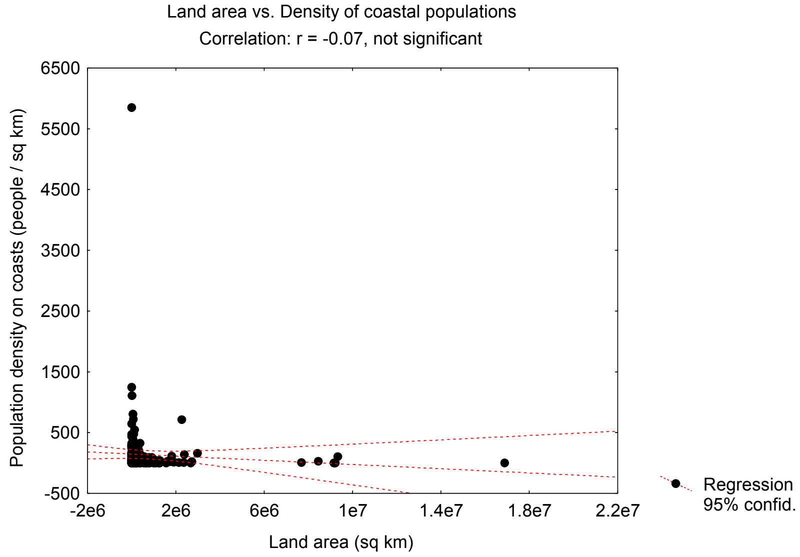
The raw data for this indicator are comprised of the size of the human population living within 100 km of the coast (calculated from WRI data on % of population within 100km of coasts) and data on the area of coastal lands derived by multiplying the length of all coastlines (maritime + lake) by 100km (see Indicator 11 for data on length of coastlines). Where the figure for area of coastal lands exceeds the total area of land in a country, the figure used was total land area. This situation can occur because of overlap of the 100km band where coasts are close together or very convoluted. Data for this indicator were available for 182 of the 235 countries examined.

The density of coastal populations around the globe varied between 0 (landlocked countries) and 5,847 people per square kilometre, with Singapore being the largest of those examined (Table 48.1). The mean density of coastal populations is around 136 people per sq km (the density found in Tonga and Algeria), half of the world's countries have less than 35 people per sq km of coasts (the median). The variance among countries is moderate, with the standard deviation being around 3.4 times the mean. The density of human coastal populations is not correlated with the size of a country (Figure 48.1).

Table 48.1: Basic statistics for density of coastal settlements. Data are from WRI 2000-2001, CIA 2001 and in-country sources.

Statistic	Density of coastal settlements (population / sq km)	LN(X+1) Density of coastal settlements
Mean	135.90	3.27
Median	35.45	3.60
Valid n	182	182
Min	0.00	0.00
Max	5847.54	8.67
SD	463.41	2.04
SE	34.35	0.15
Skewness	10.64	-0.26
SE Skewness	0.18	0.18
Kurtosis	129.13	-0.78
SE Kurtosis	0.36	0.36

Figure 48.1: Graph of the density of human coastal populations vs. size of countries. The correlation is not significant.

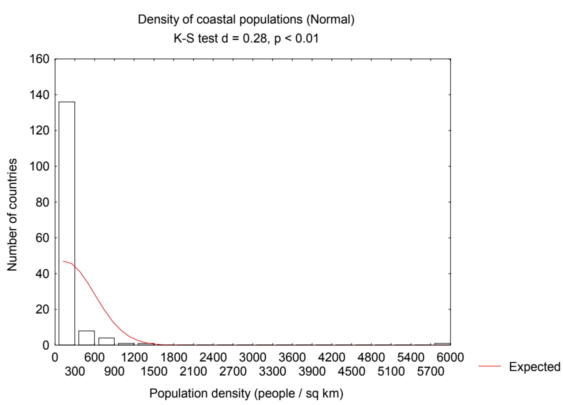


48.3 Distributional characteristics of the indicator data

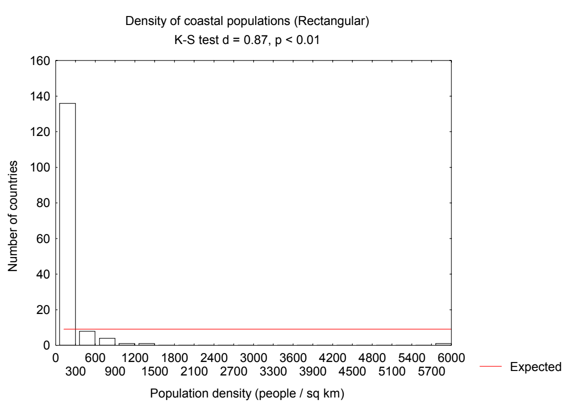
The density of coastal populations of countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying distributions (Figure 48.2). The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit. A significant difference between observed and expected values was found in the normal and rectangular models, indicating that the density of costal populations of countries around the globe do not approximate some average, and that there are not even numbers of countries with similar coastal densities. The distribution of costal populations densities was a better fit to the exponential and lognormal functions (both non-significant in the K-S tests). The observed distribution of country size was heavily skewed at the small end of the scale, with few countries at higher values (Figure 48.2).

Figure 48.2: Kolmogorov-Smirnov goodness-of-fit tests for density of coastal populations spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for fit.

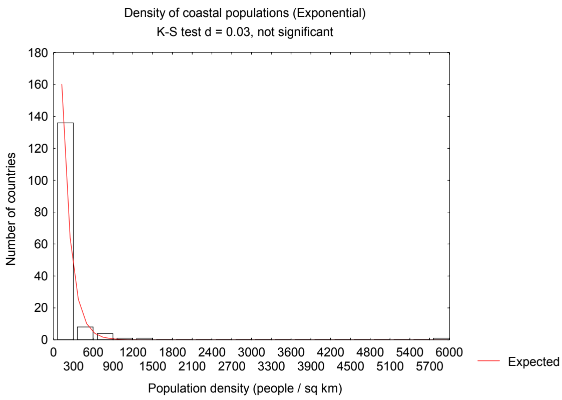
(a)



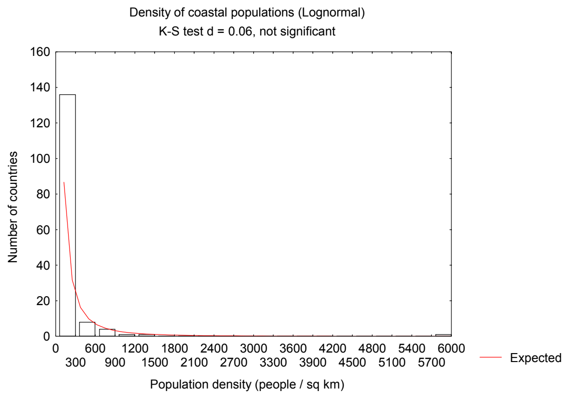
(b)



(c)



(d)

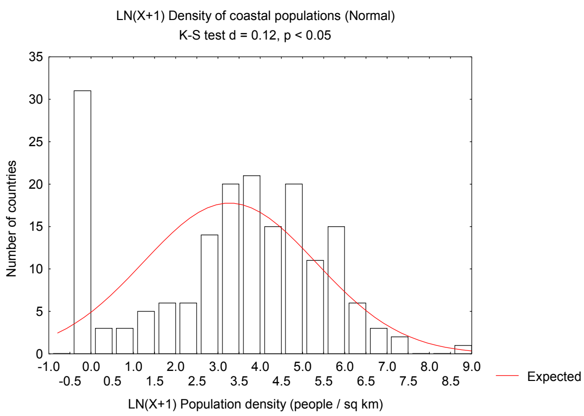


48.4 Proposed EVI scaling and distribution of the data on this scale

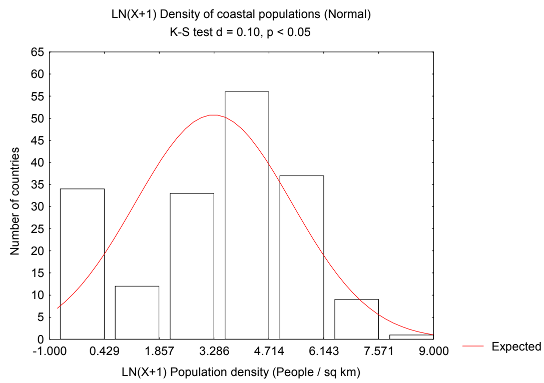
With countries varying in the density of costal populations by 4 orders of magnitude across the globe (Figure 48.1, 48.2), we propose that the raw values be transformed to a natural log scale to give a more compressed range between 0 and 8.67 and to provide better spread among the countries with lower densities. These values would in turn be scaled unevenly to create EVI scores that group countries of small and large costal population densities. Countries with less than 19 people per sq km in coastal areas and an LN(X+1) value of ≤3 were given an EVI score of 1 (including landlocked countries). All countries with an average coastal density of >243 people per sq km and an LN(X+1) value of >5.5 were given an EVI score of 7. The remaining countries were distributed evenly within the remaining EVI scale to indicate increasing vulnerability with increasing costal population density between the above ranges. The distribution of countries plotted on the proposed EVI scale is shown in Figure 48.3, Table 48.2, 48.3).

Figure 48.3: (a) Frequency distribution of LN(X+1) density of coastal populations in 20 categories; (b) is a the same distribution over 7 even categories; (c) is the frequency distribution over 7 categories with values ≤3 and >5.5 grouped; (d) is the 1-7 EVI scale for this indicator.

