A Critique of the Environmental Sustainability Index*

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Abstract

The Environmental Sustainability Index (ESI) has been proposed by collaboration of the World Economic Forum, Geneva, Center for International Earth Science Information Network, Columbia University, and Yale Center for Environmental Law and Policy, New Haven as a measure of the overall state of the environment. This paper argues that the basic design of the ESI leaves much to be desired. It has conceptual problems in its visualization of environmental degradation and sustainability. The choice of variables as well as the statistical methodology of compiling the index is also found to be wanting. The paper then proposes an alternative methodology using Principal Components Analysis and argues that this is an improvement upon the ESI methodology. Given the likely use of aggregate environmental indexes in future environmental management, the critique advanced in this paper is of considerable significance.

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I. Introduction

A central issue in the context of the environment is that of its sustainability. This presumes the development of an index that encapsulates both the current state of the environment as well as its potential to provide support for future human activity. As would be expected there is a plethora of definitions of the concept of sustainability. We have proposed that the applicability of the notion of sustainability has ultimately got to be universal and refer to the indefinite future. (Jha and Murthy (2000)).

Once the broad contours are accepted the need for a measure of sustainability arises. Obviously such a measure must be general enough to cover various dimensions of environmental degradation and potential as well as all countries in the world. Such a measure is necessary for making international and inter-temporal comparisons. This would reduce the ambiguity about the role of different countries, regions and income classes in efforts for global environmental management.

The 2002 Environmental Sustainability Index (ESI) is a significant effort in this direction. It has been developed by collaboration of the World Economic Forum, Geneva, Center for International Earth Science Information Network, Columbia University, and Yale Center for Environmental Law and Policy, New Haven and is a measure of the overall progress towards environmental sustainability developed for 142 countries. It has aroused considerable interest even at the level of the scholarly popular press[1]. The ESI is based upon a set of sixty-eight basic indicators. These are then aggregated to construct twenty core indicators (Annex I of the ESI 2002 Report). These include: air quality, water quantity, water quality, biodiversity, land, reducing air pollution, reducing water stress, reducing eco-system stress, reducing waste and consumption pressures, reducing population growth, basic human

[1] See The Economist, 16 March 2002

sustenance, environmental health, science and technology, capacity for debate, environmental governance, private sector responsiveness, eco-efficiency, participation in international collaborative efforts, reducing greenhouse gas emissions, reducing trans-boundary environmental pressures. A number of variables are used to capture each of these variables and their effect is classified according to their coverage, recency and relevance. The process of ESI construction then aggregates the 20 core indicators into five broad indicators of sustainability. These broad indicators are: a) Environmental System; b) Reducing Environmental Stress; c) Reducing Human Vulnerability; d) Social and Institutional Capacity Component; and e) Global Stewardship. These indicators are then collapsed into a single ESI. The basic structure of the ESI index is described in Figure 1.

Insert Figure 1 here

The ESI could presumably be a tool in environmental debate and, in the future, such a measure has the potential of seriously impacting domestic and international policy analysis. Hence, it is important that there be widespread acceptance of the structure and methodology of the ESI. Surely the construction of an index is an evolving process and periodic evaluation of this methodology would be useful. It needs to be compared with other such indices. The ESI report provides a review of some of the other existing indices of sustainability.[2]

This paper seeks to critically evaluate the structure and methodology of the ESI. There are two guiding concerns in doing so. First, a broad distinction has to be made between differing standpoints in relation to sustainability. Second, sustainability has to be studied within a causal framework.

Sustainability can be discussed as per at least three distinct standpoints:

[2] The ESI report compares nine indices with the ESI. See ESI 2002 Report - Table 9, P.19.

a) Environmental Degradation; b) Effects of Degradation; and c) Environmental Management. Clearly the first dimension affects the second. The third must be designed so as to affect the former two. A causal and an impacted variable should not be clubbed into one grand index. However, this is precisely what the ESI does.

Our critique of the ESI methodology operates at two levels. At a *philosophical level* we question a) the classification of variables; b) the specification (type) of the variables; and c) the coding of variables. At an *empirical level* at least three methodological problems arise: a) aggregation problem; b) problem of cause and effect; and c) weighting problems.

The classification of variables raises several questions. First, it is not clear why variables like urban NO_2 and SO_2 concentration should be a part of the 'Environmental System' whereas NO_2 or SO_2 emissions per populated land area should be a part of 'Reducing Environmental Stress'. Had these variables been defined as percentage drops there would have been some justification. Only two variables signifying change have been included here: one on forest cover, and most surprisingly, 'percentage change in projected population between 2001 and 2050'. How can a future (projected) rate of growth reduce present environmental stress? Moreover, the population variable does not match with the remaining variables. The variable 'proportion of under-nourished in total population' cannot be related directly to environmental degradation. A particularly serious lapse relates to the 'code' of the variables. For instance, in the core indicator 'Basic Human Sustenance' two variables are included, viz., proportion of under-nourished in total population' and percentage of population with access to improved drinking water. The problem with the 'code' is that if the index is low it favours the former variable and if it is high it favours the latter.

