Revista Internacional de
Sostenibilidad,
Tecnología y Humanismo
año 2008 nº 3

The second Copernican revolution in the Anthropocene: an overview

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Abstract

This article explores three recent courses in the global study of sustainability on the Earth. The first section is an overview of the *Global Environment Outlook 4: Environment for Development (GEO-4)* report, which summarizes the radical and unsustainable transformations developed in the interaction between the biosphere and the noosphere during the last twenty years. The second section presents the Hilbertian program of the Earth System Science proposed by Paul J. Crutzen and Hans Joachim Schellnhuber. They have explained that, due to the human action, we are living in an emerging geological and historical epoch: the Anthropocene. This presupposes a methodological challenge, called by the authors "the second Copernican revolution". Finally, the third section links this challenge to environmental ethics through the description of the work of Hans Jonas and Tongjin Yang.

Keywords: Anthropocene, Copernican Revolution, Earth System Science, Environmental Ethics

1 A global outlook from the noosphere: from the Brundtland Commission to the GEO-4 report

In the 1920s Vladimir Ivanovich Vernadsky noted that humankind taken as a whole is becoming a mighty geological force (Samson and Pitt 1999). According to the Russian geochemist, the biosphere became a real geological force that is changing the face of the Earth, and the biosphere is changing into the noosphere. 'This new state of the biosphere, which we approach without our noticing, is the noosphere' (Vernadsky 2005, p. 19). In Vernadsky's interpretation, the noosphere is a new evolutionary stage of the biosphere, when human reason will provide further sustainable development both of humanity and the global environment. Owing to the technology and scientific thought , the noosphere has developed a new point of view on Earth. In Vernadsky's terms: "All this is the result of 'cephalisation', the growth of man's brain and the work directed by his brain" (Vernadsky 2005, p. 19). As a result of the emerging and technological noosphere, human brains and hands have altered the surface of the Earth:

> «We are living in a brand new, bright geological epoch. Man, through his labour -and his conscious relationship to life- is transforming the envelope of the Earth, the geological region of life, the biosphere. Man is shifting it into a new geological state: Through his labour and his consciousness, the biosphere is in a process of transition to the noosphere» (Vernadsky 2000-2001, p. 22).

In this new planetary phase, the modern human being accelerates certain geological processes and changes the morphological composition on Earth. For the first time in the history of the Earth, the human being colonized its whole surface and humankind became a single totality in the life of the Earth. Humankind taken as a whole 'is becoming a mighty geological force' (Vernadsky 2005, p. 19), where the noosphere is the last of many stages in the evolution of the biosphere in geological history.

In 1987 the noosphere made an international call for the sustainable development, when the World Commission on Environment and Development (the Brundtland Commission) published a global report -*Our Common Future*- that analysed the links between development and environment, and challenged policy-makers to consider the global interrelationships among environment, economic and social issues. The report examined emerging global challenges in six issues: population and human resources, food security, species and ecosystems, energy, industry, and urbanization. The Brundtland Commission recommended institutional and legal changes in six broad areas to address these challenges: getting at the sources, dealing with the effects, assessing global risks, making informed choices, providing the legal means, and investing in our future. The report of the Brundtland Commission defined sustainable development internationally as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, p. 8). The commission further explained that, "the concept of sustainable development implies limits – not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities".

In 2007 the United Nations Environment Programme published the *Global Environment Outlook 4: Environment for Development (GEO-4)* report 20 years after the Brundtland Commission produced its seminal work. This work is the most comprehensive UN report on the environment, prepared by about 390 experts and reviewed by more than 1,000 others across the world. The GEO-4 report assesses the current state of the global atmosphere, land, water and biodiversity, describes the changes since 1987, and identifies priorities for action. It examines institutional developments and changes in thought since the mid-1980s, and explores the relationships involving environment, development and human well-being. This inquiry reviews major environmental, social and economic trends, and their impacts on environment and human well-being, and provides options to help achieve sustainable development.

