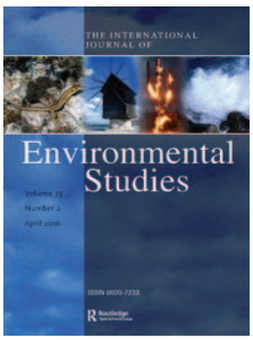

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Trends in human development and environmental protection

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Even if the will to follow a sustainable lifestyle in the Western countries is increasing, many developing countries are experiencing their phase of economic growth, threatening and overexploiting their environment. This study compares the Living Planet Index and the Human Development Index, and suggests that societies follow common patterns of development, from the indigenous lifestyle to undeveloped society, through a developing stage, towards a developed state. According to these common steps each society exploits local, regional and sometimes global natural resources to nourish its economic growth. If developing countries will not undertake strategies to skip the 'intermediate' stage of overexploitation of natural resources during their growing phase, Earth systems may not be able to keep alive the global biodiversity, and provide ecosystem services that sustain humanity.

Keywords: Human development; Environmental protection; Trends

Introduction

Our Planet is facing a series of challenges that could lead to a loss of ecosystems' integrity. These challenges are caused by human consumption of natural resources and space [1]. The recent agreement signed at the United Nations climate summit in Paris (December 2015) has been hailed as historic, ground-breaking, and unprecedented. At the same time, the targets seem to be so ambitious that many climate analysts do not believe the agreement will change the current climatic situation. The Paris agreement aims to limit temperature increase to a level below 2 °C, above pre-industrial levels, and recognizes that avoiding 1.5 °C of warming would significantly reduce the risks and impacts of climate change. Unfortunately, the emissions reduction commitments may fail to achieve these targets because it seems impossible to avoid the 1.5 °C limit without 'negative emissions', such as absorbing carbon dioxide out of the air, using technologies that are still unavailable or of questionable quality.

In addition to climate change, the major cause of biodiversity loss in recent times is the associated destruction and degradation of habitat [2]. More than half of the estimated original extent of temperate broadleaf forests had already been converted to agriculture, forest plantations and urban areas prior to 1950 [2]. In contrast, deforestation and land-use change accelerated in the tropics after 1950 [2]. The use of freshwater ecosystem services is now well beyond levels that can be sustained even at current demand [3]. Moreover,

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forecasts consistently suggest that demand for water (e.g. human water footprint) will continue to rise in most parts of the world [4]. Furthermore, the impact of an increasing global demand for palm oil products continues to be one of the main driving factors behind a recent dramatic decline in forest cover of South-east Asia [5]. For instance, figures suggest that the two orang-utan species have already undergone a tenfold decrease in population size during the twentieth century [6] and many populations are now at very low numbers. In the marine domain a high demand for fish and fish products combined with overcapacity in the global fishing fleet and inefficient fishing techniques have led to massive overfishing [7].

The most widely used indicator for human development is the United Nations Development Programme's (UNDP) Human Development Index (HDI) which, by combining income, life expectancy and educational attainment, compares countries, assessing both their economic and social development level [8]. Unfortunately it is not easy to use this index in comparison with other global indicators. For instance, the relationship between Ecological Footprint (an indicator of the impact of human actions on the environment) and HDI is not linear, and it is possible to misunderstand some points which could be fundamental to questions of development in the future. In countries with a very low level of development, the HDI is independent from per capita Footprint. But as development increases beyond a certain level, so does per person Footprint, eventually to the point where small gains in HDI come at the cost of very large Footprint increases [7]. These considerations make Ecological Footprint inadequate for analysing the state of global environmental and wildlife conservation as well as for evaluating the human impact on our Earth. Moreover, after the intersect point of increasing development/decreasing environment it is possible to find another point of increasing sustainability/decreasing footprint. This never cited second stage seems to be the only possibility to cope with a planet overpopulated by people, ensuring a high level of biodiversity protection and ecosystems conservation.

