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Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet

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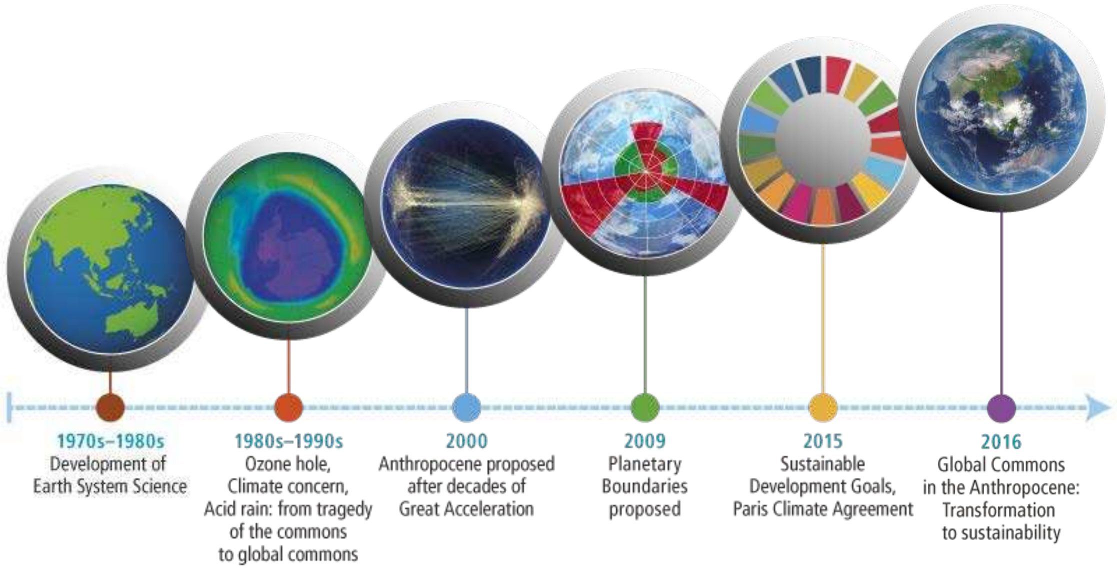
Contents

Summary

- Three decades of internationally coordinated research on the Earth system has led to the conclusion that Earth has entered a new geological epoch – the Anthropocene. The stability and resilience of the Earth system is now at risk. Yet, a stable Earth system is a prerequisite for human development.
- Nine Planetary Boundaries determine Earth system resilience. Human activities have caused the Earth system to transgress four of these boundaries, namely climate, biodiversity, land-use change (deforestation) and biogeochemical cycles (predominantly overuse of phosphorus and nitrogen in fertilizers).
- The Anthropocene changes our relationship with the planet and how societies view the "global commons". One definition of the global commons currently used by international law names: the high seas; the atmosphere; Antarctica; and outer space – as the globally common resources that fall outside national jurisdictions. However, the stability and resilience of the Earth system is also common to all. This stability and resilience is dependent upon both the global commons as recognized under international law and also the resources within national jurisdictions, for example rainforests, sea ice, mangroves and biodiversity.
- We argue that humanity must be the steward of the planet's natural resources – the ecosystems, biomes and processes that regulate the stability and resilience of the Earth system, for example the carbon cycle. These are what we term the new "Global Commons in the Anthropocene".
- The UN Sustainable Development Goals and the Paris Agreement on Climate Change indicate a paradigm shift in the global response to safeguarding the Global Commons in the Anthropocene.
- In the coming decades, four key socioeconomic megatrends will determine the trajectory of the Anthropocene: energy, food, water and urbanization.
    - Food, the world's single largest user of fresh and underground water, and the single largest reason for transgressing Planetary Boundaries on nitrogen/phosphorus, land, and biodiversity. Transformation of the food system has the potential to improve personal, societal and planetary health and wellbeing.
    - Decarbonization of the global energy system is now of critical importance for a 1.5–2°C future global temperature increase line with the Paris Agreement.
    - Water, the source of life, is under severe pressure, and water stress and scarcity are increasing in many parts of the world.
    - By 2050, 75% of the world's population will live in urban areas. This global shift requires a major focus on transformation to sustainable and livable urban environments, transportation and a circular economy.
- A focus on these four interlinked sectors holds the best chance of protecting the global commons in the Anthropocene for human prosperity and wellbeing.



Towards Global Commons in the Anthropocene The Global Commons in the Anthropocene builds upon advances in research and in the international environmental and development policy process of the past decades.

Definitions

Anthropocene: Geologists and Earth system scientists have proposed that the Holocene is at an end and that Earth is now in the Anthropocene as a result of human pressures on the Earth system. A working group under the International Commission on Stratigraphy is currently discussing this re-categorisation.

Common resources: Natural or social resources where it is difficult to exclude users and where exploitation by users reduces availability to others, for example irrigation systems, grazing land, forests, the atmosphere and fishing grounds.

Earth system: Earth's interacting physical, chemical and biological processes, including human activity (IGBP).

Externalities: In economics, externalities are the consequences of commercial activities not factored into the market price. Externalities can be positive or negative.

Global Commons: In the last few decades nations have begun to consider common resources at a planetary scale that are outside national jurisdictions. International law identifies four global commons: the high seas; the atmosphere; Antarctica; and outer space, which are recognized as the common heritage of humankind (UNEP Division of Environmental Law and Conventions). We argue that humanity must be the steward of the planet's natural resources – the ecosystems, biomes and processes that regulate the stability and resilience of the Earth system, for example the carbon cycle. These are what we term the new "Global Commons in the Anthropocene".

Holocene: According to the International Commission on Stratigraphy, the geological epoch that began at the end of the last ice age 11,700 years ago and that has continued until now is named the Holocene. The Holocene has been characterized by a remarkably stable climate.

Resilience: The capacity of a system to deal with change and continue to develop is indicative of its level of resilience.

Stable and resilient Earth system: The Earth system is dynamic and ever changing but internal regulating processes, such as negative feedback loops, ensure that fluctuations of key processes remain within boundaries so that the system is stable and resilient. However, external pressures, and internal feedback loops driven by, for example, evolution can overwhelm the internal regulating capacity of the system thereby upsetting this dynamic equilibrium.

Social-ecological systems: These are coupled systems at all scales, from local to global, where societies interact with the environment.

Acknowledgments

We would like to thank the Global Environment Facility (GEF), the International Union for Conservation of Nature (IUCN), the Earth League, as well as our home institutions, the International Institute for Applied Systems Analysis (IIASA) and the Stockholm Resilience Centre (SRC) for financial and substantive support.

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Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet

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1 Introduction

This paper was produced as a background document for a conference on "Our Global Commons – Assessing the pressures on the global environment and disrupting the systems that drive them" to explore the changing nature of the global commons in the 21st century. The paper will contribute to a broader dialogue on the need to reassess the global commons at all scales in light of growing human pressure on Earth's life-support system and catalyze renewed efforts to develop a roadmap to manage the commons for the benefit of humanity.

For millennia, communities have effectively managed common-pool resources on a small scale, for example forests, rangeland and fisheries. As industrial impact has grown, and nation-state norms have evolved, the need to manage globally common resources emerged. But now, the reality of full scale of national ecological interdependencies and human impact on the Earth system challenge this traditional thinking on the global commons. How do societies shift world views to accommodate this new thinking? Can knowledge of effective management of common resources be applied at the planetary scale? How are user rights established? The following chapters explore these issues.

In a remarkably short space of time, industrial societies have pushed Earth into a new geological epoch, the Anthropocene. As a result of human intervention, the stability of the Earth system is at risk. Indeed, scientists have identified nine Planetary Boundaries that it would be unwise to transgress. However, according to the latest assessment in 2015 (Steffen et al., 2015), four of these boundaries have been breached, namely climate, biodiversity, land-use change and biogeochemical cycles.

Here we apply research on Earth system science, management of common resources, polycentric governance approaches, transformations and resilience to re-examine the global commons. From this analysis we conclude a reassessment of the global commons in the Anthropocene is essential and step towards more effective governance of the Earth system and sustainable development. The global commons in the Anthropocene is, ultimately, a stable and resilient Earth system. In this context, "resilience" and "stability" refer to the ability of Earth to maintain the dynamic equilibrium that has allowed a global civilization to flourish.

A stable and resilient Earth system is the common heritage of all humanity and every child's birthright.

This new definition of the global commons captures the interlinkages between human and natural spheres, the interconnections between Earth's natural processes and cycles, and the need to balance human development with environmental stewardship. This leads to difficult governance issues: How will societies define boundaries? How can we ensure inclusivity of all people and future generations? How will worldviews change so that a distant rainforest or ice sheet is valued not just for its inherent beauty, its delicate ecosystem, or its economic value, but because of its role in the resilience of the planet we live on?

To build our argument we begin with the diagnostics on the current state of the planet and the long-term prognosis for planetary stability. We identify the key biomes and processes that secure this stability and resilience. We then explore a vision for the Global Commons in the Anthropocene and abundance within planetary limits, in particular in relation to poverty alleviation and inequality. Finally, we identify the underlying principles for the Global Commons in the Anthropocene, as well as the socioeconomic systems that must transform to achieve global sustainability, namely the food system, water system, energy system and urban system.

An Emerging Paradigm Shift

A rapid transformation of society towards global sustainability may be achievable economically and technologically, but the political challenge is enormous (Rogelj et al., 2015, Rockström et al., 2016). The world we live in is very different to the one inherited at the end of World War II. The number of people living in extreme poverty has halved in the last 15 years, falling from 1.95 billion people (37%) living on less than \$1.90 a day in 1990 to 896 million in 2012 (12.7%) (World Bank, 2016, World Bank, 1992). Famine has been eradicated in many parts of the world. More children now live to adulthood. Longevity is extending. And, remarkably, international violent conflict is at an all-time low (Pinker, 2011). Indeed, since the 1950s, the three constant threats to all societies since the dawn of humanity – famine, disease and conflict – have been, to a greater extent, tamed (Harari 2016).

Yet, the backdrop to the above is one of global-scale ecological degradation. We are losing biodiversity at mass extinction rates, we are changing the climate and, according to current trends there will be more plastic in the oceans than fish by weight by 2050 (Ceballos et al., 2015, IPCC, 2013, World Economic Forum et al., 2016). Currently, 7.4 billion people live on Earth. By 2050 the number is expected to hit 9.7 billion and reach 11.2 billion by 2100 (UN Population Division, 2015).

A new relationship has emerged between people and the planet, between globalization and the Earth system, and between nation states and the Earth's biosphere (Waters et al., 2016, Griggs et al., 2013). This calls for new thinking and solutions that go beyond the old model of development, beyond environmentalism and beyond traditional economic thinking.

Two events in 2015 indicate that a paradigm shift is occurring. The first is the agreement to pursue the United Nations' universal Sustainable Development Goals (SDGs) – 17 goals for people and planet to be met by 2030 (UN GA, 2015). The second is the Paris Agreement on Climate Change (UNFCCC, 2015) – an agreement with the aim of rapidly decarbonizing the global economy to keep the global average temperature to well below 2°C above pre-industrial levels and limit the increase to 1.5°C.