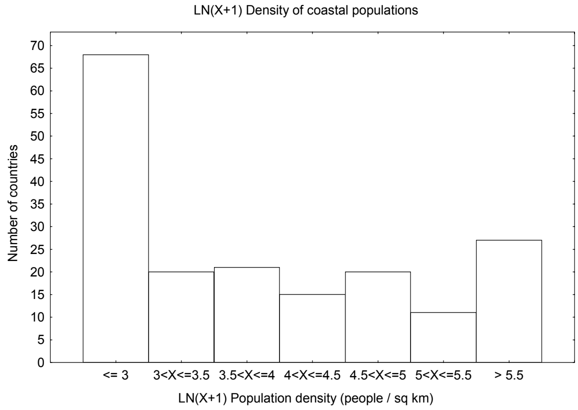
(a)



(b)



(c)



(d)

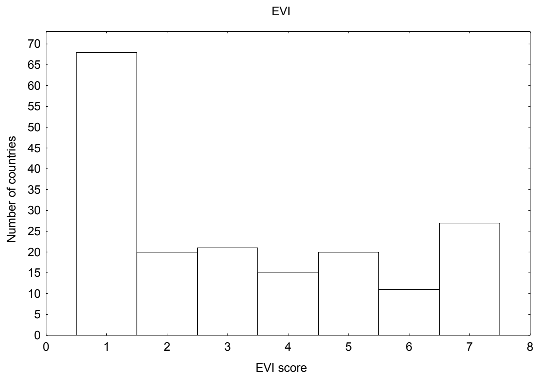


Table 48.2: Proposed EVI scaling for density of coastal populations the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Range of values (LN)	Observed # countries	Observed % of countries
1	X<3	68	37.36
2	3<X≤3.5	20	10.99
3	3.5<X≤4	21	11.54
4	4<X≤4.5	15	8.24
5	4.5<X≤5	20	10.99
6	5<X≤5.5	11	6.04
7	X>5.5	27	14.84
No data		53	29.12
NA	☑ May be used (results in EVI=1)		
ND	☑ May be used (results in no score)		

Table 48.3: Proposed EVI scaling for Indicator 48 on density of coastal populations showing the scale as defined on LN(X+1) transformed data and the equivalent values in population / square kilometre. Also shown are examples of countries that fit into each of the EVI scores.

Score	Scale for LN Land area	Scale for Land area sq km	Examples
EVI=1	X<3	X<19.09	Andorra, Kenya, Niue
EVI=2	3<X≤3.5	19.09<X≤32.12	Liberia, Uruguay, UAE
EVI=3	3.5<X≤4	32.12<X≤53.60	Germany, Honduras, Panama
EVI=4	4<X≤4.5	53.60<X≤89.02	Cook Is., Greece, Norfolk Is.
EVI=5	4.5<X≤5	89.02<X≤147.41	Gambia, Iraq, Madagascar
EVI=6	5<X≤5.5	147.41<X≤243.69	Dominican Rep, UK, India
EVI=7	X>5.5	X>243.69	Haiti, Sri Lanka, Nauru

48.5 Correlations with other indicators

Correlations with other indicators are to be assessed at a later date when scales have been set for all indicators.

48.6 Age, completeness and quality of the data

The data obtained for this indicator were from two public sources (WRI 2000-2001 and CIA 2001 and from in-country sources. Of the public sources, WRI data were used in preference to CIA data, with the latter being used where data were not given by WRI. In-country data were available for 16 of the 32 collaborating countries, with data being of good completeness and quality (Table 48.4).

Table 48.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	1.94	2.44	2.69
Valid n (in-country)	16	16	16
SD (in-country)	0.77	0.81	0.70
SE (in-country)	0.19	0.20	0.18

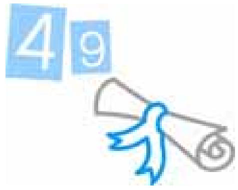
48.7 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

48.8 Additional sources & contacts

www.nso.go.th/pop2000/table/tab1.pdf (Thailand); UNDP, UNEP, World Bank, WRI. 2000 World Resources 2000-2001: People and Ecosystems: The fraying web of life. World Resource Institute. Washington, D.C.; Cook Islands - 1996 Census of Population & Dwelling. Cook Islands Statistics Office; Costa Rica - Instituto nacional de Estadisticas y Censo, 2000; Federated States of Micronesia - FSM 1999 Statistical Yearbook.
Fiji - A) 1996 Population & Housing Census. Bureau of Statistics. B) CIA World Fact book 1999; Greece - Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Report on the 1995 Census of Population, Volume 1: Basic Information & Tables; Nauru - Nauru Census, 1992. Bureau of Statistics; Niue - Niue Household Listing Report, 9 – 10 October 1999; Palau - Census of Population & Housing, 2000. Office of Planning and Statistics (OPS); Papua New Guinea - Report on 1990 National Population and Housing Census in PNG. National Statistics Office; Republic of Marshall Islands - Republic of Marshall Islands (RMI) Statistical Abstract. Contact - Jefferson Butuna's contact: 3802/ 3805/ planning@ntamar.com. Office of Planning & Statistics; Samoa - Population Census 1991 (pp 16). Statistics Department; Tonga - Population Census 1996: 1) Administrative and General Tables. Statistics Department; Tuvalu - A) Census Report, 1991. B) Cartastro Survey Project, 1991.

49. ENVIRONMENTAL AGREEMENTS



49.1 Indicator Summary

Indicator number:	49
Indicator short name:	Environmental Agreements
Sub-index	REI
Categorisation	Human Populations
Indicator text:	Number of environmental treaties in force in a country.
Signals captured:	This indicator captures the level of management and stewardship of the environment in a country. Two aspects of legislation are needed: the message to the public that environmental management is essential, and the effectiveness of controls. The benefits of good management would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.
Notes on this indicator:	1. Information for using the original form of this indicator, were generally not available, though most of our collaborators did provide valuable information for this indicator. As a result, we used public information on number of treaties in force, which is available for a large number of countries. 2. The logic of using treaties is that international environmental treaties provide guidance and support for environmental policy and implementation. Countries that are signatories to a significant number of treaties are likely to have at least considered some of their more important issues, be undertaking some monitoring and control, have access to guidance, and be under pressure to correct problems. 3. Being signatory to a treaty does not guarantee that the environment is managed or that obligations under the treaty are being met.
Are suitable data available?	Yes
Sources of data:	• SEDAC / CIESIN database 2003: http://sedac.ciesin.org • In-country
No. countries included in test:	196 of 235
Temporary modifications to data or indicator, if applicable:	• None, the shift to number of treaties is permanent.
Notes on data age, completeness and quality:	22 of the 32 collaborating countries returned data for this indicator in its original form that tries to capture both legislation and enforcement. Age, completeness and quality of the in-country data were generally considered good (value of >2 of 3 for age, completeness and quality).
Basic units:	Number of treaties in force.
Recommended transforms:	• None

Proposed EVI Scale	EVI Score = 1	60<X
	EVI Score = 2	50<X≤60
	EVI Score = 3	40<X≤50
	EVI Score = 4	30<X≤40
	EVI Score = 5	20<X≤30
	EVI Score = 6	10<X≤20
	EVI Score = 7	X≤10
	NA (not applicable)	☒ May not be used
	ND (no data)	☑ May be used
Future work on this indicator:	• A measure of the effectiveness of treaties would improve the signal being measured by this indicator. • Data should be updated for next evaluation.	

49.2 Description of raw data

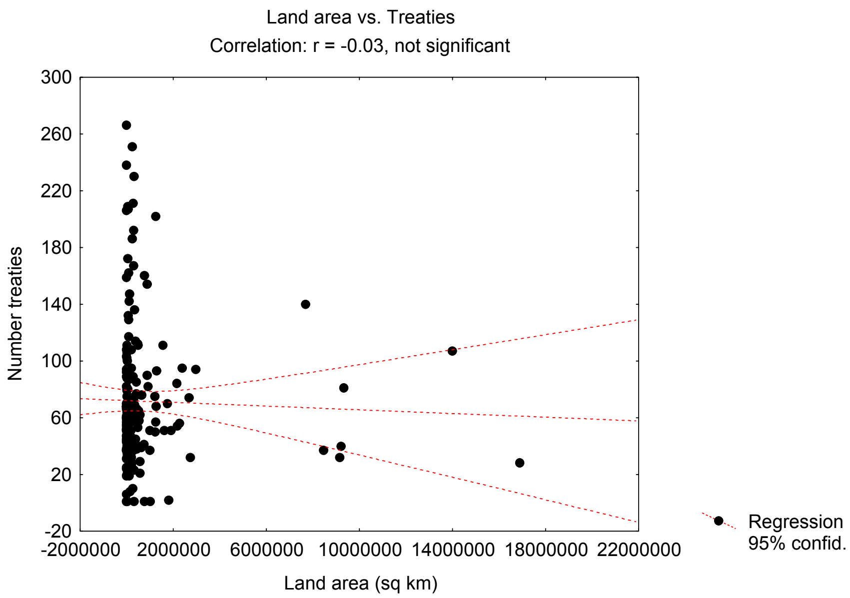
The raw data for this indicator are comprised of the total number of environmental treaties in force in the country at 2003. Data are from the SEDAC / CIESIN 2003 database http://sedac.ciesin.org, originally sourced from IUCN. Although the number of treaties in force does not guarantee that the obligations are being met, or that the environment is being properly managed, it may indicate increased awareness, monitoring, better access to information and international pressure to address environmental issues in the longer term. Because treaties are usually issue-specific, we expect that a larger number of treaties in force in a country will mean increased exposure to a greater number of issues and approaches to dealing with them. Our examination of the treaty database reveals that once the level of approximately 60 treaties is reached there is a good chance that the most important issues have been covered. At numbers lower than this, there is an increasing chance that major issues are not being addressed, at least within view of the international community. Of the 235 countries examined, these data were available for 196.

