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# The Environmental Vulnerability Index and Profiles: Outcome-focused Environmental Management at the Scale of Countries

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Environmental management now occurs at two vastly different scales: locally, often on an *ad hoc* basis in response to individual development projects (through Environmental Impact Assessments and local management plans) and at very large scales through international agreements (Intergovernmental Panel on Climate Change, Convention on Biological Diversity, and others). It is also largely process-focused, concentrating on improving practices through environmental assessments, the use of protected areas, or by limiting exploitation, degradation and pollution. These approaches are critical to our efforts at environmental management, but are insufficient to ensure a sustainable future. They do not focus on the accumulated *outcome* of our many management approaches over different spatial and temporal scales of action.

The Environmental Vulnerability Index and profiles (EVI) is among the first of tools now being developed to focus environmental management at the same meso-scales that decisions are made (economies and social systems), and focus them on outcomes. It is a method that uses 49 *smart indicators* to assess the vulnerability of the environment at the scale of entire countries. 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 made. If environmental conditions are monitored at the same time as those concerning human systems, there is better opportunity for feedback between them. Without exception, the environment is the life-support system for all human systems and is an integral part of the development and success of countries.

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## INTRODUCTION

The 'natural environment' is unequivocally the life support system for all human systems. Far from being a luxury available only to those who can afford it, successful environmental management will increasingly become the basis for the success or failure of economies and social systems of entire countries. Where in the past, there was still much natural capital to exploit, these resources (ecosystem goods and services) are rapidly being exhausted and/or damaged. Our future, to be sustainable, must be based on a more symbiotic relationship with the natural environment. 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 state, and it needs to be accounted for at this scale. Attempts to do this have been made over the past few years by developing criteria for ecologically sustainable development (1) and general conceptual frameworks for sustaining Earth's life support systems (2). Even these attempts, though valuable, tend to be process rather than outcome focused, can be cumbersome to evaluate or implement, and may not easily allow for auditing the success of the measures being taken. They are not focused on ensuring the future (3). This paper describes a tool that addresses these concerns.

Vulnerability can be defined as the potential for attributes of any system, human or natural, to respond adversely to the occurrence of hazardous events. That is, hazardous events are those that aversely affect biological integrity (4) or health of systems. We propose that vulnerability can provide a valuable measure of how sustainably humans are living within their environment because its focus is dual: looking at conditions now, while trying to predict how the environment is likely to cope with future events. It is more pro-active than measures of the state of the environment, though it includes them. A result of high vulnerability speaks of likely responses to future conditions, and may be a more appropriate measure for adaptive management, particularly at the scale of countries.

The issue of vulnerability of states to human and natural stressors has been examined for a range of responding systems including economics, other aspects of human development and natural resources. Attempts have been made to provide measures of vulnerability in single figure composite index form for economic vulnerability (5,6,7,8,9,10); Climate change and sea-level rise (11,12,13,14); human impacts on the environment (15,16); and the effect of natural disasters on human systems (17). These indices have been focused on the vulnerability of human systems as responders to social, climatic and other environmental factors or hazards. A few of the studies have included some environmental responses in their indices, but the focus has always been on direct human concerns. No other study to date has attempted to construct a vulnerability index which describes risks to and responses of the environment (as life-support system to humans) rather than on the human systems themselves.

It is now clear that vulnerability of states includes risks and their results on both the human and natural systems. Humans depend on the environment and its resources for sustaining life and for development. The environment, in turn, is dependent on both natural events and appropriate management by humans. This means that overall, vulnerability of a state should ultimately include measures of both human and natural systems and the risks that affect them.

This paper is the first of a series designed to introduce the concept of the EVI, the nature and criteria used for the development of its indicators, and to report on the first results obtained from countries of very different climatic, biogeographic, political, economic and cultural characteristics.