To interpret better the conservation state of biodiversity and ecosystems and track the pressures upon them and responses to those trends, a wide range of measures is now available [9,10]. One of the longest-running measures of trends in the state of global biodiversity is the Living Planet Index (LPI) [7]. Both the HDI and the LPI could have been driven by different antecedent conditions, such as colonization history, natural resources availability, etc.

The LPI uses a series of indicators to monitor biodiversity, human demand on renewable resources, and ecosystem services. The LPI reflects changes in the health of the planet's ecosystems by tracking trends in populations of mammals, birds, fish, reptiles and amphibians [7]. For a better understanding of the current situation in terms of the LPI, here considered as a proxy of environmental protection, it is opportune to analyse the planet according to its 5 biogeographical realms.

In North America, including Greenland there is a remarkable LPI stability. This is probably because of effective environmental protection and conservation efforts since 1970. For this biogeographical realm, the index has few inferences and a very high degree of confidence [7].

In the Afrotropical realm, instead, populations of species show signs of recovery since the mid-90s when the index reached a low −55%, even if it is still −18%. This increase may be partly caused by better protection of wildlife in nature reserves and national parks in countries where relatively good data are available, such as Uganda. Data from a greater range of African countries would provide a more detailed picture of these trends and the drivers behind them [7].

The decline in the Neotropical realm reflects widespread land-use changes and industrialization across the region since 1970, but also in part the catastrophic declines in amphibian numbers caused often by fungal disease. Tropical forest loss in this realm is estimated to be about 0.5% per year, with the total area lost between 2000 and 2005 being in the range of 3–4 million hectares per year [11,12].

The increase in the Palearctic, instead, may be caused by better environmental protection in some countries since the 1970s for populations of some species which are now recovering. This picture might change if individual countries' data were analysed, as most population data come from Europe, with comparatively few data from northern Asia [7].

The Indo-Pacific realm includes the Indo-Malayan, Australasian and Oceanic realms. Its decline reflects rapid agricultural, industrial and urban development across the region, which has led to the most rapid destruction and fragmentation of forests, wetlands and river systems – a pattern seen elsewhere in the world [2,13]. Tropical forest covers between 1990 and 2005, for example, declined more rapidly in Southeast Asia than in Africa or Latin America, with estimates ranging from 0.6 to 0.8% per year [11,12].

Currently an increase in consumption seems to be needed for an increase in development [14] but this is not always true [15]. In the World individuals from different countries consume vastly different amounts; richer and more developed countries tend to consume more than poorer, less developed countries. The scenario presented by the LPI does not tell the whole story as data have been taken since 1970 when most of populations of the Palearctic and Nearctic were already developing with damaging effects for their environment. If we were to look farther back, before the 1970s, we would probably find a lower LPI for Europe and North America and one slightly less low for the countries that have recently been developing.

A high level of human development, where people have the ability to reach their potential and lead productive, creative lives following their needs and interests [8], is clearly essential for all individuals, but it usually implies an overexploitation of natural resources and ecosystem services. This study analyses the development patterns followed by societies during human history [16–18], and shows a common trend for every civilization with an inverse relation between human development level and environmental exploitation, at least until a specific point of development. Understanding where this point is set will be fundamental to ensure that the 4–5 billion people living either under development levels or in developing countries avoid the phase of 'overexploitation' of natural resources, dangerously achieved by the 2 billion people currently living in 'developed countries'. This has caused ecosystems to collapse.

Materials and methods

To analyse the effect of human development on environmental exploitation there are several indicators, models and tools available. Two of the most valid, discussed earlier, are the LPI and the HDI. The LPI is an indicator of global biological diversity, based on trends in vertebrate populations of world. The LPI provides more reliable information on the state of wildlife than the Ecological Footprint Index, which includes more (confounding) variables, apart from biological populations. This analysis uses mainly the LPI because it provides to the general public, scientists and policy-makers the basic information on trends in the abundance of vertebrates and offers insights into ecosystems where species are rapidly declining. The HDI is a composite statistic used to rank countries by

level of 'human development'; it allows for discrete assessment of developed (high development), developing (middle development), and underdeveloped (low development) countries. The statistic is based on data of life expectancy, education and Gross National Income per-capita, as an indicator of standard of living collected at national level.

