# The Role of Sustainability Indicators as a Tool for Assessing Territorial Environmental Competitiveness

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Abstract: The Environmental Sustainability Index measures the relative sustainability of countries based on data aggregated to the level of the nation-state. Environmental sustainability is measured through 20 "indicators," each of which combines two to eight variables, for a total of 68 underlying data sets. The ESI has received attention from policy makers and the public, and has stimulated public discourse about what sustainability means, and how it can be measured. ESI is a flexible tool that, although first implemented at the national level, is suitable for application to sub-national administrative units such as municipalities. These sub-national units represent the microeconomic foundations of the new competitiveness, and measures of sustainability at this level are more useful for local policymakers, who are daily confronted by resource allocation decisions. This presentation begins by describing the approach used to construct the national-level ESI. It then presents a pilot effort to develop municipal-level indicators of sustainability for Brazil. This Brazilian municipal-level ESI will serve as a targeted instrument for different levels of local government providing them a common basis for a dialog on sustainability.

## Introduction: Indicator Definitions

Sustainability indicators have received increasing attention in the decade since the Rio Earth Summit, reflecting growing concern by the public and policy makers over environmental trends. Indicators represent an attempt to quantify these trends, and to determine if the widespread perception that environmental conditions are deteriorating is indeed correct.

The Webster's Dictionary definition of indicators is as follows:

> **in•di•ca•tor** (in/ di kā/ tər) n. (1) A person or a thing that indicates; (2) a pointing or directing device, as a pointer on the dial or a measuring instrument; (3) an instrument that indicates the condition of a machine in operation.

Evidently this definition was written before the current indicators boom! Nevertheless, we can take the third sense of the word to broadly encompass the reason for indicators – they indicate the functioning of a system, whether a machine, or an ecosystem, or a country.

To quote from the report of the *2002 Environmental Sustainability Index* (ESI) (WEF *et al.* 2002), "what matters gets measured." In other words, societies measure what they care about. The International Institute for Sustainable Development (IISD 2003) writes:

> "Measurement helps decision-makers and the public define social goals, link them to clear objectives and targets, and assess progress toward meeting those targets. It provides an empirical and numerical basis for evaluating performance, for calculating the impact of our activities on the environment and society, and for connecting past and present activities to attain future goals."

As we will see, all of these were motivating goals for creating the ESI.

## The Environmental Sustainability Index (ESI): Approach and Methodology

Three groups were involved in the creation of the ESI. The World Economic Forum's Global Leaders for Tomorrow Environment Task Force, the Yale University Center for Environmental Law and Policy, and the Center for International Earth Science Information Network of Columbia University. The team began with a Pilot ESI, which was published in January 2000. After considerable input and consultation with expert groups, the team produced the 2001 ESI in January 2001 and the 2002 ESI in February 2002. In 2002 the team also launched the Environmental Performance Index (EPI), which included more robust data for both current performance and recent progress on four key environmental parameters for the 23 OECD countries.

The Environmental Sustainability Index (ESI) measures overall progress toward environmental sustainability for 142 countries. Environmental sustainability is measured through 20 "indicators," each of which combines two to eight variables, for a total of 68 underlying data sets. The ESI tracks relative success for each country in five core components:

- Environmental Systems
- Reducing Stresses
- Reducing Human Vulnerability
- Social and Institutional Capacity
- Global Stewardship

The indicators and the variables on which they are constructed were chosen through an extensive review of the environmental literature, assessment of available data, and broad-based consultation and analysis (see Table 1).

The building blocks of the ESI are the variables. The method used to construct the ESI was first to "trim" the tails of the distribution of values for each variable so that they all fall within a 95-percentile spread. This attenuated the effect of major outliers on the distribution. For highly skewed distributions we performed a logarithmic transformation.  We then converted all the ESI variables to z-scores. A country's z-score for any given variable is calculated by taking the country's actual level of performance, subtracting the mean for all countries, and dividing by the standard deviation. This yields a standardized metric with zero representing the mean, and +1 and –1 representing plus and minus one standard deviation above and below the mean (respectively). We then "inverted" z-scores used for variables where high scores are bad to make scores comparable. The z-scores were then averaged to generate indicator values. The indicators, in turn, were average to generate the component scores and the overall ESI scores (see Figure 1).