An important principle in the formation of an index is that the sum total of the variable must yield an interpretation that is unidirectional, i.e., the 'code' must be the same.

Once the index is aggregated such differences would not be known to users but would continue to have serious implications for analysis.

There is a similar problem with the broad indicator - Environmental Governance. The greater the ‘percentage of area under protected status’ the better, presumably, is governance. However, if the subsidy is on ‘energy use’ and ‘commercial fishing’ does it still amount to better governance?

If the intention of the ESI is to be a ‘near-complete’ and an ‘almost-correct’ index, then much more needs to be said about its coverage and correctness. For instance, under ‘Environmental Governance’ certain variables that have been included are either antiquated or politically incorrect. The variables that emphasize protected areas lay stress on the so-called ‘fence and forget’ approach but ignore recent understanding on the subject of forest management. Fundamental changes in thinking about forest management have not been reflected in this approach. In real terms, a significant (though small) part of forest management is coming under co-operative management of and by the local populations (mainly tribal). This is not only more politically correct but also more appropriate because, in large parts of the world, the thorniest problem in environmental management is the reconciliation of the interest of people and nature. This approach tries to put this reconciliation into practice. The dynamics of management have evolved to ‘joint-management’, i.e., private, co-operative and government and the literature on forest management has worked out the optimal shares of the three components of management (Gjertsen and Barrett (2001)).

The broad category called ‘Social and Institutional Capacity’ is incomplete and, at least in parts, politically incorrect since it ignores gender issues. The greatest inequity in forest management is in respect of gender. The indicator called ‘Private Sector Responsiveness’ has a corporate bias. It is biased towards industry and against agriculture/forestry. It is also biased towards corporate governance against people's governance. There is an advanced system of management of common lands, agriculture and forests called 'Heritage Parks' (Henderson (1993)). This approach is *avante garde*. It envisages a private sector initiative but not necessarily through 'corporates'. The indicator is incomplete also because it does not consider the role of NGOs. There are vast tracts of countryside where the corporates cannot reach. NGOs have made inroads where there is a deadlock between the government and the 'people'.

The divide between 'Social and Institutional Capacity' and 'Global Stewardship' is artificial. For instance, the source of GHG, CFC and SO_2 export is domestic. Better domestic management by each country is the only way to curb these gases. There is no way to separately curb trans-boundary pollution while not bothering about domestic pollution. Also, it is not clear why CO_2 related variables are included *only* in Global Stewardship and excluded from indicators for environmental stress (which apparently signifies the domestic effects of pollution as opposed to the global effects). Does it imply that CO_2 is not harmful for domestic residents and adversely affects only the 'global environment' by sidestepping the local environment?

The foregoing analysis although far from being complete, makes it clear that variables included in five broad indicators need to be re-examined from the point of view of coverage, correctness, unbiasedness, and above all, uniformity of 'code'. Also it is clear that five categories are not tenable. The three broad indicators, Environmental System, Stress, and Vulnerability, need to be coalesced together and sorted into two indices: Environmental Degradation and Degradation Effect. Both these indicators need to be supplemented appropriately by drawing certain variables (on 'global environment') from 'Global Stewardship'. The remaining 'Stewardship' variables can be merged with Social and Institutional Capacity, to form an indicator called 'Environmental Management'.

Hence, there are only three logical categories of broad indicators. Any other division is not tenable. Further, these three indicators cannot be collapsed into one index since there is a causal chain amongst the three indicators. As things stand, if a country has a high index of sustainability the implication is that it has a high degree of degradation, severe degrader effects and better management as well!

There are serious problems in respect of methodology. These are: a) inter-correlation amongst variables — cause and effect; b) use of equal weights — ignoring Principal Components Analysis (PCA)[3] ; c) ignoring outliers — truncation; d) correlation with other variables; e) ambiguity of the index (changing the sign); and f)Relevance index (implicit weights). We now briefly discuss these problems.

Inter-correlation

There is a definite purpose of data-reduction methods in general and PCA in particular. It is a methodological advancement that has great utility in the area of developing indices. There are many real world situations where a large number of observable variables represent a single phenomenon. Very often these variables may not only be correlated but causally linked (with feedback) as well. For instance, excessive paper consumption would result in deforestation, which would cause a fall in water resources and a growth in CO_2 levels, which would then cause global warming, soil degradation and denudation, which would adversely affect bio-diversity and so on. In such linkages it is not possible to separate cause and effect. PCA methodology is specifically designed to deal with such a situation.

However, one of the main reasons put forward by the ESI methodology to reject the use of PCA is that the correlation amongst indicators is low (0.05) (ESI 2002 Report, p. 47).

[3] For a brief overview of PCA see Appendix.

