Review of composite environmental indicators

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Abstract. Indicators are used in almost every scientific field to quantify and/or record and/or follow the evolution of a specific parameter. Environmental indicators are related to the environment quality and are specifically used to monitor the quality of the environment and to measure the environmental performance. They can be categorized into specific, composite and personal environmental indicators. A review of the composite environmental indicators used in the literature are presented here. Composite environmental indicators include indicators coming from the synthesis of specific indicators or cover the relationships between the environment and the economic and social sectors. The main composite environmental indicators reported in the literature are: Sustainable Development Goals Index, Ecological Footprint, Environmental Performance Index, Environmental Sustainable Index, Air Quality Index, Policy Performance Index, Genuine Progress Indicator, Living Planet Index and Bhutan Gross National Happiness Index.

1 Introduction

The general term "indicator" refers to anything that indicates something. It is a sign or a measure of something [1]. The term indicator finds application in various scientific fields, such as the environment. Environmental indicators are related to the environment and are powerful tools to monitor the quality and status of the environmental and to measure the environmental performance [2].

Environmental indicators are categorized in various ways. Here, the categorization of the indicators is chosen based on the characteristic they examine. Specifically, the indicators are divided into specific, composite and personal environmental indicators. However, the limits separating indicators into specific, composite or personal are not always clear [2].

Specific environmental indicators include indicators related to the natural and to the anthropogenic environment. In particular, the specific environmental indicators for the natural environment refer to the atmosphere, water, soil and biodiversity [3]. On the other hand, the specific environmental indicators for the anthropogenic environment are mainly related to socio-economic activities. Socio-economic anthropogenic activities (e.g. waste production, energy activities, population, transport, etc.) are directly linked to the environment and the use of resources and ecosystems, as human activities have a direct impact on the environment and are in large degree the cause of change in the state of the natural environment [2]. These indicators are presented in another work [4].

The environment is considered as one of the three pillars of development, where it is directly linked to the other two pillars, the economic and the social ones. Therefore, there is a need for indicators that could capture the relationships between the environment and the other two pillars [2]. Composite environmental indicators either include all three of these pillars or are a combination of specific environmental indicators.

Personal environmental indicators are indicators related to the attitudes and behaviors of citizens towards environmental issues. The behavior of citizens towards the environment is directly related to their opinion of nature and their relationship with it [5] and various works have studied the attitude and behavior of citizens on various environmental issues e.g. climate change [6], renewable energy sources [7], waste management [8], green growth [9], etc. The personal environmental indicators are created by the researchers themselves and the main of them are the New Environmental Paradigm Scale [10], the Environmental Attitude Inventory, the General Ecological Behavior Scale, the Motivation Toward the Environment Scale, the Connectedness to Nature Scale, the Ecocentric Scale and the Anthropocentric Scale. These indicators are presented in another work [11].

This paper reviews and synthesizes the main composite environmental indicators reported in the literature, which are: Sustainable Development Goals Index, Ecological Footprint, Environmental Performance Index, Environmental Sustainable Index, Air Quality Index, Policy Performance Index, Genuine Progress Indicator, Living Planet Index and Bhutan Gross National Happiness Index. This paper is the second one of a series of three papers dealing with environmental indicators. The first one deals with the specific indicators

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[4], while the third one is focused on the personal ones [11].

2 Composite environmental indicators

Composite environmental indicators are the indicators coming from the synthesis of specific indicators or cover the relationships between the environment and the economic and social sectors [3]. The main composite environmental indicators reported in the literature are summarized below.

2.1 Sustainable Development Goals Index (SDG index)

In 2015, the United Nations 2030 Agenda for Sustainable Development was adopted by all member states. Agenda 2030 includes 17 Sustainable Development Goals (SDGs) and 169 targets and is a milestone for the international community, as for the first time "universal" goals were set internationally, where all countries, both developed and developing, are called to implement them together [12].

The 17 Sustainable Development Goals [12] are:
1. No poverty,
2. Zero hunger,
3. Good health and well-being,
4. Quality education,
5. Gender equality,
6. Clean water and sanitation,
7. Affordable and clean energy,
8. Decent work and economic growth,
9. Industry, innovation and infrastructure,
10. Reduced inequalities,
11. Sustainable cities and communities,
12. Responsible consumption and production,
13. Climate action,
14. Life below water,
15. Life on land,
16. Peace, justice and strong institutions,
17. Partnerships for the Goals.