## THE LOGICAL BASIS OF THE EVI: WHAT DOES IT SIGNAL?

The EVI is an indicator-based method for estimating the vulnerability of the environment of a state to future shocks. It is reported simultaneously as a single dimensionless index and as a breakdown profile showing the results for each indicator so that in addition to an overall signal of vulnerability, it can be used to identify specific problems. It has been designed to reflect the status of a country's 'environmental vulnerability', where 'vulnerability' 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 environment, and not the environment that has become dominated by these same human systems (e.g. cities). The natural environment, then, includes those biophysical systems that can be sustained without direct and/or continuing human support. In the context of the EVI, 'damage' refers to the loss of diversity, extent, quality and function of ecosystems.

The maintenance of ecosystem or ecological integrity is at the heart of the development of a vulnerability index for the environment, because it is threatened by natural and anthropogenic hazards which in turn affects the welfare of humans. The notion of ecosystem integrity is complex and cannot be expressed through a single indicator, but rather requires a set of 'smart' indicators at different spatial and temporal scales and hierarchical levels relating to ecosystems (18, 19). Ecosystem integrity depends on biodiversity, ecosystem function and resilience, all of which are such interrelated variables, that factors which affect just one of these can have far-reaching ecosystem-wide consequences.

## THE HAZARDS AND THE RESPONDERS

The entities at risk, or 'responders' include ecosystems, habitats, populations and communities of organisms, physical and biological processes (e.g. beach building, reproduction), energy flows, diversity, ecological resilience and ecological redundancy. Each of these 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 dual nature of environmental vulnerability requires the incorporation in the index and profiles three sub-indices. These are the *risk* to hazards, and two aspects of *resilience*, or the environment's ability to withstand the effects of hazards.

The risk-exposure sub-index (REI) is a grouping of indicators that relates to the frequency, and where possible, the intensity of hazardous events which may affect the environment. These are based on average levels observed over the past 5 years for most hazards, but may include data for much longer periods for geological events. The indicators measure potential risk based on the experience of the immediate past. This gives us only an approximate measure since there is no logical basis for an expectation that patterns of risk expression during the immediate history of a country will necessarily result in similar risk levels today or in the future.

The intrinsic-resilience sub-index (IRI) refers to the innate characteristics of a country which 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 refugia in small countries) and distance to nearest continent.

The final sub-index is the extrinsic-resilience or environmental-degradation sub-index (EDI). Extrinsic resilience results from external forces acting on the environment and describes 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 it is likely to be to future risks.

## THE INDICATORS FORMING THE EVI

A total of 49 indicators has been selected through extensive consultation with experts in major human and natural sciences (18). The measures selected are here being termed 'smart indicators' which can be defined as those which capture a large number of elements in a complex interactive system while showing how the value obtained relates to some ideal or agreed-upon condition. That is, central to the concept of smart indicators is the idea that 'good' and 'bad' performance is inherent in the way that the indicator is expressed. A high vulnerability value of 7 indicates high risk or vulnerability to ecological damage, while a score of 1 indicates that for this measure, risks or vulnerability are low.

Twenty-six of the indicators are classed as part of the Risk Exposure sub-index (REI) and relate to expected risks of hazards occurring in the future. Sixteen of the indicators form the EDI, or extrinsic resilience, and relate to damage already sustained which is expected to compromise the ability of ecosystems to cope with future hazards. The remaining 7 indicators are classed as measures of intrinsic resilience (IRI), inherent features of the country that make it more or less vulnerable to environmental damage. Independently of whether an indicator is classed as a measure of risk or intrinsic or extrinsic resilience, it is also categorised according to whether it is meteorological, geological, biological or anthropogenic in origin or nature. There are 6 meteorological, 3 geological, 8 biological and 25 anthropogenic indicators spread amongst the REI and EDI sub-indices. In general, risk exposure measures tend to be meteorological, geological or biological in nature, while extrinsic resilience measures tend to be anthropogenic. IRI measures are categorised separately, with most of the intrinsic characters of a country being either geomorphological or biogeographical in nature (18).

Humans are explicitly incorporated as indicators in the EVI, with around 50% of them being direct measures of human choices and behaviour in relation to environmental vulnerability (20). There are socio-economic indicators (indicators 25-27, 46), those dealing with use and conservation (indicators 18, 23, 29, 30, 32-35, 37, 38-39) and policy/management (indicators 44-45, 47) (18, 19).