The number of international environmental treaties in force by 2003 varied between 1 and 266 (Table 49.1). The lowest values were recorded in 6 countries, including United Arab Emirates, Anguilla, Tokelau and Cayman Islands, and the highest values were recorded in France, Germany and UK. The mean value across the globe was 71.69 treaties. Half of the countries examined had 59 treaties in force or less (the median) (Table 49.1). Variance among countries was low, with a standard deviation which is around 0.7 times the mean. The number of environmental treaties in force is not correlated with the size of a country (Figure 49.1).

Table 49.1: Basic statistics for treaties in force by 2003.

Statistic	# Treaties
Mean	71.69
Median	59.00
Valid n	196
Min	1
Max	266
SD	49.40
SE	3.53
Skewness	1.63
SE Skewness	0.17
Kurtosis	3.02
SE Kurtosis	0.35

Figure 49.1: Graphs of number of treaties in force vs. size of countries. The correlation is not significant.



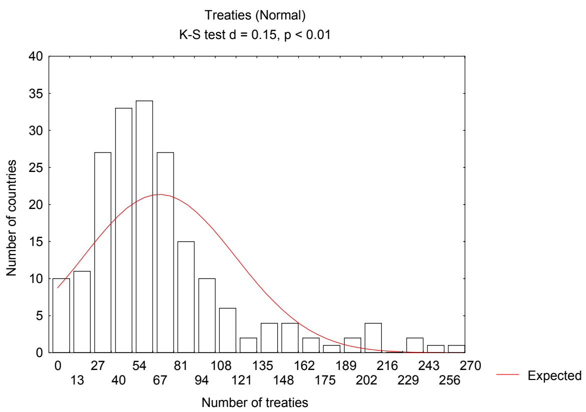
49.3 Distributional characteristics of the indicator data

The number of treaties in force in countries was plotted as frequency distributions in 20 evenly-spaced categories to identify any underlying patterns (Figure 49.2). This resulted in a skewed distribution with a peak around 50. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

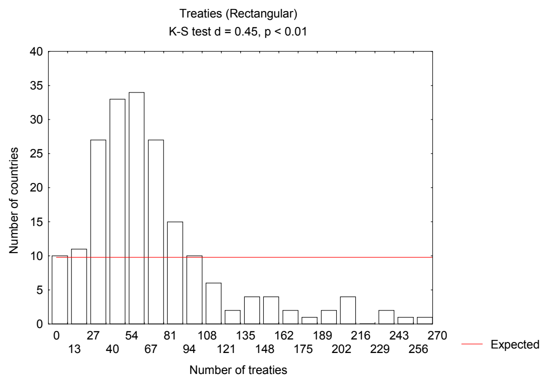
A significant difference between observed and expected values was found in all of the distributions tested (Figure 49.2). We considered that a transform would be unhelpful in scaling these data.

Figure 49.2: Kolmogorov-Smirnov goodness-of-fit tests for treaties in force spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit. None of these distributions was a good fit to the observed data.

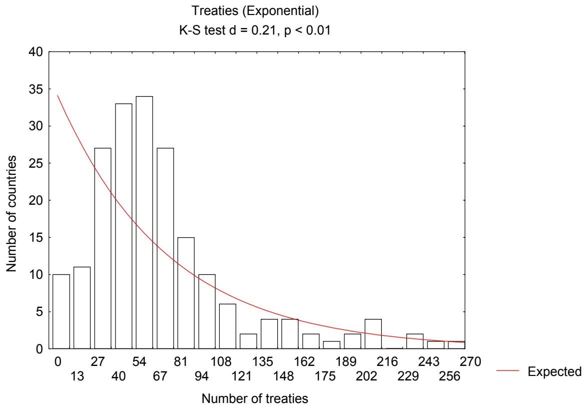
(a)



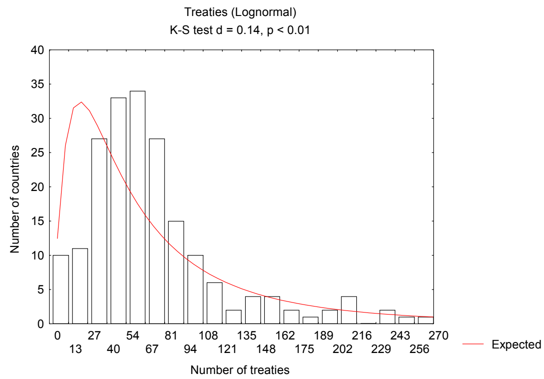
(b)



(c)



(d)

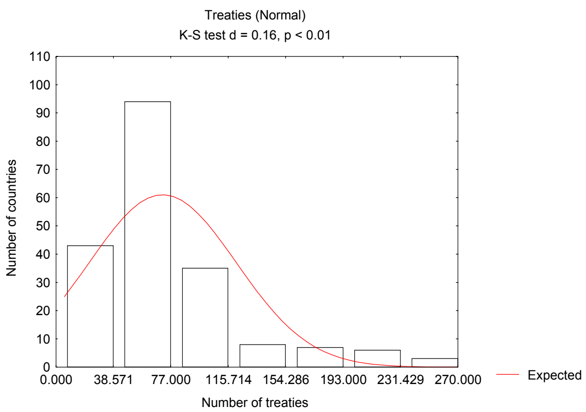


49.4 Proposed EVI scaling and distribution of the data on this scale

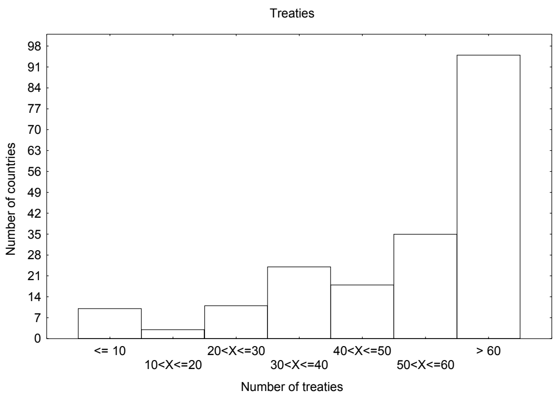
Countries varied in the number of international environmental treaties in force by two orders of magnitude, with a slight clumping of countries around the lowest quartile of the range of the data. We propose that the data not be transformed for this indicator, but used in their raw form, with countries with the lowest numbers of treaties in force being considered more vulnerable and attracting a higher EVI score. We identified those countries with >60 treaties in force as likely to be the least at risk of future environmental damage that can be curbed by treaties because the number of issues being under treaty, amount of awareness, information available, monitoring and pressure to address them is likely to be adequate (EVI=1). Countries with ≤10 treaties in force were considered the most vulnerable (EVI=7). These are countries that may not be sufficiently committed to environmental management to take advantage of the global resources available for dealing with common issues, and often given on favourable terms to developing countries. The country values between these extremes were spaced evenly to form the remainder of the EVI scale (Figure 49.3, Table 49.2, 49.3).

Figure 49.3: Frequency distribution of treaties in force in even and uneven categories and the EVI scale. (a) Frequency distribution in 7 even categories, (b) Is the distribution in seven categories which clump countries with high values, identifying them as being at the lowest risk, (c) The same distribution mirrored to form the proposed EVI scale.

(a)



(b)



(c)

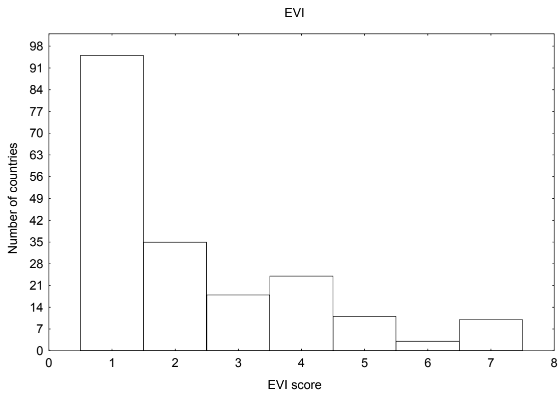


Table 49.2: Proposed EVI scaling for treaties in force showing the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Scale for Treaties in Force	Observed # countries	Observed % of countries
1	X>60	95	48.47
2	50<X≤60	35	17.86
3	40<X≤50	18	9.18
4	30<X≤40	24	12.24
5	20<X≤30	11	5.61
6	10<X≤20	3	1.53
7	X≤10	10	5.10
No data		39	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 49.3: Proposed EVI scaling for number of treaties in force showing examples of countries that fall into each of the EVI scores.

Score	Scale for Treaties in Force	Examples
EVI=1	X>60	Argentina, Canada, Luxembourg
EVI=2	50<X≤60	Iraq, Nepal, Solomon Is.
EVI=3	40<X≤50	St Lucia, Singapore, Zimbabwe
EVI=4	30<X≤40	Lao, Maldives, Tonga
EVI=5	20<X≤30	Cook Is, San Marino, Uzbekistan
EVI=6	10<X≤20	Bhutan, Eritrea, Tajikistan
EVI=7	X≤10	Anguilla, Cayman Is., Palau

49.5 Age, completeness and quality of the data

The data obtained for this indicator were from the SEDAC / CIESIN database and in-country sources. In-country data were available for 22 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 49.4).