In 2016, the European Commission issued a communication entitled "Next steps for a sustainable European future". This communication outlines the policies that contribute to the 17 UN SDGs [13]. Furthermore, in 2017, the European Commission developed a set of indicators to monitor progress towards the SDGs and their targets at local, national, regional and global levels [13]. Indicators help countries develop implementation strategies and allocate resources accordingly [14]. The set of European Union (EU) indicators for the SDGs is reviewed every year. The set of indicators for the 2022 report has been revised to align with the 8th Environment Action Plan and the new objectives of the European Pillar of Social Rights Action Plan. The analysis of secondary impacts, covering CO2 emissions, ecological footprint on Earth, material footprint and gross value added generated outside the EU from consumption within the EU, has also been improved. Finally, the report includes specific analysis

of the impacts of the Covid-19 pandemic in the SDGs [15].

In addition, each country should choose the number and range of complementary national indicators that best suit its needs and according to its capacity to collect and analyze data [14].

2.2 Ecological Footprint (EF)

The ecological footprint captures the demand and supply of nature. This indicator measures how much nature we "have" and how much we "use" [16].

On the demand side, the ecological footprint measures the ecological capital needed by a given population to produce the natural resources it consumes (including plant products, livestock and fishery products, timber and other forest products, and urban space infrastructure) and to absorb its waste, mainly its carbon emissions [16].

On the supply side, the biodiversity of a city or state represents the productivity of its ecological assets (including crops, pastures, woodlands, fishing grounds and drylands). These areas, especially if left unharvested, can also absorb much of the waste generated from the human activities, especially carbon emissions from the combustion of fossil fuels [16].

The ecological footprint identifies the use of six categories of productive land areas: 1) cropland, 2) grazing land, 3) fishing grounds, 4) built-up land, 5) forest area, and 6) carbon demand on land [16].

The ecological footprint of any city or state can be compared to its bio-capacity. If the ecological footprint of the population exceeds the biocapacity of the area, then that area has an ecological deficit. Conversely, if an area's biocapacity exceeds its ecological footprint, then it has an ecological reserve [16].

2.3 Environmental Performance Index (EPI)

The Environmental Performance Index rates 180 countries on their environmental performance. Specifically, for 2022, 40 performance indicators are used in eleven categories, covering targets for climate change performance, environmental health and ecosystem vitality. These measurements provide an indicator at a national scale and facilitate comparisons between countries in terms of environmental performance [17].

The Environmental Performance Index uses a hierarchical framework that groups indicators within categories, categories within policy objectives and policy objectives into the overall index. It is based on three policy goals: climate change, which measures climate change mitigation, environmental health, which measures threats to human health, and ecosystem sustainability, which measures natural resources and ecosystem services. These objectives reflect the dominant policy areas of environmental policy makers [17].

The 40 indicators are grouped into the following 11 categories:

1. Air quality (household solid fuels, PM2.5, VOCs, CO, SO_2, NO_x, O_3),
2. Sanitation and drinking water (sanitary, drinking water),
3. Heavy Metals (lead),
4. Waste management (solid waste, recycling, ocean plastics),
5. Biodiversity and habitat (marine protected areas, terrestrial biological protection in national and global weights, species protection index, protected area representativeness index, species habitat index),
6. Ecosystem services (tree cover loss, grassland loss, wetland loss),
7. Fisheries (fish stock status, marine trophic index),
8. Climate change mitigation (carbon dioxide in total and by energy sector, methane, nitrogen oxide, black carbon),
9. Acid rain (sulphur oxide, nitrogen oxide),
10. Water resources (wastewater treatment),
11. Agriculture (sustainable nitrogen management index, pesticides).

The overall environmental performance index rankings indicate which countries are doing the best against the environmental pressures they face. Such analysis can help improve policy choices, understand the determinants of environmental progress, and maximize the return on government investment [17].

2.4 Environmental Sustainable Index (ESI)

The Environmental Sustainable Index is a measure of overall progress towards environmental sustainability. The index provides a composite profile of national environmental management based on a collection of indicators derived from several variables [18].