**Figure 1. Construction of the ESI**

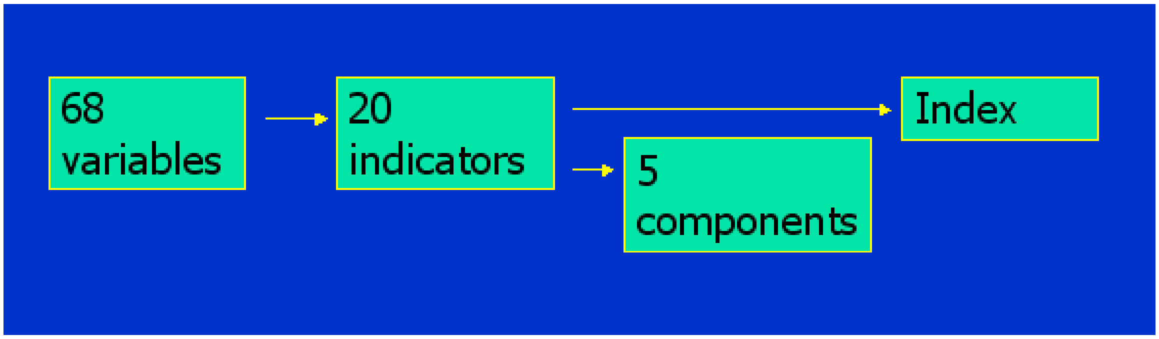



**Table 1. Environmental Sustainability Index Building Blocks**

| Component | Indicator | Variable |
|---|---|---|
| Environmental Systems | Air Quality | Urban $SO_2$ concentration |
| | | Urban $NO_2$ concentration |
| | | Urban TSP concentration |
| | Water Quantity | Internal renewable water per capita |
| | | Per capita water inflow from other countries |
| | Water Quality | Dissolved oxygen concentration |
| | | Phosphorus concentration |
| | | Suspended solids |
| | | Electrical conductivity |
| | Biodiversity | Percentage of mammals threatened |
| | | Percentage of breeding birds threatened |
| | Land | Percent of land area having very low anthropogenic impact |
| | | Percent of land area having high anthropogenic impact |
| Reducing Stresses | Reducing Air Pollution | $NO_x$ emissions per populated land area |
| | | $SO_2$ emissions per populated land area |
| | | VOCs emissions per populated land area |
| | | Coal consumption per populated land area |
| | | Vehicles per populated land area |
| | Reducing Water Stress | Fertilizer consumption per hectare of arable land |
| | | Pesticide use per hectare of crop land |
| | | Industrial organic pollutants per available fresh water |
| | | Percentage of country's territory under severe water stress |
| | Reducing Ecosystem Stresses | Percentage change in forest cover 1990-2000 |
| | | Percentage of county with acidification exceedence |
| | Reducing Waste & Consumption Pressures | Ecological footprint per capita |
| | | Radioactive waste |
| | Reducing Population Growth | Total fertility rate |
| | | Percentage change in projected pop. between 2001 & 2050 |
| Reducing Human Vulnerability | Basic Human Sustenance | Proportion of undernourished in total population |
| | | Percent of pop. with access to improved drinking-water supply |
| | Environmental Health | Child death rate from respiratory diseases |
| | | Death rate from intestinal infectious diseases |
| | | Under-5 mortality rate |

**Table 1. Environmental Sustainability Index Building Blocks (continued)**

| Component | Indicator | Variable |
|---|---|---|
| Social and Institutional Capacity | Science and Technology | Technology achievement index |
| | | Technology Innovation Index |
| | | Mean years of education |
| | Capacity for Debate | IUCN member organizations per million population |
| | | Civil & political liberties |
| | | Democratic institutions |
| | | Percentage of ESI variables in publicly available data sets |
| | Environmental Governance | WEF survey questions on environmental governance |
| | | Percentage of land area under protected status |
| | | Number of sectoral EIA guidelines |
| | | FSC accredited forest area as a percent of total forest area |
| | | Control of corruption |
| | | Price distortions (ratio of gasoline price to international average) |
| | | Subsidies for energy or materials usage |
| | | Subsidies to the commercial fishing sector |
| | Private Sector Responsiveness | Number of ISO14001 certified companies per million $ GDP |
| | | Dow Jones Sustainability Group Index |
| | | Average Innovest EcoValue rating of firms |
| | | World Business Council for Sustainable Development members |
| | | Private sector environmental innovation |
| | Eco-efficiency | Energy efficiency (total energy consumption per unit GDP) |
| | | Renewable energy production as a percent of total energy consumption |
| Global Stewardship | Participation in International Collaborative Efforts | Number of memberships in environmental intergovernmental organizations |
| | | Percentage of CITES reporting requirements met |
| | | Levels of participation in the Vienna Convention/Montreal Protocol |
| | | Levels of participation in the Climate Change Convention |
| | | Montreal protocol multilateral fund participation |
| | | Global environmental facility participation |
| | | Compliance with Environmental Agreements |
| | Greenhouse Gas Emissions | Carbon lifestyle efficiency ($CO_2$ emissions per capita) |
| | | Carbon economic efficiency ($CO_2$ emissions per dollar GDP) |
| | Reducing Transboundary Environmental Pressures | CFC consumption (total times per capita) |
| | | $SO_2$ exports |
| | | Total marine fish catch |
| | | Seafood consumption per capita |

The variable level data were compiled for a wide variety of sources, including international organizations and statistical compendiums, environmental NGOs, commercial enterprises, national governments, modeling groups, and some custom-developed data by CIESIN. The data types included Summary national reports, site measurements reported to international authority, survey data, summarized research results, and modeled data. For metadata on each variable can be found in Annex 6 of the 2002 ESI report, and an evaluation of the strengths and weaknesses of the variables can be found in Annex 1.

The ESI permits cross-national comparisons of environmental sustainability in a systematic and quantitative fashion. It assists the move toward a more analytically rigorous and data driven approach to environmental decisionmaking. In particular, the ESI enables:

- identification of issues where national performance is above or below expectations
- priority-setting among policy areas within countries and regions
- tracking of environmental trends
- quantitative assessment of the success of policies and programs
- investigation into interactions between environmental and economic performance, and into the factors that influence environmental sustainability

Although the ESI is broadly correlated with per-capita income, the level of development does not alone determine environmental circumstances. For some indicators there is a strong negative relationship with per-capita income. Moreover, within income brackets, country results vary widely. Environmental sustainability is therefore *not* a phenomenon that will emerge on its own from the economic development process, but rather requires focused attention on the part of governments, the private sector, communities and individual citizens.

The ESI combines measures of current conditions, pressures on those conditions, human impacts, and social responses because these factors collectively constitute the most effective metrics for gauging the prospects for long-term environmental sustainability, which is a function of underlying resource endowments, past practices, current environmental results, and capacity to cope with future challenges. Because the concept of sustainability is fundamentally centered on trends into the future, the ESI explicitly goes beyond simple measures of current performance.

## ESI Results

To calculate the over-arching Environmental Sustainability Index, we averaged the values of the 20 indicators and calculated a standard normal percentile for each country. The results are shown in Table 2. Countries score high in the ESI if the average of their individual indicator scores is high relative to other countries. The ESI score can be interpreted as a measure of the relative likelihood that a country will be able to achieve and sustain favorable environmental conditions several generations into the future. Given their relative strength across the past, present, and future dimensions of sustainability, countries at the top of the Index are more likely than those at the bottom to experience lasting environmental quality. The dynamic nature of the environmental realm and the lack of information on critical resource thresholds limits our ability to draw conclusions about the long term environmental sustainability of particular countries. Such a judgment would require much more detailed information on reserve depletion rates, assimilative capacities, and system interactions than is currently available. Nevertheless, global environmental data as well as the fact that every country has issues on which it is under performing makes it likely that no country is on a fully sustainable trajectory.