Let there be two curves, one for the HDI and another for the Environmental Protection level (derived from LPI). These curves are approximated by the sigmoid function, formalized as $\frac{\mathrm{dHd}}{\mathrm{d}t} = \alpha \cdot \mathrm{Hd} \cdot (1 - \frac{\mathrm{Hd}}{K})$ and $\frac{\mathrm{dEp}}{\mathrm{d}t} = \beta \cdot \mathrm{Ep} \cdot (1 - \frac{\mathrm{Ep}}{K})$, where Hd stands for Human Development, Ep for Environmental Protection, t is the time, α a growth constant variable and K is the carrying capacity of the system (Earth). The Hd function grows slowly compared to the Ep function. This means that $\alpha < \beta$. Figure 1 shows the points a and b in the graph as the intersections of the two curves and the solutions of the following system:

$$\frac{\mathrm{dHd}}{\mathrm{d}t} = \alpha \cdot \mathrm{Hd} \cdot \left(1 - \frac{\mathrm{Hd}}{K}\right) \tag{1}$$

$$\frac{\mathrm{dEp}}{\mathrm{d}t} = \beta \cdot \mathrm{Ep} \cdot \left(1 - \frac{\mathrm{Ep}}{K}\right) \tag{2}$$

The yellow area α (figure 1) is the solution of the integral function $\int_a^b \mathrm{Hd} - \mathrm{Ep}$.

To move beyond this area, in an imaginary temporal shift, which represents the loss of natural resources, biodiversity and ecosystem services during the descendent phase of the Ep function, the Hd function must move directly from the point a to the point b and this is possible only if an input factor (ε) is added to the growth variable α. Thus the equation of HD becomes

$$\frac{\mathrm{dHd}}{\mathrm{d}t} = (\alpha + \varepsilon) \cdot \mathrm{Hd} \cdot \left(1 - \frac{\mathrm{Hd}}{K}\right). \tag{3}$$

The input factor ε represents the supply of technologies, education and tools (know-how) to preserve nature and protect the environment that 'sustainable countries' (Section 5 in the graph in figure 1) and 'developed countries' (Section 4, which could shift to 'sustainable lifestyle' in the 5th stage of development, figure 1) should transfer to the undeveloped and developing countries (Sections 2 and 3, figure 1) to allow them to avoid the yellow area α of environmental overexploitation, in the next decades.

Results

According to the LPI 2014 of the 5 biogeographical World realms [7], the Nearctic region (North America and Greenland) shows a −4% loss of populations, a value close to the LPI of the 1970s, which means an improvement of the protection and conservation measures from that period. The Palearctic region has an LPI value of +43% compared to the 1970s. This clearly signals the recovery of natural animal populations and forest regrowth through better environmental protection actions. The situation, on the contrary, is markedly different in the Afrotropical, Neotropical and Indo-Pacific realms where the index is respectively

−18, −55 and −66%. These values assume great importance in the trend analyses between human development and environmental protection.

Analysing the HDI, the lowest level of human development is in Africa (with a range of 0.3–0, in a scale from 1 to 0), but this continent accounts for the highest LPI in the Southern realms. South-east Asian and South American countries show a mean HDI that varies respectively from 0.7 to 0.4 and from 0.8 to 0.6, but with a lower LPI than in the Afrotropical realm (Figure 1).

From the graphical representation of the two indices, there is obtained the graph in figure 1. The blue line is derived from the LPI, 'Environmental protection' (EP), which varies from 0 to 100 and the red line is derived from the HDI, 'Human development' (HD), which varies from 0 to 100. The *x* axis can be considered either as a static (discrete) representation of the main countries of the world grouped in 21 clusters of HDI or a dynamic evolution of human development/environmental protection during time from approximately 2000 years ago up to the present [19].