Table 49.4: Characteristics of age, completeness and quality of the data obtained from countries.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.41	2.14	2.50
Valid n (in-country)	17	21	22
SD (in-country)	0.80	0.96	0.80
SE (in-country)	0.19	0.21	0.17

49.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

49.7 Additional sources & contacts

www.sedac.ciesin.org/prod/charlotte source from IUCN; Cook Islands - Cook Islands Environment Bill 2000. Environment Services; Costa Rica - La Asamblea Legislativa De La Republica De Costa Rica. Publicación y rige: 13/11/95; Federated States of Micronesia - FSM Review of Environmental Law. Harding, E. 1992. FSM Department of Economic Affairs; Fiji - Fiji's Draft Sustainable Development Bill. 1996. Department of Environment (DoE); Greece - Contact - Dr Paula Scott (ph&f: 30 81 8 61 219, cariad@her.forthnet.gr); Kiribati - Environment Act 1999. Government of Kiribati. Environment & Conservation Division; Kyrgyzstan - Contact - Mr. Myrsaliev N(Unit of Conventions). Department of State Ecological Control and Environment Utilization; Marshall Islands - Crawford. M,1992. RMI National Environmental Strategy Report (NEMS) Report. Republic of Marshall Islands Environmental Protection Agency; Nauru - Thaman, R R and Hassall, P C. 1999 Nauru National Environmental Strategy Report (NEMS); Nepal - Contact - Mr Damodar Adhikari, Phone/Fax ++(1) 499700, E-Mail: dadhikar@Wlink.com.np President - Society For Environment and development, Kathmandu; New Zealand - Official series of New Zealand legislation: Environment act 1986, Conservation act 1987, Resource management act 1991, Fisheries act 1983 & 1996, Crown materials act 1991, Hazardous substances and new organisms act 1996, Ozone layer protection act, energy efficiency and conservation act 2000. Ministry of the Environment; Niue - Source - Environment Office. Contact - Tagaloa Cooper. Community Affairs; Palau - Contact - Robert (Bob) Marek (680 4881639 or 3600/ 4882963/ eqpb@palaunet.com) Environmental Quality Protection Board; Papua New Guinea - Contact - Katrina Solien. (EPA)/ Assistant Manager Office of Environment & Conservation. (OE & C); Philippines - Contact - Mr.Percival A. Guiuan / (632) 8965390 / pa.guiuan@nscb.gov.ph Statistical Coordination Officer. Department of Environment and Natural Resources (DENR); Singapore - Source - Ministry of the Environment, International relations Department. Contact - Jucin Chan 6567319087 Fax – 6567384468 E-Mail jacin_chan@env.gov.sg. International relations department / senior international relations executive; St Lucia - Contact - Christopher Corbin Tel: 7584685041 Fax – 7854516958 E-Mail ccorbin@planning.gove.lc. Sustainable development and environment department; Thailand - Pollution Control Department. Tel 66 2 2982253 Fax 66 2 2982240 e-mail: marinepollution_pcd@yahoo.com; Tonga - Environmental

Management Plan for the Kingdom of Tonga. UN – ESCAP. EPACS; Trinidad &Tobago - Contact - John Agard; Tuvalu - Contact – Mataio. Environment Department.

50. HUMAN CONFLICTS

50.1 Indicator Summary

Indicator number:	50
Indicator short name:	Human conflicts
Sub-index	AVI
Categorisation	Human Populations
Indicator text:	Average number of conflict years per decade over the past 50 years.
Signals captured:	This indicator captures the risk to terrestrial, aquatic ecosystems and ground waters related to human conflicts. Conflicts can result in habitat disturbance and degradation, pollution and a complete breakdown in environmental management. The direct effects include degradation through bombing, land mines, and chemicals left in the environment, temporary camps and vehicle disturbances, and damage caused by displaced people who need to support themselves under emergency conditions. This is also a proxy for the lack of environmental management during those years. The effects of civil unrest would be especially important if they were on-going, repeated, or occurring as separate events in more than one part of a country. Effects would be amplified if there are many endangered species, sensitive ecosystems, and interactions with other on-going human impacts. The time frame used reflects the long term nature of conflict-related damage to the environmental support system.
Notes on this indicator:	1. The EM-DAT database covers only the period 1991-2000. Data should be for a longer time series. 2. There is no information on the type or geographic extent of conflicts, numbers of people involved, or duration. Incorporating these measures would improve the indicator's ability to measure likely ecological effects. 3. For future evaluations of the EVI values should be calculated as mean number of conflict years per decade and used against the same scale indicated here. 4. The number of conflict years can be greater than the number of data years if there are multiple simultaneous conflicts in the country. 5. Conflict: Use of armed force between the military forces of two or more governments, or of government and at least one organized armed group, resulting in the battle-related deaths of at least 10 people or 100 affected in one year. (SIPRI definition adapted to for EMDAT). In EM-DAT, conflict includes the disaster types 'intrastate conflict' and 'international conflict'. 6. Intrastate conflict: CRED has adopted the simple Project Ploughshares' typology of modern armed conflict based on three overlapping types of intrastate conflict: state control, state formation and state failure. 7. International conflict: This includes border disputes, foreign invasion and other cross-border attacks (Project Ploughshares).
Are suitable data available?	Yes, but only for a limited number of years
Sources of data:	• EM-DAT: The OFDA/CRED International Disaster Database, http//: www.cred.be/emdat - Université Catholique de Louvain - Brussels - Belgium • In-country

No. countries included in test:	233 of 235	
Temporary modifications to data or indicator, if applicable:	• None	
Notes on data age, completeness and quality:	15 of the 32 collaborating countries returned data for this indicator. Age, completeness and quality of the in-country data were generally considered good (value > 2 of 3).	
Basic units:	Number of conflict years	
Recommended transforms:	• None	
Proposed EVI Scale	EVI Score = 1	X=0
	EVI Score = 2	Not used
	EVI Score = 3	Not used
	EVI Score = 4	Not used
	EVI Score = 5	0<X≤2
	EVI Score = 6	2<X≤5
	EVI Score = 7	X>5
	NA (not applicable)	☒ May not be used.
	ND (no data)	☑ May be used
Future work on this indicator:	• Data for a longer time period are needed. All conflicts 1950 to present should be included. • When data for a longer time period are available, data should be transformed to mean conflict years per decade and be tested on this EVI scale.	

50.2 Description of raw data

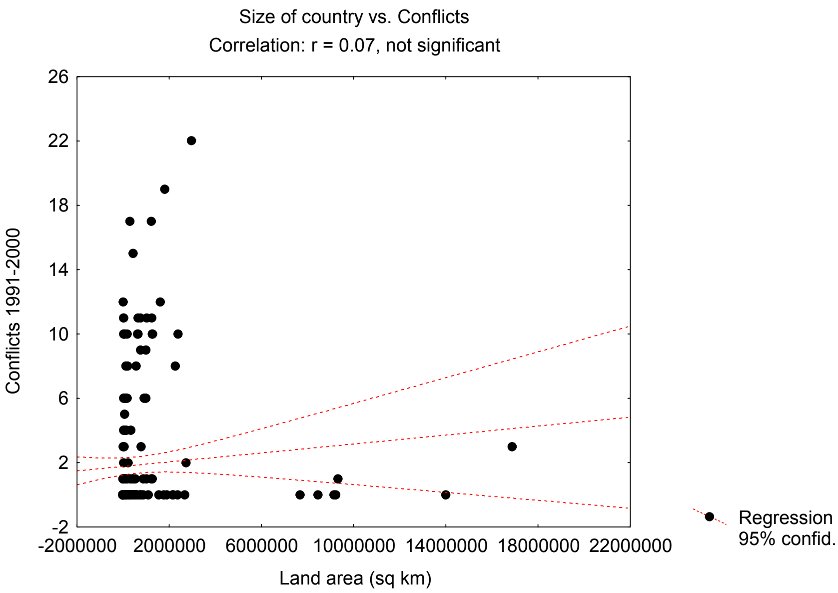
The raw data for this indicator are comprised of the total number of conflicts in any year, added up over all years of data. This includes brief conflicts concluded in a few days through to extended conflicts that last for years. Data are totals for 1991 to the beginning of 2000 and are derived from the EM-DAT database. Of the 235 countries examined, these data were available for 233.

The total number of conflict years in countries between 1991-2000 varied between 0 and 22 (Table 50.1). Zero values were recorded in 160 countries. The highest values were recorded in India, Indonesia, Philippines and South Africa. The mean value across the globe was 1.86 conflicts over the 9 year period. Variance among countries is moderate, with a standard deviation which is around 2.1 times the mean. The number of conflict years is not correlated with the size of a country (Figure 50.1).

Table 50.1: Basic statistics for conflicts. Data are for 9 years between 1991-2000.

Statistic	Conflict Years
Mean	1.86
Median	0
Valid n	233
Min	0
Max	22
SD	3.95
SE	0.26
Skewness	2.48
SE Skewness	0.16
Kurtosis	6.11
SE Kurtosis	0.32

Figure 50.1: Graphs of conflict years vs. size of countries. The correlation is not significant.



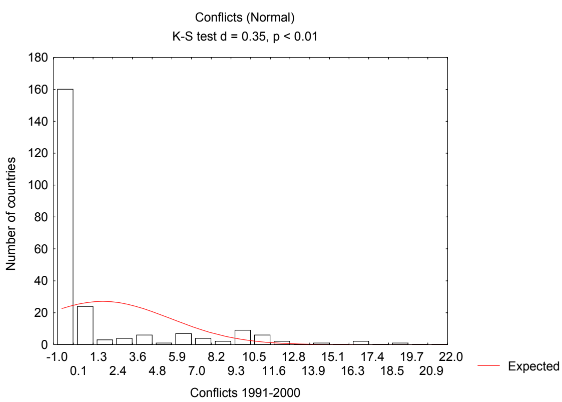
50.3 Distributional characteristics of the indicator data

The number of conflict years was plotted as frequency distributions in 20 evenly-spaced categories to identify underlying patterns (Figure 50.2). This resulted in a distribution that was heavily skewed at the lower end of the scale. The four classes of distributions examined were normal (distributed around some average), rectangular (evenly distributed), exponential (power function) and lognormal (logarithmic function). Kolmogorov-Smirnov (K-S) tests were used to test the null-hypothesis of no difference between the observed frequency distributions (bars) and the expected ones (lines), if the distribution against which the data were being tested was a good fit.