Because the 20 indicators span many distinct dimensions of environmental sustainability, it is possible, moreover, for countries to have similar ESI scores but very different environ-mental profiles. The Netherlands and Laos, for example, have very similar ESI scores of 55.2 and 56.3. But they have mirror image patterns for many indicators. Laos has relatively poor scores for human vulnerability, capacity, and water quality, areas in which the Netherlands is relatively strong. Likewise, while the Netherlands has quite poor scores for air and water pollution emissions as well as climate change and transboundary pollution, Laos has relatively good results on these metrics. Country by country profiles showing each of the 20 indicator values can be found in Annex 5 to the ESI report.

**Table 2. 2002 Environmental Sustainability Index (ESI) Scores**

| Rank | Country | ESI |
|---|---|---|
| 1 | Finland | 73.9 |
| 2 | Norway | 73.0 |
| 3 | Sweden | 72.6 |
| 4 | Canada | 70.6 |
| 5 | Switzerland | 66.5 |
| 6 | Uruguay | 66.0 |
| 7 | Austria | 64.2 |
| 8 | Iceland | 63.9 |
| 9 | Costa Rica | 63.2 |
| 10 | Latvia | 63.0 |
| 11 | Hungary | 62.7 |
| 12 | Croatia | 62.5 |
| 13 | Botswana | 61.8 |
| 14 | Slovakia | 61.6 |
| 15 | Argentina | 61.5 |
| 16 | Australia | 60.3 |
| 17 | Panama | 60.0 |
| 18 | Estonia | 60.0 |
| 19 | New Zealand | 59.9 |
| 20 | Brazil | 59.6 |
| 21 | Bolivia | 59.4 |
| 22 | Colombia | 59.1 |
| 23 | Slovenia | 58.8 |
| 24 | Albania | 57.9 |
| 25 | Paraguay | 57.8 |
| 26 | Namibia | 57.4 |
| 27 | Lithuania | 57.2 |
| 28 | Portugal | 57.1 |
| 29 | Peru | 56.5 |
| 30 | Bhutan | 56.3 |
| 31 | Denmark | 56.2 |
| 32 | Laos | 56.2 |
| 33 | France | 55.5 |
| 34 | Netherlands | 55.4 |
| 35 | Chile | 55.1 |
| 36 | Gabon | 54.9 |
| 37 | Ireland | 54.8 |
| 38 | Armenia | 54.8 |
| 39 | Moldova | 54.5 |
| 40 | Congo | 54.3 |
| 41 | Ecuador | 54.3 |
| 42 | Mongolia | 54.2 |
| 43 | Central Af. Rep. | 54.1 |
| 44 | Spain | 54.1 |
| 45 | United States | 53.2 |
| 46 | Zimbabwe | 53.2 |
| 47 | Honduras | 53.1 |
| 48 | Venezuela | 53.0 |
| 49 | Byelarus | 52.8 |
| 50 | Germany | 52.5 |
| 51 | Papua N G | 51.8 |
| 52 | Nicaragua | 51.8 |
| 53 | Jordan | 51.7 |
| 54 | Thailand | 51.6 |
| 55 | Sri Lanka | 51.3 |
| 56 | Kyrgyzstan | 51.3 |
| 57 | Bosnia and Herze. | 51.3 |
| 58 | Cuba | 51.2 |
| 59 | Mozambique | 51.1 |
| 60 | Greece | 50.9 |
| 61 | Tunisia | 50.8 |
| 62 | Turkey | 50.8 |
| 63 | Israel | 50.4 |
| 64 | Czech Republic | 50.2 |
| 65 | Ghana | 50.2 |
| 66 | Romania | 50.0 |
| 67 | Guatemala | 49.6 |
| 68 | Malaysia | 49.5 |
| 69 | Zambia | 49.5 |
| 70 | Algeria | 49.4 |
| 71 | Bulgaria | 49.3 |
| 72 | Russia | 49.1 |
| 73 | Morocco | 49.1 |
| 74 | Egypt | 48.8 |
| 75 | El Salvador | 48.7 |
| 76 | Uganda | 48.7 |
| 77 | South Africa | 48.7 |
| 78 | Japan | 48.6 |
| 79 | Dominican Rep. | 48.4 |
| 80 | Tanzania | 48.1 |
| 81 | Senegal | 47.6 |
| 82 | Malawi | 47.3 |
| 83 | Macedonia | 47.2 |
| 84 | Italy | 47.2 |
| 85 | Mali | 47.1 |
| 86 | Bangladesh | 46.9 |
| 87 | Poland | 46.7 |
| 88 | Kazakhstan | 46.5 |
| 89 | Kenya | 46.3 |
| 90 | Myanmar (Burma) | 46.2 |
| 91 | United Kingdom | 46.1 |
| 92 | Mexico | 45.9 |
| 93 | Cameroon | 45.9 |
| 94 | Vietnam | 45.7 |
| 95 | Benin | 45.7 |
| 96 | Chad | 45.7 |
| 97 | Cambodia | 45.6 |
| 98 | Guinea | 45.3 |
| 99 | Nepal | 45.2 |
| 100 | Indonesia | 45.1 |
| 101 | Burkina Faso | 45.0 |
| 102 | Sudan | 44.7 |
| 103 | Gambia | 44.7 |
| 104 | Iran | 44.5 |
| 105 | Togo | 44.3 |
| 106 | Lebanon | 43.8 |
| 107 | Syria | 43.6 |
| 108 | Ivory Coast | 43.4 |
| 109 | Zaire | 43.3 |
| 110 | Tajikistan | 42.4 |
| 111 | Angola | 42.4 |
| 112 | Pakistan | 42.1 |
| 113 | Ethiopia | 41.8 |
| 114 | Azerbaijan | 41.8 |
| 115 | Burundi | 41.6 |
| 116 | India | 41.6 |
| 117 | Philippines | 41.6 |
| 118 | Uzbekistan | 41.3 |
| 119 | Rwanda | 40.6 |
| 120 | Oman | 40.2 |
| 121 | Trinidad and Tob. | 40.1 |
| 122 | Jamaica | 40.1 |
| 123 | Niger | 39.4 |
| 124 | Libya | 39.3 |
| 125 | Belgium | 39.1 |
| 126 | Mauritania | 38.9 |
| 127 | Guinea-Bissau | 38.8 |
| 128 | Madagascar | 38.8 |
| 129 | China | 38.5 |
| 130 | Liberia | 37.7 |
| 131 | Turkmenistan | 37.3 |
| 132 | Somalia | 37.1 |
| 133 | Nigeria | 36.7 |
| 134 | Sierra Leone | 36.5 |
| 135 | South Korea | 35.9 |
| 136 | Ukraine | 35.0 |
| 137 | Haiti | 34.8 |
| 138 | Saudi Arabia | 34.2 |
| 139 | Iraq | 33.2 |
| 140 | North Korea | 32.3 |
| 141 | United Arab Em. | 25.7 |
| 142 | Kuwait | 23.9 |