These agreements are a response to the profound realization that Earth is reaching a saturation point. The United Nations' resolution on "Transforming our world: the 2030

Agenda for Sustainable Development," acknowledges that "*The survival of many societies, and of the biological support systems of the planet, is at risk*" (UN GA, 2015). The "biological support systems of the planet" refers to the Earth system: the atmosphere, oceans, ice sheets, waterways, soils and cycles, and rich diversity of life that combine to keep Earth habitable.

In addition to analytical tools and data, we need ethical, economic and political principles for the Anthropocene. The Holy Father's Encyclical Letter, *Laudato Si*, "On Care for Our Common Home," emphasizes this point: "*What is needed...is an agreement on systems of governance for the whole range of so-called 'global commons*'" (Pope Francis, 2015). There is a recognition among faith, business and political leaders that transformation of societies is urgently required characterized by new behaviors and institutions based on new values and norms.

To this end, we discuss the key principles for the proposed Global Commons in the Anthropocene. Such a new perspective on the global commons may have broad implications for governance, institutional recommendations and policy implementation. A detailed analysis of the solutions space will be tackled in subsequent papers.

2 Science Update on Trends in the Great Acceleration[1]

2.1 The Holocene

A prerequisite for human civilization is a stable Earth system.
This stability is now at risk.

Like clockwork, 11,700 years or around 400 generations ago, a regular and predictable realignment of heavenly bodies in our solar system conspired to push Earth out of a long ice age and into a new equilibrium, a warm and extraordinarily stable interglacial period (Milankovic, 1941, Wolff, 2011, Ganopolski et al., 2016). Our distant ancestors – fully modern humans – went through a dramatic social transformation, from hunter-gatherers to sedentary farmers. This was the most important step in the evolution of modern civilizations.

The first farmers to work the land and harvest crops settled down and took root in the fertile crescent of Mesopotamia between the Tigris and Euphrates rivers in the Middle East. This transformation of human livelihoods enabled social and technological differentiation, and laid the foundation for the evolution of modern civilizations, from the Mesopotamian irrigation cultures to the Babylonian, Egyptian, and Chinese empires, the Mayan and Incan high societies, and the Greek and Roman empires, to our modern civilizations of the 20th and 21st centuries. But why did this happen?

For over ten millennia the global average temperature has risen or fallen by no more than a 1°C (Marcott et al., 2013, Shakun et al., 2012). Geologists named this period the

[1] Note: No new research has been undertaken for this part of the paper. Rather, we provide an overview of the literature around this topic and in particular that on transformational futures.

Holocene epoch. Compare the Holocene equilibrium to what preceded it (Petit et al., 1999, Young and Steffen, 2009) – a 100,000-year ice age where temperatures regularly plunged and then rose rapidly (*Figure 1*). Indeed, in the last 2.6 million years ice ages have come and gone every 100,000 years or so, punctuated by warm periods known as interglacials.

Humans had barely entered the Holocene when agriculture – the domestication of animals and plants – was adopted on a large scale. We have ample archeological evidence to suggest that farming – cultivating crops and raising animals – occurred more or less simultaneously on different continents and in diverse regions of the planet. Maize in the Americas, rice in Asia, teff in Ethiopia and wheat in Mesopotamia all appeared 2–3,000 years into the Holocene (some 8,000 years ago in the Neolithic agricultural revolution).

The multiple and simultaneous agricultural revolutions on different continents indicate that agriculture was not the result of a sudden technological invention by a single hunting-and-gathering community. Rather, it suggests that farming was established knowledge among such communities across the world, but had not been adopted permanently due to a turbulent Earth system. The large climate variability in the glacial, pre-Holocene conditions meant that growing seasons and rainfall patterns were unpredictable, creating a high risk of crop failure.

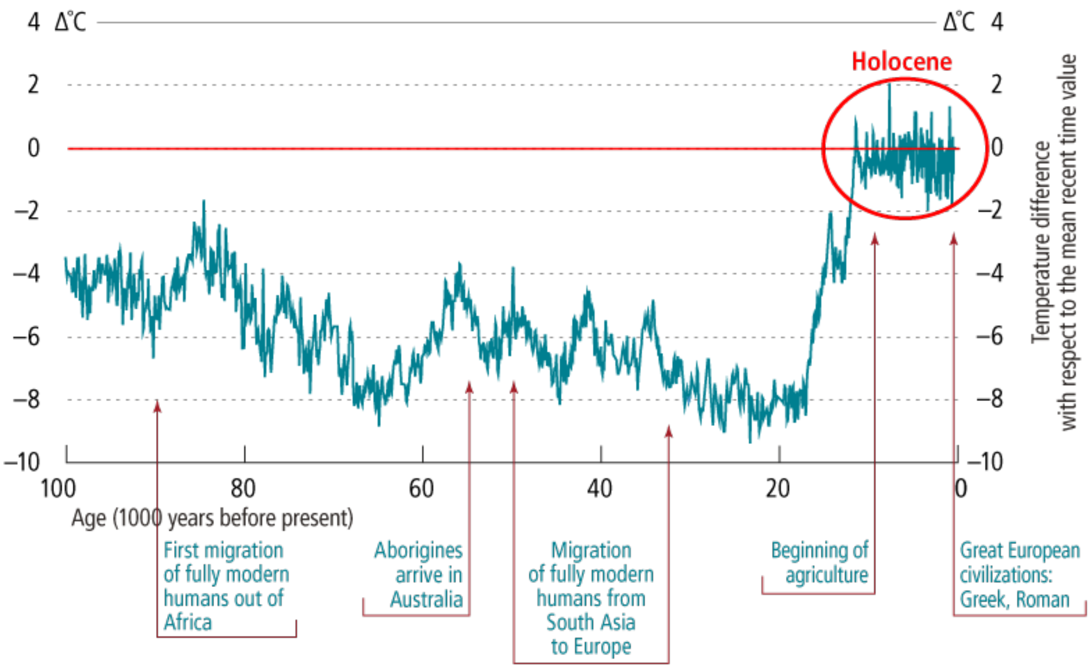

Figure 1 100,000-year-ice-core record and select events in early human history depicting the exceptional stable temperature conditions during the Holocene. Data from Petit et al., 1999, labeled as in Young and Steffen, 2009.

With the Holocene all this changed. Suddenly the environmental conditions on Earth stabilized as a result of external (solar/planetary) forces and internal biophysical processes between biosphere, hydrosphere, atmosphere, cryosphere and geosphere settling into a new planetary equilibrium *(Figure 2).* It is within this biophysical equilibrium that seasons (winter, spring, summer, and autumn) not only establish themselves firmly, but become more reliable. Those early settlers crossed a critical threshold where, in at least eight out of ten years, rains would fall and temperatures greater than 15°C would be reached for planting, and a growing season of greater than 90 days could be counted upon, thus providing a high probability of a successful harvest (Rockström and Klum, 2015).

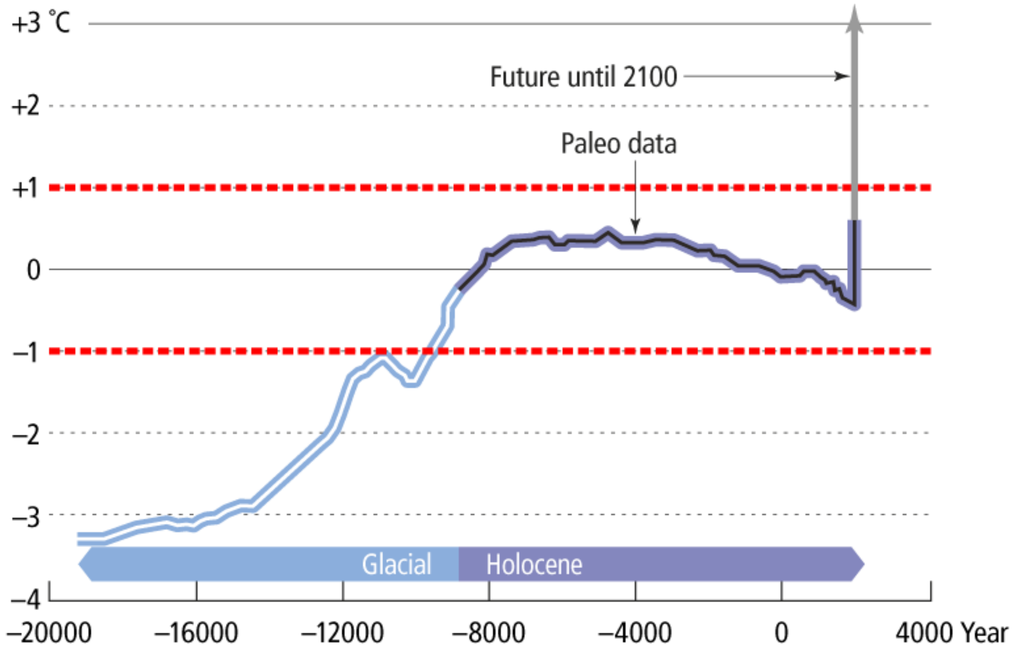

Figure 2 Holocene temperature profile including outlook to 2100. Adapted from Shakun et al., 2010 and Marcott et al., 2013.

We argue that it is the agricultural revolution that constituted the prerequisite for modern civilizations to evolve. An Earth system in a stable and resilient state, with the Holocene as our human reference point, may thus be a necessity for human prosperity and world development. The conclusion from this scientific insight is as basic as it is dramatic. With the evidence we have at hand, we can state that the interglacial state of the Holocene is the only state of the planet we know for certain that can support a world population of 7.4 billion (Rockström et al., 2009), soon to approach nine to ten billion. It is correct that modern humans have survived, and thus could survive, outside of a Holocene-like planetary stability, but there is no evidence that a globally connected society providing a minimum quality of life could flourish. As we continue along the current Anthropocene trajectory, we are experiencing manifestations of the pressures being exerted on the Earth system. Yet, we do not know where we may end up if we stay on this trajectory and if there will be an equilibrium that will be in any way comparable to that of the Holocene.

Most of Earth's history has been characterized by long periods – millions of years – of relative stability. The current glacial-interglacial cycles *(Figure 3)* go against that grain. For 2.6 million years, Earth has flipped between two states in an unusual "saw-tooth oscillatory dynamic." Now, Earth is in a rare state of instability (Lenton and Williams, 2013). In the absence of other influences, in 50,000 years the heavenly bodies – the sun, the planets and Earth's own position relative to the sun – should conspire again to push Earth into another deep ice age. However, greenhouse gases (GHGs) from industrial emissions and deforestation have put a stop to that (Ganopolski et al., 2016, CDIAC, 2016, Brook, 2008).