According to GEO-4, over the past 20 years, the international community has cut, by 95 per cent, the production of ozone-layer damaging chemicals; created a greenhouse gas emission reduction treaty along with innovative carbon trading and carbon offset markets; supported a rise in terrestrial protected areas to cover roughly 12 per cent of the Earth, and devised numerous important instruments covering issues from biodiversity and desertification to the trade in hazardous wastes and living modified organisms. But today humanity uses the equivalent of 1.3 planets to provide the resources we use and absorb our waste. This means it now takes the Earth one year and four months to regenerate what we use in a year. Moderate UN scenarios suggest that if current population and consumption trends continue, by the mid 2030s we will need the equivalent of two Earths to support us. And of course, we only have one: one planet and many people. One world and many issues: GEO-4 recalls the Brundtland Commission's statement that the world does not face separate crises: the environmental crisis, the development crisis and the energy crisis are all one. In this way, among the critical points that GEO-4 identifies are:

1- Atmosphere and energy:

There is now visible evidence of the impacts of climate change, and consensus that human activities have been decisive in the warming observed so far: global average temperatures have risen by about 0.74°C since 1906. A best estimate for this century's rise is expected to be between a further 1.8°C and 4°C. Feedbacks such as permafrost melting and increased water vapour may increase that range. Some scientists believe a 2°C increase would be a threshold beyond which the threat of major and irreversible damage becomes more plausible.

Ice cores show that the levels of carbon dioxide (CO_2) and methane (CH_4) are now far outside their ranges of natural variability over the last 500,000 years: the Earth's climate has entered a state unparalleled in recent prehistory. The average temperatures in the Arctic are rising twice as rapidly as in the rest of the world. Sea-level rise caused by thermal expansion of water and the melting of glaciers and ice sheets will continue for the foreseeable future, with potentially huge consequences: over 60 per cent of people worldwide live within 100 kilometres of the coast, and millions will have to move elsewhere.

Energy patterns and mass transport are not sustainable. While energy use per unit of wealth created has fallen in the developed world since Brundtland by an average of 1.3 per cent annually, economic growth has outpaced this improvement. Shipping and aviation are increasing globally and the present trends do not favour greenhouse gas stabilisation. Aviation saw an 80 per cent increase in distances flown between 1990 and 2003, while shipping rose from 4 billion tonnes of goods loaded in 1990 to 7.1 billion tonnes in 2005: each sector makes huge and increasing energy demands.

2- Water:

Climate change, human use of water and aquatic ecosystems, and persistent overfishing are all influencing the world's water and aquatic resources. The oceans are the main regulator of the climate and absorb massive quantities of greenhouse gases. But, the changes they are now undergoing are affecting Arctic temperatures and ice (in this region the temperature rise is 2.5 times the global average), ocean salinity, precipitation (rain, sleet and snow) and extreme weather, including droughts, floods and cyclones. More intense and longer periods of droughts have been observed in the Mediterranean, Southern Africa and parts of Southern Asia. The reduced rainfall in the Sahel has been attributed to ocean surface temperature changes. For several decades the Greenland ice sheet has been melting faster than new ice is being formed, permafrost is thawing faster and Arctic rivers freeze for shorter periods in winter.

Available freshwater resources are declining: by 2025, 1.8 billion people will live in countries with absolute water scarcity. Irrigation already takes 70-80 per cent of water from streams and groundwater, yet meeting the Millennium Development Goal on hunger will mean doubling food production -and therefore water use by crops- by 2050. Of the world's major rivers, 10 per cent fail to reach the sea for part of each year because of upstream demands for irrigation. Aquatic ecosystems are losing their capacity to provide fresh water, food and other services. Human activities mean water quality is declining too, polluted by microbial pathogens and excessive nutrients. There is rising concern about the potential impacts, on aquatic ecosystems, of personal care products and pharmaceuticals like painkillers and antibiotics. In developing countries three million people die annually from water-borne diseases, most of them under five years old. An estimated 2.6 billion people today lack improved sanitation facilities. By 2025, water withdrawals are predicted to have risen by 50 per cent in developing countries and by 18 per cent in the developed world. Globally, contaminated water remains the greatest single cause of human disease and death. Controlling sediments, pesticides and endocrine disrupters is proving increasingly difficult.

