Humanosphere Potentiality Index

Appraising Existing Indicators from a Long-term Perspective

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Abstract

This research presents the Humanosphere Potentiality Index (HPI), developed to address current global potentiality from a long-term perspective. The HPI presents a different way to envision the current condition of the world, one that is compatible with a strong sustainability paradigm approach and demonstrates the significance of tropical countries for global sustainability. A comparison between HPI and the Human Development Index (HDI) reveals a dominant developmental paradigm that justifies the HDI perspective, and comparisons between HPI and four popular environmental indicators provide insights into how human society should engage with the natural environment. This research argues that the worldview from HPI presents a perspective that asks us to pay more attention not only to development but also to global potentiality from a long-term perspective.

Keywords: biosphere, environmental sustainability, geosphere, humanosphere, Humanosphere Potentiality Index, human society

More than a quarter of a century has passed since the publication of the landmark Brundtland report "Our Common Future," from the World Commission on Environment and Development, which defined sustainable development as "development that meets the needs of the present without comprising the ability of future generations to meet their own needs" (WCED 1987: 41). Since then, international society has made various efforts to assess sustainability and there now exists a prevailing consensus that recognizes both present and future risks of global warming and biodiversity loss (IPCC 2013, 2014; MEA 2005). Increasingly, research on global environmental changes has been accompanied by calls for profound societal change (ISSC 2016), and for future forms of governance that can respond to uncertainty, a key issue at the heart of debates on sustainability (e.g., Bäckstrand 2006; Jordan 2008; van Zeijl-Rozema et al. 2008). Within this heightened context, there has been a boom in the development of sustainability indicators that have come to be increasingly recognized as useful tools for informing policy decisions and communicating changes taking place at a global level (KEI 2005).

Indicators are a link to the world that allow for the condensation of complexity into manageable meaningful information that informs decisions and directs action

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(Bossel 1996).[1] They also arise from societal values (we measure what we care about) and create values (we care about what we measure) (Meadows 1998). Truly "objective" indicators do not exist. The greater the influence of the indicator developed, the greater the strength and reinforcement of biases at play in the selection of variables that constitute indicators. This can potentially weaken the ability of human society to respond to changing circumstances (Mine 2012). As such, there is a crucial need to critically evaluate the values that underlie such indicators. At present, three classes of bias appear in most sustainability indicators, a monetary bias, human-centric bias, and a relatively short-term perspective on the environment.

Many "developed countries" that achieved "developed status" following the industrial revolution have narrowly set societal goals to include production, increased productivity, and economic growth. Through such values, gross domestic product (GDP) has become widely used measure and yardstick of the wealth of nations. The advantage of the GDP approach is that it involves only a single measure, but disadvantages have also been repeatedly pointed out (Constanza 2014; Dietz and O'Neil 2013; Stiglitz et al. 2009). One is that GDP includes only things that can be converted to money. Productive activities that cannot be valued in monetary terms are not included, although efforts have been made through the calculation of genuine savings or net adjusted savings (Hamilton and Clemens 1999; Hartwick 1990; Neumayer 2013). As such, GDP cannot be taken as a reliable gauge of individual and collective well-being in various societies and different environmental settings.

In 1990, the Human Development Index (HDI) was strategically developed as an indicator that could compete with and replace GDP. It aimed to express the concept of human development, based on Amartya Sen's capability approach (Fukuda-Parr and Kumar 2009; UNDP 1990). To date, the United Nations Development Programme (UNDP) has focused on health, education, and income as basic functions that should be included in approaches toward human development and adopted average life expectancy, literacy rate, and enrollment rate as educational indicators,[2] and per capita GDP as a component. However, the world based on HDI country rankings does not depart radically from that based on GDP rankings, although HDI includes factors other than production levels. As its name implies, HDI focuses primarily on human society and, in that sense, it is limited by its strong bias toward humans in that it does not directly consider environmental constraints. As such, there is a need to rethink the capability approach and reassess how we can measure present global potentiality within the framework of sustainability and go beyond the primary focus of the needs of human society.

Within the above framework created to measure human development, there has also been intensive work on developing environmental indicators, such as the Ecological Footprint (EF) (Wackenagel and Rees 1996), the Environmental Performance Index (EPI) (Esty et al. 2006), and the Environmental Vulnerability Index (EVI) (SOPAC and UNEP 2005), among many others. These popular indicators share one common feature: they allow us to consider the future based on assessments carried out over the past few decades. Such assessments may provide high assessments and appraisals of economically developed countries, ignoring previous trends of environmental degradation. Some, such as Alexander Mather (1990), have analyzed the historical trends of forest coverage in several countries and regions, and proposed a forest transition model in relation to economic development: forest coverage decreased in the initial stages of economic development but started to increase after that. This has led scholars to call for the deeper integration of regional and global historical, archaeological, and paleo-environmental records in order to use the past as a guide to informing decisions that can affect a sustainable future (Constanza 2007). In line with this research orientation, there is an acute need to develop indicators focusing on environmental assessment from a long-term perspective. These would allow for a deeper macro-level overview and inform us of long-term global-level transformations, which many of the above indicators have not satisfactorily engaged in.

The above three biases—monetary, human-centric, and short-term—may have been created from a direct and instant demand to measure current environmental/societal performance. Such an approach is based on reformist theories, which assume that the best path to a sustainable world is to work within existing political and economic systems at a global level (Fukai 2006). To overcome these limitations observed in existing indicators, a new analytical framework is needed that is independent of the existing political and economic systems, and based on historical facts that fundamentally support our web of life. For this purpose, this article proposes a Humanosphere Potentiality Index (HPI) based on an analytical framework called the Humanosphere. In this research, we expand Sen's capability approach with the aim of bridging the existing divide between socio-economic and environmental approaches toward sustainability to reassess global potentiality.

This article is composed in the following order: a literature review, an overview of the conceptualization, and a materials and methods section. We contextualize, explain, and define "the humanosphere" and the analytical framework of the HPI within broader current discussions on human interactions and impacts on global ecosystems. Then, we identify and explain the factors that constitute the HPI and describe calculation methods. The first part of the results and discussion section presents the worldview from the HPI perspective and the extrapolated findings of the research. The second part presents a more detailed examination of how the world can be viewed from the perspective of HPI through a comparison with HDI, and four other well-known environmental indicators—the Environmental Performance Index (EPI), Ecological Footprint (EF), Biocapacity (BC), and Environmental Vulnerability Index (EVI). The article concludes with a summary confirmation of the significance of HPI.

Literature Review, Materials, and Methods

Previous Conceptual Research

The construction of the humanosphere arises out of a concern about how to conceptualize and locate human societal impacts on global ecosystems from a long-term perspective and within a broad web of life.[3] Over the past decades, different disciplinary endeavors have produced conceptual frameworks focusing on and refining a "systems approach" toward different interacting spheres. One predominant disciplinary framework has been the earth sciences. These have provided a productive ground to analyze interactions within the geosphere (composed of the atmosphere, hydrosphere, lithosphere, and cryosphere), biosphere, and pedosphere. Interactions in the biophysical environment form an overarching global ecosystem that has been used as an analytical frame of reference. Arising out of concerns as to how human society was influencing environments at the regional and global levels, from the early 1990s, analytical approaches in the environmental sciences have focused on chemical metabolic processes that analyze physical flows, stocks of energy, and matter that flows between the different entities within the earth system. Peter Baccini and Paul Brunner refined the focus on metabolic systems to define the anthroposphere: a complex technical system of energy, material, and information flows that deals with the physico-chemical uptake, transport, and storage of all substances by human society, including the processing of both the quantity and quality of all refuse produced within it (2012: 1). This has served as a productive conceptual framework for observing, analyzing, and weighing both recent historical and present-day human–urban interactions within ecosystems across a spectrum of population densities, magnitudes of urban development, and differing levels of energy and material consumption flows.

Current research suggests the need to consider human societies as historical techno-cultural constructions. Any analysis at a macro or micro level should be clearly situated in space and time, different historico-cultural contexts, and under different technological regimes. These differential approaches to development provide a useful framework for analysis as societies have procured and metabolized energy and managed material flows for millennia. In this context, metabolic approaches to society have developed in tandem with urban energy systems analytical approaches. These have taken integrated systems of energy—focusing on exosomatic energy—as a starting point for analyses (Georgescu-Roegen 1977; Mayumi 2001; Şorman 2015). These approaches toward theorizing the metabolisms of societies have informed debates on the failure of conventional economic approaches to contextualize how we appropriate and use dwindling stocks of natural capital and available resources in an increasingly urbanized world population (Rees 1992). Consequently, these debates have further stimulated the impetus to conceptualize and formulate indicators that sufficiently measure transformations.

In societal terms, resource-intensive development has been brought about by revolutions in exosomatic energy procurement, and human activities now rival geologic-scale forces. Yet this has unleashed a cascade of critical environmental changes producing a negative feedback loop that transforms both the biosphere and geosphere and a pressing need to measure them. Historically, pre-industrial human societies were characterized by their dependence on solar energy for agricultural production to sustain both rural and urban dwellers, and Western societies were agriculturally self-sustaining until the convergence of scientific knowledge coupled with capitalist economic growth-oriented production. These convergences triggered the development of new technologies to extract fossil energy, technological innovations in transport, improved energy efficiency and agricultural production, and capitalist expansion connecting urban cities to regional hinterlands and beyond. In the mid-nineteenth century, for the first time in human history, a switch to large-scale energy carriers not permanently renewable on the same scale occurred (Sieferle 2010: 42). This permitted the development of urban regions with large metabolic footprints that, through dependence on fossil fuels, have allowed for a "temporary emancipation from land" (Mayumi 1991). This emancipation has, over the course of the past hundred years, allowed claims to be made on the biosphere's zoomass, stocks, and natural capital leading to an unprecedented and destructive transformation of natural terrestrial biomes, natural vegetation, and heterotrophic diversity (Smil 2013: 235). The expansion and transformation of land given over to agriculture, urbanization, and expansion has depended on a dominant energy-intensive mode of capitalist production and growth.

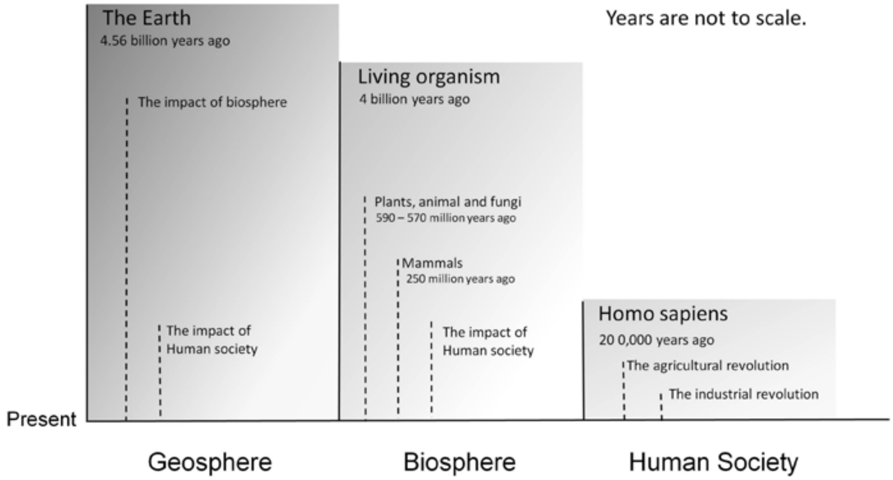
The capacity of terrestrial land is reaching clear limits with stark implications for human populations, flora, and fauna.[4] The twentieth century witnessed a doubling of human appropriation of net primary production with human activities affecting three-quarters of all vegetated land (Krasumann et al. 2013). Globally, 11 percent of the world's land surface is allocated for crop production using 70 percent of water drawn from aquifers, streams, and lakes (FAO 2011). In some regions this has pushed humankind toward critical limits of what different biophysical systems can deal with in providing for human societies. This has led to calls to clearly delineate planetary boundaries within which human societies should operate (Rockström et al. 2009). Homo sapiens now possesses a force without precedent in nature to produce climatic and geological change, reshape a large part of the terrestrial biosphere, and effect most of its physical processes. How we conceptually and analytically approach human societies in different regions of the Earth and how we produce principles, criteria, and indicators to measure transformations are crucial in order to produce new ways of envisioning the present and the future basis for societal well-being and to present alternative paths of development.