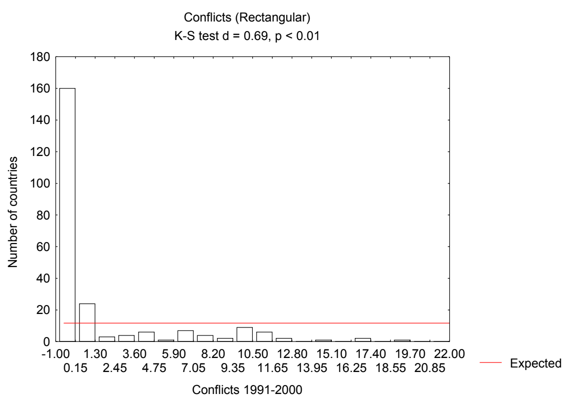
A significant difference between observed and expected values was found in all of the distributions tested (Figure 50.2). No indication is given by these tests of a data transformation that could be used as a better scale for comparison.

Figure 50.2: Kolmogorov-Smirnov goodness-of-fit tests for conflict years in countries spread over 20 categories (bars) and compared with (a) normal, (b) rectangular, (c) exponential and (d) lognormal distributions (lines). Each observed distribution was compared with the expected line using a K-S test for goodness of fit.

(a)



(b)



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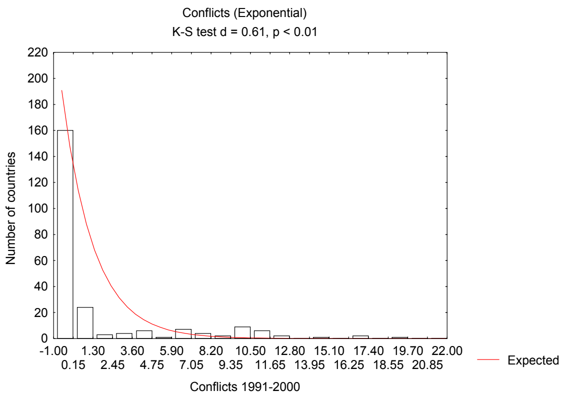

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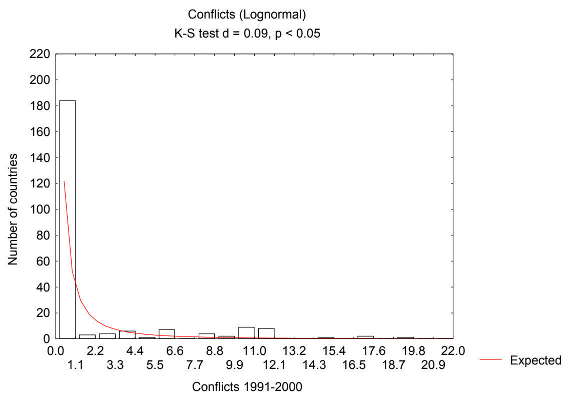


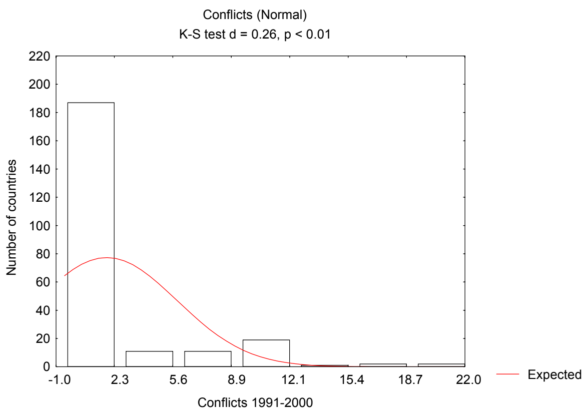
50.4 Proposed EVI scaling and distribution of the data on this scale

The number of conflict years in countries between 1991 and the beginning of 2000 varied between 0 and 22, with most countries not having any conflicts during that period. We propose that the data not be transformed for this evaluation of the indicator. However, as the present data cover only a period of 9 years, and the indicator requires more than 50 years of data, it will be necessary to transform the data in future evaluations of the EVI to keep the scale proposed here comparable. If data for additional years becomes available, we propose that the data be expressed as conflict years per decade and the scale proposed below used without further modification.

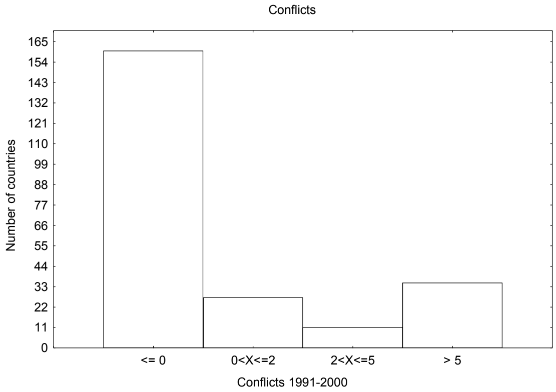
We identified those countries with no conflicts as the only ones with low risk of environmental damage (the risk is never zero since conflicts could arise at any time and the EVI focuses on the likelihood of environmental damage due to a factor) (EVI=1). Countries with ≤2 conflict years (over the period 1991-2000 or per decade) were considered vulnerable and given a moderately high EVI score of 5. An EVI score of 6 was used for countries with more than 2, but ≤5 conflict years, and countries with more conflict years were given an EVI score of 7 and identified as being highly vulnerable to conflict-related environmental issues. EVI scores 2-4 were not used for this indicator. The risks associated with any conflicts were considered too high for these scores to be used (Figure 50.3, Table 50.2, 50.3).

Figure 50.3: Frequency distribution of conflict years in even and uneven categories and the EVI scale. (a) Frequency distribution conflict years 7 even categories, (b) Is the distribution in 4 categories that indicate the thresholds we propose for the EVI for this indicator, identifying all countries with any conflicts as being at the highest risk. (d) The proposed EVI scale.

(a)



(b)



(d)

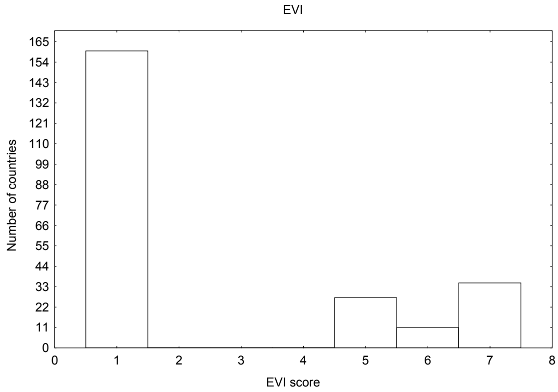


Table 50.2: Proposed EVI scaling for conflict years the number and % of countries falling in each EVI scoring category. NA=Not applicable in a country; ND=No data currently available.

EVI Scale	Conflict years or Conflict years / decade	Observed # countries	Observed % of countries
1	X=0	160	68.67
2	Not used		
3	Not used		
4	Not used		
5	0<X≤2	27	11.59
6	2<X≤5	11	4.72
7	X>5	35	15.02
No data		2	
NA	☒ May not be used		
ND	☑ May be used (results in no score)		

Table 50.3: Proposed EVI scaling for conflict years showing examples of countries that fit into each of the EVI scores.

Score	Conflict years or Conflict years / decade	Examples
EVI=1	X=0	Austria, Botswana, Hungary
EVI=2	Not used	
EVI=3	Not used	
EVI=4	Not used	
EVI=5	0<X≤2	Cyprus, Ghana, Kuwait
EVI=6	2<X≤5	Congo, Djibouti, Georgia
EVI=7	X>5	Colombia, Algeria, Israel

50.5 Age, completeness and quality of the data

The data obtained for this indicator were from The EM-DAT International Disaster Database, as well as in-country sources. In-country data were available for 15 of the 32 collaborating countries, with data being considered by collaborators to be of good age, completeness and quality (Table 50.4).

Table 50.4: Characteristics of age, completeness and quality of the data for conflict years collected from in-country sources.

Characteristic	Age	Completeness	Quality
Value of 3	Most recent data are <2 years old	Data are complete and relevant for the time frame required	Data are well supported by publications, records or other documentation and are considered accurate.
Value of 2	Most recent data are from between 1995 and 1999	Partial data are available for some regions and/or some years	Data are based on incomplete information and/or are completed through statistical projections (interpolation or extrapolation)
Value of 1	Most recent data are older than 1995	Data are not available for this indicator for the country	Data are based on best guesses
In-country score	2.67	2.50	2.00
Valid n (in-country)	12	8	15
SD (in-country)	0.65	0.76	0.93
SE (in-country)	0.19	0.27	0.24

50.6 Variations among sources of data

Alternative appropriate sources of data are not at present available for this indicator.

50.7 Additional sources & contacts

www.cred.be/emdat Université Catholique de Louvain - Brussels – Belgium; Botswana - Office of the President. Contact - Mr Pitlagano Gabasiane350804 – Phone581028 - Faxpgabasiane@gov.bw - email. Principal Administration OfficerPolitical Affairs Division; Cook Islands - Contact - Antoine Nia (682 21256/ 682 22256) Environment Services; Costa Rica - San José, C.R[Ed]. 1998 Guerra civil en costa rica/Jhon Patrick bell -4a; Kyrgyzstan - Contact - Mr. Myrsaliev N(Unit of Conventions). Department of State Ecological Control and Environment Utilization; Marshall Islands - Contact - Ellia Sablan (8262 or 5632/ 5447 or 5130/ ellia_sablan@hotmail.com) Marshall Islands Marine Resources Authority; Nauru - Contact - Davey Roxen Pene Agadio (674 4443181/ 4443791) Department of Island Development & Industries (Dept. of IDI); New Zealand - Contact - Hine-Wai Loose. Ministry for the Environment; Niue - Contact - Sisilia Talagi (683 4200/ 4232/ secgov.Premier@mail.gov.nu) Premier's Department/ Secretary to Government; Samoa - Contact - Vainuupo Jungblut. Lands, Surveys & Environment; Singapore - A periodical history of Singapore/ National heritage board-Journey into nationhood, National heritage board-National dictionary of Singapore, Newspapers Official records. (National archives of Singapore); St Lucia - Mr Crispin D'Auvergne (cdauvergne@planning.gov.lc) Ministry of Justice; Thailand - Source: Department of Local Administration, Ministry of Interior. Contact - Mr. Prapun Sangwichit. Chief of Economics and Social Faculty, Administration Institute of Development; Trinidad & Tobago - Contact - Cindy Buchoon; Tuvalu - Environment Unit GOT and SPREP, 1995. Department of Lands and Survey; Vanuatu - Police Records. Vanuatu Police Force.