Since 2005, the environmental sustainable index has incorporated 76 variables into 21 environmental sustainability indicators for 146 countries. These indicators fall into the following five broad categories [19]:
1. Environmental systems,
2. Reduction of environmental stresses,
3. Reducing human vulnerability to environmental stresses,
4. Social and institutional capacity to respond with environmental challenges,
5. Global stewardship.

The purpose of this index is to create a comparative index of environmental sustainability at the national level and to provide a mechanism to make environmental management more quantitative, more empirically justified and more systematic [18].

2.5 Air Quality Index (AQI)

The air quality index is a tool for measuring ambient air quality. It is used to express the level of risk to human health associated with air pollution from particulate and gaseous pollutants [20].

The index was first introduced by the US Environmental Protection Agency in 1998 and classified

ambient air quality according to the concentrations of the main air pollutants: PM10, PM2.5, O3, SO2, NO2 and CO. Subsequently, similar indicators were developed in various countries (e.g. France, Great Britain, Germany etc.), as well as in Greece [21, 22].

In the case of the USA, the United States Environmental Protection Agency (EPA) has established national air quality standards to protect public health. The index ranges from 0 to 500. The higher the value, the higher the level of air pollution and the greater the health concern. The range of the index is divided into 6 levels and defines the air quality as follows: 1) 0 – 50 = good, 2) 51 – 100 = moderate, 3) 101 – 150 = unhealthy for sensitive groups, 4) 151 – 200 = unhealthy, 5) 201 – 300 = very unhealthy and 6) 301 – 500 = hazardous [23]. Every day, the maximum concentrations of the most important pollutants are monitored in more than a thousand locations. These measurements are converted to an air quality index value for each pollutant using standardized formulas developed by the Environmental Protection Agency. The higher of these values is referred to as the air quality index value for that day. Many cities also provide forecasts of the next day's index price [23].

In the case of Europe, the European Environment Agency's European Air Quality Index allows users to understand more about the air quality where they live. Updated data for the entire Europe is provided daily so that users can obtain information about the air quality of European countries, regions and cities [24]. Three different indexes have been developed to enable the comparison of the three different time scales: Hourly index (describes today's air quality, based on hourly values and updated hourly), Daily index (represents the general air quality status of yesterday, based on daily values and updated once a day) and Annual index (represents the general state of air quality on an annual basis and is compared to European air quality standards) [25].

2.6 Policy Performance Index (PPI)

The Policy Performance Index creates a map of reforms that are necessary in key policy areas for each country, asking how well individual countries have succeeded in achieving sustainable policy outcomes. Central issues at the international level concerning sustainability, social progress and quality of life are examined [26].

The Policy Performance Index measures the performance of 41 countries under review based on three key dimensions of sustainability: economic, social and environmental policies. A total of 16 individual policy areas are examined, the effects of which are captured through a wide range of quantitative and qualitative data [26].

When evaluating the three individual policy areas, the following issues are considered [26]:
• Economic policies - growth prospects without limitations in the areas: economy, labour markets, taxes, budgets, research and innovation, global financial system,

• Social policies - ensuring the participation of current and future generations in the areas of: education, social inclusion, health, family, pensions, integration policy, safe living conditions, global social inequalities,
• Environmental policies in the areas of environmental policy on energy and climate, waste and air pollution and natural resources, and global environmental protection.

A wide range of quantitative indicators underpinning this category also allows for the systematic assessment of environmental policy outcomes (e.g. greenhouse gas emissions, renewable energy sources, particulate pollution, waste recycling) and the assessment of issues of concern to the planet, e.g. evaluation of policies to mitigate the Covid-19 pandemic [27].

This model incorporates the idea that the long-term sustainability of economic, social and environmental systems can only be achieved by measures that consider these systems as a whole [26].

2.7 Genuine Progress Indicator (GPI)

The Genuine Progress Indicator is an indicator to measure the economic development of a country. It is considered an alternative measurement to the Gross Domestic Product (GDP) measurement, aiming to better approximate sustainable economic well-being [28].

The genuine progress indicator is a macroeconomic indicator to measure whether the environmental impacts and social costs of economic production and consumption in a country are negative or positive factors in the overall health and well-being of its citizens [29]. The indicator starts with GDP and adds "goods" that are not counted in GDP, such as child/elderly care and volunteering, subtracts "costs", such as oil spills and crime, and balances out long-term investment costs, such as spending on roads and drainage systems [30].