The problem appears to be the level at which the correlation has been measured. At the level of the twenty Core Indicators the data has already been processed to a great extent since the extreme values have been truncated and the code problem remains because of which after aggregation of individual variables at the level of indicators the correlation may be ironed-out. Moreover, an ambiguous procedure of switching the numerator has been followed for obtaining the Z-scores.

Equal weights

The use of equal weights can be criticized on several counts. First, if only three separate indices were to be formed (degradation, effects, and management) and if all 68 variables were to be apportioned by ensuring the proper code, the inter-correlations would have shown-up. Second, if the arbitrary procedures were not adopted, this trend would have been more prominent. Third, the use of PCA under such circumstance would have given different results. Fourth, the 'relevance' attached to each of the variables negates the argument that 'in our judgment there was no firm basis for applying differential weights given the current state of scientific understanding' (ESI 2002 Report, p. 47).

The second argument advanced for rejecting PCA is that 'the principal component (did not) have any sensible interpretations' (p. 47 of ESI 2002 Report). However, this might have happened because of the choice, code, grouping and treatment of variables. Second, where results are not interpretable the procedure of rotation can be used in PCA methodology – an aspect that has been ignored in the construction of the ESI.

Ignoring outliers

A serious problem with the methodology is that the outliers of the variables were trimmed. Observed values above 97.5 percentile and below 2.5 percentile were reset. A meaningful and attractive part of PCA methodology is that it identifies and distinguishes them from influential observation. This is very relevant for environmental analysis, given the wide diversity. Removing outliers unnecessarily irons-out the variation.

Correlation with other drivers

The ESI Main Report uses the correlation between ESI and other indicators like measures of democratic institutions, control of corruption, and civil liberties. The justification for doing so is

> ‘recognizing that per capita income does not alone *determine* the ESI or its constituent indicators, it becomes important to try to identify other factors which, when combined with per capita income, help to explain the observed variation in environmental outcomes’. (ESI 2002 Report, p. 22)

Further, it is said that, ‘a number of variables have significant correlation with ESI, making them plausible drivers of environmental sustainability`!

However, some of these variables are already a part of ESI and for *determining* the *drivers* of environmental sustainability a causal framework as well as the Environmental Kuznets Curve literature exist[4]. Such an important question cannot be decided on the basis of some *ad hoc* correlations.

Ambiguity

Apart from the ambiguity caused by the code of variables an *ad hoc* procedure was used which would have created further ambiguity. This is reflected in the following statement made in the context of calculating Z-scores.

[4] For an analysis of the environmental Kuznets curve in a global context see Jha and Murthy (2003).

> "For variables in which high observed values correspond to low values of environmental sustainability, we reversed the terms in the numerator to preserve this ordinal relationship". (ESI 2002 Report, p. 46)

Relevance index

Although the methodology avoids using differential weights, it implicitly believes in one. In Table A.1.1, in Annex 1 of the ESI Report, there is a column named 'relevance'. Here the authors of the Index have implicitly specified qualitative weights for each of the 68 variables. All these variables are grouped into 20 core indicators, which are then combined into five broad indicators. We have assigned a numerical weight from 1–7 for the qualitative weights specified. This range of weights depends on the nature of comments about relevance. The weight is 1 for low and goes up to 7 for extremely high. A weighted average of such weight has been calculated for each of the 5 broad indicators. Table 1 shows the ordering amongst them.

Insert Table 1 here.

In light of this, when ESI has an implicit weighting system, why did they not use differential weights? Secondly, ESI implies that each of these indicators may hold different levels of importance for different users. In such a situation merely continuing with the five indicators cannot be rationalized.

Hence, it can be said that ESI suffers from both conceptual as well as empirical problems. Before the index can be popularized it is necessary to thoroughly rework the entire index with the help of standard methodology like PCA instead of *ad hoc* procedures. More importantly, we need to develop a clearer understanding of the concept of environmental sustainability and its constituents. We proceed now to our use of this methodology.

III. Data, Methodology and Results

A basic criticism of the ESI methodology is that it does not use Principal Component Analysis. Their own justification is in terms of the low correlation amongst variables.[5] The very nature of many of the variables is such that, many of them are closely related, if not causally related. It is quite telling that, out of forty-five correlation coefficients ((10x10) - 10 (own correlation)/ 2), only sixteen are not significant, at the 5% level. The remaining variables are highly correlated and have statistically significant correlation coefficients. Thus around two thirds of the variables are correlated (See Table 2).

Insert Table 2 here

It is fairly well know that if variables are correlated then PCA is ideally suited for such a situation. This is further confirmed even in cases where there are a large number of variables. The ESI is based on 68 variables. However since

" Principal Component Analysis (PCA), is a statistical technique that linearly transforms an original (*large*) set of variables into a substantially smaller set of uncorrelated variables, that *represents most of the information* in the original set of variables"[6] (emphasis added) the use of PCA is justified. We report results on PCA here.