To help facilitate relevant comparisons across countries with similar profiles, we have undertaken a “cluster” analysis. Cluster analysis provides a basis for identifying similarities among countries across multiple heterogeneous dimensions. The cluster analysis performed on the ESI data set reveal five groups of countries that had distinctive patterns of results across the 20 indicators. The results are presented in Table 3.

In Table 4 these clusters are compared according to the average values of their scores on the ESI and its five core components, as well as the values of other variables that may play a role in explaining their cluster membership.

The first two clusters have roughly similar scores on environmental systems and reducing stresses, but starkly disparate scores on vulnerability and capacity. These two groups are the two most divergent in terms of their socio-economic conditions, institutions, and locations. The first group is generally poor, vulnerable to corruption, undemocratic, and economically uncompetitive. The second cluster tends to show the opposite characteristics. Note that the first group has superior scores on global stewardship, largely reflecting its very low levels of consumption (and thus a limited burden on the global commons) induced by economic underdevelopment and poverty.

Comparing the second and third clusters, the main difference in terms of environmental sustainability measures is that the third group has markedly lower scores on environmental systems and stresses; the other scores are roughly similar. These two groups are quite similar in terms of socioeconomic conditions and institutions. The third group has generally higher population densities and significantly smaller average territory size.

In comparing the fourth and fifth groups, other differences come to the fore. Although the fourth group has slightly better vulnerability scores, it ranks lower in the other four categories and on the overall ESI average. Group four has especially low capacity scores, which portend a weak ability to cope with unfolding environmental challenges. The main institutional difference between these groups is that group four is, on average, less democratic than group five. It is interesting that the less democratic group produces lower ESI scores in spite of the fact that its average per-capita income about 25 percent higher. These undemocratic poor countries also score anomalously lower on measures of global stewardship than the other poor countries. Thus, the cluster analysis seems to confirm the earlier observation that, while income (i.e., level of development) is an important determinant of environmental results, other factors are equally significant.

There are other ways to divide the world into categories, but this analysis, based on measures of environmental sustainability, reveals a set of useful patterns. It suggests a number of interesting areas for future research and policy debate concerning potential drivers of environmental sustainability.

**Table 3. Cluster Analysis Results**

| 1) High human vulnerability; moderate systems and stresses | 2) Low vulnerability; moderate systems and moderate stresses | 3) Low vulnerability; poor systems and high stresses | 4) Moderate vulnerability, systems and stresses; but low capacity | 5) Moderate vulnerability, systems and stresses; average capacity |
|---|---|---|---|---|
| Angola | Australia | Austria | Azerbaijan | Albania |
| Benin | Canada | Belgium | Iraq | Algeria |
| Bhutan | Estonia | Czech Republic | Kazakhstan | Argentina |
| Bolivia | Finland | Denmark | Kuwait | Armenia |
| Burkina Faso | Iceland | France | Libya | Bangladesh |
| Burundi | Ireland | Germany | North Korea | Bosnia and Herze. |
| Cambodia | Israel | Hungary | Oman | Botswana |
| Cameroon | New Zealand | Italy | Russia | Brazil |
| Central Af. Rep. | Norway | Japan | Saudi Arabia | Bulgaria |
| Chad | Sweden | Macedonia | Trinidad and Tobago | Byelarus |
| Congo | United States | Netherlands | Turkmenistan | Chile |
| Ethiopia | | Poland | Ukraine | China |
| Gabon | | Slovakia | United Arab Emirates | Colombia |
| Gambia | | Slovenia | Uzbekistan | Costa Rica |
| Ghana | | South Korea | | Croatia |
| Guatemala | | Spain | | Cuba |
| Guinea | | Switzerland | | Dominican Rep. |
| Guinea-Bissau | | United Kingdom | | Ecuador |
| Haiti | | | | Egypt |
| Ivory Coast | | | | El Salvador |
| Kenya | | | | Greece |
| Laos | | | | Honduras |
| Liberia | | | | India |
| Madagascar | | | | Indonesia |
| Malawi | | | | Iran |
| Mali | | | | Jamaica |
| Mauritania | | | | Jordan |
| Mozambique | | | | Kyrgyzstan |
| Myanmar | | | | Latvia |
| Nepal | | | | Lebanon |
| Nicaragua | | | | Lithuania |
| Niger | | | | Malaysia |
| Nigeria | | | | Mexico |
| Pakistan | | | | Moldova |
| Papua New Guinea | | | | Mongolia |
| Paraguay | | | | Morocco |
| Rwanda | | | | Namibia |
| Senegal | | | | Panama |
| Sierra Leone | | | | Peru |
| Somalia | | | | Philippines |
| Sudan | | | | Portugal |
| Tanzania | | | | Romania |
| Togo | | | | South Africa |
| Uganda | | | | Sri Lanka |
| Zaire | | | | Syria |
| Zambia | | | | Tajikistan |
| | | | | Thailand |
| | | | | Tunisia |
| | | | | Turkey |
| | | | | Uruguay |
| | | | | Venezuela |
| | | | | Vietnam |
| | | | | Zimbabwe |