Conceptualization of the Humanosphere: An Analytical Framework for a Sustainable World

This research proposes the framework of the humanosphere, a conceptualized compound of three spheres: the geological, biological, and societal, each of which operates according to an internal "logic" (figure 1). It incorporates an encompassing life-centric and long-term intergenerational equity approach that recognizes and respects the logic inherent in each sphere. This approach is compatible with a strong sustainability paradigm that recognizes that existing stocks of natural capital must be maintained and enhanced, insofar as the functions they perform cannot be duplicated by manufactured capital. Our framework of the humanosphere endeavors to capture the environment as it is. We present the "humanosphere" as a framework that recognizes and measures the current condition of the world by extending the capability approach to include future generations by acknowledging and respecting the "logic" of three spheres that compose our environment.

We use the term *environment*, expanding the definition of Michael Begon and colleagues (2006) to include human beings: modified, it consists of all those factors

Figure 1: The historical evolution of the humanosphere.



and phenomena surrounding and influencing us, whether they are physical and chemical (abiotic), other organisms (biotic), or societal. This definition corresponds to the definition of *humanosphere*, which is composed of the geosphere, biosphere, and human society.

Amartya Sen refers to a person's capability as an alternative combination of functionings—the various things a person may value doing or being that are feasible for them to achieve (1999b: 75). The sustainability definition put forward by the WCED (1987) clarifies that a form of substantive freedom that achieves an alternative functioning combination has to be secured for all life in the present and in the future. Jérôme Ballet and colleagues (2011) have indicated that relationships with the environment can be understood as choices within the different types of freedom available to individuals (that they value). In this sense, the values we place on the natural capital we construe to have utility for not only human well-being, but also for sustaining a broader web of life, must be considered as a de facto ethical responsibility of present-day human societies.

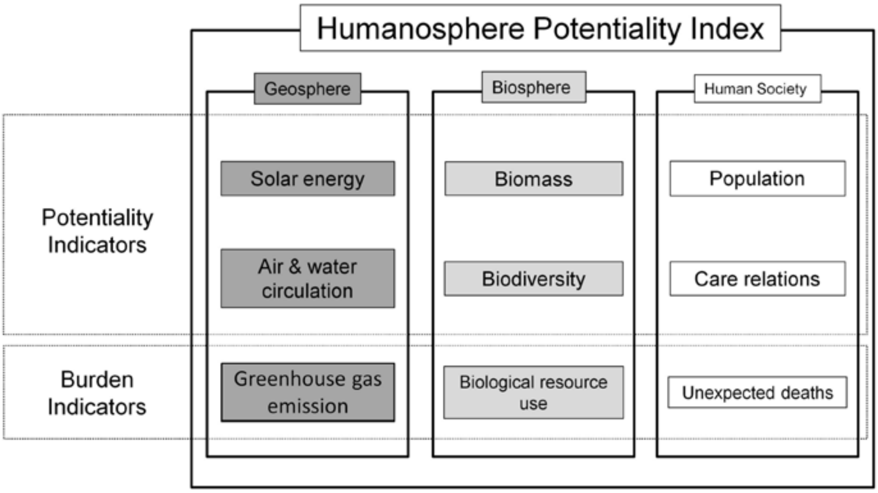
To extend discussions on sustainability beyond a welfare economics approach to human societies, the humanosphere has been developed to synthesize an approach that arises within three different scientific branches and their engagements with environmental sustainability. In order, these are earth science, life science, and social science. The geosphere is analyzed under the domain of earth science; the biosphere under life science; and the human society under social science. A number of justifications are necessary. First, an integrated transdisciplinary combination of the above three branches of research allows us to conceptualize new ways to understand the development of human society within the deeper geological and biological "well of history." Second, this allows us to contextualize our current predicament as a species that has enacted unprecedented transformations at a planetary level. Third, merging these broad disciplinary approaches allows us to situate what has been perceived as a short-term issue (planetary transformation by one species) in a longer-term frame of reference (geological and biological transformation).

The oldest and largest sphere, the geosphere, provides the geophysical basis for the other two spheres. Incoming solar radiation, a primary source for almost all the energy existing on the Earth, acts as and provides the driving force for the global circulation of air and water. The biosphere, under solar radiation and global air and water circulation, converts organic materials into an astonishing diversity of self-replicating organisms. In this research, human society is treated as the most recent development and resides within a societal sphere. Productive activities within this latter sphere have—in an unprecedentedly short time—started to significantly alter the conditions of the latter two.

Human society has emerged as a part of the biosphere, yet our existence is essentially limited by the "logics" of both geological and biological systems. In other words, the sustainability of human society is limited by the natural capital that forms in the geosphere and biosphere. Nevertheless, as highlighted above, the productive activities of human society, since the start of the industrial revolution and their subsequent metabolic activities, have gone far beyond their capacity to maintain previous forms of life.

A "sustainable" humanosphere is achievable only when the interlinking potentialities of all three spheres are considered and measured. To do so, this research identifies those constituting factors that can illuminate *potentialities for* and *burdens on* a sustainable humanosphere. Potentialities are defined as those factors that represent the potential of the geosphere, biosphere, and human society that constitute the basis for a sustainable humanosphere. Burdens are defined as factors that represent burdens inflicted by human activity on the geosphere/biosphere and as the factors that represent burdens imposed on human society by geospheric, biospheric, and societal activities (figure 2).

Figure 2: Components of the Humanosphere Potentiality Index (HPI).



Geospheric Factors for a Sustainable Humanosphere

Incoming solar radiation accounts for almost all the energy available to the Earth since the formation of the geosphere. Energy is most intense across equatorial regions and scarce at higher latitudes and is a prominent factor constituting geospheric potentiality for the humanosphere. Incoming radiation provides the driving force for the global circulation of air and water, which results in an alleviation of solar energy disparity at different latitudes (Burroughs 2001). Air and water circulation is taken to be another constituting factor that represents geographic potential for a sustainable humanosphere, and was calculated by subtracting annual actual evapotranspiration from annual precipitation.

Greenhouse gas (GHG) emissions were identified as a factor that best illuminates the sustainability crisis in the geosphere, and adopted per capita CO_2 emissions as an indicator. A surge of GHG emissions from human activities affects the global circulation of the atmosphere, and the anticipated consequences of these are rapid changes in heat and rainfall patterns or, in other words, the hard-to-predict and hard-to-adopt changes of the geosphere in different parts of the world. Hence, GHG emissions are the greatest burden imposed on geospheric potentialities by anthropogenic activities.

Biospheric Factors for a Sustainable Humanosphere

Two biospheric elements were identified as constituting factors for a sustainable humanosphere: biomass and biodiversity. Forest biomass represents approximately 90 percent of global living plant biomass. Living plant biomass represents “active capital” capable of generating “interest” in the form of new growth or net primary production (Begon et al. 2006: 500). Biodiversity is also taken to be another constituting factor of the biosphere. Current levels of biodiversity are at their highest than at any other time during the past 540 million years (Benton 2009) and have developed as a result of adaption and selection in the biosphere. Genetic diversity that has accumulated over the course of the biosphere’s evolutionary history is also taken to be an essential resource for future generations.

Biological resources use was also identified as a burden on biospheric potentiality. Human appropriation of net primary production (HANPP) was adopted as an indicator expressed in terms of the amount per capita in each country. This is based on the assumption of positive species–energy relationships—that is, HANPP increase has resulted in the loss of biomass and biodiversity.

Societal Factors for a Sustainable Humanosphere

The analytical framework used in this research also construes care and population as two constituting factors for a sustainable humanosphere. Care is an essential determinant for individual and collective social well-being, and societies cannot reproduce and replenish themselves if they fail to provide adequate access to care. Problems related to access to care have become increasingly prevalent in those societies that have demonstrated the highest achievements in terms of economic productivity and human development (Myrskylä et al. 2009). Across different regions, these include increasing costs of elder care (Rechel et al. 2013), a sub-replacement fertility rate (Butler 2004; Ezeh et al. 2012), an increasing burden on household caregivers, and societal isolation. This research adopts household size and female-to-male population ratio (FMR) as a fundamental expression of care relations. Household size was selected based on the rationale that people who are regularly in close proximity to the cared for are the primary determinants of regular care (Nishi et al. 2013). FMR was also selected to represent sex disparity in care in some societies and how household-level decisions about organization and distribution of care affect well-being and strain the population structure of some countries (Nishi et al. 2013).

Population is taken as a potential of human society rather than a threat to sustainable development. As explained above, per capita GHG emissions and per capita biological resource use, rather than overall population sizes, are considered a threat to a sustainable humanosphere. At present, human societies are bearing witness to a decreasing growth rate in the global population. The challenges of a declining population will become acutely more evident in some parts of the industrialized world and, shortly, in newly industrializing countries where care for burgeoning aging populations will become necessary. Hence, this article proposes a shift from viewing populations as threats to viewing them as a transformative potential.

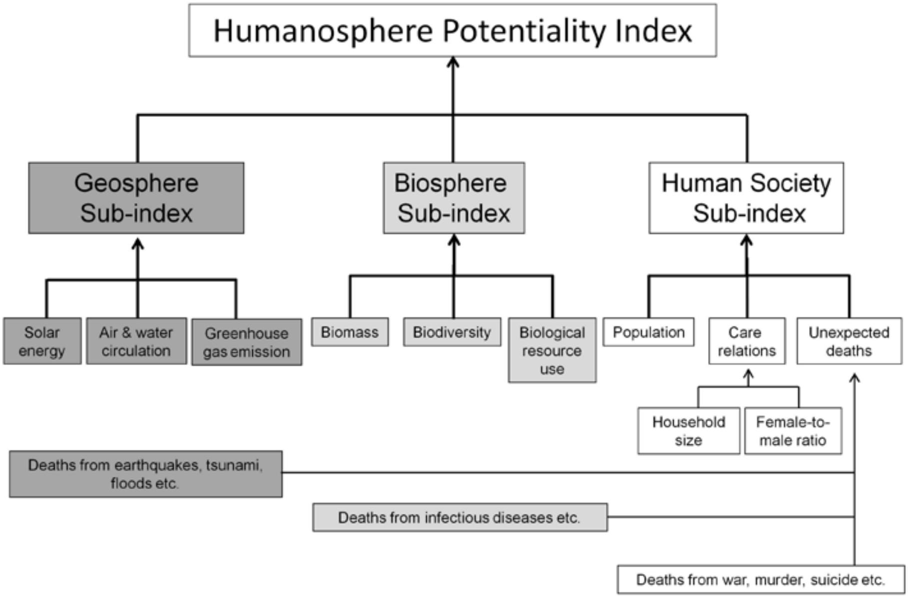
This research constructs the burden on societal potentialities as a compound of geospheric, biospheric, and societal causes for unexpected deaths. It identifies mean crude death rates caused by earthquakes, tsunamis, floods, and volcanic actions to represent the burden imposed by geospheric activities; crude death rates caused by three major infectious diseases (tuberculosis, HIV/AIDS, and malaria) as the burden imposed by biospheric elements; crude death rates caused by conflicts, homicide, and suicide as the burden imposed by humans themselves.