7.5 EVI and sub-index scores

Classification	Region	ISO	Country	SIDS	LLock	Collab	EVI	%	Hazards	%	Resistance	%	Damage	%
At risk	Europe	AD	Andorra		LL		257	42	1.78	28	3.29	88	3.33	50
Vulnerable	Middle East & Nth Africa	AE	United Arab Emirates				293	90	3.37	84	2.63	100	2.00	100
Vulnerable	Middle East & Nth Africa	AF	Afghanistan		LL		289	76	2.81	66	2.75	100	3.20	90
Vulnerable	Central America & Caribbean	AG	Antigua & Barbuda	SIDS			307	56	2.00	47	5.00	88	3.86	60
Vulnerable	Central America & Caribbean	AI	Anguilla	SIDS			312	52	2.00	44	4.57	88	4.33	50
Highly vulnerable	Europe	AL	Albania				330	94	3.21	91	3.38	100	3.64	100
At risk	Asia	AM	Armenia		LL		247	72	2.26	59	2.50	100	3.10	90
Highly vulnerable	Central America & Caribbean	AN	Netherlands Antilles	SIDS			323	60	2.94	50	4.14	88	3.38	70
At risk	Sub-Saharan Africa	AO	Angola				225	96	2.27	94	2.00	100	2.27	100
At risk	Antarctica	AQ	Antarctica				235	40	2.90	31	2.29	88	0.75	30
Vulnerable	Sth America	AR	Argentina				287	94	3.10	91	2.88	100	2.09	100
Extremely vulnerable	Oceania	AS	American Samoa				436	50	3.31	41	5.29	88	5.80	50
Extremely vulnerable	Europe	AT	Austria		LL		369	84	3.96	81	3.00	100	3.67	80
At risk	Oceania	AU	Australia			Y	238	96	2.63	94	2.38	100	1.55	100
Vulnerable	Central America & Caribbean	AW	Aruba	SIDS			291	46	1.80	31	4.43	88	3.57	60
Highly vulnerable	Asia	AZ	Azerbaijan		LL		354	74	3.60	63	3.38	100	3.70	90
Vulnerable	Europe	BA	Bosnia & Herzegovina				306	70	3.11	59	2.25	100	3.78	80
Extremely vulnerable	Central America & Caribbean	BB	Barbados	SIDS		Y	403	70	3.20	63	4.75	100	5.75	70
Highly vulnerable	Asia	BD	Bangladesh			Y	340	94	3.45	91	2.00	100	4.64	100
Extremely vulnerable	Europe	BE	Belgium				387	94	3.93	91	2.88	100	4.73	100
At risk	Sub-Saharan Africa	BF	Burkina Faso		LL		229	82	2.25	75	2.00	100	2.70	90
Highly vulnerable	Europe	BG	Bulgaria				323	96	3.47	94	3.00	100	2.82	100
Highly vulnerable	Middle East & Nth Africa	BH	Bahrain	SIDS			326	62	2.71	53	4.29	88	4.00	70
Vulnerable	Sub-Saharan Africa	BI	Burundi		LL		288	80	2.67	75	2.25	100	4.44	80
Vulnerable	Sub-Saharan Africa	BJ	Benin				278	92	2.71	88	2.25	100	3.45	100
Extremely vulnerable	Central America & Caribbean	BM	Bermuda	SIDS			373	52	2.92	41	4.71	88	4.71	60
Vulnerable	Asia	BN	Brunei Darussalam				313	62	2.88	53	3.83	75	3.22	80
At risk	Sth America	BO	Bolivia		LL		250	84	2.52	78	3.00	100	1.90	90
Vulnerable	Sth America	BR	Brazil				281	94	3.10	91	2.63	100	2.09	100
At risk	Central America & Caribbean	BS	Bahama	SIDS			248	62	2.18	53	3.71	88	2.00	70
At risk	Asia	BT	Bhutan		LL		253	68	2.65	53	2.75	100	2.20	90
Vulnerable	Antarctica	BV	Bouvet Island				271	42	1.33	28	4.86	88	2.00	50
Resilient	Sub-Saharan Africa	BW	Botswana		LL	Y	181	84	2.04	78	1.50	100	1.40	90
At risk	Europe	BY	Belarus		LL		239	72	2.55	63	2.38	100	2.11	80
At risk	Central America & Caribbean	BZ	Belize				258	90	2.85	84	2.38	100	1.91	100
At risk	North America	CA	Canada				251	98	2.90	97	2.25	100	1.45	100
Vulnerable	Asia	CC	Cocos (Keeling) Islands				285	40	2.44	28	4.29	88	1.60	40
Resilient	Sub-Saharan Africa	CF	Central African Rep		LL		193	80	2.00	72	2.00	100	1.60	90
At risk	Sub-Saharan Africa	CG	Congo				219	94	2.24	91	2.50	100	1.73	100
Highly vulnerable	Europe	CH	Switzerland		LL		348	88	4.00	84	2.63	100	3.00	90
At risk	Sub-Saharan Africa	CI	Cote d'Ivoire				248	92	2.48	91	2.71	88	2.36	100
Extremely vulnerable	Oceania	CK	Cook Islands	SIDS		Y	383	82	3.07	84	5.50	100	4.86	60
Vulnerable	Sth America	CL	Chile				287	94	3.00	91	3.25	100	2.18	100
At risk	Sub-Saharan Africa	CM	Cameroon				229	96	2.27	94	2.50	100	2.27	100
Highly vulnerable	Asia	CN	China				360	94	3.69	91	3.38	100	3.64	100
Vulnerable	Sth America	CO	Colombia				296	96	3.03	94	2.50	100	3.09	100
Highly vulnerable	Central America & Caribbean	CR	Costa Rica			Y	354	96	3.73	94	2.88	100	3.55	100
Highly vulnerable	Central America & Caribbean	CU	Cuba	SIDS			329	90	3.00	84	3.13	100	4.27	100
Vulnerable	Sub-Saharan Africa	CV	Cape Verde	SIDS			282	66	2.28	56	4.00	88	3.22	80
Highly vulnerable	Oceania	CX	Christmas Islands				350	44	2.44	28	5.00	88	3.14	60
Vulnerable	Middle East & Nth Africa	CY	Cyprus	SIDS			314	70	3.05	63	2.86	88	3.67	80
Highly vulnerable	Europe	CZ	Czech Rep		LL		315	78	3.50	75	2.00	100	3.50	70
Highly vulnerable	Europe	DE	Germany				357	98	3.74	97	2.88	100	3.82	100
Resilient	Sub-Saharan Africa	DJ	Djibouti				210	62	1.88	53	2.86	88	1.86	70
Highly vulnerable	Europe	DK	Denmark				345	98	3.74	97	2.88	100	3.18	100
Highly vulnerable	Central America & Caribbean	DO	Dominican Rep	SIDS			324	90	2.96	84	4.00	100	3.64	100
Vulnerable	Middle East & Nth Africa	DZ	Algeria				275	96	2.73	94	2.38	100	2.91	100
Vulnerable	Sth America	EC	Ecuador				304	96	3.27	94	2.88	100	2.55	100
Vulnerable	Europe	EE	Estonia				280	92	2.89	88	2.63	100	2.73	100
Vulnerable	Middle East & Nth Africa	EG	Egypt				298	96	3.07	94	2.50	100	3.18	100
Resilient	Sub-Saharan Africa	EH	Western Sahara				175	48	1.82	34	2.14	88	1.14	60
At risk	Sub-Saharan Africa	ER	Eritrea				254	78	2.41	69	2.63	100	2.80	90
Highly vulnerable	Europe	ES	Spain				352	96	3.77	94	3.00	100	3.27	100
At risk	Sub-Saharan Africa	ET	Ethiopia		LL		260	80	2.39	72	2.50	100	3.30	90
Vulnerable	Europe	FI	Finland				265	98	3.26	97	1.75	100	1.45	100
Highly vulnerable	Oceania	FJ	Fiji	SIDS		Y	333	92	3.36	88	4.25	100	2.55	100
At risk	Sth America	FK	Falkland Islands				223	60	1.67	47	3.57	88	2.00	80
Extremely vulnerable	Oceania	FM	Fed. States Micronesia	SIDS		Y	392	74	3.14	69	5.25	100	5.00	70
Vulnerable	Europe	FO	Faroe Islands				296	54	2.29	44	4.14	88	3.14	60
Highly vulnerable	Europe	FR	France				361	98	3.81	97	3.13	100	3.55	100
Resilient	Sub-Saharan Africa	GA	Gabon				211	90	2.37	84	2.25	100	1.27	100
Extremely vulnerable	Europe	GB	United Kingdom				373	96	3.83	94	3.00	100	4.18	100
Highly vulnerable	Central America & Caribbean	GD	Grenada	SIDS			316	62	2.29	53	4.43	88	4.38	70
At risk	Asia	GE	Georgia				261	82	2.39	72	3.13	100	2.82	100
Resilient	Sth America	GF	French Guiana				174	62	1.71	53	2.29	88	1.25	70