Environmental variables are usually closely related. By working with a large number of variables, the estimate (of the ESI) is prone to the vagaries of the accumulation or compounding of reporting or measurement errors. The data on environmental variables is highly prone to such errors. The ESI document is itself replete with such allusions. While many other controversial methods have been used, PCA has been consciously avoided.

The environmental variables at the global level are also prone to have non-normal or skewed distributions. Here again PCA has an advantage. It does not need the normality assumption. While observing worldwide data the variance is likely to be very high. Here again PCA has the advantage that it does not have to explain the correlation (or covariance) amongst the largest possible ("fully

[5] We have tested their raw variables to confirm this (Table 2).

specified") set of variables. It is very economical because it uses the least number of variables to explain the full contours (of a widely spread) phenomenon by accounting for the maximum possible variance.

It is also economical because it minimizes the effort and time while achieving similar results. It reduces the cost of data collection. This is relevant especially, if the authors of ESI want it to be a model index for emulation. It can be sustained only if it is economical. Especially, if governments of poor countries are expected to collect bulky data from their own resources, the cost of collection becomes very relevant. These governments would either be dependent on donors (rich countries or Institutions) for funds for such purposes (which may have other implications) or would `cut corners` because of which data coverage, reliability and quality would suffer.

There are set procedures for scientifically selecting these variables from amongst many.[7] The chosen variables are known as "principal variables". There are certain measures that can be used for judging the utility (explanatory power) of such variables. Define Total Variation Explained (TVE) = $n_r + \sum_{i \in d} R^2{}_{i,r}$ where the set d consists of all variables; n_r is the number of retained variables, and $R^2{}_{i,r}$ stands for the squared multiple correlation of the ith discarded variable with the *r* retained variables obtained by regressing each of the discarded variables on the four retained variables. The number of retained variables is added because each of the retained variables explains its own variation (variance = 1). The measure $R^2{}_{i,r}$ is summed over the discarded variables because it represents the variation in the discarded variables explained by the retained variables. Now, the (TVE/Total Variation) is a measure of the explanatory power. The measure of total variation is *d* x 1 = *d* (since the total variation can be 100% if all variables are included).

Another advantage with PCA is that, unlike Factor Analysis it does not have to assume any underlying hypothetical factors. Yet it is possible to have a meaningful interpretation with the help of

[6] See Dunteman in Lewis-Beck (1994)..
[7] See McAbe, (1984) and Jolliffe, (1986).

select variables. It only reduces the redundancy of data. The method of rotation allows better interpretation while explaining the same amount of variance. For instance, it allows us to pick up one air quality variable out of many, one bio-diversity variable amongst many, and so on. A spectrum of variables can be represented by a few.

We reduced the number of variables using three procedures: a) some variables have a `code' problem or are not very relevant; b).the variables can easily be sorted into "Environmental Degradation Variables", "Degradation Effect Variables " and "Environmental Management Variables". This reduces the number in each category to around fifteen. The variables are chosen according to the following five criteria: a) uniformity of code; b) high coverage; c) representativeness of each aspect of the environment; d) ease of interpretations; and e) relevance. On this basis the following ten variables were selected:

VOCKM - VOCs per populated land area.

SO2KM - SO2 emissions per populated land area.

PRTMAM - Percentage of mammals threatened.

PRTBRD - Percentage of birds threatened.

NOXKM - NOx emissions per populated land area.

FERTHA - Fertilizer consumption per hectare of arable land.

COALKM - Coal consumption per populated land area.

C02PC - CO2 emissions per capita.

CO2GDP - CO2 emissions per $ GDP.

CARSKM - Vehicles per populated land area.

We have applied Varimax Rotation Criterion (Kaiser (1958)) and have accordingly retained four variables.

i) VOCKM - representing air quality.

ii) COALKM - representing depletion of resource.

iii) PRTMAM - representing bio-diversity

iv) CO2GDP - representing global pollution.

The explanatory power of these 4 variables is given by:

= 4 + 2.735 = 6.735 / 10 or 67.35%. (as per formula above).

The Component Scores of these variables that have been used for building the EDI (Environmental Degradation Index) are given in Table 3.

Insert Table 3 here

Finally, the EDI was constructed on the basis of component scores. The ranks were established on the basis of ascending value of EDI. This was done to make the ESI and EDI comparable. The logic is, that a low value of EDI corresponds to a more sustainable environment, which can be represented by a higher value of the ESI. This makes the code of both comparable. Then the relative ranks of the 2002ESI and our EDI were compared (See Table 4).

Insert Table 4 here

Ideally, the rank correlation should have been (+) unity. This would have endorsed that there is no flaw in the estimation of 2002ESI. However, the rank correlation coefficient was only 0.1067 and the Z value was only 1.2. Hence, the rank correlation was not significantly different from zero. A test using the *Z* value confirms that the rank correlation is (statistically significantly) below +1.