HPI Calculation Methodology

Figure 3 indicates how the aforementioned nine components are synthesized in the HPI. The two indicators that express potentiality and one indicator that expresses the burden are integrated into the sub-index of each sphere using the procedures of normalization and integration. All the data sources for calculating HPI are summarized in table 1.

In order to ensure normalization, two processes are carried out: (1) the distribution of the target parent population is converted into a normal distribution that uses 0.5 to represent the mean value, and (2) if any scores fall under 0 or above 1, these scores are replaced with 0 and 1, respectively. The first process is used to calculate the deviation of each sample population to the entire targeted parent population, and the second process is aimed at reducing the influence that any outliers in the population can exert on the evaluation of other samples. Through this normalization, the three indicators in each sphere are converted into scores that fall between 0 and 1. Although the analysis for constructing HPI employs 115 countries in the world as the parent population, due to restrictions to accessible data, the spatial bias introduced by

Figure 3: Structure of the Humanosphere Potentiality Index (HPI).



defective data is relatively small as illustrated in the maps (this will be discussed later). Hence, the score calculated through normalization reveals how the components of HPI are ubiquitously distributed across space when viewed from a global perspective. The three indicators for each sphere (figure 2) are integrated into the sub-index of each sphere through the following equation:

$$\textit{Sub-Index} = \frac{(\textit{Potentiality indicator } 1) + (\textit{Potentiality indicator } 2) + (1 - \textit{Burden indicator})}{3}$$

The sub-index of each sphere refers to the simple average of three normalized characteristic indicators and treats all three equally without being weighted.[5] Thus, HPI is an index that synthesizes three sub-indices; the geosphere sub-index, the biosphere sub-index, and a human society sub-index. After normalization, the index is then calculated through the following equation:

$$\textit{Humanosphere Potentiality Index} = \frac{(\textit{geosphere sub-index}) + (\textit{biosphere sub-index}) + (\textit{human society sub-index})}{3}$$

Table 1: Data Sources Employed in Humanosphere Potentiality Index (HPI)

Sub-index	Indicator	Contents	Unit	Datasets (years)
Geosphere	Solar energy	Net Radiation on the Earth's Surface (Barkstrom et al. 1990)	MJ/m^2	1984–1990 (Average)
	Air and water circulation	Difference in annual rainfall and actual evapotranspiration (FAO 2000, 2009)	mm	1961–1990 (Average)
	Greenhouse gas emissions	Total CO_2 emissions by Gas excluding LUCF (WRI 2015)	Ton/Person	2005
Biosphere	Biomass	Carbon Stock in Living Forest Biomass (FAO 2010)	Ton/ha	2010
	Biodiversity	Diversity Index based on the number of species of vascular plants, amphibian, reptiles, birds and mammals (Groombridge and Jenkins 2002)	–	Years unknown
	Biological resources use	Human Appropriation of Net Primary Production in the terrestrial ecosystem (HANPP) (Imhoff et al. 2004; Imhoff and Bounoua 2006)	Ton/Person	1995
Human Society	Population	World Population Prospects 2010 revision (UN 2011)	Person/km^2	2005
	Care relations	Average Household Size (Dorling 2007)	Person/Household	2002
		Male to Female Population Ratios (FMR) (UN 2011)	Person/Person	2005
		Death rate from Geospheric burden (earthquake, mass movement, volcano, flood and storm) (CRED 2011)	Death per 100,000 persons	1980–2011 (Average)
	Unexpected deaths	Death rate from Biospheric burden (Tuberculosis, HIV/AIDS and Malaria) (WHO 2004)		2004
		Death rate from Societal burden (suicide, murder and conflict) (WHO 2004)	Death per 100,000 persons	2004

Results and Discussion

The Worldview from the Humanosphere Potentiality Index

This section examines the worldview from HPI using figure 4, table 2, and table 3. Figure 4 presents thematic maps that illustrate the worldview from the sub-indices of the three spheres and HPI. These clearly show that the indices for tropical countries are relatively high in all four indices.[6] As such, a correlation analyses will be applied in three geographical groups: the world, the tropics, and the temperate zone.

First, figure 4a illustrates the geosphere sub-index. This will be higher in the areas with an abundance of solar energy and available water, which are related to global heat and water circulation, while the score will be lower in areas with high levels of burden caused by human society in terms of GHG emissions. Countries with high scores were concentrated in the tropical zone. In spite of their geographical locations, the scores in the Sahel area, the southern part of the African continent, the Middle East, and Mexico all demonstrate relatively low scores primarily due to dry climates. In particular, the low figure found in the oil-producing states is led by high GHG emissions. The dry climate found in these areas is largely the result of the subtropical high-pressure belt that is generated by Hadley circulation. Temperate countries generally show low figures. However, those countries that have unique characteristics in their geographical conditions or energy consumption patterns tend to present a relatively higher figure, as is the case with Japan due to its abundance of water resources, and Afghanistan with its low levels of GHG emissions.

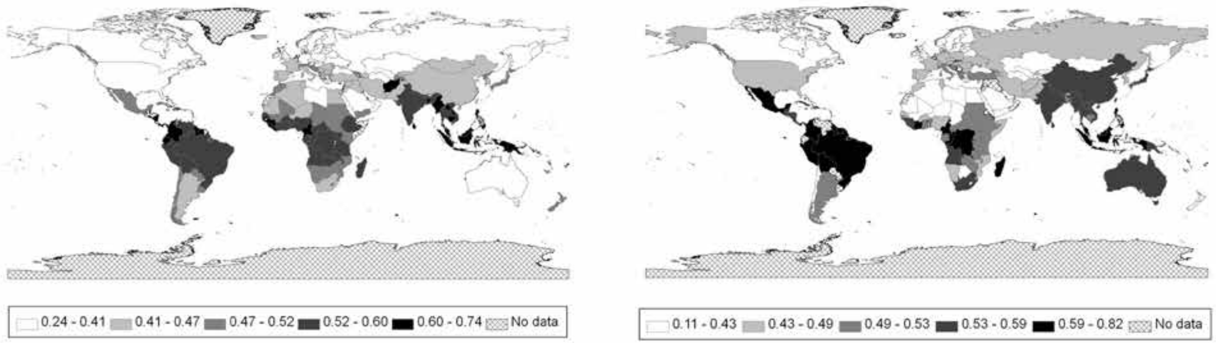
Table 3 shows a correlation among the components of the geosphere sub-index, and no correlation between solar energy and GHG emission in the tropical zone, while there is a significant negative correlation in the temperate zone. Furthermore, in terms of the relationship between solar energy and air and water circulation, no positive correlation is found in the temperate zone, whereas a significant positive correlation is observed in the tropical zone. This reflects the fact that tropical countries rely on solar energy but temperate countries rely on fossil fuels, in terms of energy usage in the modern world.

Next, figure 4b offers a comparison between a world map of the geosphere and one illustrating the biosphere sub-index. It is clear that the biosphere sub-indices for the tropical zone are also, in general, high. Table 3 shows that four indicators—solar energy, air and water circulation, biomass, and biodiversity—are strongly correlated and significant *at* the *1 percent level* in the tropics. On the other hand, there is a strong correlation between solar energy and biodiversity and also between air and water circulation and biomass, but none between air and water circulation and biodiversity or between solar energy and biomass in temperate zones. In both the temperate and tropical zones, an observable tendency reveals that biological resource use is high in places with strong air and water circulation and an abundance of biomass. However, in the temperate zone, an inverse correlation between the strength of solar energy and biological resource use can be seen. Figure 4b also highlights that the biosphere sub-index is slightly elevated in temperate countries such as Australia, the United States, China, South Africa, Japan, and Argentina. As indicated in table 2, the reasons for the

Figure 4: The worldview from the Humanosphere Potentiality Index (HPI).

(a) Geosphere Sub-index

(b) Biosphere Sub-index



(c) Human Society Sub-index

(d) Humanosphere Potentiality Index

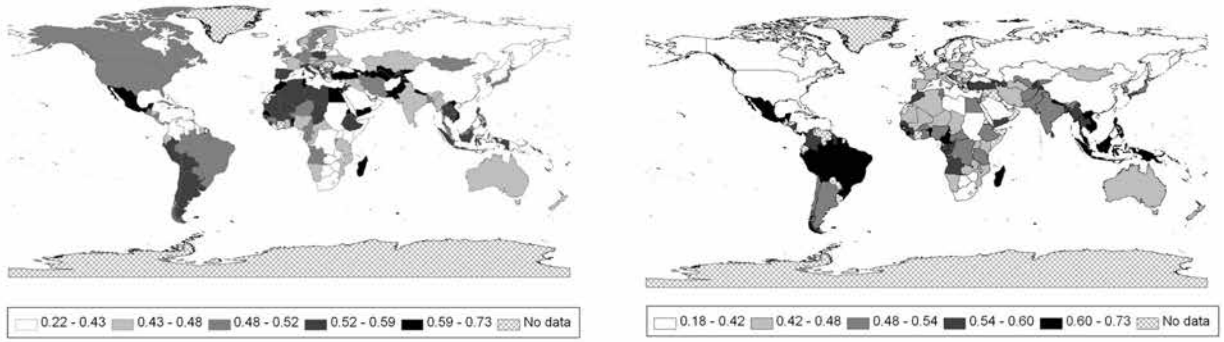


Table 2: Humanosphere Potentiality Index and Its Components

	Country	Humanosphere Potentiality Index	Geosphere				Biosphere				Human Society			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
1	Indonesia	0.726	0.712	0.661	0.710	0.453	0.611	0.598	0.731	0.497	0.545	0.481	0.538	0.490
2	Suriname	0.693	0.611	0.612	0.609	0.501	0.680	0.916	0.554	0.431	0.459	0.470	0.458	0.489
3	Philippines	0.684	0.687	0.631	0.679	0.442	0.556	0.476	0.647	0.454	0.583	0.498	0.557	0.486
4	Vietnam	0.667	0.604	0.563	0.587	0.444	0.576	0.501	0.674	0.445	0.647	0.493	0.591	0.446
5	Peru	0.657	0.597	0.588	0.548	0.444	0.606	0.586	0.667	0.435	0.531	0.472	0.465	0.421
6	Panama	0.647	0.656	0.618	0.646	0.456	0.582	0.542	0.653	0.447	0.492	0.474	0.453	0.453
7	Malaysia	0.646	0.695	0.669	0.732	0.517	0.559	0.661	0.658	0.642	0.494	0.477	0.442	0.444
8	Madagascar	0.639	0.566	0.566	0.495	0.429	0.559	0.491	0.658	0.471	0.607	0.473	0.576	0.453
9	Brazil	0.634	0.599	0.592	0.560	0.456	0.584	0.605	0.678	0.533	0.523	0.472	0.530	0.495
10	Sierra Leone	0.632	0.692	0.617	0.691	0.429	0.522	0.496	0.569	0.500	0.534	0.477	0.648	0.607
11	Mexico	0.630	0.507	0.562	0.444	0.488	0.572	0.450	0.702	0.436	0.627	0.475	0.575	0.433
12	Belize	0.630	0.584	0.575	0.564	0.472	0.554	0.605	0.561	0.503	0.581	0.471	0.591	0.493
13	Bolivia	0.629	0.549	0.579	0.469	0.449	0.566	0.523	0.607	0.433	0.593	0.471	0.532	0.422
14	Laos	0.618	0.627	0.558	0.624	0.430	0.522	0.537	0.523	0.494	0.570	0.472	0.558	0.473
15	Cameroon	0.615	0.608	0.627	0.520	0.432	0.559	0.561	0.592	0.477	0.520	0.473	0.598	0.568
16	Nepal	0.615	0.576	0.522	0.558	0.428	0.527	0.506	0.564	0.489	0.608	0.487	0.636	0.527
17	Cambodia	0.615	0.647	0.621	0.601	0.431	0.507	0.486	0.494	0.459	0.570	0.476	0.587	0.507
18	Papua New Guinea	0.611	0.738	0.645	0.762	0.438	0.540	0.547	0.655	0.583	0.415	0.471	0.425	0.505
19	Benin	0.605	0.548	0.588	0.441	0.432	0.519	0.481	0.550	0.475	0.631	0.476	0.648	0.503

Note: Background color: ▨ Top 1/3 values; ░ Middle 1/3 values; ☐ Bottom 1/3 values.