Classification	Region	ISO	Country	SIDS	LLocke	Collab	EVI	%	Hazards	%	Resistance	%	Damage	%
Vulnerable	Sub-Saharan Africa	GH	Ghana				279	96	2.80	94	2.63	100	3.00	100
Highly vulnerable	Europe	GI	Gibraltar				328	50	2.57	44	4.29	88	4.60	40
At risk	Europe	GL	Greenland				243	56	2.69	50	2.57	88	1.33	50
Vulnerable	Sub-Saharan Africa	GM	Gambia				277	94	2.52	91	3.25	100	3.27	100
At risk	Sub-Saharan Africa	GN	Guinea				254	92	2.71	88	2.38	100	2.18	100
Extremely vulnerable	Central America & Caribbean	GP	Guadeloupe				412	50	3.42	38	4.43	88	5.43	60
At risk	Sub-Saharan Africa	GQ	Equatorial Guinea				243	80	2.73	69	2.75	100	1.45	100
Highly vulnerable	Europe	GR	Greece			Y	353	98	3.77	97	3.25	100	3.09	100
At risk	Antarctica	GS	Sth Georgia & Sth Sandwich				245	40	2.38	25	3.29	88	1.33	50
Highly vulnerable	Central America & Caribbean	GT	Guatemala				338	94	3.45	91	2.50	100	4.00	100
Extremely vulnerable	Oceania	GU	Guam	SIDS			390	62	2.83	56	4.86	88	6.14	60
Vulnerable	Sub-Saharan Africa	GW	Guinea-Bissau				271	84	2.83	75	3.00	100	2.27	100
Resilient	Sth America	GY	Guyana				207	90	2.15	84	2.63	100	1.36	100
Vulnerable	Asia	HK	Hong Kong				309	44	2.78	28	3.50	75	3.14	70
Vulnerable	Antarctica	HM	Heard & McDonald Is.				294	36	1.29	22	4.86	88	2.20	40
Vulnerable	Central America & Caribbean	HN	Honduras				273	90	2.70	84	2.88	100	2.82	100
Highly vulnerable	Europe	HR	Croatia				343	92	3.73	94	2.13	100	3.67	80
Highly vulnerable	Central America & Caribbean	HT	Haiti	SIDS			343	92	3.04	88	3.75	100	4.55	100
Highly vulnerable	Europe	HU	Hungary		LL		363	86	3.85	81	3.13	100	3.60	90
Highly vulnerable	Asia	ID	Indonesia				316	98	3.06	97	3.25	100	3.55	100
Highly vulnerable	Europe	IE	Ireland				318	98	3.23	97	2.75	100	3.45	100
Extremely vulnerable	Middle East & Nth Africa	IL	Israel				380	90	3.56	84	3.38	100	5.00	100
Extremely vulnerable	Asia	IN	India				385	92	3.79	88	2.88	100	5.00	100
Vulnerable	Asia	IO	British Indian Ocean Territor				295	38	1.38	25	4.86	88	2.60	40
Highly vulnerable	Middle East & Nth Africa	IQ	Iraq				344	86	3.54	81	2.63	100	3.80	90
Vulnerable	Middle East & Nth Africa	IR	Iran, Islamic Rep				313	96	3.23	94	2.63	100	3.18	100
Vulnerable	Europe	IS	Iceland				298	96	2.93	94	3.13	100	2.82	100
Extremely vulnerable	Europe	IT	Italy				386	98	4.06	97	3.50	100	3.73	100
Vulnerable	Europe	an Maye	Jan Mayen				300	34	2.67	19	5.17	75	0.83	50
Extremely vulnerable	Central America & Caribbean	JM	Jamaica	SIDS		Y	385	94	3.31	91	4.50	100	5.00	100
Vulnerable	Middle East & Nth Africa	JO	Jordan				310	96	3.33	94	2.13	100	3.27	100
Extremely vulnerable	Asia	JP	Japan				389	94	4.38	91	2.88	100	3.64	100
At risk	Sub-Saharan Africa	KE	Kenya			Y	262	94	2.45	91	2.75	100	3.00	100
At risk	Asia	KG	Kyrgyzstan		LL	Y	234	76	2.33	66	3.00	100	1.80	90
Vulnerable	Asia	KH	Cambodia				270	88	2.92	81	1.88	100	2.91	100
Extremely vulnerable	Oceania	KI	Kiribati	SIDS		Y	395	82	3.32	78	5.25	100	4.67	80
Vulnerable	Sub-Saharan Africa	KM	Comoros	SIDS			277	62	1.94	53	4.00	88	4.00	70
Highly vulnerable	Central America & Caribbean	KN	St. Kitts and Nevis	SIDS			359	54	3.07	44	5.29	88	3.29	60
Highly vulnerable	Asia	KP	Korea, Dem People's Rep				363	82	3.88	75	3.14	88	3.64	100
Extremely vulnerable	Asia	KR	Korea, Rep				373	96	4.03	97	2.57	88	3.91	100
Highly vulnerable	Middle East & Nth Africa	KW	Kuwait				323	94	3.45	91	2.63	100	3.27	100
Highly vulnerable	Central America & Caribbean	KY	Cayman Islands	SIDS			343	60	2.65	53	4.71	88	4.29	60
At risk	Asia	KZ	Kazakhstan		LL		215	80	2.13	72	2.50	100	1.80	90
At risk	Asia	LA	Lao People's Dem Rep		LL		243	80	2.63	75	2.50	100	1.78	80
Extremely vulnerable	Middle East & Nth Africa	LB	Lebanon				387	94	3.97	91	3.25	100	4.36	100
Extremely vulnerable	Central America & Caribbean	LC	Saint Lucia	SIDS		Y	393	58	3.20	47	4.57	88	5.13	70
Highly vulnerable	Europe	LI	Liechtenstein		LL		346	52	3.15	41	3.86	88	4.00	60
Highly vulnerable	Asia	LK	Sri Lanka				331	98	3.06	97	2.63	100	4.82	100
Vulnerable	Sub-Saharan Africa	LR	Liberia				271	82	2.78	72	2.75	100	2.55	100
Vulnerable	Sub-Saharan Africa	LS	Lesotho		LL		280	80	2.83	72	2.13	100	3.40	90
Vulnerable	Europe	LT	Lithuania				314	88	3.23	81	2.63	100	3.36	100
Highly vulnerable	Europe	LU	Luxembourg		LL		327	66	3.33	56	2.71	88	3.89	80
Vulnerable	Europe	LV	Latvia				270	92	2.46	88	2.63	100	3.36	100
At risk	Middle East & Nth Africa	LY	Libyan Arab Jamahiriya				256	90	2.59	84	2.13	100	2.64	100
Vulnerable	Middle East & Nth Africa	MA	Morocco				315	96	3.13	94	2.63	100	3.64	100
Highly vulnerable	Europe	MAC	Macedonia, FYR		LL		316	64	3.59	53	2.00	100	3.50	70
Highly vulnerable	Europe	MC	Monaco				332	44	2.75	38	4.57	88	3.75	30
Highly vulnerable	Europe	MD	Moldova, Rep		LL		322	74	3.36	69	2.13	100	4.13	70
Vulnerable	Sub-Saharan Africa	MG	Madagascar				279	94	2.55	91	2.88	100	3.27	100
Highly vulnerable	Oceania	MH	Marshall Islands	SIDS		Y	348	80	3.13	75	4.75	100	3.67	80
Resilient	Sub-Saharan Africa	MI	Mali		LL		215	82	2.00	75	1.88	100	2.60	90
Vulnerable	Asia	MM	Myanmar				270	92	2.61	88	2.63	100	3.09	100
Resilient	Asia	MN	Mongolia		LL		208	80	2.30	72	1.63	100	1.80	90
Extremely vulnerable	Asia	MO	Macau				407	54	3.60	47	4.71	88	5.00	50
Extremely vulnerable	Oceania	MP	Nothern Mariana Islands				378	46	1.90	31	4.86	88	5.71	60
Highly vulnerable	Central America & Caribbean	MQ	Martinique				364	56	3.07	47	4.29	88	4.71	60
At risk	Sub-Saharan Africa	MR	Mauritania				233	92	2.18	88	1.75	100	3.00	100
Highly vulnerable	Central America & Caribbean	MS	Monserrat	SIDS			342	48	2.67	38	5.14	88	3.00	50
Extremely vulnerable	Europe	MT	Malta	SIDS		Y	368	68	3.16	59	4.00	88	4.89	80
Highly vulnerable	Sub-Saharan Africa	MU	Mauritius	SIDS		Y	358	66	2.78	56	4.00	88	5.22	80
Extremely vulnerable	Asia	MV	Maldives	SIDS		Y	383	58	3.19	50	5.14	88	4.43	60
At risk	Sub-Saharan Africa	MW	Malawi		LL		249	82	2.54	75	2.50	100	2.60	90
Vulnerable	Central America & Caribbean	MX	Mexico				306	94	3.45	91	2.88	100	2.18	100
Vulnerable	Asia	MY	Malaysia				312	98	3.35	97	2.50	100	3.00	100
At risk	Sub-Saharan Africa	MZ	Mozambique				227	88	2.00	81	2.75	100	2.55	100
Resilient	Sub-Saharan Africa	NA	Namibia				200	90	2.04	84	2.25	100	1.64	100
Vulnerable	Oceania	NC	New Caledonia				290	60	2.75	50	3.43	88	2.50	70
Resilient	Sub-Saharan Africa	NE	Niger		LL		208	80	1.87	72	1.75	100	2.70	90
Extremely vulnerable	Oceania	NF	Norfolk Island				368	44	2.33	28	5.14	88	4.00	60
Highly vulnerable	Sub-Saharan Africa	NG	Nigeria				336	94	3.41	91	2.38	100	4.09	100