There are wide differences in the ranks of many countries giving anomalous results. For instance, Australia has a difference of (-)119 in rank(ESI minus EDI). This means that it is highly sustainable and extremely degrading (both simultaneously)!! Only very few countries retain the ranks. On the other hand Guinea-Bissau is hardly degrading but almost unsustainable!! This is true of most poor countries. Most of the rich countries have extremely high vehicular traffic and pollution and are by the EDI highly degrading but are fairly sustainable by the count of their ESI.

IV. Conclusions

This paper has argued that the basic design of the ESI leaves much to be desired. It has conceptual problems in its visualization of environmental degradation and sustainability. The choice of variables as well as the statistical methodology of compiling the index are also found to be wanting. The paper has proposed an alternative methodology using Principal Components Analysis and argued this is an improvement upon the ESI methodology. Given the likely use of aggregate environmental indexes in future environmental management, the critique advanced in this paper is of considerable significance.

Appendix

Basic Analytics of Principal Components

This appendix discusses some basic issues in Principal Components Analysis. For a fuller treatment see Lewis-Beck (1994).

If we need to choose the essential variables and arrive at relative weights for the purpose of consolidating these variables into a single index we chose Principal Components Analysis (PCA). This is popular in the literature since it has a number of desirable properties.

Consider *p* random variables – x_1, x_2, .x_p. such that

$$y_1 = a_{11}x_1 + a_{12}x_2 + ... + a_{1p}x_p = \sum_{i=1}^{p} a_{1i}x_i \qquad (1)$$

PCA is a statistical technique that linearly transforms an original set of variables into a smaller set of uncorrelated variables that represents most of the information in the y_1, the first principal component, is defined such that the variance of y_1 is maximized subject to the constraint that the sum of squared weights is equal to 1, i.e.,

$$\sum_{i=1}^{p} {a_{1i}}^2 = 1.$$

If the variance of y_1 is maximized then the sum of the squared correlations with the original variables is also maximized. This is written as:

$$\sum_{i=1}^{p} {r^2}_{y,xi}$$

PCA finds the optimal weight vector ($a_{11,}$ $a_{12,}$…a_{1p}) and the associated variance of y_1 which is denoted as λ_1.

The second principal component y_2, is

$$y_2 = a_{21}*x_1 + a_{22}*x_2 + … + a_{2p}*x_p \qquad (2)$$

such that the variance of y_2 is maximized subject to the constraint that the squared weights of the second weight vector ($a_{21}, a_{22} \ldots a_{2p}$) is equal to one:

$$\sum_{i=1}^{p} a^2{}_{2i} = 1$$

Here, y_2 is orthogonal to y_1 so that

$$\sum_{i=1}^{p} a_{1i} a_{2i} = 0$$

Hence, y_2 has the second largest sum of squared correlation with the original variables. As successive components are extracted the variance of the principal components gets smaller. The first two principal components have the highest possible sum of squared correlation with the original variables. Therefore,

$$\sum_{i=1}^{p} R^2{}_{xi.y1,y2}$$

is maximized by extracting the first two principal components. This is a measure of the explanatory power of the components.

Component Scores

The principal components are an exact mathematical transformation of the raw variables. If the objective is a simple summary of the information contained in the raw data the use of component scores is desirable. It is possible to represent the components exactly from the combination of raw variables. The scores are obtained by combining the raw variables with weights that are proportional to their component loadings. Thus if b_{ij} is the component loading of the jth variable on the ith. component and λ_i is the associated eigenvalue then the component score is given by b_{ij}/λ_i (=w_i) .

Division by the eigenvalue assures that the resulting index has a variance equal to 1. In our case the component scores have been used for determining the weight of each of the raw variables in constructing a composite EDI for the ith country and, similarly, for other countries.

$$EDI_i = \sum_{j=1}^{5} w_j . x_{ji}$$

where j = index of selected variables.

References

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); and World Resources Institute (WRI), *Gridded Population of the World (GPW), Version* 2, Palisades, NY: CIESIN, Columbia University, 2000 (available at http://sedac.ciesin.colum-bia.edu/plue/gpw).

Consultative Group on Sustainable Development Indicators, "Dashboard of Sustainable Development Indicators," dataset dated 9 January 2002.

Dunteman, G.H. " Principal Component Analysis (PCA)", in Lewis-Beck (1994).P.158

Dixon, Frank, "Financial Markets and Corporate Environmental Results," pp. 44-53 in World Economic Forum, Yale Center for Environmental Law and Policy, and Center For International Earth Science Information Network, *Environmental Performance Measurement: The Global Report 2001-200*2, New York: Oxford University Press, 2002.

Esty, Daniel C. and Peter Cornelius, ed., *Environmental Performance Measurement: The Global Report 2001-200*2, New York: Oxford University Press, 2002.

Esty, Daniel C., and Michael E. Porter (2001), "Ranking National Environmental Regulation And Performance: A Leading Indicator of Future Competitiveness?" pp. 78-101 in World Economic Forum (WEF), *The Global Competitiveness Report 2001*, New York: Oxford University Press.