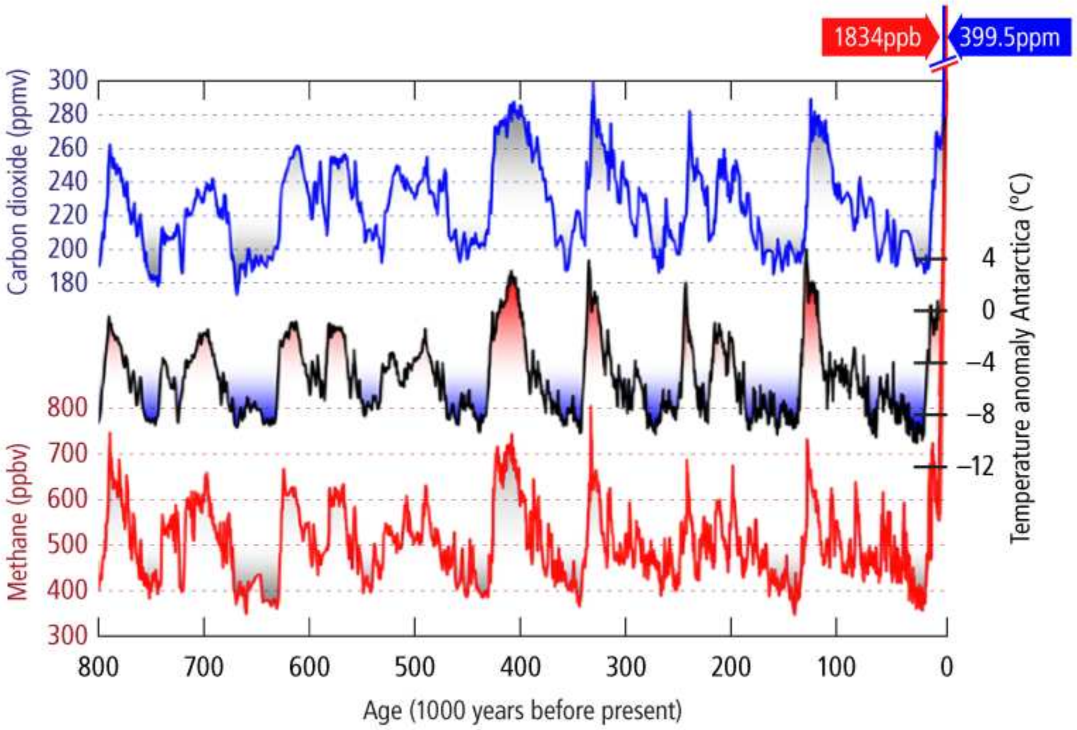

Figure 3 800,000-year ice-core record with temperature reconstruction; 2015 carbon dioxide and methane levels from CDIAC 2016. Adapted from Brook, 2008.

2.2 The Great Acceleration

Production and consumption are on exponential trajectories and on a collision course with the Earth system.

It took all of modern human history – 200,000 years – for the population to grow steadily to one billion people by 1800. The establishment of the nation state, colonialism, new economic ideologies and the Enlightenment created the conditions for the first sparks to ignite the Industrial Revolution in northern Britain around 1750 that accelerated after the 1820s with the diffusion of the steam engine, railways and coal (Grubler et al., 1999). The Industrial Revolution spread rapidly across Europe, North America and Japan, and with a time lag to regions elsewhere. The population began to increase, and economic development, driven by cheap abundant fossil fuels, changed gear and people began swarming toward cities thereby fueling creativity in the arts and sciences and enormous growth.

Then, in the first half of the 20th century, the Haber Bosch process to fix nitrogen and create artificial fertilizers, coupled with the introduction of new machinery, led to agricultural intensification. The world had the resources to feed many more people. The emergence of antibiotics, vaccinations and new medical techniques also meant more people could live longer than at any time in human history. In the "developed" world we now expect all children to live to adulthood. During the past two centuries, the global population has increased more than sevenfold to some 7.4 billion today, and over half of us live in cities

(UN Population Division, 2014). Economic output has grown around 100-fold to over $100 trillion (measured by purchasing power parity) or some $70 trillion (measured by market exchange rates) (Steffen et al., 2015).

At the same time, pervasive industrialization accompanied by mass production spurred a huge leap in productivity, as well as resource accessibility and use. At the center of these productivity increases lay innovation, which has led to the diffusion of new technologies and organizational structures. For example, automobile production has increased in a century to 90 million units per year (OICA, 2016), bicycles to 133 million (NPD, 2016), and only in a couple of decades, the annual production of computers has reached 240 million (Statista, 2016a) and cellphones 1.8 billion (Statista, 2016b). Consequently, the growing population has gained access to new technologies and rising income levels have led to higher use.

While the Industrial Revolution created the conditions for a radical change in how humans live and consume, the most profound growth occurred after the Second World War. The 1950s witnessed the beginning of what has become known as “the Great Acceleration” in human activity (Steffen et al., 2004, Steffen et al., 2011, Steffen et al., 2015) *(Figure 4).* From international tourism and foreign direct investment (FDI), to population and gross domestic product (GDP), the pace and scale of change has taken on an exponential trajectory. The Great Acceleration has delivered huge improvements in human wellbeing for parts of the world’s population, but this has come at a cost: Earth’s resilience to change – its ability to absorb shocks and remain stable – is declining rapidly. Disaggregating population and GDP by developed and developing nations shows that this phenomenal growth is largely driven by globalization and neoclassical economic policies that propel growth at all costs by promoting ever higher production and consumption in wealthy nations, not population growth *per se* (Steffen et al., 2015).

An important consequence of this rapid development is that the high affluence of around one billion people has led to global-scale environmental problems – the Anthropocene Effect. The “global middle class,” which is expected to grow from 1.8 billion in 2009 to 3.2 billion by 2020 and 4.9 billion by 2030 (Pezzini, 2012), is expected to also take up resource-intensive lifestyles following the trend of consumerism in developed countries (Kharas, 2010). At the same time, several billion people have not benefited from this development: still 2.4 billion do not have access to sanitation ((WHO and UNICEF, 2015) and three billion lack access to clean cooking technologies (GEA, 2012), but they do have to bear the brunt of the negative externalities associated with development and transgression of the Planetary Boundaries.

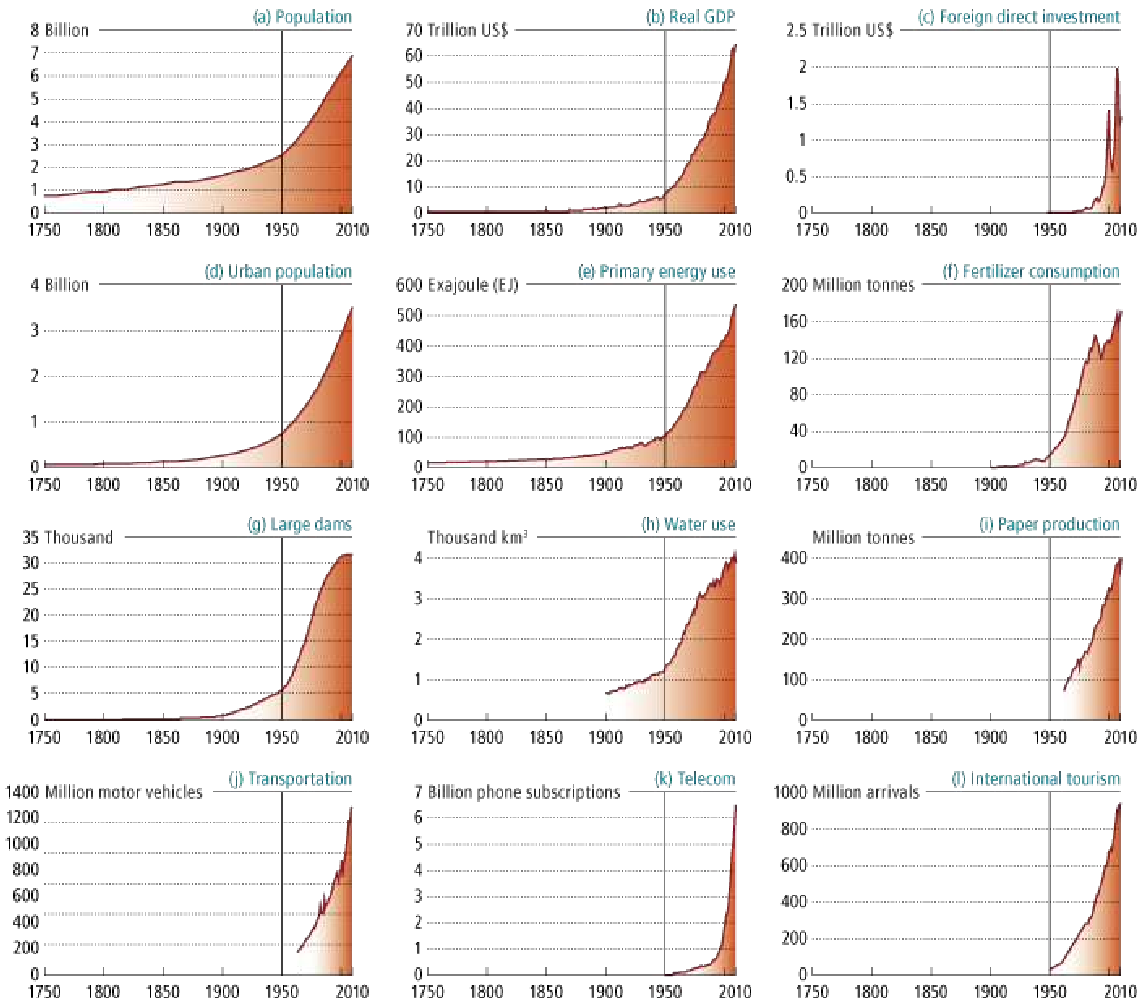

Figure 4 The Great Acceleration – socioeconomic trends in (a) population, (b) real GDP, (c) FDI, (d) urban population, € primary energy use, (f) fertilizer consumption, (g) large dams, (h) water use, (i) paper production, (j) transportation, (k) telecommunications and (l) international tourism. *Source:* Steffen et al., 2015.

2.3 The Anthropocene

"The Anthropocene changes our relationship with the planet. We have a new responsibility and we need to determine how to meet that responsibility"
Nobel Laureate Elinor Ostrom (1933–2012)
(Planet Under Pressure 2012)

At some point after 1950, the socioeconomic system coupled strongly with the Earth system – the oceans, atmosphere, ice sheets, soils, cycles and waterways and diversity of life that combine to keep Earth habitable. Now, the socioeconomic system is the primary driver of change in the Earth system and this is taking place at an unprecedented magnitude and speed (*Figure 5*, (Crutzen, 2002, Crutzen and Stoermer, 2000, Waters et al., 2016, Rockström et al., 2009, Steffen et al., 2004). With increasing population and GDP, the human system is increasingly infringing on Earth's buffering capacity, threatening Earth resilience.