The indicators incorporated into the EVI model are of a heterogeneous nature. Responses may be 'yes' or 'no' answers, categorical information or numerical data which could be used in their raw state. Even for numerical data, the distributions are heterogeneous occurring on linear or non-linear scales or have different maximum and minimum values. To deal with this heterogeneity, we chose to map the possible responses to each indicator on a simple scale from 1 to 7. This allows for a reasonable spread while permitting relatively easy processing of different types of data, a central score and the well understood concepts of average, maximum and minimum which can be used to anchor the responses for the non-scientists likely to be evaluating the index. The score of 1 was also allocated for cases in which a question was considered not applicable to a country, such as volcanoes (which do not occur) in Tuvalu. This will indicate that vulnerability relating to this hazard is very low. In cases where data are unavailable, the indicator is omitted from the calculation and the EVI becomes based on those indicators remaining. It was decided that a minimum of 80% of the indicators has to be evaluated for an EVI result to be valid. This was done to ensure reasonable comparability, while allowing some flexibility for missing data.

Reporting for the EVI is done at three levels. Scores for indicators are accumulated as simple averages (also ranging between 1 and 7) for the overall index and three sub-indices, giving signals for overall environmental vulnerability and measures of risk and resilience (REI, IRI and EDI). 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 of the index. The EVI profiles are direct reports of the value of each indicator between 1 and 7 and are valuable for identifying the problems that may be leading to a poor overall vulnerability signal.

## FUNCTIONS AND USES OF THE EVI

The EVI is essentially a shortcut. It is a relatively quick and inexpensive way of characterising the vulnerability of natural systems at the level of a region, state, province or island. It can also provide feedback to environmental managers working at these scales on changes through time in response to policy changes. By using a common index, the characterisation can be comparative through space and time because there is a common basis for the measurements. The alternatives to using the EVI are *ad hoc* assessments done on a case-by-case basis for each country or time.

The EVI has been designed to meet a range of requirements for global and domestic environmental management processes. In its present form, it may be used as: one of the criteria for determination of Least Developed Country (LDC) status; obtaining a general sense of the environmental vulnerability of a country; and for its predictive value in identifying vulnerability issues and the types of hazards and approaches to stewardship of the environment. If re-evaluated through time, for example every 5 years, the EVI can be used as a tool for adaptive management at the scale of the country, and ultimately for monitoring 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. Although not itself a measure of the state of the environment (SOE) (because it incorporates risks of hazards and intrinsic resilience), the EVI is a useful proxy. The EDI sub-index comprises measures of degree of environmental degradation at the scale of a country, many of which would be part of the information that is currently being collected during SOE reporting. For countries with severely limited budgets and capacity, using the EDI, or indeed the entire EVI, as a proxy for SOE will go a long way towards identifying the main stresses and actions that need to be taken.

## WHAT IS NATURAL?

The risks to the environment are any events or processes that can cause damage to ecosystem integrity. These include natural and human events and processes such as 'the weather' and 'pollution'. Some researchers have identified natural hazards as those in which natural environmental conditions depart from 'normal' to such an extent that systems of interest (human, environmental) may be adversely affected. The problem with this definition is that unless we identify certain natural events as being anthropogenically altered (e.g. anthropogenically-accelerated sea-level rise), all events are 'normal'. The implication from this line of reasoning is that the changes we see to the natural world as a result of natural hazards are deemed 'unacceptable' from a human perspective. This means that in the case of natural hazards what we really are examining are unacceptable departures from our (human) view of how the environment should change. Given that the current world environment is changing at an unprecedented rate, with most of the changes being mediated by humans, we consider this approach reasonable. Under current conditions, even the action of natural events is being modified by previous human damage (e.g. effects of cyclones are worse where reef and shoreline ecosystems have been degraded).