Table 2: Humanosphere Potentiality Index and Its Components (*continued*)

	Country	**Humanosphere Potentiality Index**	**Geosphere**				**Biosphere**				**Human Society**			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
20	Thailand	0.600	0.597	0.611	0.565	0.482	0.533	0.464	0.585	0.451	0.545	0.481	0.530	0.481
21	Nicaragua	0.599	0.631	0.580	0.617	0.439	0.529	0.493	0.565	0.472	0.518	0.474	0.518	0.491
22	Morocco	0.596	0.480	0.499	0.416	0.451	0.494	0.435	0.454	0.406	0.722	0.477	0.648	0.407
23	Colombia	0.592	0.669	0.602	0.682	0.450	0.609	0.571	0.711	0.455	0.323	0.473	0.534	0.713
24	Myanmar	0.589	0.648	0.553	0.669	0.430	0.535	0.484	0.557	0.434	0.469	0.476	0.587	0.613
25	Congo	0.589	0.579	0.613	0.495	0.451	0.576	0.668	0.569	0.509	0.465	0.471	0.557	0.582
26	Guinea	0.587	0.627	0.615	0.565	0.429	0.524	0.484	0.542	0.453	0.506	0.473	0.539	0.524
27	Sri Lanka	0.583	0.649	0.678	0.554	0.437	0.522	0.445	0.572	0.450	0.479	0.497	0.525	0.563
28	Georgia	0.573	0.513	0.441	0.529	0.441	0.517	0.498	0.508	0.454	0.603	0.475	0.530	0.413
29	Bangladesh	0.572	0.624	0.526	0.650	0.430	0.508	0.438	0.501	0.414	0.506	0.564	0.431	0.506
30	Guyana	0.571	0.637	0.609	0.619	0.457	0.578	0.625	0.591	0.481	0.368	0.470	0.448	0.576
31	Tajikistan	0.569	0.493	0.468	0.462	0.440	0.455	0.423	0.424	0.483	0.727	0.474	0.677	0.428
32	Senegal	0.566	0.536	0.581	0.426	0.434	0.490	0.467	0.485	0.480	0.615	0.475	0.634	0.505
33	Angola	0.566	0.548	0.597	0.445	0.446	0.547	0.508	0.564	0.430	0.502	0.471	0.614	0.601
34	Dominican Republic	0.561	0.557	0.601	0.470	0.457	0.547	0.481	0.574	0.414	0.483	0.488	0.453	0.476
35	Yemen	0.558	0.490	0.512	0.412	0.441	0.453	0.423	0.409	0.474	0.712	0.474	0.663	0.430
36	Gabon	0.554	0.594	0.610	0.559	0.482	0.509	0.678	0.566	0.718	0.499	0.470	0.560	0.549
37	Turkey	0.551	0.469	0.464	0.457	0.480	0.512	0.450	0.524	0.438	0.613	0.478	0.546	0.421
38	Azerbaijan	0.548	0.449	0.471	0.418	0.486	0.486	0.440	0.497	0.480	0.674	0.475	0.598	0.406

Note: Background color: ▨ Top 1/3 values; ░ Middle 1/3 values; □ Bottom 1/3 values.

Table 2: Humanosphere Potentiality Index and Its Components (*continued*)

	Country	Humanosphere Potentiality Index	Geosphere				Biosphere				Human Society			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
39	India	0.544	0.547	0.531	0.507	0.443	0.544	0.445	0.609	0.422	0.464	0.503	0.410	0.469
40	Congo, DRC	0.542	0.592	0.634	0.476	0.427	0.575	0.634	0.568	0.476	0.361	0.472	0.557	0.695
41	Burkina Faso	0.541	0.536	0.573	0.428	0.427	0.476	0.450	0.495	0.516	0.589	0.475	0.648	0.546
42	Pakistan	0.540	0.469	0.486	0.395	0.439	0.496	0.430	0.478	0.419	0.620	0.487	0.591	0.468
43	Ethiopia	0.539	0.546	0.582	0.439	0.428	0.500	0.428	0.543	0.472	0.534	0.476	0.579	0.536
44	Liberia	0.539	0.656	0.601	0.636	0.429	0.521	0.571	0.511	0.518	0.385	0.473	0.585	0.698
45	Argentina	0.535	0.467	0.507	0.417	0.486	0.513	0.450	0.548	0.459	0.582	0.471	0.534	0.437
46	Bosnia & Herzegovina	0.530	0.481	0.437	0.523	0.495	0.507	0.479	0.468	0.426	0.568	0.476	0.515	0.437
47	Central African Republic	0.529	0.600	0.641	0.485	0.427	0.511	0.535	0.486	0.489	0.439	0.470	0.636	0.688
48	Slovenia	0.528	0.478	0.422	0.592	0.553	0.545	0.637	0.507	0.509	0.500	0.478	0.477	0.473
49	Ghana	0.525	0.560	0.607	0.445	0.432	0.511	0.464	0.567	0.498	0.471	0.478	0.482	0.509
50	Japan	0.523	0.477	0.469	0.570	0.581	0.545	0.525	0.563	0.452	0.490	0.499	0.443	0.470
51	Tunisia	0.521	0.451	0.456	0.415	0.464	0.471	0.425	0.420	0.431	0.642	0.476	0.565	0.407
52	Croatia	0.514	0.476	0.437	0.525	0.506	0.519	0.532	0.472	0.447	0.519	0.477	0.477	0.451
53	Nigeria	0.512	0.561	0.597	0.463	0.437	0.498	0.452	0.510	0.470	0.469	0.485	0.534	0.569
54	Tanzania	0.511	0.550	0.600	0.428	0.428	0.517	0.479	0.583	0.511	0.444	0.474	0.577	0.628
55	Egypt	0.506	0.433	0.435	0.398	0.460	0.463	0.423	0.373	0.407	0.646	0.477	0.563	0.402
56	Uzbekistan	0.500	0.412	0.431	0.393	0.494	0.424	0.423	0.440	0.491	0.665	0.475	0.605	0.423

Note: Background color: ■ Top 1/3 values; ▒ Middle 1/3 values; □ Bottom 1/3 values.

Table 2: Humanosphere Potentiality Index and Its Components (*continued*)

	Country	**Humanosphere Potentiality Index**	**Geosphere**				**Biosphere**				**Human Society**			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
57	Chile	0.496	0.523	0.492	0.541	0.485	0.457	0.467	0.523	0.619	0.547	0.472	0.500	0.440
58	Afghanistan	0.494	0.704	0.475	0.426	0.000	0.480	0.425	0.455	0.442	0.322	0.474	0.285	0.465
59	Kyrgyzstan	0.494	0.469	0.460	0.427	0.444	0.456	0.430	0.424	0.487	0.598	0.472	0.568	0.454
60	South Korea	0.489	0.470	0.490	0.538	0.584	0.495	0.489	0.427	0.429	0.517	0.513	0.469	0.482
61	Slovakia	0.487	0.413	0.397	0.479	0.544	0.523	0.530	0.526	0.486	0.523	0.479	0.462	0.435
62	Turkmenistan	0.485	0.390	0.442	0.408	0.562	0.452	0.423	0.420	0.488	0.667	0.471	0.636	0.447
63	Italy	0.484	0.445	0.465	0.486	0.555	0.500	0.469	0.486	0.456	0.525	0.487	0.439	0.417
64	Mauritania	0.477	0.470	0.472	0.408	0.435	0.453	0.423	0.383	0.447	0.569	0.470	0.575	0.490
65	Algeria	0.477	0.441	0.449	0.411	0.472	0.461	0.423	0.364	0.404	0.584	0.471	0.543	0.443
66	Mozambique	0.476	0.529	0.556	0.433	0.428	0.490	0.476	0.494	0.502	0.442	0.472	0.575	0.627
67	Mali	0.475	0.489	0.498	0.410	0.427	0.444	0.428	0.409	0.505	0.563	0.471	0.618	0.540
68	Chad	0.475	0.492	0.503	0.412	0.427	0.460	0.435	0.398	0.455	0.531	0.471	0.611	0.567
69	Greece	0.475	0.426	0.469	0.463	0.573	0.498	0.438	0.510	0.455	0.529	0.478	0.439	0.403
70	Kenya	0.474	0.531	0.584	0.411	0.431	0.505	0.442	0.566	0.493	0.410	0.476	0.543	0.631
71	Portugal	0.474	0.467	0.482	0.484	0.527	0.470	0.450	0.482	0.521	0.535	0.480	0.469	0.429
72	Jordan	0.474	0.439	0.456	0.411	0.483	0.476	0.423	0.454	0.449	0.553	0.476	0.475	0.412
73	Uganda	0.474	0.557	0.624	0.418	0.428	0.515	0.438	0.574	0.467	0.366	0.481	0.569	0.711
74	Switzerland	0.474	0.476	0.411	0.571	0.526	0.497	0.510	0.471	0.490	0.478	0.485	0.416	0.443
75	Namibia	0.471	0.492	0.524	0.411	0.448	0.486	0.430	0.508	0.480	0.477	0.470	0.599	0.612
76	Moldova	0.470	0.435	0.417	0.420	0.461	0.491	0.445	0.443	0.416	0.523	0.479	0.494	0.466
77	Malawi	0.468	0.550	0.590	0.439	0.428	0.510	0.459	0.554	0.485	0.371	0.481	0.530	0.665

Note: Background color: ▩ Top 1/3 values; ▨ Middle 1/3 values; ☐ Bottom 1/3 values.