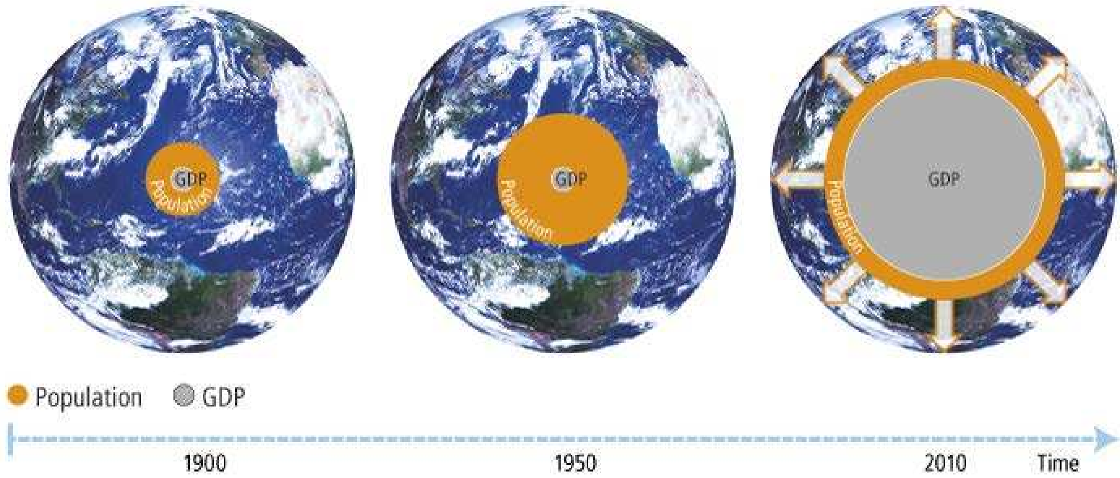

Figure 5 The trajectory of the Anthropocene.

The Great Acceleration (*Figures 4 and 6*) is pushing Earth out of the Holocene epoch. Greenhouse gas levels as high as seen today may not have been seen for at least three million years. Earth is losing biodiversity at mass extinction rates (Ceballos et al., 2015). The chemistry of the oceans is changing faster than at any point in perhaps 300 million years (Hönisch et al., 2012). Our own technology has had what is arguably the largest and most rapid impact on the nitrogen cycle for some 2.5 billion years (Williams et al., 2015). We see similarly severe impacts on the carbon and water cycles. Humans have now modified the structure and functioning of Earth's biosphere to such an extent that it has been proposed that Earth is at the beginning of a third stage of evolution, following the microbial stage that began 3.5 billion years ago and the metazoan that started 650 million years ago (Williams et al., 2015).

In 2000, two scientists, Dutch Nobel-prize winning chemist Paul Crutzen and U.S. ecologist Eugene Stoermer, proposed that Earth was no longer in the Holocene (Crutzen and Stoermer, 2000). Based on the overwhelming evidence that was being compiled at that time by the International Geosphere-Biosphere Programme, the academics argued that human activity had pushed Earth into a wholly new epoch, which they named the Anthropocene. Crutzen originally proposed that the beginning of the Industrial Revolution might mark the beginning of this new epoch (Crutzen, 2002). He then revised his estimate to conclude that the beginning of the Great Acceleration was a more likely candidate. This view is gaining ground in academic circles. The Anthropocene Working Group of the International Commission on Stratigraphy, which is assessing the claim, is now leaning toward this timeframe being a "Golden Spike," a term used by geologists to indicate an unmistakable marker in the fossil record (Waters et al., 2016). This marker coincides with the first atomic bomb test on July 16, 1945 which heralded the "Atomic Age." The fallout from this explosion, and subsequent nuclear tests up to the ban in 1963, will leave a distinct signature in the sedimentary record into the future.

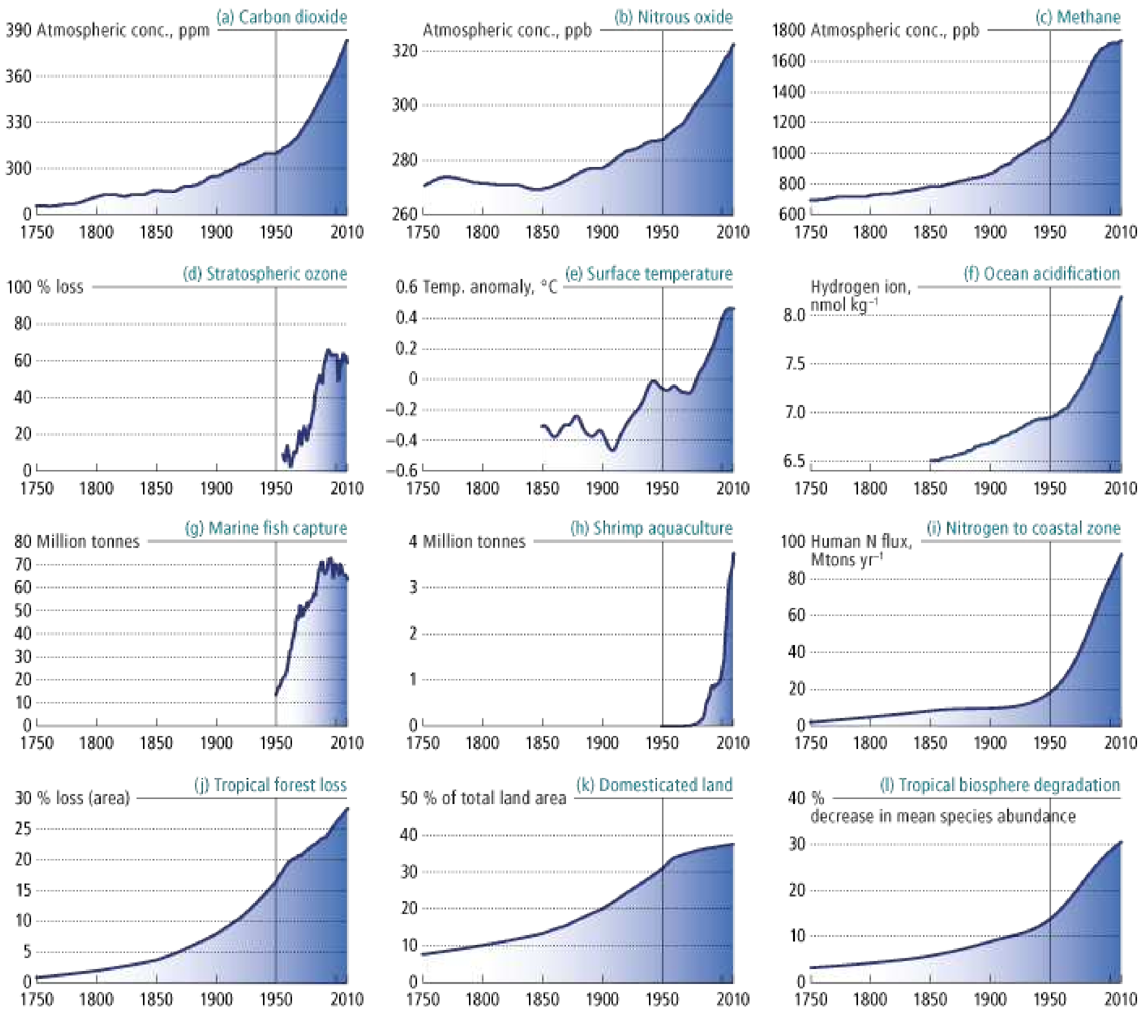

Figure 6 The Great Acceleration – Earth system trends in (a) carbon dioxide, (b) nitrous oxide, (c) methane, (d) stratospheric ozone, € surface temperature, (f) ocean acidification, (g) marine fish capture, (h) shrimp aquaculture, (i) nitrogen to coastal zone, (j) tropical forest loss, (k) domesticated land (land use change) and (l) tropical biosphere degradation. *Source:* Steffen et al., 2015.

2.4 The Anthropocene Effect

In a globalized world of mass consumption and production, the aggregated and cumulative effects of individual actions and decisions are leading to emergent behavior at the Earth system scale, the "Anthropocene Effect" (*Figures 4 and 6*); behavior that cannot be predicted from analysis of individual parts. Understanding the Anthropocene and pathways to global sustainability is now a rapidly growing area of research, with five journals established recently: The Anthropocene, The Anthropocene Review, Elementa: Science of the Anthropocene, Earth's Future and Global Sustainability.

While the links between economic development and environmental degradation at the local and the regional scale have been studied extensively, do the same principles apply at the planetary scale? It has been proposed that as societies develop, pollution and environmental degradation increase. However, once a society reaches certain levels of development, efforts increase to improve environmental conditions. As people become more affluent the desire and ability to reduce pollution and environmental degradation at local and regional level increases. However, is the environmental degradation simply exported beyond city limits or national jurisdictions to rural hinterlands, less-developed countries and planetary-level buffers – the oceans or atmosphere? Moreover, the broader question is would the same principle apply at the planetary scale at very high levels of affluence across countries?

Several cases demonstrate that development can reduce some of the negative environmental externalities (*Figure 7*).; examples are access to sanitation and improvements to indoor and regional air pollution such as reduced emissions of sulfur dioxide and particulate matter (McGranahan and Satterthwaite, 2000, Smith and Akbar, 1999, Nakicenovic et al., 1998, UNDP et al., 2000). With increasing income, environmental awareness increases, health impacts matter more and it becomes affordable to protect the environment. A further explanation is that strong institutions and policies have induced technological innovation and economic efficiency in developed countries. This could serve and an important example in helping developing countries embark on alternative development pathways based on good governance. With strong governance and institutions some aspects of environmental protection can become integrated in regulatory mechanisms, such as standards.

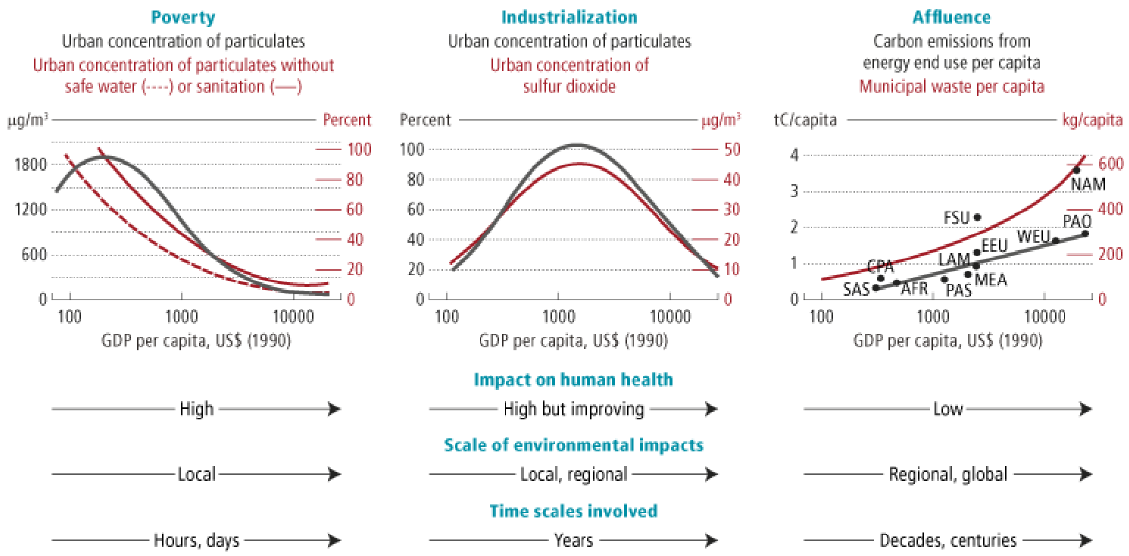

Figure 7 Environmental Kuznets curves for urban concentration of particulates and carbon emissions for different development levels. Source: Nakicenovic et al., 1998.