Marine fish catches are being maintained only by fishing ever further offshore and at deeper levels (devastating some species very quickly), and increasingly further down the food chain. Fish consumption has been more than tripled from 1961 to 2001. The demand for fish, to meet population growth, is expected to increase by about 1.5 per cent annually in the coming decade. Subsidies have created excess fishing capacity, estimated at 250 per cent more than is needed to catch the oceans' sustainable production. Exploitation of West Africa's fish by Russian, Asian and European Union fleets increased six fold from the 1960s to the 1990s. The license fees paid to the countries concerned is only 7.5 per cent of the value of their fish once it has been processed. Due to this over-exploitation, which affects livelihoods, many coastal West African artisanal fishers are now migrating to some of the regions that are exploiting their resources.

3.- Land, food and pollution:

Population growth, economic development and global markets are driving land use change at an unprecedented rate. Since 1987, the expansion of cropland has slackened, but land-use intensity has increased dramatically. The average farmer then produced 1 tonne: output is now 1.4 tonnes. A hectare of cropland, which then yielded on average 1.8 tonnes, now produces 2.5 tonnes. Unsustainable land use is causing degradation, a threat as serious as climate change and biodiversity loss. It affects human well-being, through pollution, soil erosion, nutrient depletion, water scarcity, salinity, and disruption of biological cycles. The food security of two-thirds of the world's people depends on fertilisers, especially nitrogen. Poor people suffer disproportionately from the effects of land degradation, especially in the drylands (which support some 2 billion people). Damaged soils release organic carbon: land use change has caused about a third of the increase in atmospheric CO_2 over the last 150 years. Loss of nutrients means less productive soils in many tropical and sub-tropical uplands, endangering food security.

Chemical contamination takes many forms, and is likely to increase: more than 50,000 compounds are used commercially, hundreds more are added annually. Global chemical production is projected to increase by 85 per cent over the next 20 years. The food security of two-thirds of the world's people depends on fertilizers, especially nitrogen. Nutrients running off farmland increasingly cause algal blooms, and sometimes affect whole ecosystems (such as in the Gulf of Mexico and the Baltic Sea) through hypoxia (dead zones without oxygen). Likewise, acid rain is now much less a problem in Europe and North America, but more challenging in such countries as Mexico, India and China.

A third of Mediterranean Europe is susceptible to desertification, along with 85 per cent of US rangelands. Degradation and poverty reinforce one another. Dryland developing countries lag in human development terms. For example, their average infant mortality rate (54 per thousand) is 23 per cent above that in other developing countries and 10 times that of industrialized countries. There are competing claims for land. Water scarcity undermines development, health and ecosystems. By 2030 developing countries will probably need 120 million more hectares to feed themselves. Population growth and the continued shift from cereal to meat consumption mean food demand will increase to 2.5-3.5 times the present scenario.

4.- Biodiversity and unequal world:

Current biodiversity changes are the fastest in human history. Species are becoming extinct a hundred times faster than the rate shown in the fossil record. It is feasible that extinction rates will increase to the order of 1,000-10,000 times background rates over the coming decades. Of the major vertebrate groups that have been assessed comprehensively, over 30 per cent of amphibians, 23 per cent of mammals and 12 per cent of birds are threatened. Populations of freshwater vertebrates declined on average by nearly 50 per cent from 1987 to 2003, much faster than terrestrial or marine species. Of some 270,000 known species of higher plants about 10,000-15,000 are edible, and about 7,000 of them are used in agriculture. However, increased globalization threatens to diminish the varieties that are traditionally used in most agricultural systems. For example, only 14 animal species currently account for 90 per cent of all livestock production, and only 30 crops dominate global agriculture, providing an estimated 90 per cent of the calories consumed by the world's population. Of the ecosystem services examined by the Millennium Ecosystem Assessment, 60 per cent are being degraded or used unsustainably. With biological diversity, cultural diversity is rapidly being lost, mainly for the same reasons. Over half the world's 6,000 languages are endangered, and some believe up to 90 per cent of all languages may not survive this century.