Table 2: Humanosphere Potentiality Index and Its Components (*continued*)

	Country	Humanosphere Potentiality Index	Geosphere				Biosphere				Human Society			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
78	North Korea	0.465	0.499	0.481	0.498	0.477	0.478	0.457	0.394	0.418	0.471	0.487	0.427	0.463
79	Bulgaria	0.461	0.428	0.435	0.449	0.522	0.496	0.469	0.472	0.453	0.502	0.476	0.447	0.437
80	Spain	0.460	0.421	0.469	0.440	0.561	0.481	0.442	0.471	0.471	0.535	0.478	0.462	0.420
81	Iran	0.456	0.434	0.481	0.418	0.526	0.494	0.428	0.469	0.414	0.490	0.474	0.452	0.454
82	Niger	0.452	0.471	0.464	0.410	0.428	0.455	0.423	0.428	0.486	0.515	0.471	0.573	0.546
83	Macedonia	0.447	0.457	0.456	0.457	0.494	0.515	0.481	0.503	0.440	0.412	0.477	0.449	0.536
84	Zambia	0.441	0.554	0.591	0.447	0.430	0.507	0.501	0.503	0.484	0.320	0.471	0.557	0.737
85	Mongolia	0.433	0.436	0.449	0.415	0.486	0.457	0.433	0.395	0.458	0.508	0.470	0.469	0.448
86	New Zealand	0.431	0.497	0.459	0.600	0.562	0.443	0.540	0.491	0.701	0.468	0.471	0.409	0.432
87	Poland	0.431	0.377	0.366	0.448	0.551	0.475	0.501	0.396	0.472	0.531	0.480	0.477	0.442
88	Australia	0.429	0.356	0.526	0.417	0.721	0.526	0.445	0.657	0.523	0.457	0.470	0.391	0.424
89	France	0.428	0.430	0.412	0.483	0.529	0.472	0.476	0.433	0.493	0.477	0.480	0.424	0.446
90	Ukraine	0.421	0.395	0.389	0.436	0.528	0.488	0.455	0.428	0.418	0.471	0.476	0.484	0.509
91	Hungary	0.421	0.414	0.420	0.435	0.519	0.478	0.462	0.435	0.462	0.468	0.479	0.439	0.470
92	Czech Republic	0.418	0.366	0.397	0.456	0.612	0.494	0.535	0.448	0.501	0.483	0.481	0.424	0.441
93	Lesotho	0.417	0.504	0.519	0.419	0.428	0.462	0.425	0.448	0.486	0.398	0.476	0.599	0.701
94	United Kingdom	0.416	0.410	0.355	0.539	0.567	0.453	0.438	0.364	0.444	0.507	0.492	0.416	0.418
95	Swaziland	0.413	0.490	0.508	0.416	0.440	0.488	0.455	0.539	0.529	0.359	0.476	0.599	0.742

Note: Background color: ▩ Top 1/3 values; ▨ Middle 1/3 values; □ Bottom 1/3 values.

Table 2: Humanosphere Potentiality Index and Its Components (*continued*)

	Country	Humanosphere Potentiality Index	Geosphere				Biosphere				Human Society			
			Sub-index	Solar energy	Air and water circulation	GHG emission	Sub-index	Biomass	Bio-diversity	Biological resource use	Sub-index	Population	Care relations	Unexpected deaths
96	Germany	0.411	0.373	0.370	0.470	0.585	0.480	0.520	0.394	0.474	0.486	0.490	0.409	0.431
97	Sudan	0.406	0.500	0.527	0.407	0.431	0.506	0.438	0.506	0.425	0.303	0.471	0.586	0.785
98	Libya	0.402	0.386	0.426	0.410	0.556	0.426	0.423	0.321	0.466	0.552	0.470	0.482	0.414
99	China	0.401	0.466	0.485	0.444	0.493	0.534	0.440	0.592	0.431	0.278	0.482	0.217	0.452
100	United States	0.399	0.321	0.436	0.450	0.733	0.495	0.474	0.576	0.566	0.489	0.473	0.439	0.441
101	South Africa	0.386	0.442	0.514	0.411	0.537	0.535	0.440	0.611	0.446	0.270	0.473	0.599	0.834
102	Zimbabwe	0.382	0.511	0.545	0.419	0.440	0.509	0.455	0.532	0.461	0.240	0.473	0.596	0.862
103	Denmark	0.381	0.369	0.349	0.468	0.569	0.454	0.445	0.411	0.493	0.477	0.481	0.409	0.433
104	Kazakhstan	0.376	0.357	0.407	0.407	0.589	0.457	0.425	0.419	0.473	0.472	0.470	0.500	0.517
105	Ireland	0.367	0.387	0.347	0.534	0.599	0.420	0.430	0.333	0.503	0.491	0.475	0.424	0.427
106	Latvia	0.366	0.412	0.350	0.460	0.478	0.428	0.530	0.422	0.667	0.449	0.473	0.447	0.492
107	Belarus	0.363	0.385	0.356	0.449	0.526	0.459	0.493	0.394	0.512	0.415	0.474	0.439	0.520
108	Lithuania	0.356	0.400	0.342	0.457	0.490	0.449	0.481	0.423	0.556	0.404	0.474	0.439	0.533
109	Norway	0.352	0.388	0.300	0.541	0.559	0.417	0.455	0.351	0.554	0.465	0.471	0.399	0.425
110	Russia	0.336	0.330	0.333	0.437	0.599	0.493	0.472	0.470	0.464	0.356	0.470	0.454	0.595
111	Botswana	0.335	0.480	0.519	0.408	0.463	0.463	0.450	0.457	0.519	0.258	0.470	0.493	0.737
112	Sweden	0.302	0.372	0.312	0.459	0.517	0.344	0.498	0.356	0.823	0.511	0.472	0.454	0.432
113	Canada	0.250	0.282	0.331	0.445	0.699	0.343	0.459	0.363	0.794	0.498	0.470	0.437	0.428
114	Saudi Arabia	0.247	0.350	0.450	0.409	0.649	0.426	0.423	0.348	0.492	0.278	0.471	0.197	0.422
115	Finland	0.182	0.319	0.298	0.446	0.595	0.278	0.489	0.346	1.000	0.439	0.471	0.401	0.454

Note: Background color: ■ Top 1/3 values; ▨ Middle 1/3 values; □ Bottom 1/3 values.

high figures are that the first two countries have high biodiversity, and the latter four countries have both a high level of biodiversity and low biological resource use. In Russia where boreal forests and terrestrial biomes such as the Taiga are widespread, the biosphere sub-index is also high when compared to the low geosphere sub-index. This finding, however, is led by low biological resource use. There are significant and identifiable differences between the tropical zone and temperate zone when we look at the relationships between the biosphere composite index and its components. Table 3 shows a tendency in the tropical zone for the biosphere composite index to be boosted by biomass, but this tendency is not found in the temperate zone. Conversely, the biosphere composite index in the temperate zone is boosted by low biological resource use whereas there is no correlation between these two factors in the tropical zone.

Finally, figure 4c presents the human society sub-index and clearly shows that there is a high score in Southeast Asia and in the Great Arid Zone, which stretches from Morocco to Mongolia, and a high score in temperate countries including those found on the North American continent and the temperate countries of South America. The elevated score of the tropical zone is not as evident here as in the sub-indices of the geosphere and biosphere.

It is crucial to address the reasons that the human society composite index is found to be relatively low in certain parts of the tropical zone. The factor that causes patchy patterns in Southeast Asia, South Asia, West Asia, and North Africa is variations in what are care relations. Particularly in West Asia, North Africa, and South Asia, there are many large households but these regions also include countries where a significant FMR imbalance exists within the population. When the influence of FMR imbalance is set aside, the sub-indices for South Asian countries, where the average number of people per household and the population density are both high, present the highest scores. However, when the human society sub-index is employed, because it addresses the adjusted care relations that include FMR imbalance, the scores of these countries become low. Alternatively, the low score of the human society sub-index in tropical Africa is led by a number of facts; population is lower than in comparison with Asia, the size of the household is smaller than Asia, and unexpected deaths from infection and conflicts are much more frequent. In particular, the low score for Sub-Saharan Africa is strongly influenced by the number of deaths from infections including tuberculosis, HIV/AIDS, and malaria. In South America, the low score in some countries such as Colombia and Venezuela is notable, but this is the result of high rates of death from murder and conflict, in addition to a low population. The low scores in temperate industrial countries, particularly in Northern Europe and Russia, are influenced by high rates of suicide in addition to a low population and the small size of households.

An examination of the relation between the human society sub-index and its constituent components shows a positive correlation between care relations and unexpected deaths in both the temperate and tropical zones (table 3). The higher the population, the less unexpected death occurs in the tropical zone, while there is no correlation between these two variables in the temperate zone.

Table 3: Pearson Correlation Coefficients among Humanosphere Potentiality Index (HPI) and Its Components

		1. HPI	**2. Geo-All**	**3. Bio-All**	**4. Human-All**	**5. Geo-P1**	**6. Geo-P2**	**7. Geo-B**	**8 Bio-P1**	**9. Bio-P2**	**10. Bio-B**	**11. Human-P1**	**12. Human-P2**	**13. Human-B**
1. Humanosphere Potentiality Index (HPI)	World													
	Tropical zone													
	Temperate zone													
2. Geosphere Sub-index (Geo-All)	World	.803**												
	Tropical zone	.755**												
	Temperate zone	.677**												
3. Biosphere Sub-index (Bio-All)	World	.790**	.681**											
	Tropical zone	.744**	.622**											
	Temperate zone	.692**	.442**											
4. Human Society Sub-index (Human-All)	World	.458**	.006	−.014										
	Tropical zone	.632**	.168	.077										
	Temperate zone	.614**	.078	.016										
5. Solar energy (Geo-P1)	World	.745**	.858**	.710**	−.023									
	Tropical zone	.600**	.795**	.600**	.063									
	Temperate zone	.688**	.593**	.606**	.205									
6. Air and water circulation (Geo-P2)	World	.561**	.658**	.497**	−.018	.401**								
	Tropical zone	.681**	.885**	.547**	.039	.523**								
	Temperate zone	.128	.247*	.164	−.100	.124								

Table 3: Pearson Correlation Coefficients among Humanosphere Potentiality Index (HPI) and Its Components (*continued*)

		1. HPI	**2. Geo-All**	**3. Bio-All**	**4. Human-All**	**5. Geo-P1**	**6. Geo-P2**	**7. Geo-B**	**8 Bio-P1**	**9. Bio-P2**	**10. Bio-B**	**11. Human-P1**	**12. Human-P2**	**13. Human-B**
7. GHG emissions (Geo-B)	World	–.470**	–.704**	–.292**	–.086	–.485**	–.114							
	Tropical zone	–.188	–.323**	.210	–.202	–.239	.124							
	Temperate zone	–.416**	–.842**	–.255*	–.095	–.284*	–.051							
8. Biomass (Bio-P1)	World	.424**	.426**	.605**	–.122	.370**	.701**	–.001						
	Tropical zone	.507**	.481**	.753**	–.056	.472**	.658**	.271*						
	Temperate zone	–.030	.005	.162	–.232	–.223	.719**	.065						
9. Biodiversity (Bio-P2)	World	.691**	.683**	.824**	.002	.760**	.435**	–.357**	.402**					
	Tropical zone	.705**	.656**	.756**	.113	.604**	.453**	–.058	.335**					
	Temperate zone	.400**	.326**	.743**	–.029	.701**	.152	–.268*	.225					
10. Biological resource use (Bio-B)	World	–.404**	–.186*	–.453**	–.167*	–.215*	.223**	.171*	.239**	–.078				
	Tropical zone	–.038	.120	–.189	–.150	.164	.316**	.190	.216*	.068				
	Temperate zone	–.655**	–.341**	–.712**	–.201	–.437**	.250*	.187	.404**	–.120				
11. Population (Human-P1)	World	.155	.117	.082	.241**	.057	.068	.209**	.064	.105	–.041			
	Tropical zone	.147	.218	–.036	.321**	.066	.127	.252*	.127	.139	–.045			
	Temperate zone	.272*	.143	.300*	.082	.147	–.083	.264*	–.102	.130	–.038			
12. Care relations (Human-P2)	World	.453**	.377**	.240**	.468**	.404**	–.047	–.531**	–.019	.315**	–.199**	–.077		
	Tropical zone	.155	.174	–.195	.427**	.168	–.221*	–.577**	–.180	.040	–.178	–.064		
	Temperate zone	.502**	.257*	.222	.602**	.301*	–.152	–.452**	–.165	.266*	–.198	–.115		
13. Unexpected deaths (Human-B)	World	–.070	.316**	.195*	–.574**	.410**	–.108	–.304**	–.021	.255**	–.101	–.137	.442**	
	Tropical zone	–.536**	–.010	–.176	–.670**	.091	–.258*	–.301**	–.193	–.056	–.146	–.224*	.364**	
	Temperate zone	–.225	.075	.146	–.494**	.167	–.173	–.174	–.023	.230*	–.053	–.103	.392**	

Note: * and ** indicate significance at the 5 percent and 1 percent levels, respectively. Shaded cells indicate correlation coefficients between index or sub-index, which indicators were aggregated.