The Anthropocene Effect highlights the problems of scaling from local and regional environmental consequences to planetary, where impacts operate on different scales, often both in terms of time and space. For example, the adverse health impacts of indoor air pollution are immediate and local and the benefits of elimination are immediate too. In contrast, climate change is a global and cumulative problem and mitigation or a lack thereof cast a long shadow into the future.

The relationships between development and the environment are often represented by "environmental Kuznets curves." Simon Kuznets presented his hypothesis that there is an inverse U-shaped relationship between development and income disparity at the 1954 American Economic Association (Kuznets, 1995). However, the last two decades have witnessed increasing inequalities even in the most affluent parts of the world and this appears to contradict, at least for the time being, the original Kuznets curve. However, the idea has been generalized in the literature to find a relationship between improvement of environmental quality and development (World Bank, 1992). The question is whether such a phenomenological relationship based on some empirical examples of local and regional environmental impacts could be valid in the future for reducing pressures on the Earth system in the Anthropocene, as we are seeing different types of curves for different parameters.

So far, the opposite seems to be the case. Municipal waste and carbon dioxide emissions have tended to increase with rising income. The Paris Agreement and the adoption of the 17 SDGs might be an early sign that things are changing and that efforts are underway to reach the emissions peak soon and that this peak will thereafter decline with increasing global income.

The problem, however, is that emissions and waste are continuing to increase despite the recent slowdown in carbon dioxide emissions (Jackson et al., 2016). Also, the slowdown is likely to be temporary until deep decarbonization occurs in the world. Past emissions of GHGs have already led to 1°C warming and have virtually committed the world to about a 1.5°C warming above pre-industrial levels (IPCC, 2013). Thus, the whole world cannot follow the historical fossil fuel-intensive development path of industrialized parts of the world *(Figure 8,* black curve) without transcending the planetary climate boundary as agreed in Paris (UNFCCC, 2015). This infringement of the Planetary Boundaries is likely to be further aggravated by other global megatrends that have together led to the Anthropocene Effect (see Section 2.5).

Humanity must reach peak emissions immediately, which means that developing nations must follow new pathways to economic development (*Figure 8,* green curve for GHG emissions), even though they have neither contributed to the problem nor bear the responsibility for it. Yet, they can do so through leapfrogging and using learnings from the mistakes of developed countries in order to embark on more sustainable development pathways as soon as possible (Goldemberg, 1998). Leapfrogging would be required to achieve the 17 SDGs or to “tunnel” through the Kuznets curves (Munasinghe, 1999). The global North now needs to abruptly and immediately embark on sustainable zero-emissions development pathways while the global South would need to avoid repeating the historical experience of the global North and proceed immediately on a sustainable development pathway. Avoiding historical environmental Kuznets curves is thus an essential aspect of protecting the Earth system and reducing the Anthropocene Effect.

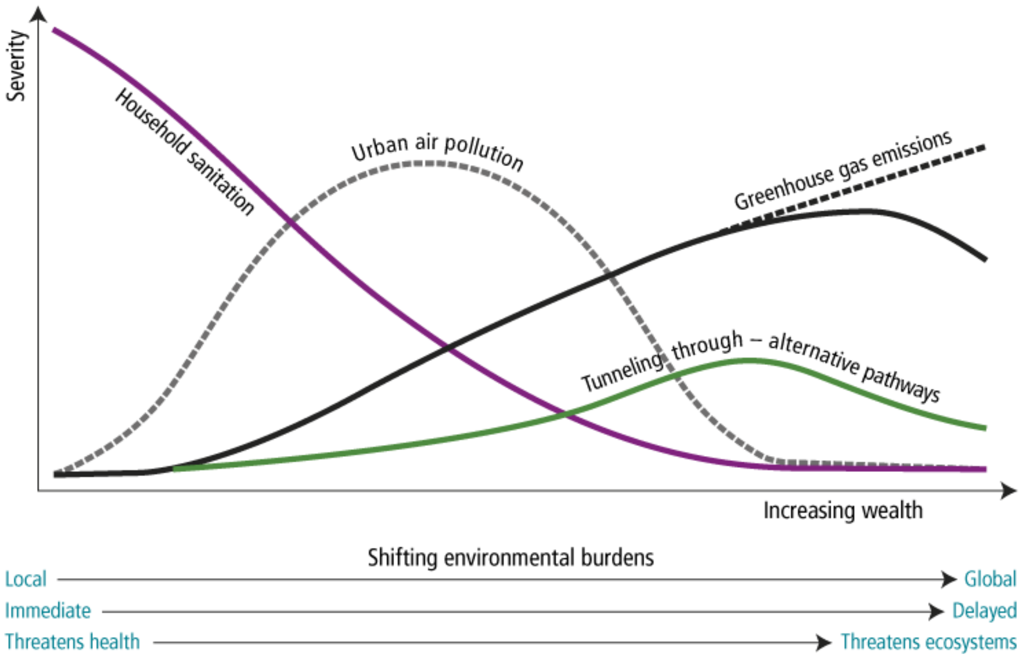

Figure 8 Historical environmental Kuznets curves showing that household sanitation and urban air pollution can be resolved with development in contrast to GHG emissions. Adapted from Smith and Akbar, 1999, McGranahan and Satterthwaite, 2000, UNDP et al, 2000.

2.5 Global Megatrends to 2100

"It is difficult to make predictions, especially about the future."
Danish proverb often attributed to Niels Bohr

The Great Acceleration captures the key global megatrends of the 20th century. How will these trends evolve in the 21st century? While future megatrends are inherently unpredictable, six critical trends that are likely to determine the future state of the Earth system are population growth, GDP, urbanization, energy use, GHG emissions and land-use change. These drivers are not parallel; population growth and GDP are the primary drivers, and they exert a strong influence on the others. Rather than attempting to predict the future, scenarios are used to understand how the future might emerge under different conditions with different drivers. The literature on scenarios is huge; there are more than 1,000 global scenarios available just in the context of climate change (IAMC, 2014).

In order to illustrate possible future socioeconomic trends, we have selected groups of scenarios, or pathways, which have been developed by several research groups for the Intergovernmental Panel on Climate Change (IPCC). These "Shared Socioeconomic Pathways" (SSPs) incorporate knowledge from a wide range of modeling communities, including integrated assessment models that capture socioeconomic drivers, coupled climate- and Earth system models, and impacts and vulnerability models. Each of the five scenarios, which run to the end of the century, makes assumptions about the challenges to mitigation and adaptation and about the intensity and combinations of megatrends such as economic growth or population growth (*Figure 9*). Here we have selected SSP1 and SSP3 to demonstrate the differences between possible extreme future development paths.

Shared Socioeconomic Pathway 1

SSP1 showcases our ideal scenario. In SSP1 the world is shifting gradually to a more sustainable pathway within Planetary Boundaries. Cooperation and collaboration on all levels and between diverse actors support this shift in the long term, as does the population by peaking by mid-century. In this scenario *"the challenges for mitigation and adaptation are low. Sustainable development proceeds at a reasonably high pace, inequalities are lessened, technological change is rapid and directed toward environmentally friendly processes, including lower carbon energy sources and high productivity of land"* (O'Neill et al., 2014, O'Neill et al., 2015, in press).

Shared Socioeconomic Pathway 3

SSP3 is our dynamics-as-usual scenario where current trends might continue in the future, but it is not the worst case one can imagine from the global commons perspective: *"The challenges for mitigation and adaptation are high. Unmitigated emissions are high due to moderate economic growth, a rapidly growing population, and slow technological change in the energy sector, making mitigation difficult. Investments in human capital are low, inequality is high, a regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity"* (O'Neill et al., 2014, O'Neill et al., 2015, in press).

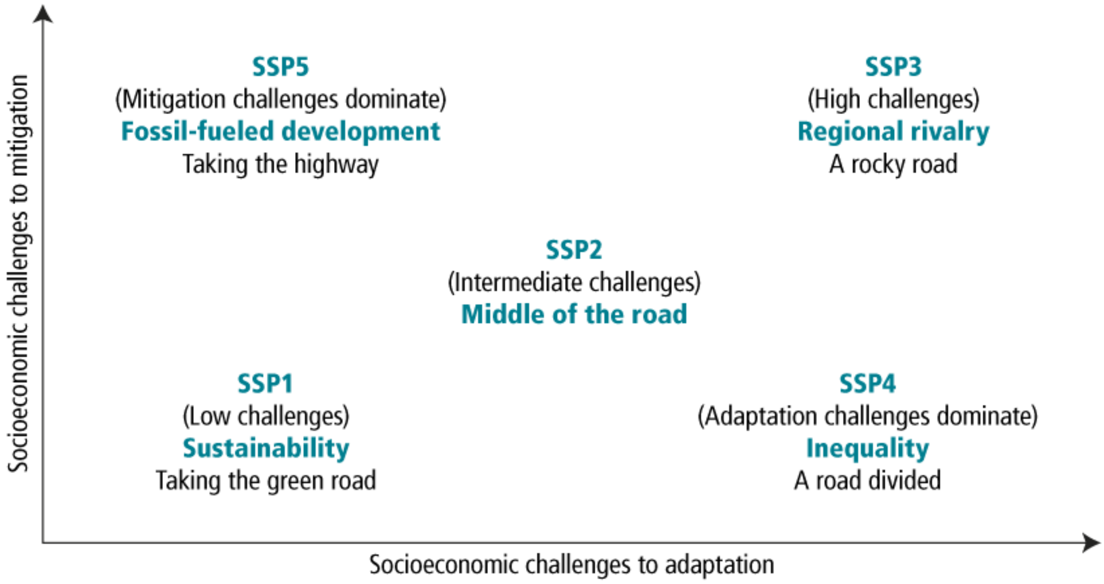

Figure 9 Mitigation and adaptation – the challenges space for five domains according to the Shared Socioeconomic Pathways SSP1-SSP5. Adapted from O'Neill et al., 2014.

By 2100, the two worlds that emerge as a result of these two scenarios are very different (*Figures 10 and 11).* In SSP3, the global population is nearly double compared with SSP1, while economic output is less than half and shared less equally. While energy demand stabilizes in SSP1, it doubles in SSP3. In terms of environmental impacts, SSP1 manages to peak in terms of carbon dioxide and methane concentrations, mean temperature and land use, while SSP3 shows a future of ever increasing, often still exponentially, environmental degradation. When following the SSP1 pathway, the world manages to stay below a 2°C global mean temperature increase. In SSP3 the global mean temperature increase reaches 4°C by the end of the century. As well as the increases in concentration in carbon dioxide, methane and nitrous dioxide among others, the SSP3 scenario would entail a range of further incalculable impacts and a range of feedback on the Earth's system, some of which are set forth below.