**Table 4. Characteristics of Clusters**

| | Cluster: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Number of countries | 46 | 11 | 18 | 14 | 53 |
| Average values of ESI Component Values | ESI | 46.0 | 63.0 | 52.7 | 37.1 | 51.9 |
| | Environmental Systems | 50.8 | 65.6 | 44.2 | 41.6 | 50.1 |
| | Reducing Environmental Stress | 54.2 | 44.7 | 34.2 | 43.0 | 58.3 |
| | Reducing Human Vulnerability | 18.2 | 82.9 | 82.1 | 62.0 | 62.3 |
| | Social and Institutional Capacity | 39.0 | 75.3 | 67.4 | 29.5 | 44.5 |
| | Global Stewardship | 61.3 | 47.8 | 51.5 | 22.1 | 49.2 |
| Average values of other characteristics | Spatial Index of Density (31 to 91) | 58.1 | 49.3 | 76.6 | 57.0 | 63.1 |
| | Per Capita Income | $1,417 | $22,216 | $18,260 | $7,481 | $5,210 |
| | Democratic Institutions (-9 to 10) | .15 | 9.64 | 9.50 | -4.57 | 4.10 |
| | Controlling Corruption (-1.3 to 2.1) | -.66 | 1.66 | .99 | -.52 | -.23 |
| | Current Competitiveness Index (0 to 10) | .75 | 8.32 | 7.55 | 3.38 | 3.41 |
| | Total Area (square kilometers) | 535,624 | 2,507,768 | 178,269 | 1,849,669 | 874,352 |
| | Distance from Equator (degrees latitude) | 11.9 | 52.8 | 46.6 | 35.4 | 27.6 |

Along with the cluster analysis, we produced country reports for each country. Figure 2 shows country report for Brazil. In the upper left-hand corner we report Brazil's Environmental Sustainability Index score and its rank (out of the 142 countries in the ESI). We also report the average Index score for the countries in the Brazil's peer group as defined by GDP per capita (Purchasing Power Parity).

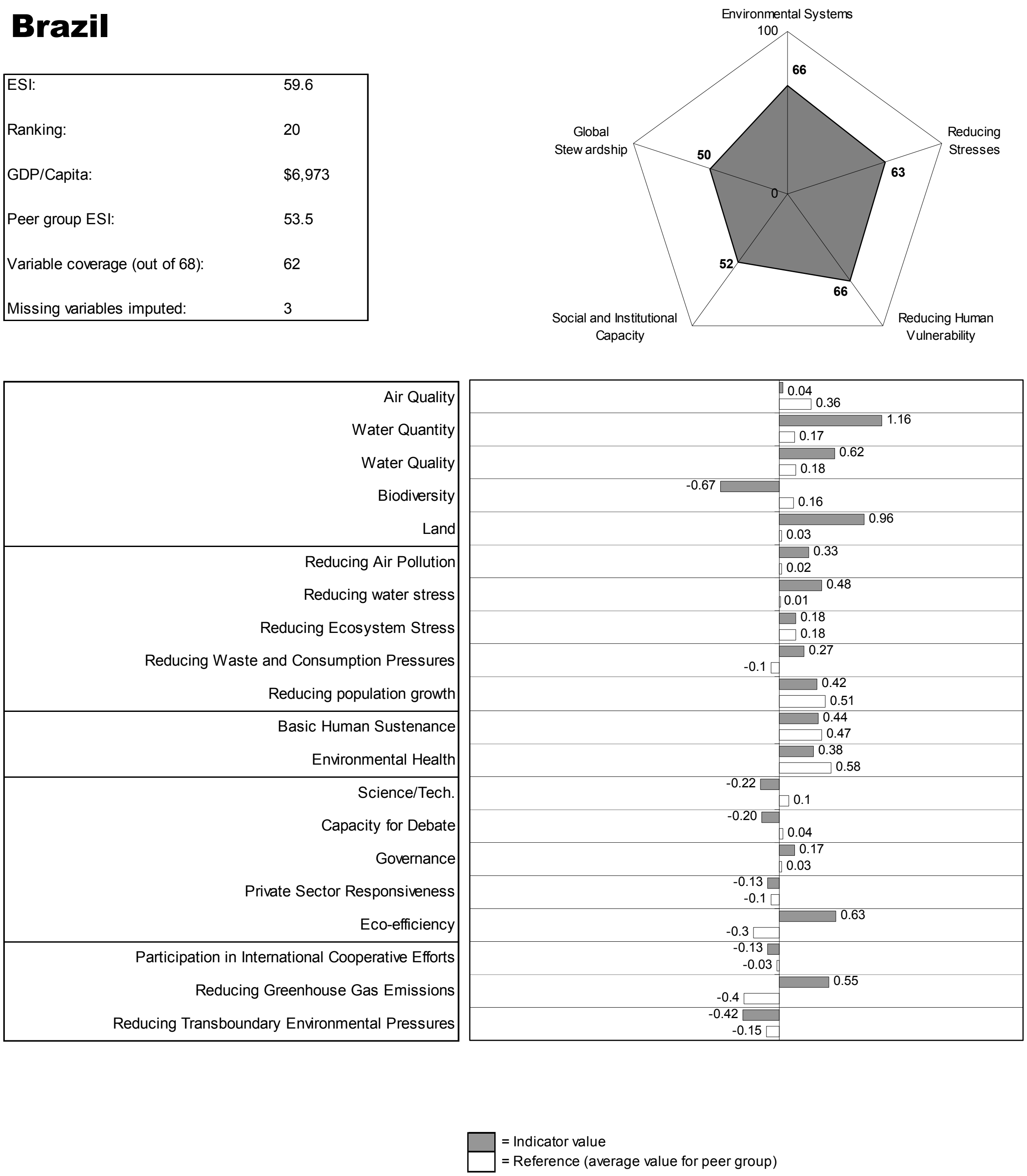
We use income to assign peer groups not because we wish to privilege the view that income determines environmental performance. To the contrary, one of our conclusions is that within similar levels of economic performance countries exhibit significant variation in their levels of environmental sustainability. By comparing a country's Index score with that of others in its peer group, one can get a useful measure of how effective its environmental efforts are.

In the upper right of each page we show a graph that provides a snapshot of Brazil's performance along the five components of environmental sustainability. These graphs have five axes that begin at a single point and radiate out in opposite directions. Brazil's score for each component is marked on each axis, and then the points are connected to form a closed area. The size of this area is a measure of its overall performance on these five components. The shape of the area reflects the particular distribution of scores across the five components. These provide a useful benchmark for comparing performance in a slightly more precise manner than the single Index score.