Figure 4d offers a synthesis of the three spheres. The index that indicates the average of all three sub-indices is the HPI. In this index, the scores for the tropical zones of Southeast Asia and Latin America are high, as are the scores for Central Africa. Table 2 shows that in the countries with the highest figures of the HPI, the human society sub-index is above average in most of the countries. This is in addition to the fact that the sub-indices of geosphere and biosphere are also generally high.

As discussed in the materials and method section, the foundation for evaluating the three spheres is rooted in the effort to take into account the logics of each sphere. Based on this understanding, we offer an interpretation of what HPI actually signifies from the mutual relationships between the three spheres' sub-indices in table 3. These do not display any substantial differences between the tropical and temperate zones. The high correlation between the geosphere and the biosphere is recognizable but the relationship between the human society sub-index and the other sub-indices does not reveal any significant correlation. Considering the chronological order of the formation of the three spheres, the biosphere and human society progressively inherit the logics of the preceding spheres as well as forming/possessing their own unique logics. Mutual relations among the three sub-indices indicated the inheritance of logic from the geosphere to the biosphere, and a high independency of the logic in human society. This independency can be interpreted as referring to a high level of evolution evident in human society. However, when considered from a different perspective, it can be an indication that currently, human society does not significantly pay due consideration to both the geosphere and biosphere.

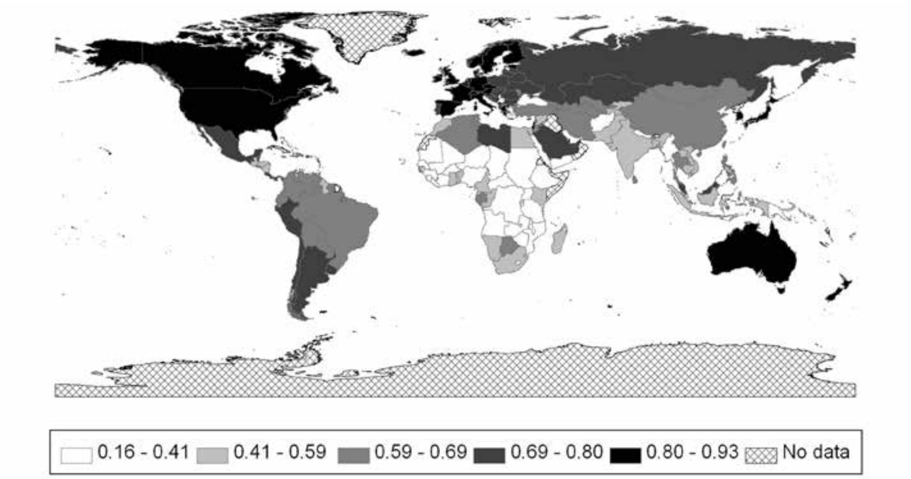
The Differences between the Human Development Index and the Humanosphere Potentiality Index

To understand the perspective of HPI, a comparison with the HDI presents an alternative view. Figure 5 offers a worldview from HDI in 2005 (UNDP 2010). North America, Western Europe, Japan, Korea, Australia, and New Zealand, which all display high economic development, long average life expectancy, and long schooling years, are high-ranked countries. On the other hand, Sub-Saharan African, South Asian, and Southeast Asian countries are ranked low.

A visibly evident gap exists between the HPI (figure 4d) and the HDI (figure 5). In order to examine the relationship between these two indices, the correlation between them is illustrated in figure 6, through categorizing the world (115 countries) into temperate countries (60 countries) and tropical countries (55 countries). Tropical countries show a significant positive correlation whereas the temperate countries indicate a negative correlation, significant *at* the *0.01 level.* Entirely converse correlations are evident in these two zones, but what does this difference signify?

Table 4 indicates the correlation between the HDI and each of the components of the HPI in the tropical and temperate countries. First, examining tropical countries that indicate a positive correlation between the HDI and HPI, we clearly see a strong correlation between the biosphere sub-index and the HDI. This is due to the fact that tropical areas with high HDI are areas that possess an abundance of biomass and biodiversity as well as enough air and water circulation. However, a positive correlation

Figure 5: The worldview from the Human Development Index (HDI).



was also observed between HDI and GHG emissions. The correlation observed between the HDI and the constituent components of the HPI in the tropical countries is considered a reflection of the connection to "ecosystem services" as described in the Millennium Ecosystem Assessment conducted by the United Nations (MEA 2005).

Second, we examine the temperate countries that demonstrate a negative correlation between the HPI and the HDI. Among the components of the HPI, the negative correlation between the geosphere and biosphere sub-indices and HDI is significant. Examining the specific components of the sub-index individually, the

Figure 6: Relationships between the Humanosphere Potentiality Index (HPI) and the Human Development Index (HDI).

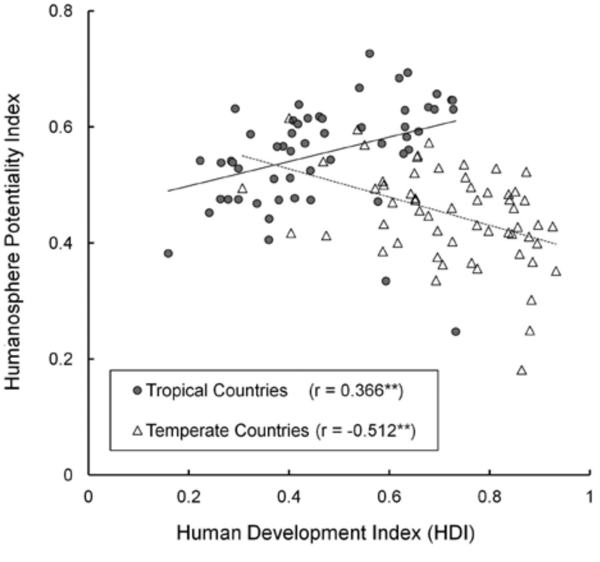


Table 4: Pearson Correlation Coefficients among HDI and the Components of the Humanosphere Potentiality Index

	Tropical countries (55 countries)				**Temperate countries (60 countries)**			
Correlations	*Sub-index*		*Component*		*Sub-index*		*Component*	
Positive	Biosphere	0.491**	Air and water circulation	0.357**			Air and water circulation	0.426**
			GHG emissions$^{\#}$	0.609**			GHG emissions$^{\#}$	0.612**
			Biomass	0.351**			Biomass	0.399**
			Biodiversity	0.338**			Biological resource use	0.386**
Negative			Care relations	0.562**	Geosphere	0.582**	Solar energy	0.517**
			Unexpected deaths$^{\#}$	0.553**	Biosphere	0.241*	Biodiversity	0.250*
							Care relations	0.462**
							Unexpected deaths$^{\#}$	0.375**

Note: $^{\#}$ indicates burden indicator. * and ** indicate significance at the 5 percent and 1 percent levels, respectively.

temperate countries that demonstrate a high HDI score also possess characteristics of weak solar energy, low biodiversity, high air and water circulation, and an abundance of biomass. However, the zone also has tendencies to display high GHG emissions and a high biological resource use, which is indicative of how far the geosphere and biosphere are disturbed.

A similar elevated tendency is recognized in both the HPI and the HDI in tropical countries, but such a tendency disappears in temperate countries and represents an interesting finding. Nonetheless, as table 4 indicates, there is a clearly observed correlation in countries with high HDI and high GHG emissions in both tropical and temperate zones. This means that the countries that have achieved a high level on the HDI have been contributing to the deterioration of the environment regardless of where the country is located.

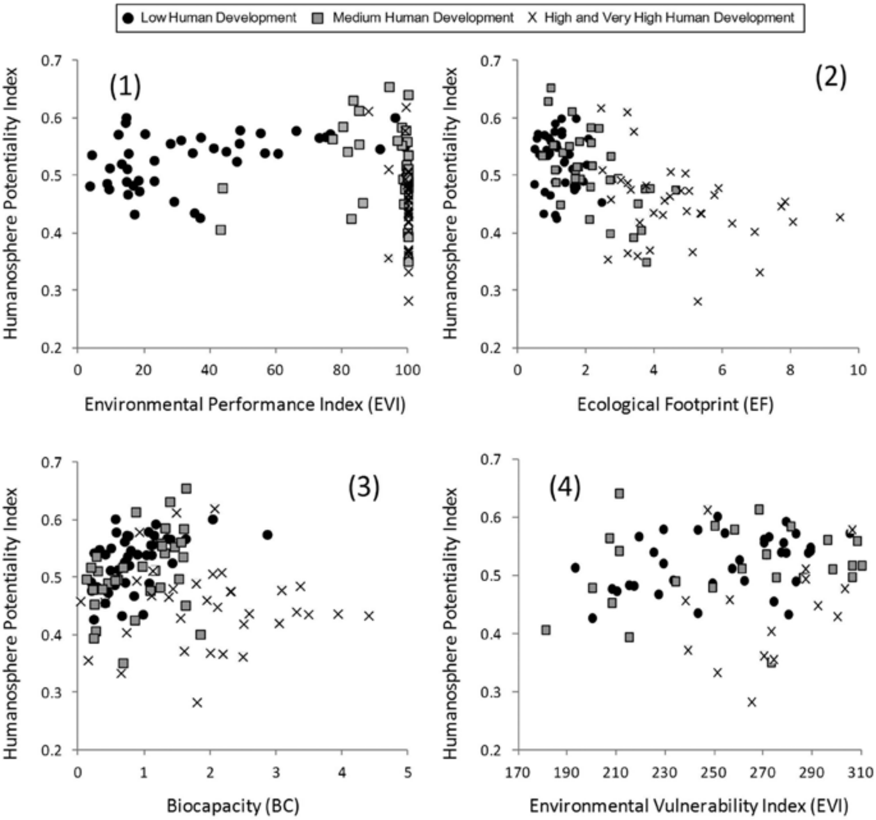
Finally, there is a need to discuss and situate the concept of "care," an important value in human society and integral indicator in this research. In both temperate and tropical countries, a strong negative correlation between care relations and HDI can be recognized, and a correlation between unexpected deaths and HDI is also observed (table 4). Focusing on the direction of causality, the correlation suggests that care found in the household does not render HDI low, but importantly, care in the household is compensating for a situation in which public societal services have not yet been sufficiently implemented. Thus, HDI is improved by establishing public sector provisions for education and health care in developed economies. In countries lacking these conditions, we can statistically verify that care within a household serves as the foundation of human society. The question facing us now is how to expand care into the public sphere without losing the essential value provided in the intimate sphere.