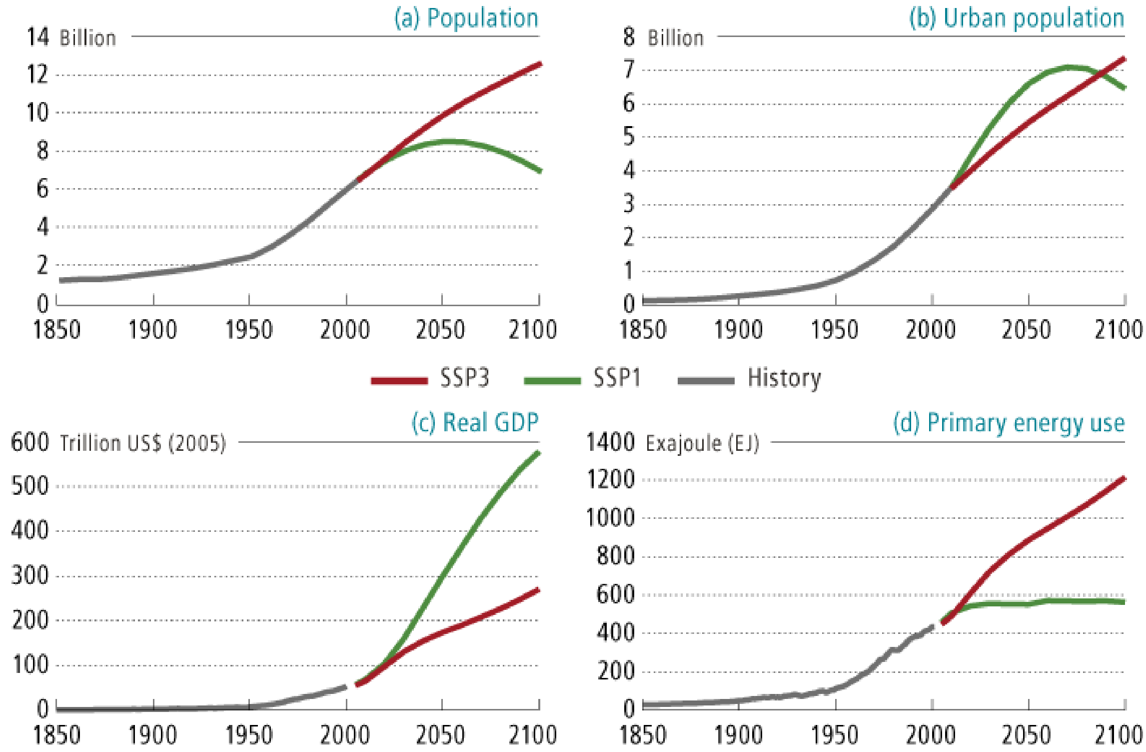

Figure 10 Two megatrend scenarios illustrating alternative development pathways (O'Neill et al. 2015, in press, Riahi et al., 2016, forthcoming) for (a) population (KC and Lutz, 2015, in press), (b) urban population (Jiang and O'Neill, 2015, in press), (c) real GDP (Dellink et al., 2015, in press) and (d) primary energy used based on Shared Socioeconomic Pathways SSP1 (van Vuuren et al. 2016, in press) and SSP3 (Fujimori et al 2016, in press). Historical data from Grubler et al, 2012, Steffen et al, 2015.

The outlook of these megatrends (Riahi et al., 2016, forthcoming, Popp et al., 2016, in press, Meinshausen et al., 2011, KC and Lutz, 2014, in press, Jiang and O'Neill, 2015, in press, Dellink et al., 2015, in press, Grubler et al., 2012, Fujimori et al., 2016, in press, van Vuuren et al., 2016, in press) in the 21st century guide us toward the key systems where holistic interventions are needed to change the future pathways in a favorable way, to stay within the range of the desired SSP1. As a priority, we have to decrease the impact of human life on Earth in the four key systems which, while they are the current main culprits, also provide ample room for solutions. The nexus systems crucial for global sustainability and development are the:

- energy system
- food system
- water system and
- urban system; as the majority of the population will live in cities, sustainable urban solutions will have large impacts.

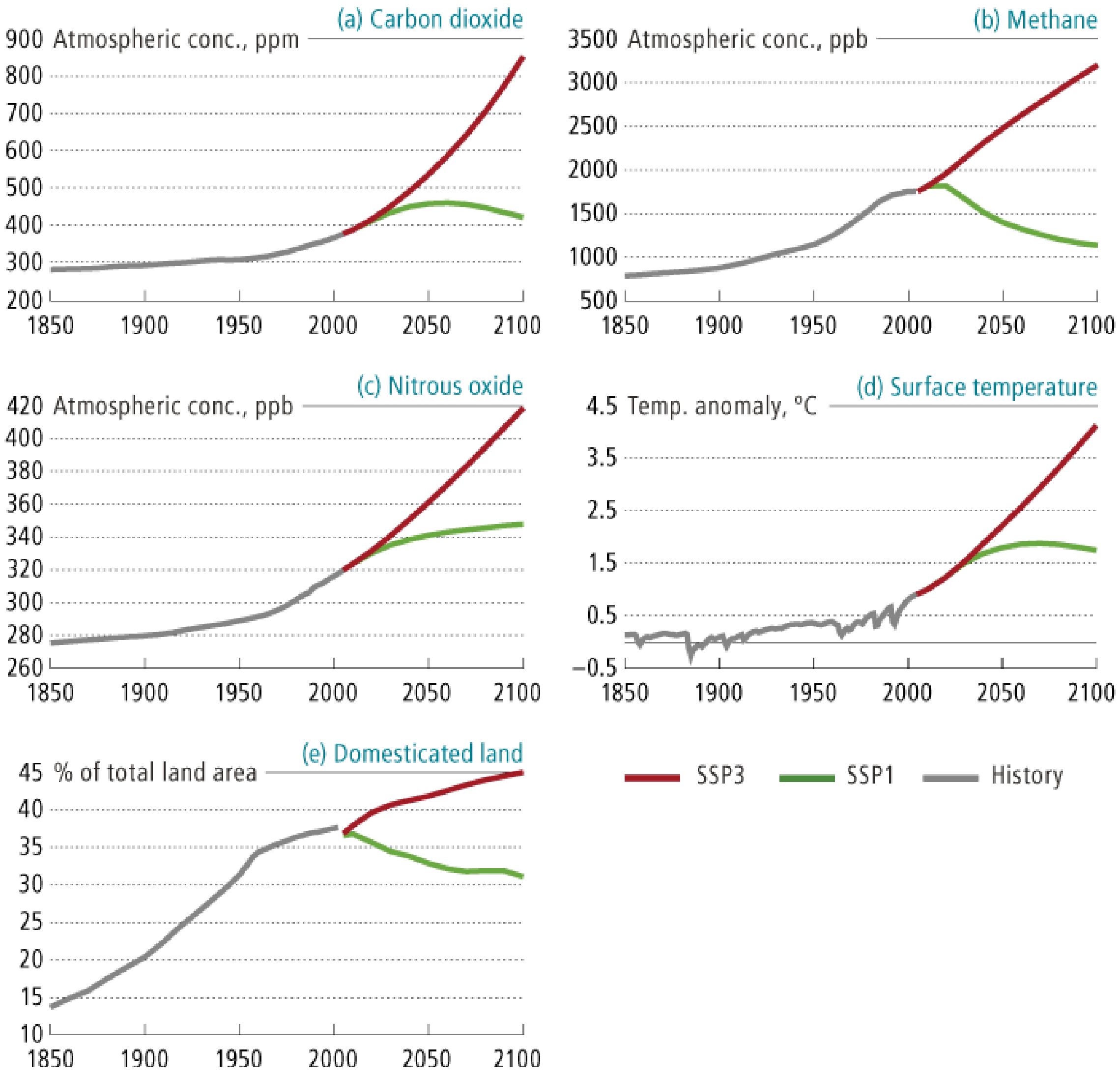

Figure 11 Two megatrend scenarios illustrating alternative development pathways (O'Neill et al. 2015, in press, Riahi et al. 2016, forthcoming) for (a) carbon dioxide, (b) methane concentration, (c) nitrous oxide concentration, (d) temperature (Meinshausen et al., 2011) and € domesticated land (Land use change) base on Shared Socioeconomic Pathways SSP1 and SSP3. Historical data from Steffen et al, 2015.

2.6 Regime Shifts, Tipping Points, Nonlinearities and Thresholds

Humanity is interfering with the delicate balance of key components of the Earth system: Antarctica, the Arctic, the Amazon rainforests and the global carbon cycle.

The notion that a single stable equilibrium is the natural state of Earth is not supported by observations of past global changes (Steffen et al., 2004). The behavior of the Earth system is typified not by stable equilibria, but by strong nonlinearities, where relatively small changes in a forcing function can push the system across a threshold and lead to abrupt changes in key aspects of system functioning where the internal dynamics of the system kick in and accelerate change – we call these "tipping elements" or "tipping points" (Lenton et al., 2007). Examples include the rapid ending of ice ages, the exceptionally rapid warming and cooling events in the North Atlantic region, mega-droughts and other extreme events.

Tipping points are part of our culture. The old saying "The straw that broke the camel's back" acts as a warning to expect the unexpected, even when change is at most incremental and, at times, almost imperceptible to the naked eye. The saying has counterparts in many languages indicating that the concepts of regime shifts, tipping points, tipping elements, nonlinearities and thresholds in systems are well understood across cultures, though the complex mathematics underpinning these systems remains elusive to many.

Scientific knowledge of complex ecological and social systems has grown significantly in recent decades. Incremental change may push a system – a city, economy, forest or fishing zone for example – to a bifurcation point where, after incremental change, it is pulled irresistibly toward a new basin of attraction and so a new equilibrium state. Or a system, after long periods of incremental change, may suddenly collapse irreversibly into a new state. While the force to initiate change can often start out externally, internal drivers can take over creating positive feedback loops amplifying the change leading to collapse.

Analysis of the large-scale subsystems of the Earth system – ocean circulations, permafrost, ice sheets, Arctic sea ice, the rainforests and atmospheric circulations (*Figure 12*) – indicates that these systems are prone to large-scale change and collapse (Lenton et al., 2007). Moreover, human activities, such as industrial scale farming and fishing, are reducing the resilience of these subsystems to absorb shocks, and pushing these subsystems toward new states. If one system collapses to a new state, it may set up positive feedback loops amplifying the change and triggering changes in other subsystems. This might be termed a "cascading collapse" of key components of the Earth system. Given that the stability of the Earth system underpins human civilization and welfare, avoiding this fate would seem to be an attractive course of action.