The world has changed radically since 1987, economically, environmentally, socially and politically. Population has increased by almost 34 per cent, trade is almost three times greater, and average income per head has gone up by about 40 per cent. In developing countries, extreme poverty (those living on less than US$1/day) fell from 28 per cent in 1990 to 19 per cent in 2002: actual numbers decreased from 1.2 billion to just over 1 billion in 2002. Consumption has been growing faster than population, but unequally: the total annual income of nearly 1 billion people, the population of the richest countries, is almost 15 times that of the 2.3 billion people in the poorest countries. The world is shrinking and there are fewer resources to share: the amount of land per capita is about a quarter of what it was a century ago, and is expected to fall to about one-fifth of the 1900 level by 2050. Urbanization is another significant pressure: by 2025 coastal populations alone are expected to reach six billion. The year 2007 is the first in human history when more than half of all people live in cities.

2 The Anthropocene and the Hilbertian program for Earth System Science

The GEO-4 report presents an assessment of the interlinkages within and between the biophysical components of the Earth system. Our planet functions as a system: atmosphere, land, water, biodiversity and human society are all linked in a complex web of interactions and feedbacks. Environment and development challenges are interlinked across thematic, institutional and geographic boundaries through social and environmental processes. Environmental change and development challenges are caused by the same sets of drivers. They include population change, economic processes, scientific and technological innovations, distribution patterns, and cultural, social, political and institutional processes -all elements of the noosphere-. Due to the complexity of human-ecological systems, one form of human activity can cause several reinforcing environmental effects and affect human well-being in many ways. Emissions of carbon dioxide, for example, contribute both to climate change and to acidification of oceans. In addition, land, water and atmosphere are linked in many ways, particularly through the carbon, nutrient and water cycles, so that one form of change leads to another. Examining these interlinkages, biophysical and social systems are dynamic, and characterized by thresholds, time-lags and feedback loops. Thresholds are common in the Earth system, and represent the point of sudden, abrupt, or accelerating and potentially irreversible change triggered by natural events or human activities. Owing to the complexity of this web of interactions and feedbacks, the biophysical and social systems also have the tendency to continue to change, even if the forces that caused the initial change are removed (United Nations Environment Programme 2007, pp. 362-375).

In this interplay between the biosphere and the noosphere, it is clear that the global metabolism and the global anatomy are changing on the Earth. The global metabolism (the cycling of essential elements, including carbon, nitrogen, phosphorus and sulphur) and the global anatomy (the landscape textures of the habitable continents) are largely a product of socioeconomic action. This can be perceived as the latest step on the grand co-evolutionary ladder of entwined transitions of information and environment, since global industrialization has induced the transition into the "Anthropocene" (Lenton, Schellnhuber and Szathmáry 2004). Some scientists have employed this term to describe the most recent period in the Earth's history, because of the anthropogenic disturbances.