Flatz, Alois, "Corporate Sustainability and Financial Indexes," pp. 66-81 in Daniel C. Esty and Peter Cornelius, ed., *Environmental Performance Measurement: The Global Report2001-200*2, New York: Oxford University Press, 2002.

Frankel, Jeffrey, and Andrew Rose, "Is Trade Good or Bad for the Environment? Sorting out the Causality," (unpublished manuscript, 2002).

Gjertsen, H. and C. B. Barrett (2001) “Context-Dependant Bio-diversity Conservation Management Regimes”, *Working Paper Series,* Social Science Research Network Library, 11 February.

Harbaugh, William, Arik Levinson and David Wilson (2000), “Reexamining the Empirical Evidence for an Environmental Kuznets Curve,” National Bureau of Economic Research Working Paper No. 7711, May.

Henderson, N. (1993) “Heritage landscapes : A new Approach to the Preservation of Semi-Natural Landscapes in Canada and the United States”, in Turner, R.K. (Ed.) *Sustainable Environmental Economics and Management, Principles and Practice.* Belhaven, London.

Jha, R. and K.V. Bhanu Murthy (2000) “Sustainability – Property Rights, Behaviour and Economic Growth”, *World Congress on Managing and Measuring Sustainability, Ontario, August 2000.*

Jha, R. and K. V. Bhanu Murthy (2003) “An Inverse Global Environmental Kuznets Curve” forthcoming *Journal of Comparative Economics*.

Jolliffe, T.I. (1986) *Principal Component Analysis*, New York, Springer-Verlag.

Kaiser, H. F. (1958) "Varimax criterion for analytical rotation in factor analysis", *Psychometrica*, 187 –200

Levy, Marc A. (2001) “Corruption and the 2001 Environmental Sustainability Index,” pp. 300-302 Robin Hodess, ed., *Global Corruption Report 2001,* Berlin: Transparency International.

Levy, Marc A., “Measuring Nations’ Environmental Sustainability,” pp. 12-23 in Daniel C. Esty, and Peter Cornelius, ed., *Environmental Performance Measurement: The Global Report 2001-200*2, New York: Oxford University Press, 2002.

Lewis-Beck, M.(ed.) *Factor Analysis and Related Techniques*, New Delhi: Sage Toppan, 1994

McAbe, G.P. (1984) "Principal Variables", *Technometrics*, 26: pp. 137-144.

Parris, Thomas M. and Robert W. Kates (2001), “Characterizing a Sustainability Transition: The International Consensus,” paper prepared for presentation at the Open Meeting of The Human Dimensions of Global Environmental Change Research Community, 7 October, Rio de Janeiro, Brazil.

Porter, Michael, (1991) “America’s Green Strategy,” *Scientific America*n, August.

Prescott-Allen, Robert, *The Wellbeing of Nation*s, Washington, DC: Island Press, 2001.

Schiller, Andrew, *Signatures of Sustainability: A Framework for Interpreting Relationships Among Environmental, Social, and Economic Conditions for United States Metropolitan Area*s. Dissertation, Clark University, 2001.Ann Arbor: UMI, AA13003109.

United Nations, Economic and Social Council, “Implementing Agenda 21: Report of the Secretary General,” E/CN.17/2002/PC.2/7, 20, December 2001.

World Economic Forum (WEF), *The Global Competitiveness Report 2001-2002*, New York: Oxford University Press, 2002.

World Economic Forum (WEF) *The 2002 Environmental Sustainability Index*.

Table 1: Weight Structure for Five Broad Indicators

Indicator	Rank	Relevance Index
Environmental System	1	5.15
Reducing Stress	2	4.53
Global Stewardship	3	3.61
Social and Institutional Capacity Component	4	3.40
Human Vulnerability	5	3.0