Considering the modern global situation we can subdivide the human populations in 5 categories represented by the Sections (1–5) in the graph. Section 1 includes every population living in a real 'indigenous' lifestyle. Today, this category does not account for more than 300 million people, worldwide, scattered in small groups. Section 2 represents the undeveloped (or 'Third world') populations, about 1 billion people living under the level of development (<0.3 HDI), mostly in Africa. Section 3 includes the developing countries, accounting for more than 3.5 billion people, particularly distributed in South America, South-East Asia and India. Section 4 includes the developed countries with a population of 2 billion people, living especially in North America, Eurasia and Japan. Section 5 represents a small number of 'sustainable countries' with a population of about 500 million

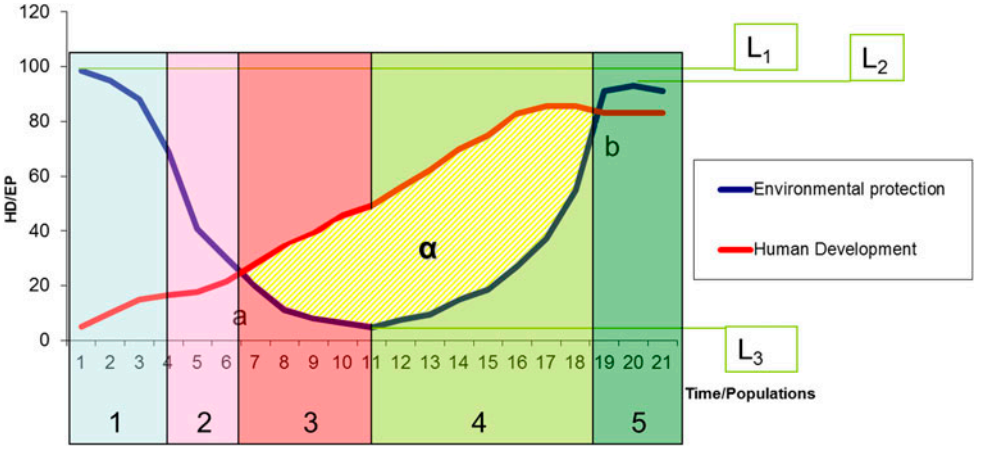

Figure 1. Global trends of human development (HD) during time in relation with different levels of environmental protection (EP).
The abscissa is a temporal scale of societies evolution. Ordinate is the level of HD/EP. The 5 sectors represent different stages of development and simplify the condition of the World populations (see the text for more details). The points (a) and (b) are the intersections of the two curves (HD and EP) in the low and high states. The α area indicates the period of human development during which populations exploit the environment leading to a loss of biodiversity and ecosystem services, before moving beyond the point (b) to reach high level (L2) of environmental protection. L1 is the environmental protection level of 'indigenous' populations. L3 is the lowest level of EP during the developing phase.

people living in some European countries (Germany, Norway, Sweden, etc.) and some in the USA. These countries have reached the sustainable life level with a high standard of nature conservation and environmental protection.

Figure 1 can be seen in a dynamic way as showing a discrete period during human history. Considering the abscissa as the time-scale from 2000 year ago to the present (thus, twenty-first centuries) we have an illustration of the global trends of populations' development. From an indigenous state (Section 1) where only a little proportion of humanity survives, many civilizations moved towards the underdevelopment stage (Section 2) even if most of the African societies are still there. Then, through a developing step (Section 3), where we can find the big percentage of today's modern civilizations, some societies (Euro Asiatic, Japanese and North American in particular) reached the 'developed standards' (Section 4) during the nineteenth–twentieth century. Most of these still keep that standard and do not move ahead. Very few countries reached in the twenty-first century the 'sustainable' life standard (Section 5), such as a lifestyle that is considered 'developed' according to HDI definitions but which allows, at the same time, a high level of LPI.