Classification	Region	ISO	Country	SIDS	LLocke	Collab	EVI	%	Hazards	%	Resistance	%	Damage	%
Vulnerable	Central America & Caribbean	NI	Nicaragua				272	92	2.86	88	2.25	100	2.73	100
Extremely vulnerable	Europe	NL	Netherlands				388	98	4.45	97	2.13	100	3.82	100
Vulnerable	Europe	NO	Norway				273	98	3.23	97	2.63	100	1.27	100
Vulnerable	Asia	NP	Nepal		LL	Y	305	84	2.92	78	3.25	100	3.50	90
Extremely vulnerable	Oceania	NR	Nauru	SIDS		Y	421	76	3.59	69	4.88	100	5.44	80
Vulnerable	Oceania	NU	Niue	SIDS		Y	309	68	2.53	59	5.00	100	2.25	70
Vulnerable	Oceania	NZ	New Zealand			Y	292	98	3.10	97	3.63	100	1.73	100
At risk	Middle East & Nth Africa	OM	Oman				250	96	2.60	94	2.38	100	2.18	100
At risk	Central America & Caribbean	PA	Panama				247	94	2.38	91	2.63	100	2.64	100
Vulnerable	Sth America	PE	Peru				268	94	2.72	91	2.50	100	2.64	100
Extremely vulnerable	Oceania	PF	French Polynesia				381	62	3.11	56	4.00	88	5.43	60
At risk	Oceania	PG	Papua Niugini	SIDS		Y	251	94	2.69	91	3.38	100	1.27	100
Extremely vulnerable	Asia	PH	Philippines			Y	402	94	4.17	91	2.88	100	4.73	100
Extremely vulnerable	Asia	PK	Pakistan				373	90	3.78	84	3.25	100	4.18	100
Highly vulnerable	Europe	PL	Poland				354	96	3.70	94	2.75	100	3.82	100
Vulnerable	North America	PM	St. Pierre & Miquelon				296	48	2.42	38	4.43	88	2.17	50
Vulnerable	Oceania	PN	Pitcairn				304	48	2.08	38	5.29	88	2.00	50
Highly vulnerable	Central America & Caribbean	PR	Puerto Rico				334	64	2.47	53	3.71	88	5.11	80
Highly vulnerable	Europe	PT	Portugal				335	98	3.52	97	2.75	100	3.45	100
Highly vulnerable	Oceania	PW	Palau	SIDS		Y	338	78	2.65	72	4.88	100	3.89	80
At risk	Sth America	PY	Paraguay		LL		260	84	2.96	78	2.13	100	1.90	90
At risk	Middle East & Nth Africa	QA	Qatar				229	62	2.41	53	2.71	88	1.88	70
Highly vulnerable	Sub-Saharan Africa	RE	Réunion				341	58	2.94	50	3.86	88	4.57	60
Highly vulnerable	Europe	RO	Romania				335	96	3.70	94	2.75	100	3.00	100
Vulnerable	Europe	RU	Russian Federation				273	88	2.69	81	3.00	100	2.45	100
Vulnerable	Sub-Saharan Africa	RW	Rwanda		LL		298	80	2.78	72	2.50	100	4.20	90
Vulnerable	Middle East & Nth Africa	SA	Saudi Arabia				274	92	2.96	88	2.38	100	2.27	100
Vulnerable	Oceania	SB	Solomon Islands	SIDS			281	86	2.92	78	4.13	100	1.45	100
Highly vulnerable	Sub-Saharan Africa	SC	Seychelles	SIDS			355	66	2.84	59	4.43	88	4.75	70
Vulnerable	Sub-Saharan Africa	SD	Sudan				274	94	2.48	91	2.88	100	3.18	100
Vulnerable	Europe	SE	Sweden				311	94	3.38	91	2.75	100	2.55	100
Extremely vulnerable	Asia	SG	Singapore	SIDS		Y	428	92	3.83	91	4.50	100	5.70	90
Vulnerable	Sub-Saharan Africa	SH	St. Helena				279	48	1.42	38	4.71	88	3.00	50
Highly vulnerable	Europe	SI	Slovenia				362	90	3.75	88	3.00	100	3.90	90
At risk	Europe	SJ	Svalbard				215	40	1.38	25	3.29	88	1.67	50
Vulnerable	Europe	SK	Slovakia		LL		303	76	3.26	72	3.00	100	2.63	70
Vulnerable	Sub-Saharan Africa	SL	Sierra Leone				283	92	2.61	88	2.88	100	3.45	100
Vulnerable	Europe	SM	San Marino		LL		305	40	2.11	28	3.71	88	4.60	40
Vulnerable	Sub-Saharan Africa	SN	Senegal				277	96	2.63	94	2.13	100	3.64	100
Vulnerable	Sub-Saharan Africa	SO	Somalia				265	80	2.65	72	2.63	100	2.50	90
Resilient	Sth America	SR	Suriname				211	88	2.31	81	2.63	100	1.18	100
At risk	Sub-Saharan Africa	ST	Sao Tome & Principe	SIDS			265	62	2.00	56	4.14	88	3.29	60
Highly vulnerable	Central America & Caribbean	SV	El Salvador				348	92	3.46	88	2.75	100	4.36	100
Highly vulnerable	Middle East & Nth Africa	SY	Syrian Arab Rep				350	92	3.71	88	2.25	100	3.91	100
At risk	Sub-Saharan Africa	SZ	Swaziland		LL		243	60	2.69	50	2.57	88	2.00	70
Vulnerable	Central America & Caribbean	TC	Turks & Caicos Islands	SIDS			292	52	2.08	41	5.00	88	2.43	60
At risk	Sub-Saharan Africa	TD	Chad		LL		217	82	2.04	75	1.75	100	2.70	90
Vulnerable	Sub-Saharan Africa	TG	Togo				293	92	2.75	88	2.63	100	3.73	100
Vulnerable	Asia	TH	Thailand			Y	308	100	3.34	100	2.38	100	3.00	100
Vulnerable	Asia	TJ	Tajikistan		LL		271	68	2.94	53	3.00	100	2.10	90
Highly vulnerable	Oceania	TK	Tokelau	SIDS			328	58	1.87	47	5.71	88	4.00	70
At risk	Asia	TM	Turkmenistan		LL		249	70	2.95	59	1.88	100	1.89	80
Vulnerable	Middle East & Nth Africa	TN	Tunisia				306	94	3.41	91	2.13	100	2.91	100
Extremely vulnerable	Oceania	TO	Tonga	SIDS		Y	392	74	3.14	69	5.00	100	5.13	70
Highly vulnerable	Middle East & Nth Africa	TR	Turkey				353	94	3.62	91	3.25	100	3.55	100
Extremely vulnerable	Central America & Caribbean	TT	Trinidad and Tobago	SIDS		Y	381	94	3.79	91	3.75	100	4.18	100
Extremely vulnerable	Oceania	TV	Tuvalu	SIDS		Y	367	78	2.74	72	5.63	100	4.67	80
Highly vulnerable	Asia	TW	Taiwan				324	58	3.47	53	3.00	75	3.43	60
At risk	Sub-Saharan Africa	TZ	Tanzania, United Rep				257	92	2.32	88	2.88	100	3.00	100
Highly vulnerable	Europe	UA	Ukraine				317	92	3.50	88	2.50	100	2.91	100
Vulnerable	Sub-Saharan Africa	UG	Uganda		LL		283	80	2.67	75	2.25	100	4.00	80
Vulnerable	North America	US	United States of America				300	94	3.41	91	2.63	100	2.00	100
At risk	Sth America	UY	Uruguay				259	92	2.93	88	1.75	100	2.27	100
Vulnerable	Asia	UZ	Uzbekistan		LL		286	72	3.16	59	2.38	100	2.80	90
Vulnerable	Europe	VA	Vatican City State (Holy See		LL		293	28	1.50	19	4.80	63	3.75	30
Highly vulnerable	Central America & Caribbean	VC	St. Vincent & Grenadines	SIDS			337	54	2.38	41	4.43	88	4.50	70
Vulnerable	Sth America	VE	Venezuela				291	94	3.17	91	2.63	100	2.36	100
Extremely vulnerable	Central America & Caribbean	VG	UK Virgin Islands	SIDS			377	44	3.10	31	6.17	75	2.86	60
Extremely vulnerable	Central America & Caribbean	VI	US Virgin Islands	SIDS			396	46	2.80	31	5.29	88	4.71	60
Highly vulnerable	Asia	VN	Viet Nam				357	88	3.59	84	3.00	100	4.30	90
Vulnerable	Oceania	VU	Vanuatu	SIDS		Y	285	80	2.83	72	4.13	100	1.70	90
Vulnerable	Oceania	WF	Wallis & Futuna Islands				304	54	1.69	41	5.14	88	3.50	70
Highly vulnerable	Oceania	WS	Samoa	SIDS		Y	328	78	2.87	72	4.38	100	3.44	80
Vulnerable	Middle East & Nth Africa	YE	Yemen				289	94	2.69	91	2.50	100	3.73	100
Vulnerable	Sub-Saharan Africa	YT	Mayotte				304	46	1.45	34	4.43	88	5.00	50
Highly vulnerable	Europe	YU	Yugoslavia				324	76	3.61	72	2.29	88	3.22	80
Highly vulnerable	Sub-Saharan Africa	ZA	South Africa				324	90	3.44	84	2.25	100	3.45	100
Resilient	Sub-Saharan Africa	ZM	Zambia		LL		210	82	2.17	75	2.38	100	1.60	90
Vulnerable	Sub-Saharan Africa	ZR	Congo, Dem Rep				288	82	2.75	75	2.50	100	3.40	90
Resilient	Sub-Saharan Africa	ZW	Zimbabwe		LL		200	78	2.22	72	2.00	100	1.44	80