The term was coined in 2000 by the scientist Paul Crutzen (Crutzen and Stoermer 2000, Crutzen 2002), a Nobel Prize winner for his work on the ozone layer. In this task, he has explored Vernadsky's noosphere -the world of thought- "to mark the growing role of human brain-power in shaping its own future and environment" (Crutzen 2002). Thus, Crutzen has assigned the word "Anthropocene" to the present, in many ways human-dominated, geological epoch, supplementing the Holocene, the warm period of the past 10-12 millennia. The Anthropocene started in the latter part of the eighteenth century, when analyses of air trapped in polar ice show the beginning of growing global concentrations of carbon dioxide and methane. This date also coincides with James Watt's design of the steam engine in 1784. Recently, a group of 21 researchers from the Stratigraphy Commission of the Geological Society of London has applied Crutzen's criteria. They have concluded that, since the start of the Industrial Revolution, sufficient global evidence has emerged of stratigraphically significant change for recognition of the Anthropocene as a new geological epoch, distinct from that of the Holocene (Zalasiewicz et al. 2008).

All these facts and data imply a new science paradigm. The study of the Earth system and the Anthropocene needs a new and global scientific program to develop a sustainable noosphere. In 1900 David Hilbert proposed a monumental program for the advancement of mathematics in the twentieth century at the World Conference for Mathematics in Paris. This program basically consisted of a rather eclectic list of 23 problems to be solved by the scientific community. Few years ago, the international Earth system science community has formulated their own Hilbertian program (Schellnhuber and Sahagian 2002, p. 21; Clark, Crutzen and Schellnhuber 2004, pp. 8-14; Schellnhuber, Crutzen, Clark and Hunt 2005), which lists 23 crucial questions that need to be addressed for global sustainability. The Hilbertian program for the advancement of Earth system understanding in the (first decades of the) twenty-first century emerged from an extended email conference organized in 2001 by GAIM (Sahagian and Schellnhuber 2002) -the transdisciplinary think-tank of the International Geosphere-Biosphere Programme (IGBP). The list of questions was arranged in four blocks emphasizing analytical, methodological, normative, and strategic questions, respectively:

A- Analytical questions:

1. What are the vital organs of the ecosphere in view of operation and evolution?
2. What are the major dynamical patterns, teleconnections, and feedback loops in the planetary machinery?
3. What are the critical elements (thresholds, bottlenecks, switches) in the Earth System?
4. What are the characteristic regimes and timescales of natural planetary variability?
5. What are the anthropogenic disturbance regimes and teleperturbations that matter at the Earth-system level?
6. Which are the vital ecosphere organs and critical planetary elements that can actually be transformed by human action?
7. Which are the most vulnerable regions under global change?
8. How are abrupt and extreme events processed through nature-society interactions?

B- Operational questions:

9. What are the principles for constructing "macroscopes", i.e., representations of the Earth system that aggregate away the details while retaining all systems-order items?
10. What levels of complexity and resolution have to be achieved in Earth System modelling?
11. Is it possible to describe the Earth System as a composition of weakly coupled organs and regions, and to reconstruct the planetary machinery from these parts?
12. What might be the most effective global strategy for generating, processing and integrating relevant Earth System data sets?
13. What are the best techniques for analyzing and possibly predicting irregular events?
14. What are the most appropriate methodologies for integrating natural science and social science knowledge?

C- Normative questions:

15. What are the general criteria and principles for distinguishing non-sustainable and sustainable futures?
16. What is the carrying capacity of the Earth?

17. What are the accessible but intolerable domains in the co-evolution space of nature and humanity?
18. What kind of nature do modern societies want?
19. What are the equity principles that should govern global environmental management?

D- Strategic questions:

20. What is the optimal mix of adaptation and mitigation measures to respond to global change?
21. What is the optimal decomposition of the planetary surface into nature reserves and managed areas?
22. What are the options and caveats for technological fixes like geoengineering and genetic modification?
23. What is the structure of an effective and efficient system of global environment and development institutions?

3 The second Copernican revolution and post-Kantian environmental ethics

The Hilbertian program for Earth System Science reflects an emerging paradigm: the second Copernican revolution. In 2001, delegates from more than 100 countries participating in the four major international research programs on global environmental change endorsed the "Amsterdam Declaration", which formally established the "Earth System Science Partnership" and set the stage for a second Copernican revolution (Clark, Crutzen and Schellnhuber 2004).