Discussion

Analysing step by step the situation described in figure 1, it is possible to define three levels of environmental protection. Level 1 (L1) is maintained when the population lives in an 'indigenous way' that is usually completely compatible with the environment. This is the case, for instance, of Maasai in Serengeti, the Baka in Central Africa, some other African tribes and a few groups in South America, Northern, Central and South-East Asia. As the development begins the two curves converge towards the point (a) where the levels of HD and EP are low, as in the case of African and some Indo-Pacific populations. When societies evolve through the development of economies and the growth of populations, the level of natural resources and ecosystem exploitation reaches its maximum and the index of environmental protection declines (L3). This is the current condition of India, part of China, Indonesia, some South American and a few African countries above all. As societies move beyond the developing stage and reach the developed state (>0.7 HDI) the environment begins to recover. Europe and North America are experiencing this phase at present. The passage point from a 'developed society' (Section 4) and a 'sustainable society' (Section 5) is represented by the point (b), where the two curves intersect again, but this time near to the highest level of HD and EP. From this point, the level of EP (L2) is close to or lower than that of 'indigenous' people. Very few countries putting the conservation and environmental programmes at the top of political agenda and allowing nature to regain its wildness reached the L2 level.

Finally, figure 1 shows the area α enclosed between the two curves, which represents the loss of natural resources and ecosystem services during the development phase. Currently only 2 billion people are in the developing phase included in the α area but, according to the Global Footprint Index 2010, all of humanity is consuming the resources of more than 1.5 planets. Accordingly, when the remaining 5–7 billion people enter the development stage following the European and American development model and reach the yellow area α, humanity will consume more than 5 planet Earths. Obviously this is impossible and the risk is that this will reduce the ecosystem services to a level that does not allow the maintenance of planetary regulating feedback. At this point an adjustment of

human population growth rate can be expected, but the socio-economic disequilibrium and the high impacts on the environment could already be too high.

Conclusion

A recent study [20] argued that it is not correct that richer societies have larger ecological footprints and are more inclined toward environmental protection. In fact, according to Van de Vliert and Vlek [20] all countries, but especially richer countries, have larger ecological footprints under more demanding thermal climates. Indeed, societies seems to follow common development patterns and currently we see a situation where few civilizations live in a sustainable stage and the majority are in the process (α area in figure 1) of overexploitation of natural resources and ecosystem services. This situation is unsustainable but will not end soon – or painlessly. As 5–7 billion people will develop in the future following the global patterns described in this study, ecosystems and biodiversity will be subject to a high level of stress with no assurance of resilience.

Economists [21–24] have firmly related human development to the so-called equatorial Grand Canyon – the hot belt several thousand kilometres in width encircling the earth at the equator, where more lower-income countries can be found than anywhere else. Keeping in mind the trends shown here, the only solution – which must be undertaken together with technological inventions and ecosystem innovations – for human and environmental survival in a healthy state is that the countries that currently are living in the α area (in the 3rd–4th sector of the graph in figure 1) quickly shift to the 5th stage after the point (b), putting in action a series of mechanisms that move towards an efficient and renewable energy supply, a closed waste cycle, with biodegradable chemicals carbon neutral transport systems, an organic diet [25], a severely reduced level of consumption of natural resources, a series of environmental protection regulations, and the development of wildlife conservation measures. At the same time – as the necessary and sufficient condition – it is fundamental that the countries that are shifting into the 5th sector of figure 1 confront the question of the development of countries that will be, or already are, in the 2nd, 3rd and 4th stages; providing them with know-how and sustainable technologies; supplying them environmental, health and sexual education; and giving them the same right to develop as the 5th stage's countries, but avoiding to pass through the α area, which will not be able to sustain the consumption of natural resources and ecosystem services of the expected 7–9 billion people, *an equivalent of 5 planets* in the next 3–4 decades.

Finally, figure 1 shows that the best lifestyle for environmental protection in the world is that of indigenous people, where the L1 is higher than L3 of 'sustainable economies', even if they are the best option in a 'civilized' world [26–29]. The gap between L1 and L3 comes from the deep interconnection of indigenous people with their environment [30,31] and their high level of knowledge of nature (e.g. traditional medicaments, food resources, fibres, mythology, etc.) that is lacking even in sustainable societies in the 5th stage [32]. This means that if non-indigenous societies (civilized world) will continue to destroy the last indigenous cultures and will consider L3 as the unique possible level of environmental protection, even if it is the most sustainable for developed civilizations, all humanity will lose a piece of fundamental knowledge that only indigenous people preserve [33].

Disclosure statement

No potential conflict of interest was reported by the author.

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