Understanding the complex interactions between rapidly changing systems is an active area of research. Sea ice thickness and area is shrinking in the Arctic. As the sea ice melts, it exposes dark ocean underneath which absorbs more heat than the white surface, thus causing more warming and so melting in the region. Warmer water is contributing to the melting of the Greenland ice sheet which pouring more freshwater into the north Atlantic, potentially interfering with the north Atlantic overturning circulation. All these events can potentially affect El Nino in the Pacific Ocean, which affects melting in Antarctica, the Indian monsoon, rainfall in Africa and coral reefs.

A recent analysis of tipping elements in the Earth system (*Figure 13*) indicates that at temperatures of between 2–3°C above pre-industrial temperatures the risk of the subsystems of the Earth system collapsing becomes high, though many uncertainties remain (Schellnhuber et al., 2016). This analysis follows the tipping point definitions of Lenton et al. (2007) where irreversibility is not a requirement, hence the inclusion of sea ice cover. Earth has now reached 1°C above pre-industrial levels as a result of human actions. With locked in emissions and inertia in the socioeconomic system we are virtually committed to about 1.5°C (Rogelj et al., 2015). Moreover, while nations have agreed to keep global temperature increase well below 2°C with a long-term aim of stabilization at

1.5°C, aggregated national proposals to reduce emissions will lead to a warming of 2.7–3.5°C (Climate Action Tracker, 2015). The most likely scenario is that the world will overshoot the target and attempt to recover by creating new carbon sinks.

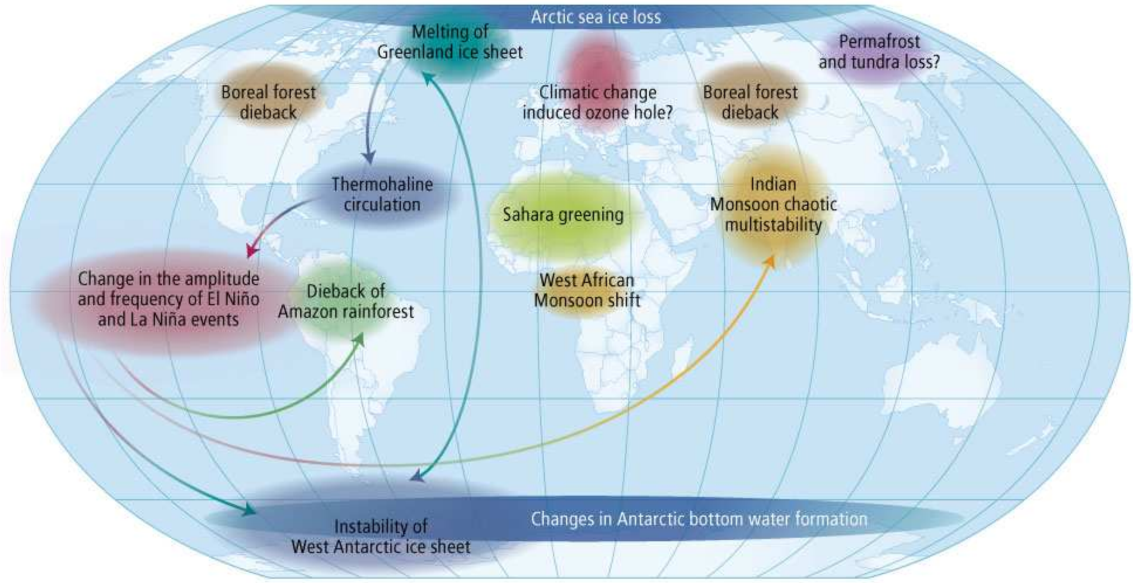

Figure 12 Tipping elements and some potential cascading impacts across the Earth system. Adapted from Lenton et al., 2007, Lenton and Williams, 2013.

The Arctic

A key tipping element in the Earth system is the Arctic. This is of concern to the research community because the Arctic is the fastest warming region on the planet. While global average temperatures are predicted to rise at least 4°C by 2100, without deep transformations of the global energy system the temperatures in the Arctic are set to increase significantly more than that (IPCC, 2013). Sea ice reflects heat away from Earth due to its white surface. As sea ice melts more ocean is exposed. The dark surface of the ocean absorbs more heat, leading to increased melting. The concern is that the melting can thus feed itself causing an acceleration in melting. *Figure 14* highlights the Arctic temperature anomaly in February 2016, the warmest February on record (Hansen et al., 2010, GISTEMP Team, 2016). Warming in the Arctic is noticeably more pronounced than elsewhere on Earth. Localized regime shifts in the Arctic could cascade through social and ecological systems and cascade beyond the Arctic with far-reaching effects. *Table 1* illustrates key potential regime shifts that have been identified in the Arctic (Stockholm Resilience Centre, 2016).

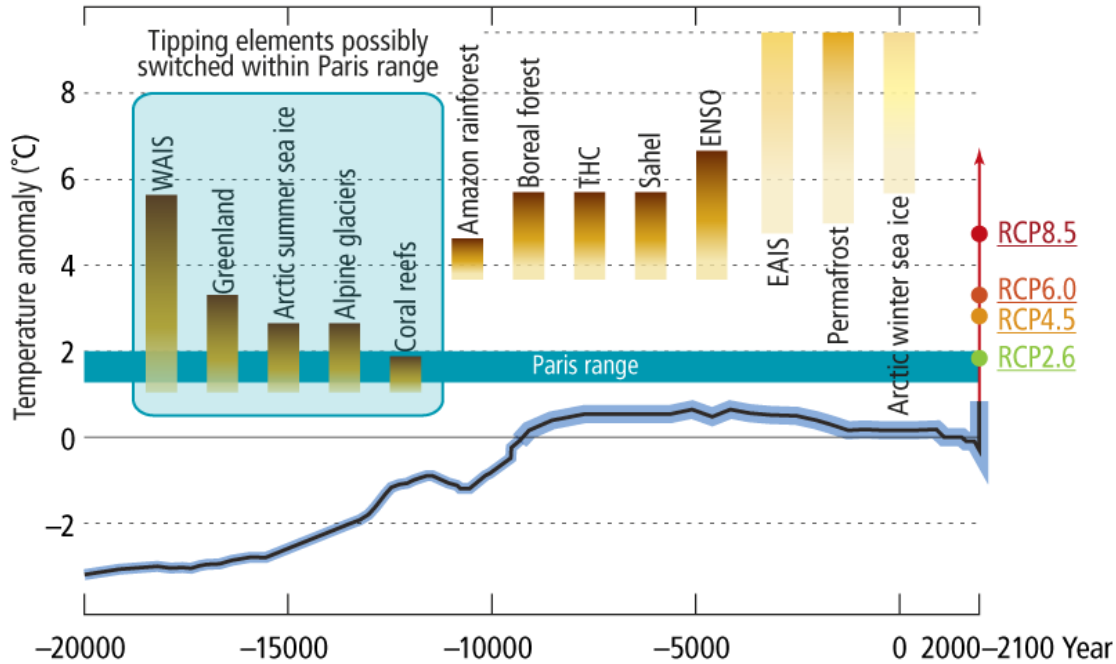

Figure 13 Evolution of global mean surface temperature from the Last Glacial Maximum through the Holocene and future global warming scenarios (RCP, Representative Concentration Pathways) related to tipping elements. WAIS, West Antarctic ice sheet; THC, thermohaline circulation; ENSO, El Niño-Southern oscillation; EAIS, East Antarctic ice sheet. Adapted from Schellnhuber et al., 2016.

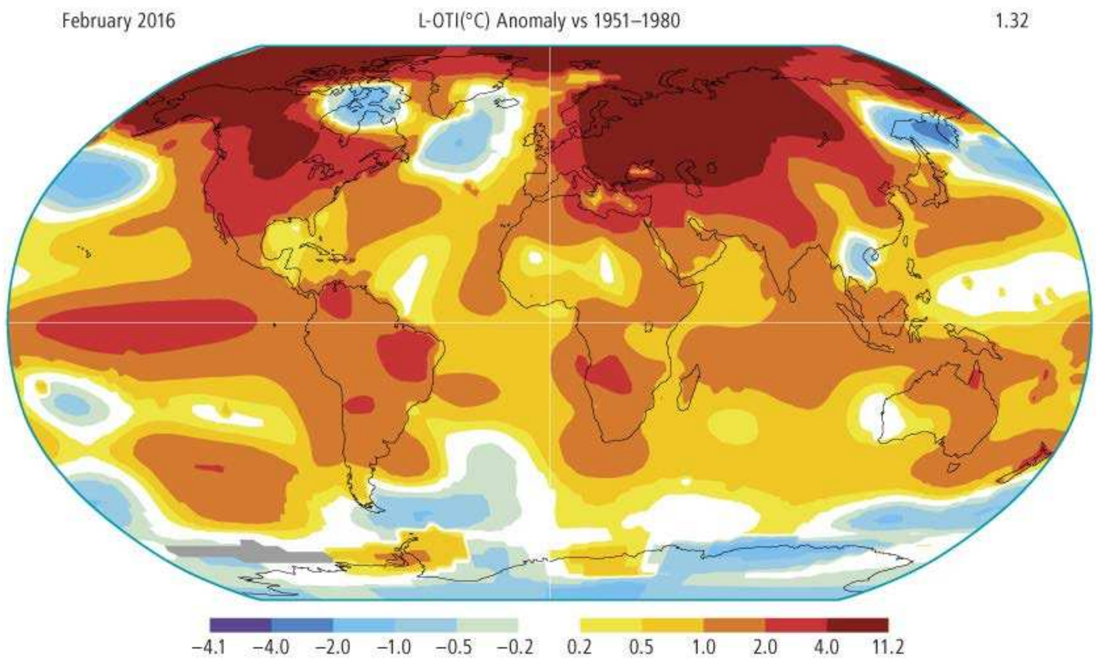

Figure 14 Surface temperature anomalies for February 2016, in °C. *Source*: Hansen et al., 2010; GISTEMP Team, 2016. *Note*: Gray areas signify missing data. Ocean data are not used over land or within 100 km of a reporting station.

Table 1 Potential regime shifts in the Arctic and their global implications. *Source:* Stockholm Resilience Centre's Regime Shift Database, 2016.

Regime shift	Impact	Likelihood
Arctic sea ice	The amount of summer sea ice has been falling for at least three decades. There is a high likelihood of sea ice collapse in the summer months if average global temperature increase reaches around 2°C. This may induce positive feedback because dark waters absorb more heat than white surfaces, and consequences for ecosystems.	Likely
Greenland ice sheet stability	There may be irreversible collapse if the temperature rises by 3°C resulting in an eventual sea-level rise of 7 meters.	Likely
Ocean circulation	Freshwater from melting Arctic ice could disrupt the North Atlantic Meridional Circulation which contributes to Europe's mild climate. According to the IPCC (2013), it is very likely that this circulation will weaken considerably.	Very unlikely to undergo a collapse in the 21st century (IPCC 2013)
Permafrost	By 2100, the diagnosed near-surface permafrost area is projected to decrease by between 37% (RCP2.6) and 81% (RCP8.5) for different climate change scenarios (IPCC 2013). Permafrost may release trapped greenhouse gases, e.g., methane leading to a positive feedback loop exacerbating warming.	Very likely to see significant melting

The Amazon

The stability of Earth's major carbon sinks is of increasing concern to scientists. Carbon sinks on land absorb one quarter of human carbon dioxide emissions. The Amazon rainforest alone is responsible for one quarter of that absorption (Sitch et al., 2015). In a high carbon dioxide world with warmer temperatures we might expect forests to absorb more carbon becoming greater carbon sinks and providing an additional boost to efforts to curb climate change. Indeed, in recent decades the land carbon sink has increased. While tropical forests contributed to this increase in the 1980s and 1990s, recent research (Brienen et al., 2015) suggests this may no longer be the case. In the past decade, the percentage of trees dying has been increasing and the rate of tree growth has stalled: the carbon absorbed annually by the Amazon fell from an average of 0.54 GtC per year in the 1990s to 0.38 GtC in the 2000s – a decrease of 30%. The authors conclude: "*If our findings for the Amazon are representative for other tropical forests, and if below-ground pools have responded in the same way as above-ground biomass, then an apparent divergence emerges between a strengthening global terrestrial sink on one hand and a weakening tropical sink on the other*" (Brienen et al. 2015).