TABLE 2

		Correlation Matrix									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Correlation	VOCKM	1.00	0.29	-0.05	0.03	0.91	0.24	0.25	0.37	0.06	0.43
	SO2KM	0.29	1.00	0.08	0.24	0.36	0.14	0.61	0.32	0.17	0.49
	PRTMAM	-0.05	0.08	1.00	0.50	0.02	0.27	0.11	0.03	-0.07	0.15
	PRTBRD	0.03	0.24	0.50	1.00	0.04	0.08	0.13	0.28	0.16	0.08
	NOXKM	0.91	0.36	0.02	0.04	1.00	0.29	0.32	0.48	0.13	0.45
	FERTHA	0.24	0.14	0.27	0.08	0.29	1.00	0.17	0.29	0.00	0.45
	COALKM	0.25	0.61	0.11	0.13	0.32	0.17	1.00	0.42	0.13	0.72
	C02PC	0.37	0.32	0.03	0.28	0.48	0.29	0.42	1.00	0.52	0.42
	CO2GDP	0.06	0.17	-0.07	0.16	0.13	0.00	0.13	0.52	1.00	0.03
	CARSKM	0.43	0.49	0.15	0.08	0.45	0.45	0.72	0.42	0.03	1.00
Level of Significance.	VOCKM	1.00									
(1-tailed)	SO2KM	0.00	1.00								
	PRTMAM	**0.29**	**0.17**	1.00							
	PRTBRD	**0.37**	0.00	0.00	1.00						
	NOXKM	0.00	0.00	**0.42**	**0.30**	1.00					
	FERTHA	0.00	0.04	0.00	**0.16**	0.00	1.00				
	COALKM	0.00	0.00	**0.09**	**0.06**	0.00	0.02	1.00			
	C02PC	0.00	0.00	**0.35**	0.00	0.00	0.00	0.00	1.00		
	CO2GDP	**0.23**	0.02	**0.21**	0.03	**0.07**	**0.50**	**0.06**	0.00	1.00	
	CARSKM	0.00	0.00	0.04	**0.17**	0.00	0.00	0.00	0.00	**0.36**	1.00

NOTE: Only sixteen correlation co-efficients (in bold print) not significant at 5% level.
All the rest are highly statistically significant.

TABLE 3

Component Score Coefficient Matrix				
	Component			
	1	2	3	4
VOCKM	-0.135	**0.478**	-0.070	-0.014
SO2KM	0.405	-0.141	-0.045	0.040
PRTMAM	-0.050	0.003	**0.577**	-0.130
PRTBRD	-0.067	-0.075	0.486	0.214
NOXKM	-0.113	0.454	-0.045	0.031
FERTHA	-0.039	0.251	0.261	-0.186
COALKM	**0.503**	-0.174	-0.078	-0.037
C02PC	0.000	0.096	0.039	0.416
CO2GDP	-0.074	-0.087	-0.050	**0.643**
CARSKM	0.365	0.046	-0.002	-0.176

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

NOTE: Component scores of retained variables in bold print.

TABLE 4

ESIRANK	EDIRANK	EDI	COUNTRY	DIFF. IN RANK (ESIRANK-EDIRANK)
59	1	0.62458	MOZAMBIQUE	58
75	2	1.55871	EL SALVADOR	73
127	3	2.01717	GIUNEA-BISSAU	124
52	4	2.61727	NICARAGUA	48
67	5	2.8593	GAUTEMALA	62
103	6	2.87162	GAMBIA	97
95	7	2.90059	BENIN	88
39	8	3.06554	MOLDOVA	31
24	9	3.11001	ALBANIA	15
25	10	3.13468	PARAGUAY	15
82	11	3.30512	MALAWI	71
101	12	3.50494	BURKINA FASO	89
105	13	3.59708	TOGO	92
98	14	3.84096	GUINEA	84
115	15	3.89209	BURUNDI	100
46	16	4.02468	ZIMBABWE	30
47	17	4.23463	HONDURAS	30
81	18	4.3492	SENEGAL	63
9	19	4.35966	COSTA RICA	-10
76	20	4.51507	UGANDA	56
10	21	4.52639	LATVIA	-11
69	22	4.56842	ZAMBIA	47
65	23	4.66908	GHANA	42
6	24	4.8458	URUGUAY	-18
43	25	4.99391	CENT.AFR.REP.	18
111	26	5.03658	ANGOLA	85
134	27	5.36618	SIERRA LEONE	107
123	28	5.58538	NIGER	95
119	29	5.64527	RWANDA	90
36	30	5.66084	GABON	6
109	31	5.72327	ZAIRE	78
85	32	5.92607	MALI	53
21	33	5.95842	BOLIVIA	-12
93	34	5.96559	CAMEROON	59
40	35	5.98248	CONGO	5
121	36	6.00767	TRIN. & TOBAGO	85
108	37	6.03453	IVORY COAST	71
27	38	6.04522	LITHUANIA	-11
17	39	6.1389	PANAMA	-22
49	40	6.15244	BYELARUS	9
102	41	6.16058	SUDAN	61
130	42	6.2086	LIBERIA	88
56	43	6.24054	KYRGYZSTAN	13
107	44	6.32885	SYRIA	63
5	45	6.49228	SWITZERLAND	-40
29	46	6.62939	PERU	-17