## STATUS AND CONCLUSIONS

The EVI is still under development. Although the overall approach and methods of calculation have been established, and preliminary results obtained for 14 countries, there remains the task of finalising the 1-7 scoring for each indicator. This is being done within the global context, with data being collected on 40 countries which represent the world extremes of biogeography, climate, and other intrinsic characters in addition to economic, social and cultural conditions. The focus is on setting the scoring for each indicator in terms of ideals and real conditions without setting the standards at present levels if they have already resulted in unsustainable conditions and poor ecosystem resilience. Under these conditions, the EVI will serve to identify actions that increase sustainability and provide a comparative system within the context of which countries may monitor their own policies and the outcome of their actions.

## REFERENCES AND NOTES


1. Heinonen, S., Jokinen, P., and Kaivo-oja, J. 2001. The ecological transparency of the information society, *Futures 33*, 319-337.
2. Daily, G.C. 1999. Developing a scientific basis for managing earth's life support systems. *Conservation Ecology 3(2):* 14 [online] (http://www.consecol.org/vol3/iss2/art14).
3. Tonn, B.E. 2000. Ensuring the future, *Futures 32*, 17-26 (2000).
4. Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management, *Ecological Applications 1*, 66-84 (1991).
5. Briguglio, L. 1993. The Economic Vulnerabilities of Small Island Developing States. *Report to CARICOM for the Regional Technical Meeting of the Global Conference on the Sustainable Development of Small Island Developing States, Port of Spain, Trinidad and Tobago, July, 1993*.
6. Briguglio, L. 1995. Small Island States and their Economic Vulnerabilities. *World Development 23*, 1615-1632.

7. Briguglio, L. 1997. Alternative Economic Vulnerability Indicators for Developing Countries with Special Reference to SIDS. *Report to the Expert Group on Vulnerability Indices UN-DESA, 17-19 December, 1997*.

8. Wells, J. 1996. Composite vulnerability index: A preliminary report*. Report to Commonwealth Secretariat, London*.

9. Wells, J. 1997. Composite vulnerability index: A revised report. *Report to Commonwealth Secretariat, London*.

10. Atkins, J., Mazzi, S. and Ramlogan, C. 1998. A Composite Index of Vulnerability*. Report to Commonwealth Secretariat, London*.

11. IPCC. 1991. The seven steps to the vulnerability assessment of coastal areas to sea-level rise - Guidelines for case studies. *IPCC Report*, 24pp.

12. IPCC. 1992. Global climate change and the rising challenge of the sea*. IPCC RSWG Report*, 34pp.

13. Pernetta, J.C. 1990. Projected climate change and sea-level rise: A relative impact rating for the countries of the Pacific Basin. In*: Implications of expected climate changes in the South Pacific Region: an overview.* Pernetta, J.C. and Hughes, P.J. (eds). UNEP Regional Seas Report, 14-23.

14. Downing, T.E. 1992. Climate change and vulnerable places: Global food security and country studies in Zimbabwe, Kenya, Senegal and Chile*. Research Report 1, Environmental Change Unit, University of Oxford*.

15. Ehrlich, P.R. and Ehrlich, A.H. 1991. *Healing the planet*. Addiison-Wesley Publication Co. Inc., Menlo Park, CA.

16. UNEP. 1998. Human development report 1998. UNDP Report. Oxford University Press, 228 pp.

17. Pantin, D. 1997. Alternative Ecological Vulnerability Indicators for Developing Countries with Special Reference to SIDS. *Report Prepared for the Expert Group on Vulnerability Indices, UN-DESA, 17-19 December* 1997.

18. Kaly, U. L. 2000. Lessons from the EVI and smart indicators for coral reefs. *Information management and decision support for marine biodiversity protection and human welfare: Coral Reefs: a workshop. Australian Institute of Marine Science, Townsville and UNEP, Nairobi,* pp 69-76.

19. Kaly, U.L. Smart Indicators, the Environmental Vulnerability Index (EVI) and describing ecosystem health, *Ambio*, this volume.

20. Done, T. and Diop, S. 1999. Information management and decision support for marine biodiversity protection and human welfare: coral reefs. *Background paper for Information management and decision support for marine biodiversity protection and human welfare: Coral Reefs: a workshop. Australian Institute of Marine Science, Townsville and UNEP, Nairobi,* 14pp.

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