Both the Index score and the Component scores are presented as standard normal percentiles. These have a theoretically possible range of 0-100; the shape of the distribution of scores determines the actual range across all the countries. In all cases higher scores represent higher measures of environmental sustainability.

Finally, we present the scores of the 20 indicators in a set of bar graphs. The shaded bars represent the scores for Brazil, and the empty bars show the average scores for the peer group. These scores represent the average of the standardized z-scores of the variables that comprise the indicators. Higher numbers represent higher levels of performance; scores near the central axis are closer to the mean score for that indicator for the complete set of 142 countries included in the ESI.

## Figure 2. Brazil's Profile




Brazil, for example, performs above average for its peer group in terms of water quantity and quality, abundant lands that have relatively little human influence, the energy efficiency of its economy, and its carbon-dioxide emissions per person and per unit GDP. It performs below average for its reference group on the percent of mammals and birds that are threatened, its scientific and technological capacity and capacity for debate, and on its transboundary impacts (e.g. probably mostly related to its marine catch).

## A Pilot Sustainability Index for Brazilian Municipalities

So, shifting gears, how might we use a similar methodology to assess the sustainability of Brazilian municipalities? First of all, why would we want to do that? Because:

1. National-level measures are of little relevance to local decision-makers
2. Municipalities are the microeconomic foundations of the new economic competitiveness
3. Indicators can act as an incentive to take sustainability seriously

In short, a municipal-level sustainability index will serve as a targeted instrument for different levels of local government, providing a common basis for dialog on sustainability. It is worth noting that the municipal-level Human Development Index for Brazil has, just like its international counterpart, spurred policy makers to take seriously issues of human wellbeing, and to invest more in efforts to raise the levels of human development.

So, in a very preliminary manner, I set out to create a measure of environmental and human development potential based upon available and comparable data at the municipality level, and assumptions regarding pre-requisites for rural sustainable development. I considered these to be human capital, a supply of adequate water and sanitation services, and agricultural potential. Note that I did not have ready access to data on market access or roads and other infrastructure, which in an ideal index would also be included. The variables used for Human Capital and Supply of Adequate Services were the following, all obtained from the Atlas of Human Development for Brazil (1991).

<u>Human Capital</u>
Human Development Index
Percent of children 7-14 who attend school
Percent of population >25 years with more than 11 years of schooling
Adult literacy rate

<u>Supply of Adequate Services</u>
Percent of domiciles with adequate water supply
Percent of domiciles with adequate sewerage

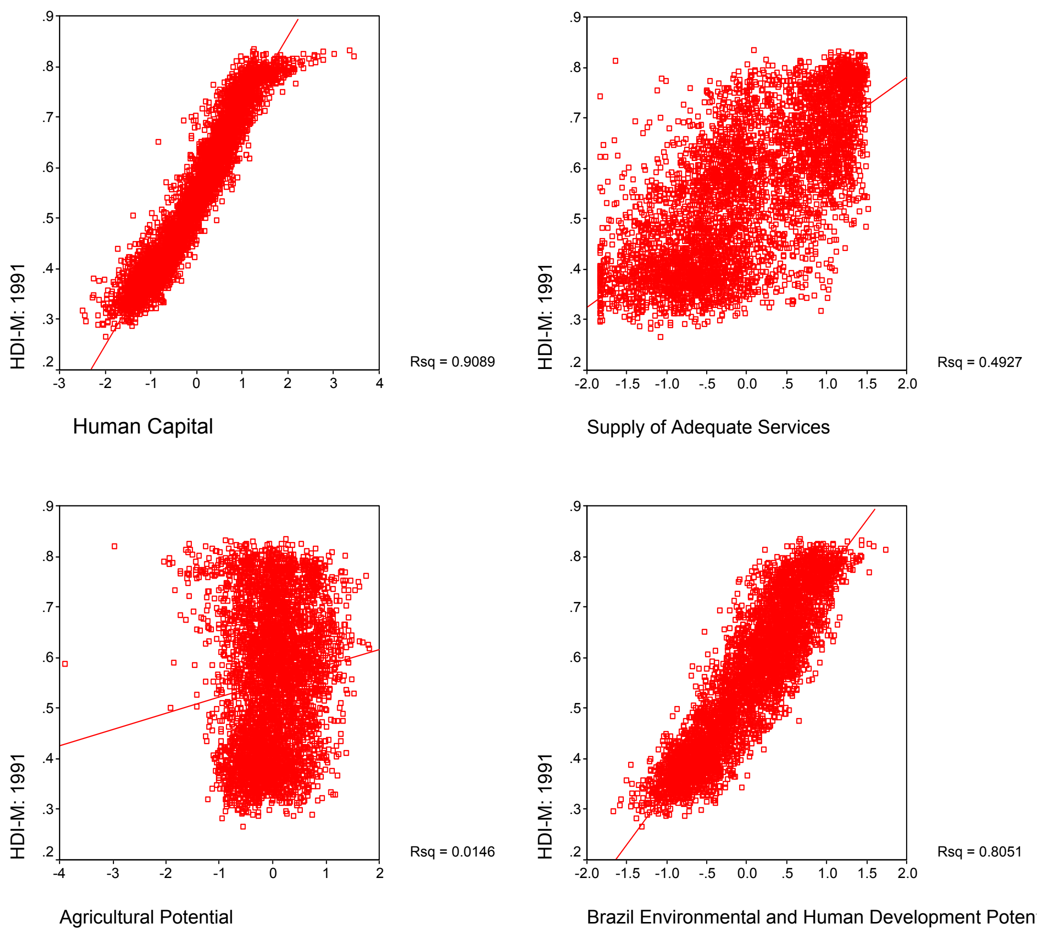
I then added some of our own, CIESIN-generated variables to measure agricultural potential. All of these were data sets on a 1 km square grid. Values for municipalities represent some aggregation of the values of the grid cells within that municipality. The variables include:

<u>Agricultural Potential</u>
The proportion of the territory in the top 3 crop suitability classes (from the FAO/IIASA Global Agro-ecosystem Zone Assessment)
The average level of climatic, soil and terrain slope constraints (from the same Assessment)
The average level of human impact on the environment (from CIESIN's Human Footprint data set)

Using the same method as described above for the ESI, I calculated the z-score for each variable, and took the inverse of the z-score for those variables in which high scores would be considered bad. I then averaged all the variables to produce the index for environmental and human development potential.