Differences between Current Environmental Indices and the Humanosphere Potentiality Index

As indicated, there has also been intensive work on developing environmental indicators such as the EPI, EF, and EVI. All of these have been developed to measure—with uncertainty—biological and ecological systems, and the rate of chemical and physical processes in an attempt to put forward quantitative appraisals on the present flows and future estimated stocks of the biosphere in different climatic regions. Although the above indicators have different approaches, utilize different indicators and categories to conceptualize, calculate, weight, and measure, they are all concerned with providing a detailed snapshot of the current state of humanity's impact on the planet. With the exception of EVI, these environmental indicators measure the present country-level performance related to environmental sustainability; therefore, a comparison with HPI provides an explanation as to how performance contributes to sustainability in the long run.

Figure 7 and table 5 present the comparison of the Humanosphere Potentiality Index with EPI, EF, BC, and EVI, with categorical information of Human Development (HD). The EPI is constructed through calculating and aggregating more than twenty indicators that reflect national-level environmental data. These

Figure 7: Comparison of the Humanosphere Potentiality Index (HPI) with other environmental indicators (HDI ranking in 2005 [UNDP 2010] was also used for country categorization).



1. EPI scores in 2010 (Hsu et al. 2016)
2. EF scores (global ha per personal) in 2005 (GFN 2008)
3. BC scores (global ha per unit country area) in 2005 (FAO 2016; GFN 2008)
4. EVI scores in 2004 (Kaly et al. 2004)

form nine categories under two objectives: ecosystem vitality and environmental health. Within these there are policy categories (sub-categories) and indicators. The indicator has a proximity to target that benchmarks performance against targets. EPI and HPI have a significant negative relationship for 114 countries, although most of the countries except those with a low HD status score high EPI value. This means that environmental policies in the countries with higher HD were better maintained from the perspective of the EPI. On the other hand, the relationship between EPI and HPI are positively correlated in low HD countries. As high HPI scores are commonly observed in the countries where geosphere and biosphere sub-indices were also high, this correlation means that countries possessing rich ecosystem services may try to conserve their value through the implementation of environmental policies.

Table 5: Pearson Correlation Coefficients between the Humanosphere Potentiality Index (HPI) and Four Environmental Indicators

	All countries	**Low Human Development**	**Medium Human Development**	**High and Very High Human Development**
EPI	–0.214**	0.444***	0.076	–0.354**
EF	–0.574***	–0.176	–0.595**	–0.305*
BC	–0.133	0.478***	0.390*	–0.015
EVI	0.017	0.447***	0.166	0.233

Notes: *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent levels, respectively. EPI—Environmental Performance Index; EF—Ecological Footprint; BC—Biocapacity; EVI—Environmental Vulnerability Index.

The Ecological Footprint Accounts set out to measure the supply of and demand on the natural environment, based on the idea of human appropriated carrying capacity proposed by Rees (1992). On the demand side, EF is a measure of how much area of biologically productive land a population/activity is required to produce all resources consumed and absorb generated waste. It accounts for the flow of energy and matter to and from a defined economy. Highly significant negative relationships were observed between EF and the HPI among all countries, although this relationship was not observed in the low HD countries group (table 5). It is natural that increasing EF will threaten future sustainability through decreasing natural capitals, but these correlations indicate that the threat to long-term global sustainability is the higher consumption level in medium and higher HD countries. High EF scores in high HD countries were caused by higher emissions of carbon dioxide (WWF 2014); therefore, GHG emissions in these countries have to be regulated even though environmental policies are considered well implemented from EPI assessment.

From the supply side of the ecological footprint accounts, BC, is the capacity of ecosystems to produce useful biological materials demanded by the economy and to absorb waste materials generated by human society. A positive correlation between BC and HPI in the low HD country group was significant at the 1 percent level, but its significance decreased as HD level increased (table 5). Considering the positive impact of the geosphere and biosphere sub-indices on HPI scores, this fact implies that natural environment conditions limited agricultural production in lower HD countries. This suggests that it is necessary to consider the introduction of appropriate technology and institutions in these countries.

EVI has been designed to reflect the extent to which the natural environment of a country is prone to damage and degradation (Kaly et al. 2004). Based on fifty indicators estimating the vulnerability of the environment of a country and its future shocks, these are combined—by simple averaging and simultaneously reporting as a single index—a range of policy-relevant thematic sub-indices. As a profile it produces results for each indicator (SOPAC and UNEP 2005). A highly significant relationship between EVI and HPI was observed in the low HD country group. This means that long-term sustainability in these countries can be accomplished only through the careful management of their natural environments. This suggests that there are limits in the approaches of the above indexes and how they capture and present our current "perceived" conditions.

Limitations of the Humanosphere Potentiality Index

After publishing the results of the HPI in Japanese, several criticisms were raised toward our approach (Furusawa 2012; Kurosaki 2013; Yamagata 2013), as well as a critical appraisal of the humanosphere program itself (Kato 2015). These included criticisms of the HPI development objectives, the selection of relatively static variables that do not respond to performance changes, the integration of indicators with different characteristics, and the choice of the indicators. We acknowledge these limitations and have tried to justify the HPI approach within such constraints. In particular, with the geosphere and biosphere potentiality indicators, we have employed a relatively static value that is not affected by societal performance on the natural environment. In addition, the HPI presented here provides only a snapshot of how things have progressed so far. Therefore, we cannot predict any trends in the decrease of forested areas and we cannot propose or evaluate ideal technologies or special structures for institutions in different regions to deal with changes. However, when combined with the performance indicator, we can provide a reference point for thinking about how we can overcome current assessments and biases as observed in the previous section. It enables us to provide an indication of the world's current situation in a much more comprehensive manner by presenting an agenda that is neither included nor addressed by the HDI or other current indicators.

For the calculation of HPI, indicator values are standardized, integrated into the sub-index, and those sub-indices in the three spheres were integrated again without weighing. We understand that such a calculation process makes the trade-off relationship between the variables invisible. However, our aim has been to provide a simple index expressing sustainability from a long-term perspective. In formulating the HDI, Sen (1999a) has noted how the economist Mahbub al Haq insisted on the need for a crude but convenient index expressed in a simple number. We agree with Haq's considerations and this informed and enabled the combination with other indicators.

We also acknowledge problems in the selection of the indicators. This is due to limitations in data availability. Care relations might be expressed far better from the evaluation of work–life balance or average time spent with family than from the combination of household size and FMR. However, such indicators are available only in selected, mainly industrialized, countries. We cannot extrapolate and evaluate developing or newly industrializing countries based on such limited data. We have compromised indirect indicators as we aimed to provide a global view of humanosphere potentiality. Further research in indicator studies and the development of clear data sets at a global level would provide opportunities to refine our approach.

Conclusion: From Capability to Potentiality

The aim of this research has been to develop HPI to provide a new framework that extends the capability approach to address future environmental sustainability. To conclude this article, we affirm the significance of the research.

HPI was developed using the framework called the "Humanosphere," to enable a different way to understand the current condition of the world that is compatible with a strong sustainability paradigm. As a result, tropical countries where the geosphere and biosphere sub-indices possess high scores were positively evaluated. In particular, HPI demonstrates the significance of tropical countries for global sustainability. The well-being of future generations and humanity very much depends on the way we confront the role of the geosphere and biosphere in these countries. The comparison between the HDI and HPI clearly asks us to reconsider current developmental paradigms, as indicated by the HDI, emphasizing health, education, and income. Comparisons with other environmental indicators reveal the need to control societal demands on biological resources, and the importance of appropriate technological and institutional development in countries with lower human development status while considering their environmental vulnerability. This research suggests the need to transform our way of life and recognize intergenerational equity for societal access and utilization of natural capital. The HPI shows that we should not minimize the roles of the geosphere and biosphere by considering their use values solely in terms of providing for the material prosperity of human society. Instead we should pay much more attention to the logics intrinsic to the geosphere and the biosphere and how they support human society. This requires that we include ongoing evolutionary and terrestrial history and place the geosphere and biosphere at the heart of debates for the global long-term sustainability of human society in the present and for the future.

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Notes

1. In this article, we use the term "indicator" following Meadows (1998). Indicators are necessary part of the stream of information used to understand the world, make decisions, and plan our actions in the present and for the future. Terms such as "index" or "sub-index" are used where indicators are aggregated.
2. In 2010, the enrollment rate was changed to number of years in school.
3. Between 2007 and 2012, a large-scale, five-year Japanese Ministry of Education (MEXT) funded government program brought together more than a hundred scholars to conduct a wide range of interdisciplinary studies on sustainable development in Asia and Africa from a global, long-term perspective.
4. Without serious goals and global political will for meeting food security and environmental sustainability against projected population trends and the growth of middle classes in newly industrialized countries, current agricultural production trends will come under stress by the mid-twenty-first century (Foley 2011

et al.; Randers 2012). Further expansion of croplands for human needs and biofuel also degrades carbon stocks in natural vegetation and soils (West 2010).

5. With the burden indicator, by subtracting from 1, the evaluation that the figure provides is reversed in a positive direction.
6. The concept of a tropical country can include various definitions in terms of nature, geology, ecology, and culture, but the term "tropical zone," as used in this article, refers to the country's territories located in the area lying between the tropics of Cancer and Capricorn centered around the equator.

References

Baccini, P., and P.H. Brunner. 2012. *Metabolism of the Anthroposphere: Analysis, Evaluation, Design.* 2nd ed. Cambridge, MA: MIT Press.

Bäckstrand, K. 2006. "Democratizing Global Environmental Governance? Stakeholder Democracy after the World Summit on Sustainable Development." *European Journal of International Relations* 12: 467–498.

Ballet, J., D. Bazin, J-L. Dubois, and F-R. Mahieu. 2011. "A Note on Sustainability Economics and the Capability Approach." *Ecological Economics* 70: 1831–1834.

Barkstrom, B.R., E.F. Harrison, and R. B. Lee. 1990. "Earth Radiation Budget Experiment: Preliminary Seasonal Results—EOS Transactions." *American Geophysical Union* 71(9): 297–304.

Begon, M., C.R. Townsend, and J.L. Harper. 2006. *Ecology: From Individuals to Ecosystems*. 4th ed. Malden, MA: Wiley-Blackwell.

Benton, M.J. 2009. "The Red Queen and Court Jester: Species Diversity and the Role of Biotic and Abiotic Factors through Time." *Science* 323: 728–732.

Bossel, H. 1996. "Deriving Indicators of Sustainable Development." *Environmental Modeling and Assessment* 1: 193–218.

Burroughs, W.J. 2001. *Climate Change: A Multidisciplinary Approach*. 2nd ed. New York: Cambridge University Press.

Butler, D. 2004. "The Fertility Riddle." *Nature* 432: 38–39.