The Genuine Progress Indicator addresses five key weaknesses of GDP [28]:
1. Poor linkages between consumption and quality of life,
2. Failure to account for defensive expenditures that do not improve welfare,
3. Failure to address sustainability,
4. Exclusion of all non-market benefits and costs,
5. Failure to be responsive to inequality.

The Genuine Progress Indicator is expressed by an equation containing seven significant sums of 26 underlying indicators that can be traced to each of the key concepts: prosperity and sustainability. The equation is as follows [28]:

$$GPI = Cadj + G + W - D - S - E - N \quad (1)$$

where:
Cadj = personal consumption adjusted to account for income distribution,
G = growth in capital and net change in international position,
W = non-monetary contributions to welfare (e.g. household labor, volunteer work),
D = defensive private expenditures,

S = depletion of social capital (e.g. cost of crime, family breakdown, lost leisure time),
E = costs of environmental degradation, and
N = depletion of natural capital.

The Genuine Progress Indicator can be used to capture the costs of policies that degrade environmental policy, as well as the goods of those that improve it, such as those that reduce the costs of pollution or those that reverse the depletion of natural capital through ecological restoration [28].

2.8 Living Planet Index (LPI)

The Living Planet Index is a set of global indicators used to monitor progress towards the Aichi Biodiversity Targets agreed by the Convention on Biological Diversity in 2010. The Aichi Targets require states to take effective and urgent action to stop the loss of biodiversity and to ensure that ecosystems are resilient and continue to provide essential services, thereby ensuring the life of the planet and contributing to human well-being and the eradication of poverty [31].

The Living Planet Index is a measure of the state of global biodiversity based on population trends of vertebrate species from around the world [32]. The index tracks abundance trends of a large number of populations of vertebrate species. It is based on time series data for 16,704 populations consisting of 4,005 species of mammals, birds, reptiles, amphibians and fish from around the world, collected from various sources. The data used are time series of either population size (population size per unit area), abundance (number of individuals per sample), or an abundance proxy (eg, the number of nests or breeding pairs, rather than a direct population count). For each population, the rate of change from one year to the next is calculated [31].

The Living Planet Index is an indicator of population trends, based solely on available verified data. The index is constantly updated and changes with each new species or population added, showing population changes [31].

2.9 Bhutan Gross National Happiness Index (GNH)

The phrase 'Gross National Happiness (GNH)' was first coined by the 4th King of Bhutan, King Jigme Singye Wangchuck, in 1972 when he declared, "Gross National Happiness is more important than Gross Domestic Product". The concept implies that sustainable development should take a holistic approach towards notions of progress and give equal importance to non-economic aspects of wellbeing [33].

The GNH Index includes both traditional areas of socio-economic concern and less traditional aspects of culture and psychological wellbeing. It is a holistic reflection of the general wellbeing of the Bhutanese population rather than a subjective psychological ranking of 'happiness' alone [33].

In the first publication, GNH was understood as containing four different aspects: good governance, sustainable socio-economic development, preservation

and promotion of culture and environmental conservation [34]. By 2008, these four pillars were further refined into nine domains, which articulated the different elements of GNH in greater detail and formed the basis of GNH measurements, indices and screening tools [35]:
1. Good governance.
2. Living standards.
3. Community vitality.
4. Education.
5. Time use.
6. Psychological well-being.
7. Cultural resilience.
8. Health.
9 .Environment.

In accordance with the nine pillars of the GNH index, Bhutan has developed 38 sub-indexes, 72 indicators and 151 variables that are used to define and analyze the happiness of the Bhutanese people [35].

In 2008, GNH was made part and parcel of Bhutanese policy making when it was enshrined in the Constitution of 2008: "[…] if the Government cannot create happiness for its people, there is no purpose for the Government to exist." [36].

The GNH Index is decomposable by any demographic characteristic, meaning it can be broken down by population group, for example, to show the composition of GNH among men and among women, or by district, and by dimension, for example to show which group is lacking in education. The indicators and domains aim to emphasise different aspects of wellbeing, and different ways of meeting underlying human needs [33].

3 Conclusions

Environmental indicators are indicators related to the environmental quality. The main composite environmental indicators either include the three pillars of development (environment, economic and social) or are a combination of individual specific environmental indicators and are powerful tools for the monitoring of the quality and status of environmental progress and for the measurement of the environmental performance.

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