Figure 3 shows the relationship between the three components and the Human Development Index scores for the 4,492 municipalities. Human Capital is most closely related to HDI, though it focuses slightly more on education; the supply of Adequate Water and Sanitation Services and the Agricultural Potential do not seem to be highly related to the HDI scores for municipalities.

**Figure 3. Relationship Between the Three Components, the overall Index, and the HDI**




So, what are the results? Figure 4 provides a map of scores for Brazil. The darker municipalities represent those with higher environmental and human development potential. It is not terribly surprising that the sourthern most parts of Brazil are the ones that have the highest potential. The index reflects the fact that these are the regions that people have historically found most suitable for agriculture and human industries, and therefore they have been settled longest, and are also the most densely settled. Nevertheless, there are several municipalities in Amazonia and the northeast that have high levels of potential. Table 5 provides a list of the top ten and the bottom ten scoring municipalities (with State name abbreviations), and Figure 5 provides a zoom of the southern part of Brazil.

**Figure 4. Environmental and Human Development Potential**

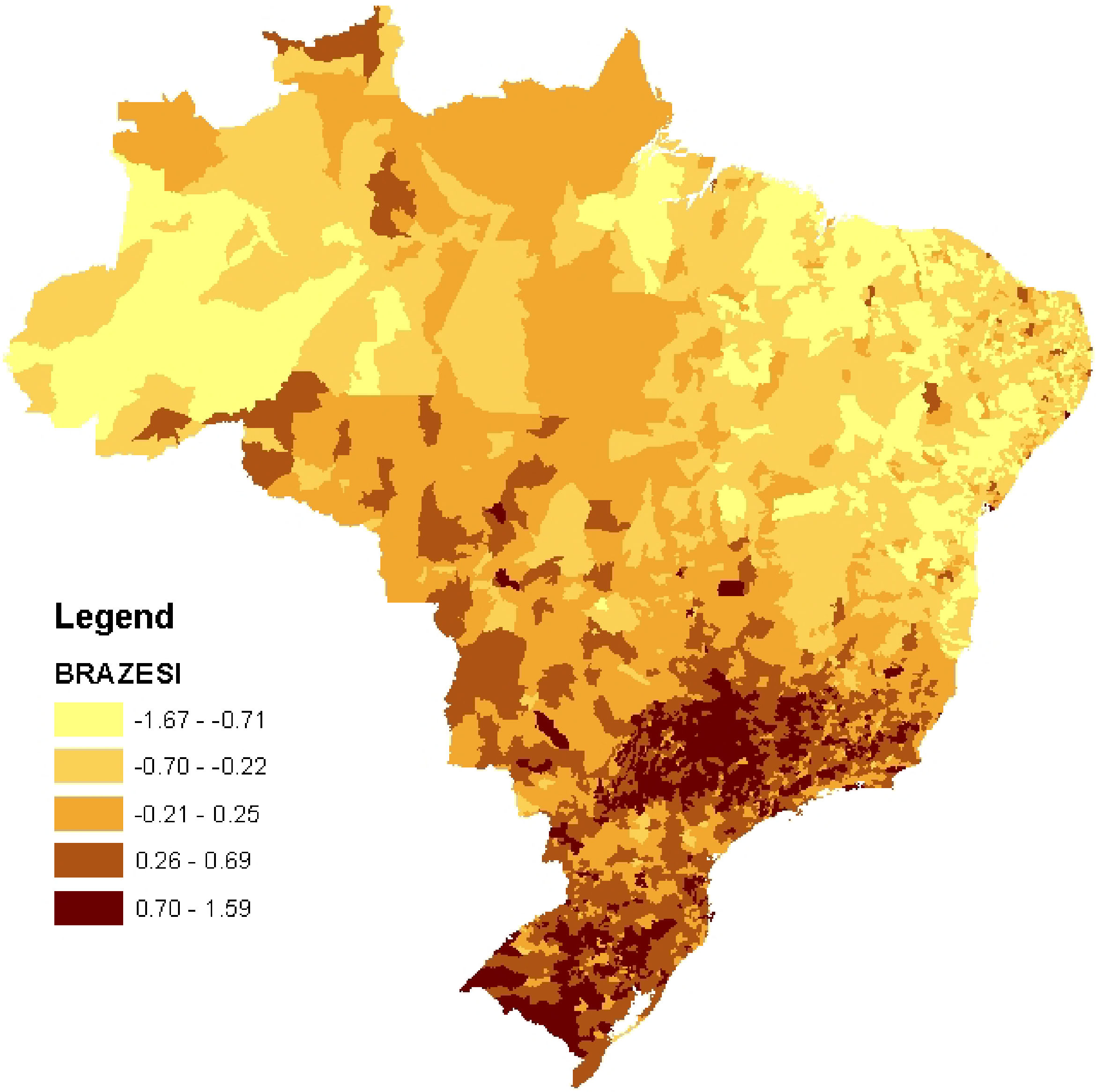
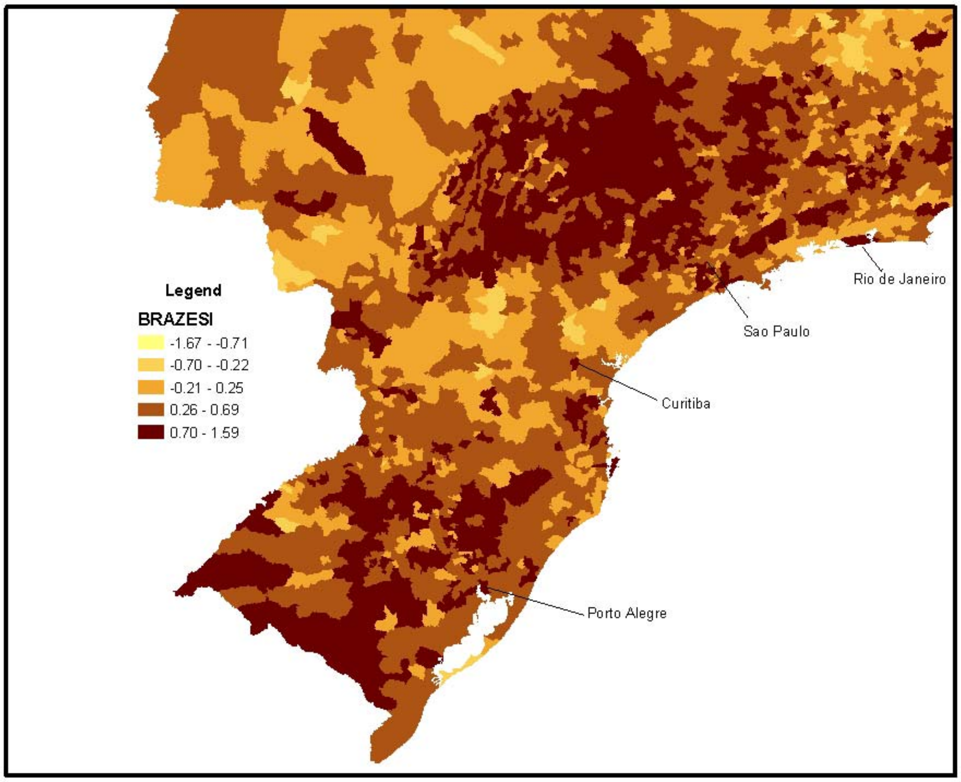