Centre for Research on the Epidemiology of Disasters (CRED). 2011. EM-DAT, International Disaster Database. http://www.emdat.be.

Constanza, R. 2007. "Sustainability or Collapse: What Can We Learn from Integrating the History of Humans and the Rest of Nature?" *Ambio* 36(7): 522–527.

Constanza, R. 2014. "Time to Leave GDP Behind." *Nature* 505: 283–285.

Daly, H. 1996. *Beyond Growth: The Economics of Sustainable Development*. Boston: Beacon Press.

Dietz, R., and D. O'Neil. 2013. *Enough Is Enough: Building a Sustainable Economy in a World of Finite Resources*. Oakland, CA: Berrett-Koehler.

Dietz, S., and E. Neumayer. 2006. "A Critical Appraisal of Genuine Savings as an Indicator of Sustainability." In *Sustainable Development Indicators in Ecological Economics: Current Issues in Ecological Economics*, ed. P. Lawn, 117–138. Cheltenham: Edward Elgar.

Dorling, D. 2007. Worldmapper Dataset 191: Households. SASI. University of Sheffield. http://www.worldmapper.org/display.php?selected=191# (accessed 15 November 2016).

Esty, D.C., T. Srebotnjak, C.H. Kim, M.A. Levy, A. de Sherbinin, and B. Anderson. 2006. *Pilot 2006 Environmental Performance Index*. New Haven, CT: Yale Center for Environmental Law and Policy.

Ezeh, A.C., J. Bongaarts, and B. Mberu. 2012. "Global Population Trends and Policy Options." *Lancet* 380: 142–148.

Foley, J.A. et al. 2011. "Solutions for a Cultivated Planet." *Nature* 478: 337–342. doi:10.1038/nature10452.

Food and Agriculture Organization of the United Nations (FAO). 2000. Global Map of Monthly Precipitation: 10 Arc Minutes. http://ref.data.fao.org/map?entryId=dabc5510-88fd-11da-a88f-000d939bc5d8&tab=about (accessed 5 December 2016).

Food and Agriculture Organization of the United Nations (FAO). 2009. Global Map of Yearly Actual Evapotranspiration: 5 Arc Minutes. http://ref.data.fao.org/map?entryId=750d56ca-f92a-405e-8bbc-302221d55917&tab=about (accessed 5 December 2016).

Food and Agriculture Organization of the United Nations (FAO). 2010. *Global Forest Resources Assessment 2010*. Rome.

Food and Agriculture Organization of the United Nations (FAO). 2011. *The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk*. Abingdon: Earthscan.

Food and Agriculture Organization of the United Nations (FAO). 2016. *FAOSTAT: Land-Country Area*. http://www.fao.org/faostat/en/#data/RL (accessed 5 December 2016).

Fukai, S. 2006. "Comparative Study of Theories on Sustainability at the World Level." *Academia (Journal of the Nanzan Academic Society): Humanities and Social Sciences* 82: 409–451.

Fukuda-Parr, S., and A.K.S. Kumar, eds. 2009. *Oxford Handbook of Human Development: Concepts, Measures, and Policies*. New Delhi: Oxford University Press.

Furusawa, T. 2012. "Book Review: T. Sato, T. Wada, K. Sugihara, and Y Mine, eds., 2012, Humanosphere Potentiality Index: Beyond the *P*erspective of *the* Human Development Index." *Asian and African Area Studies* 12(1): 104–107 (in Japanese).

Georgescu-Roegen, N. 1977. "Inequality, Limits and Growth from a Bio-economic Viewpoint." *Review of Social Economy* 35(3): 361–375.

Global Footprint Network (GFN). 2008. National Footprint Accounts 2008 Edition. Available at http://www.footprintnetwork.org/download.php?id=507 (accessed December 5 2016).

Groombridge, B., and M.D. Jenkins. 2002. *World Atlas of Biodiversity: Earth's Living Resources in the 21st Century*. Berkeley: University of California Press.

Hamilton, K., and M. Clemens. 1999. "Genuine Savings Rates in Developing Countries." *World Bank Economic Review* 13: 333–356.

Hartwick, J.M. 1990. "Natural Resources, National Accounting and Economic Depreciation." *Journal of Public Economics* 43: 291–304.

Hsu, A. et al. 2016. *Environmental Performance Index*. New Haven, CT: Yale University. www.epi.yale.edu.

Imhoff, M.L., and L. Bounoua. 2006. "Exploring Global Patterns of Net Primary Production Carbon Supply and Demand Using Satellite Observations and Statistical Data." *Journal of Geophysical Research* 111: D22S12. doi:10.1029/2006JD007377.

Imhoff, M.L., L. Bounoua, T. Ricketts, C. Loucks, R. Harriss, and W.T. Lawrence. 2004. "Global Patterns in Human Consumption of Net Primary Production." *Nature* 429(24): 870–873.

Intergovernmental Panel on Climate Change (IPCC). 2013. "Climate Change 2013: The Physical Science Basis." https://www.ipcc.ch/report/ar5/wg1 (accessed 15 November 2016).

Intergovernmental Panel on Climate Change (IPCC). 2014. "Climate Change 2014: Mitigation of Climate Change." Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. http://ipcc.ch/report/ar5/wg3 (accessed 15 November 2016).

International Institute for Sustainable Development (IISD). 2011. "Compendium: A Global Directory to Indicator Initiatives." http://www.iisd.org/measure/compendium (accessed 15 November 2016).

International Social Science Council (ISSC). 2016. "Transformations to Sustainability." http://www.worldsocialscience.org/activities/transformations (accessed 15 November 2016).

Jordan, A. 2008. "*The Governance of Sustainable Development: Taking Stock and Looking Forwards*." *Environment and Planning C: Government and Policy* 26: 17–33.

Kaly, U.L., C.R. Pratt, and J. Mitchell. 2004. "The Demonstration Environmental Vulnerability Index (EVI) 2004." *SOPAC Technical Report* 384.

Kato, T. 2015. "'Humanosphere' and the Future of Area Studies." *Asian and African Area Studies* 15(1): 94–124 (in Japanese).

Knowledge Economy Indicators (KEI). 2005. "Work Package 7: State-of-the-Art Report on Simulation and Indicators."

Krausmann, F., et al. 2013. "Global Human Appropriation of Net Primary Production Doubled in the 20th Century. *PNAS* 100(25): 10324–10329.

Kurosaki, T. 2013. "Book Review: T. Sato, T. Wada, K. Sugihara and Y. Mine, eds. 2012. *Humanosphere Potentiality Index: Beyond the Perspective of the Human Development Index*." *Socio-Economic History* 78(4): 146–147 (in Japanese).

Mather, A.S. 1990. *Global Forest Resources*. London: Belhaven Press.

Mayumi, K. 2001. *The Origins of Ecological Economics: The Bioeconomics of Georgescu-Roegen.* London: Routledge.

Meadows, D. 1998. *Indicators and Information Systems for Sustainable Development: A Report to the Balaton group.* Hartland, VT: Sustainability Institute.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

Mine, Y. 2012. "Measuring the Humanosphere: Beyond the GDP and HDI Perspective." In *Humanosphere Potentiality Index: Beyond the Perspective of the Human Development Index*, ed. T. Sato et al., 25–46. Kyoto: Kyoto University Academic Press (in Japanese).

Myrskylä, M., H-P. Kohler, and F.C. Billari. 2009. "Advances in Development: Reverse Fertility Declines." *Nature* 460: 741–43. doi:10.1038/nature08230.

Neumayer, E. 2013. *Weak versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms.* 4th ed. Cheltenham: Edward Elgar.

Nishi, M., T. Sato, and T. Wada. 2013. "Measuring Care Practices: The Key Issue for a Sustainable Human Society." Proceedings of the Third Annual Conference of the Japan Association for Human Security Studies. Keio University, Japan, 21 September.

Randers, J. 2012. *2052: A Global Forecast for the Next Forty Years.* White River Junction, VT: Chelsea Green.

Rees, W.E. 1992. "Ecological Footprints and Appropriated Carrying Capacity: What Urban Economics Leaves Out. *Environment and Urbanization* 4(2): 121–130.

Rechel, B., E. Grundy, J-M. Robine, J. Cylus, J.P. Mackenbach, C. Knai, and M. McKee. 2013. "Ageing in the European Union." *Lancet* 381(9874): 1312–1322.

Rockström, J. et al. 2009. "A Safe Space for Humanity." *Nature* 461: 472–475. doi:10.1038/461472a.

Sen, A. 1999a. Assessing Human Development*:* UNDP, *Human Development Report 1999*. New York: Oxford University Press.

Sen, A. 1999b. *Development as Freedom.* Oxford: Oxford University Press.

Sierferle, R.P. 2010. *The Subterranean Forest: Energy Systems and the Industrial Revolution.* Cambridge: White Horse Press.

Smil, V. 2013. *Harvesting the Biosphere: What We Have Taken from Nature.* Cambridge, MA: MIT Press.

Şorman, A.H. 2015. "Societal Metabolism." In *Degrowth: A Vocabulary for a New Era*, ed. G. D'Alisa, F. Demaria, and G. Kallis, 41–45. London: Routledge.

South Pacific Applied Geoscience Commission and United Nations Environment Programme (SOPAC and UNEP). 2005. "Environmental Vulnerability Index: EVI Country Profiles." http://gsd.spc.int/environmental-vulnerability-index (accessed 15 November 2016).

Stiglitz, J.E., A. Sen, and J-P. Fitoussi. 2009. "Report by the Commission on the Measurement of Economic Performance and Social Progress." http://www.stiglitz-sen-fitoussi.fr/en/index.htm (accessed 15 November 2016).

United Nations (UN). 2011. "The World Population Prospects 2010 Revision." http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2010/WPP2010_Volume-I_Comprehensive-Tables.pdf (accessed 15 November 2016).

United Nations Development Programme (UNDP). 1990. Human Development Report 1990. New York: Oxford University Press.

United Nations Development Programme (UNDP). 2010. Human Development Report 2010. New York: Oxford University Press

van Zeijl-Rozema, A., R. Cörvers, R. Kemp, and P. Martens. 2008. "Governance for Sustainable Development: A Framework." *Sustainable Development* 16(6): 410–421.

Wackenagel, M., and W.M. Rees. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island, BC: New Society.

World Commission on Environment and Development (WCED). 1987. "Report of the World Commission on Environment and Development: Our Common Future." http://www.un-documents.net/our-common-future.pdf (accessed 15 November 2016).

West, P.C. et al. 2010. Trading Carbon for Food: Global Comparison of Carbon Stocks vs. Crop Yields on Agricultural Land. *PNAS* 107(46): 19645–19648.

World Health Organization (WHO). 2004. "The Global Burden of Disease: Disease and Injury Country Estimates." http://www.who.int/healthinfo/global_burden_disease/estimates_country/en (accessed 15 November 2016).

World Resources Institute (WRI). 2015. "CAIT-Historical Emission Data: CAIT Country GHG Emissions." http://www.wri.org/resources/data-sets/cait-historical-emissions-data-countries-us-states-unfccc (accessed 15 November 2016).

World Wildlife Foundation (WWF). 2014. *Living Planet Report 2014 Species and Spaces, People and Places.* WWF International, Gland Switzerland.

Yamagata, T. 2013. "The Humanosphere Potentiality Index: Its Implications and Challenges to It." *Southeast Asian Studies* 51(1): 173–178 (in Japanese).