Optical magnification instruments once brought about the Copernican revolution that put the Earth in its correct astronomical place. Today, some 500 years after Nikolaus Copernicus, sophisticated information-compression techniques including simulation modelling are now ushering in a second Copernican revolution (Schellnhuber 1999). The latter revolution is in a way a reversal of the first: it enables us to look back on our planet to perceive one single, complex, dissipative, dynamic entity, far from thermodynamic equilibrium. Such revolution strives to understand the Earth system as a whole and to develop, on this cognitive basis, concepts for global environmental management. From this new perspective, our planet is a global network of living information, provided by real, virtual, and global interfaces between the biosphere and the noosphere. In this geopolitical interplay toward a sustainable scenario, we, women and men, should not use the *global* (world-teletechnologies) to exploit the *real* (raw materials, environmental resources) to obtain the *virtual* (financial speculation). We must use the *virtual* (mathematics, software, biocomputering, Internet) to measure the *real* (biogeochemical-physical) to obtain the *global* (ecological economics and human ecology in Gaia, our planet) (Ayestaran 2005, 2006 and 2007).

The concept of this novel Copernican revolution is rooted in the original one, yet transcends it in several crucial ways (Clark, Crutzen and Schellnhuber 2004, p. 7):

1. The scientific eye is re-directed from outer space to our "living Earth", which operates as one single dynamical system far from the thermodynamic equilibrium characterizing "dead" planets like Venus.
2. Scientific ambition is re-qualified by fully acknowledging the limits of understanding as highlighted by the notorious uncertainties associated with nonlinearity, complexity, and irreproducibility.
3. The scientific ethos is re-balanced by accepting that knowledge generation is inextricably embedded in the cultural-historical context. The research community becomes part of its own riddles, the research specimens become part of their own explanations, and co-production becomes the normal way of coping with the cognitive challenges of a changing Earth.

The first Copernican revolution placed our planet in its correct astrophysical context. A second Copernican revolution is underway that places humanity in its appropriate environmental nexus (Miller 2003). The sustainability of the geobiosphere now is seen to be inseparably bound up with human development in a global and symbiotic system -as Lynn Margulis (1998) has put it, we live on a symbiotic planet. The essence of a second Copernican revolution, therefore, is the recognition of and respect for the unalterable symbiotic relationship between humanity's future well-being and the integrity of those environmental processes that are requisite for sustaining the future. This presupposes an epistemic and cognitive challenge, both in science and philosophy, because it implies a revolution for the sustainability of the noosphere.

The second Copernican revolution entails a second Enlightenment with regard to sustainable noosphere. To illustrate this, let us choose a normative consideration directly related to the Question 15 of the Hilbertian program ("What are the general criteria and principles for distinguishing non-sustainable and sustainable futures?") and partially related to the Question 19 ("What are the equity principles that should govern global environmental management?"), and let us apply to the realm of the old Copernican ethics, for instance, the case of Immanuel Kant. The thinker of Königsberg has been read, often inadvertently, as a kind of Copernican revolution or hypothesis in modern philosophy (Miles 2006). The preface to the second edition of the *Critique of the Pure Reason* (*Kritik der reinen Vernunft*) contains a reference to the "original thought" of Copernicus -"der erste Gedanke des Copernicus"- (KrV, B XVI). He himself described his philosophy as "analogisch" to that of Copernicus (KrV, B XXII). In the last third of the eighteenth century, Kant placed the human subject in the enlightened centre of the epistemic and moral universe, and formulated his universal categorical imperatives in a Galilean or Newtonian-like way. Later, in the last third of the twentieth century, Hans Jonas revisited the formulation of the categorical imperatives, especially when Kant said in the *Groundwork for the Metaphysics of Morals*: "Act so that you *can* will that the maxim of your action be made the principle of a universal law" (Jonas 1984, pp. 10-11).