**Table 5. Top Ten and Bottom Ten Municipalities**

| Top Ten | | Bottom Ten | |
|---|---|---|---|
| Pirassununga | SP | Adustina | BA |
| Niterói | RJ | Envira | AM |
| Ribeirão Preto | SP | Bom Jesus da Serra | BA |
| Cornélio Procópio | PR | Poranga | CE |
| Florianópolis | SC | Olho d'Água Grande | AL |
| Araraquara | SP | Itapebi | BA |
| Águas de São Pedro | SP | Santana de Mangueira | PB |
| Cruzália | SP | Araioses | MA |
| Londrina | PR | Coronel João Sá | BA |
| Maringá | PR | Pedro Alexandre | BA |

**Figure 5. Zoom of the Southern Part of Brazil**




It is worth noting that another group at CEDEPLAR, lead by Tania Braga who has visited with us twice at CIESIN, has developed an Urban Sustainability Index (USI) that is inspired by the ESI (Braga *et al.* 2003). It was developed for the metropolitan areas of Sao Paulo and Belo Horizonte. The USI includes a wider range of data, as shown in Table 6. It is an example of what can be achieved with more intensive data compilation.

**Table 6. Variables Used in the Construction of the USI**

| Index | Indicator | Type | Variable | Delineation |
|---|---|---|---|---|
| Human Wellbeing | Environmental Health and Security | State | Under-1 mortality rate* | Intra-urban |
| | | | Child death from respiratory diseases* | Intra-urban<br>Urban-Global |
| | | | Death from intestinal infectious diseases* | Intra-urban<br>Urban-Region |
| | | | Homicides* | Intra-urban |
| | | | Death from car accident* | Intra-urban |
| | Education | State | Illiteracy* | Structural |
| | | | Adults under 4 years education* | Structural |

| | | | | |
|---|---|---|---|---|
| | | | Adults over 11 years education | Structural |
| | | | Median years of education | Structural |
| | Housing quality | State | Squatters* | Intra-urban |
| | Sanitation | State | Improved water Supply | Intra-urban |
| | | | Improved sewage | Intra-urban |
| | | | Improved waste collection | Intra-urban |
| | Income | State | Income inequality* | Intra-urban |
| | | | Household Income | Intra-urban |
| Environmental Quality | Water quality | State | Water quality | Urban-Region |
| | Air quality | State and Pressure | Air quality | Urban-Region<br>Urban-Global |
| | | | Vehicles* | Urban-Region<br>Urban-Global |
| | Vegetation | State | Forest | Urban-Region |
| | Industrial Stress | Pressure | Energy efficiency | Urban-Region<br>Urban-Global |
| | Household stress | Pressure | Bedroom density* | Intra-Urban |
| | | | Average household members* | Intra-Urban |
| | Urban Stress | Pressure | Waste treatment | Intra-Urban |
| | | | Urban drainage | Intra-Urban |
| | Consumption | Pressure | Energy consumption* | Urban-Region<br>Urban-Global |
| Institutional Capacity | Local Autonomy | Result | Fiscal autonomy | Structural |
| | | | Indebtedness* | Structural |
| | | | Electoral weight | Structural |
| | Urban Governance | Result | Staff | Structural |
| | | | Information systems | Structural |
| | | | Participation in urban policy decision making | Structural |
| | | | Urban planning tools | Intra-urban |
| | Environmental Governance | Result | Participation in environmental policy decision making | Structural |
| | | | Areas under protected status | Intra-urban |
| | Capacity for debate | Result | Environmental NGOs | Structural |
| | | | Electoral participation | Structural |
| | | | Press (newspapers) | Structural |
| | | | Press (radios) | Structural |

Note: * inverse variables – the highest the variable value, the lowest the sustainability.

From the foregoing presentation of Brazil's municipal-level environmental and human development potential we can make the following observations. The example analysis of Brazil has many limitations, but it represents a first approximation. The approach is comparative and relies on common data across all municipalities; it does not tell us if municipalities are sustainable in any absolute sense. A better approach would be to tailor the indicators to the local needs and locally available data

## Conclusions

In conclusion, indicators can be used to alert policy-makers to problem areas. They are also management tools, and can be used to measure progress. Together with the Open City Foundation, we are exploring the possibility of developing a certification scheme based on such indicators to attract new investment to rural municipalities. In developing such a municipal-level certification scheme, it will be important to consult with mayors and other rural officials to determine which kinds of indicators are most appropriate to rural municipalities.

## References

Braga, Tania, Fausto Brito, Ana Paula Freitas, Denise Marques. 2003. *Urban Sustainability Index: results of pilot application for the metropolitan areas of Sao Paulo and Belo Horizonte.* Working paper by CEDEPLAR/Universidade Federal de Minas Gerais.

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