132	47	6.64947	SOMALIA	85
38	48	6.67212	ARMENIA	-10
15	49	6.70431	ARGENTINA	-34
1	50	7.29555	FINLAND	-49
18	51	7.35067	ESTONIA	-33
32	52	7.66932	COLOMBIA	-20
48	53	7.67526	VENEZUELA	-5
26	54	7.7244	NAMIBIA	-28
96	55	7.81316	CHAD	41
142	56	8.00832	KUWAIT	86
110	57	8.07057	TAJIKISTAN	53
41	58	8.25199	ECUADOR	-17
53	59	8.32665	JORDAN	-6
113	60	8.328	ETHIOPIA	53
112	61	8.40256	PAKISTAN	51
133	62	8.4418	NIGERIA	71
4	63	8.65471	CANADA	-59
3	64	8.66775	SWEDEN	-61
12	65	8.71303	CROATIA	-53
80	66	8.8542	TANZANIA	14
90	67	9.0557	MYANMAR	23
7	68	9.10917	AUSTRIA	-61
13	69	9.18838	BOTSWANA	-56
42	70	9.2829	MONGOLIA	-28
11	71	9.32622	HUNGARY	-60
88	72	9.3603	KHAZAKSTAN	16
61	73	9.40425	TUNISIA	-12
118	74	9.45583	UZBEKISTAN	44
14	75	9.48531	SLOVAKIA	-61
54	76	9.49893	THAILAND	-22
138	77	9.51953	SAUDI ARABIA	61
32	78	9.64126	LAOS	-46
23	79	9.77934	SLOVENIA	-56
73	80	9.82109	MOROCCO	-7
99	81	9.82138	NEPAL	18
89	82	9.85971	KENYA	7
45	83	9.89014	USA	-38
57	84	10.20874	BOSNIA	-27
92	85	10.25236	MEXICO	7
62	86	10.36063	TURKEY	-24
139	87	10.57948	IRAQ	52
106	88	10.58927	LEBANON	18
70	89	10.63378	ALGERIA	-19
131	90	11.12831	TURKMENISTAN	41
126	91	11.23059	MAURITANIA	35
97	92	11.23149	CAMBODIA	5
68	93	11.2354	MALAYSIA	-25
120	94	11.46368	OMAN	26
104	95	11.48112	IRAN	9
2	96	11.71628	NORWAY	-94
60	97	11.77489	GREECE	-37

94	98	11.82076	VIETNAM	-4
31	99	11.89112	DENMARK	-68
74	100	12.04668	EGYPT	-26
84	101	12.06898	ITALY	-17
114	102	12.28929	AZERBAIJAN	12
20	103	12.43598	BRAZIL	-83
83	104	12.4496	MACEDONIA	-21
30	105	12.6481	BHUTAN	-75
72	106	12.79747	RUSSIA	-34
64	107	13.00743	CZECH. REP.	-43
37	108	13.50234	IRELAND	-71
86	109	13.86052	BANGLADESH	-23
55	110	13.89491	SRILANKA	-55
33	111	14.00751	FRANCE	-78
66	112	14.38907	ROMANIA	-46
77	113	14.40977	SOUTH AFRICA	-36
35	114	14.66261	CHILE	-79
71	115	14.66431	BULGARIA	-44
122	116	14.78393	JAMAICA	6
129	117	14.9677	CHINA	12
63	118	15.08481	ISRAEL	-55
141	119	15.13046	UAE	22
136	120	15.39076	UKRAINE	16
51	121	15.50105	PAPUA N.G.	-70
87	122	16.94476	POLAND	-35
140	123	17.25569	N. KOREA	17
28	124	17.54867	PORTUGAL	-96
124	125	17.65342	LIBYA	-1
50	126	17.94292	GERMANY	-76
44	127	19.04128	SPAIN	-83
116	128	19.18586	INDIA	-12
100	129	19.26648	INDONESIA	-29
34	130	19.54603	NETHERLANDS	-96
117	131	19.98959	PHILLIPINES	-14
78	132	20.17706	JAPAN	-54
128	133	20.9927	MADAGASCAR	-5
125	134	21.04391	BELGIUM	-9
16	135	21.42015	AUSTRALIA	-119
58	136	21.77766	CUBA	-78
91	137	22.51975	UK	-46
135	138	24.91617	SOUTH KOREA	-3
79	139	31.12179	DOMINICAN REP.	-60
8	140	35.79837	ICELAND	-132
19	141	47.41392	NEW ZEALAND	-122
137	142	77.26458	HAITI	-5

NOTE:

EDI ranks (based on ascending order) is given below:

Rank Corr.= 0.106789525

Stand. Err. = 0.084215192

Z value = **1.268055346**

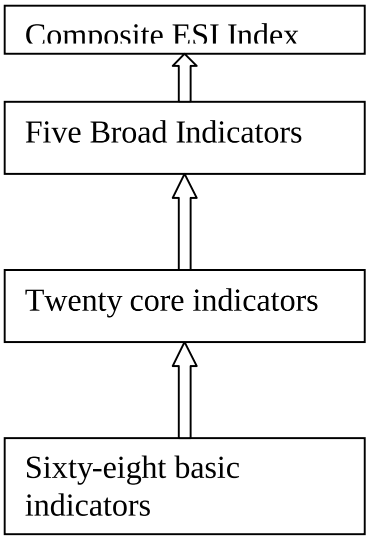
Composite ESI Index
Five Broad Indicators
Twenty core indicators
Sixty-eight basic indicators

Figure 1