Jonas examined the Kantian imperative in the context of ecology and the future of the Earth. The "can" invoked by Kant is that of actual reason and its consistency with itself. The "I *can* will" or "I *cannot* will" expresses logical compatibility or incompatibility imagined as a general practice of a community of human agents (acting rational beings), where the action must be such that it can without self-contradiction be imagined for that community. But there is no self-contradiction in the thought that the present generations would be bought with the unhappiness or even non-existence of later ones. From the Kantian formulation, the non-existence or unhappiness of the later generations may be bought with the existence or happiness of the present generations, against the aim of the sustainable development. Kant's categorical imperative is for the present logic, but it is unable to speak about the future Earth system and the next generations. For that reason Jonas proposed a new kind of categorical imperative:

"An imperative responding to the new type of human action and addressed to the new type of agency that operates it might run thus: 'Act so that the effects of your action are compatible with the permanence of genuine human life'; or expressed negatively: 'Act so that the effects of your action are not destructive of the future possibility of such life'; or simply: 'Do not compromise the conditions for an infinite continuation of humanity on Earth'; or, again turned positive: 'In your present choices, include the future wholeness of Man among the objects of your will'" (Jonas 1984, p. 11).

Jonas' imperatives replenish the Kantian ethical vacuum taking a long-term perspective with regard to intergenerational equity. This sort of sustainable ethics includes in origin the philosophy of the second Copernican revolution and the Hilbertian program for Earth System Science. The first Copernican-Kantian revolution was for the present transcendental subjects, but not for the future vulnerable subjects on Earth. Beyond Kant, Jonas has placed the subject of ethics in the interlinkage between the biosphere and the noosphere, and has gone further into biophysical and societal interlinkages that offer opportunities for more effective policy responses, according to the Question 15. Therefore, this incipient ethics proposes new dimensions for the imperative of human responsibility in the search of the future of humankind and nature. Moreover, we may extend Jonas' proposal related to the sustainable future regarding three ethical demands: the need for environmental justice among the present generation (especially to eliminate absolute poverty), the need to care for future generations, and the need to live harmoniously with nature (Yang 2000 and 2006). Though there are many debates about the philosophical foundations of this sort of global environmental ethics, there is much consensus at three normative areas (Yang 2000):

1. *Principle of environmental justice*: Environmental justice is the minimum ethical stance of environmental ethics. There are two dimensions to environmental justice. Distributive environmental justice concerns the equal distribution of environmental benefits and burdens, whereas participatory environmental justice focuses on opportunities to participate in decision-making.

2. *Principle of intergenerational equality*: The principle of intergenerational equality is an

extension of that of equality. Equal rights constitute the core of the principle of equality. The rights to life, liberty and happiness are basic human rights shared by everyone, future generations as well as the present generation.

3. *Principle of respect for nature*: We have a duty to conserve and protect the integrity of the ecosystem and its biodiversity. The prosperity of human beings depends on the prosperity of nature. Human beings are part of nature, and the human economy is a sub-system of nature's economy; the former must fit into the latter and abide by the laws of the latter.

Thus, we have a call for Jonas' imperative of responsibility trough three principles: the principle of environmental justice, the principle of intergenerational justice, and the principle of respect for nature. These ethical principles offer a partial answer to normative Question 19. In order to address a complete answer, they require an implementation within a "triple bottom (or top) line" framework, besides the democratic appeal of including all stakeholders in the light of the Hilbertian program and the second Copernican revolution, in the spirit of the sustainable noosphere, in the matter of the future biosphere. Likewise, in the eighteenth century the Age of the Enlightenment was *Aufklärung*, *le siècle des Lumières*, the century of the lights, but, today, in the century of the electric and electronic lights, the Age of the Anthropocene requires a second Enlightenment, a renewed and renewable Enlightenment highlighting sustainability. Kant brought to light an idea for a universal history from a cosmopolitan point of view. Now an idea for a planetary history from a sustainable point of view comes to light in the noosphere of the Anthropocene.

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