Deforestation in the Amazon, which affects biodiversity, cultural diversity and the stability of a major global carbon sink, may also influence rainfall patterns. By 2050, high deforestation rates could cause an 8% reduction in annual rainfall in the Amazon basin (Spracklen and Garcia-Carreras, 2015), and in the long term, Amazon dieback may cause parts of the Amazon to shift to a savanna state with implications for the global water cycle and other components of the Earth system.

The concern is rising that we are witnessing a severe reduction in the Amazon's resilience capacity. This pattern is likely to be repeated elsewhere for example in the rainforests of the Congo basin, Borneo and Indonesia.

Antarctica

The poles operate as a critical thermostat to keep Earth cool. According to IPCC (2013), there is high confidence that the Antarctic ice sheet has lost mass during the last two decades. Independent studies have also shown that in the past global temperatures rises of 2°C above pre-industrial temperatures have been linked to global sea levels of 6–13 meters higher than today (Dutton et al., 2015). Antarctic ice has been implicated in this sea-level rise, but the mechanism that would lead to such a catastrophic collapse of ice has remained elusive until now.

Recently, two studies have indicated how parts of the ice sheet can collapse rapidly and how this might be irreversible (Rignot et al., 2014, Winkelmann et al., 2015). It is of significant concern that both studies state that the West Antarctic ice sheet has reached a point of no return. Melting from underneath the ice sheet, caused by warmer waters, has now reached a point where no natural barrier will prevent further melting, which would lead to the complete collapse of this section of Antarctica and cause the global sea level to rise six meters or more (Rignot et al. 2014). It has also been shown that burning the remaining known reserves of fossil fuels will add enough GHG to the atmosphere to melt the entire Antarctic ice sheet, which alone will raise sea levels by around 58 meters (Winkelmann et al., 2015).

The stability of important parts of Antarctica is now in the balance. The West Antarctic ice sheet appears vulnerable to collapse if global average temperatures reach 2°C, however many uncertainties remain and the tipping point may be sooner than this.

2.7 Earth Resilience and Planetary Boundaries

There is a need to search for a safe operating space for humanity.

In recent years, the cascade of concepts in Earth system science – the Great Acceleration, the Anthropocene, regime shifts and tipping elements – has focused research toward an analysis of Earth resilience and an assessment of the boundary conditions that keep Earth in a Holocene-like state, that is, with a stable global climate, abundant ecosystem services, rich biodiversity, fertile soils and oceans and a healthy atmosphere. In 2009, this work led us to identify nine control variables or Planetary Boundaries which it would be unwise either to transgress or to risk crossing their related thresholds in the Earth system (Rockström et al., 2009). At the time of publication we estimated that three boundaries had been transgressed: climate, biodiversity and biogeochemical flows (predominantly nitrogen use). Following six years of intense scrutiny, a reassessment of the Planetary Boundaries was published in 2015 (Steffen et al., 2015) (*Figure 15*), which concluded that in addition to these three boundaries, a fourth boundary relating to land-use change (largely deforestation) had also been crossed and that phosphorus use (included as a biogeochemical flow) was also in a zone of uncertainty. The authors also identified two further boundaries that merit particular attention – climate and biosphere integrity – due to their individual potential to push the Earth system into a wholly new state. Crossing a boundary does not equate to crossing a threshold or tipping element in the Earth system. It relates to scientific knowledge and uncertainty around these thresholds. Within the boundaries, there is general agreement that the risk of crossing identified thresholds is low. Beyond the boundaries, the general agreement is that the risk is high.

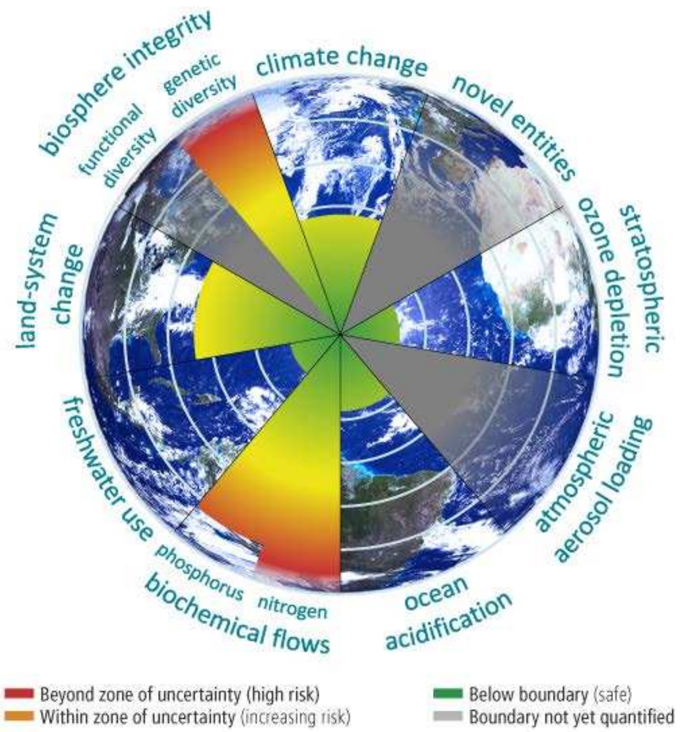

Figure 15 Planetary Boundaries – green areas show where human activities are within safe margins; yellow indicates where safe margins may or may not have been exceeded, red where they have been exceeded, and gray where they have not yet been determined. Adapted from Steffen et al., 2015.

A framework was developed to quantify the Planetary Boundaries. Based on empirical evidence, it provides a tool for monitoring Earth system stability and resilience *(Table 2)* and provides guidance on what could be considered a safe operating space for humanity on a finite planet. Efforts are underway to adapt the framework to provide sustainability guidance at national and regional levels, and within sectors. The World Wide Fund for Nature and the World Business Council for Sustainable Development have already adopted it (WWF et al., 2014, Stockholm Resilience Centre and World Business Council for Sustainable Development, 2015).

The framework will evolve over time. Intense research is underway to reduce uncertainties, improve quantification and assess the interlinkages between boundaries. There is currently no global quantification for the boundary relating to novel entities. Scientists discovered just in time that novel entities such as chlorofluorocarbons (CFCs) used industrially from the 1950s destroy ozone in the upper atmosphere with potentially large-scale impacts for life on land. There are over 100,000 substances used industrially. We have limited understanding of how they interact and affect emergent behavior at the Earth system level, either through aggregation, accumulation or both (Steffen et al., 2015).

The Planetary Boundaries that we have already transgressed or are likely to transgress due to system lock-ins (biochemical flows of nitrogen and phosphorus, genetic diversity of the biosphere, climate change, and land-system change) emphasize the areas where humanity urgently needs to act to safeguard Earth resilience: the energy, water, food and urban systems are the significant pressure points driving exponential change and these must be the priority areas to search for solutions.

Table 2 Quantification of the Planetary Boundaries. *Source:* Steffen et al, 2015.

Earth system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Climate change (comparison with first Planetary Boundary processes: Rockström et al. 2009: same)	Atmospheric CO_2 concentration, ppm Energy imbalance at top-of-atmosphere, Wm^{-2}	350 ppm CO_2 (350–450 ppm) Energy imbalance: +1.0 Wm^{-2} (+1.0–1.5 Wm^{-2})	396.5 ppm CO_2 2.3 Wm^{-2} (1.1–3.3 Wm^{-2})
Change in biosphere integrity (Rockström et al. 2009: Rate of biodiversity loss)	*Genetic diversity* Extinction rate	<10 E/MSY (10–100 E/MSY) but with an aspirational goal of ~1 E/MSY* (the background rate of extinction loss). *E/MSY = extinctions per million species-years	100–1000 E/MSY
	Functional diversity Biodiversity Intactness Index (BII) *Note* These are interim control variables until more appropriate ones are developed	Maintain BII at 90% (90–30%) or above, assessed geographically by biomes/large regional areas (e.g., southern Africa), major marine ecosystems (e.g., coral reefs), or by large functional groups	84%, applied to southern Africa only
Stratospheric ozone depletion (Rockström et al. 2009: same)	Stratospheric O_3 concentration, DU	<5% reduction from preindustrial level of 290 DU (5–10%), assessed by latitude	Only transgressed over Antarctica in Austral spring (~200 DU)
Ocean acidification (Rockström et al. 2009: same)	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ωarag)	≥80% of the preindustrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80 – ≥70%)	~84% of the preindustrial aragonite saturation state
Biogeochemical flows: Phosphorous (P) and Nitrogen (N) cycles (Rockström et al. 2009: Biogeochemical flows – interference with P and N cycles)	**P cycle** *Global* P flow from freshwater systems into the ocean	11 Tg P yr^{-1} (11–100 Tg P yr^{-1})	~22 Tg P yr^{-1}
	Regional P flow from fertilizers to erodible soils	6.2 Tg yr^{-1} mined and applied to erodible (agricultural) soils (6.2–11.2 Tg yr^{-1}). Boundary is a global average but regional distribution is critical for impacts.	~14 Tg P yr^{-1}
	N cycle *Global* Industrial and intentional biological fixation of N	62 Tg N yr^{-1} (62–82 Tg N yr^{-1}) Boundary acts as a global "valve" limiting introduction of new reactive N to Earth system, but regional distribution of fertilizer N is critical for impacts.	~150 Tg N yr^{-1}
Land-system change (Rockström et al. 2009: same)	*Global* Area of forested land as % of original forest cover	75% (75–54%) Values are a weighted average of the three individual biome boundaries and their uncertainty zones	62%
	Biome Area of forested land as % of potential forest	*Tropical* 85% (85–60%) *Temperate* 50% (50–30%) *Boreal* 85% (85–60%)	
Freshwater use (Rockström et al. 2009: Global freshwater use)	*Global* Maximum amount of consumptive blue water use (km^3 yr^{-1})	4000 km^3 yr^{-1} (4000–6000 km^3 yr^{-1})	~2600 km^3 yr^{-1}
	Basin Blue water withdrawal as % of mean monthly river flow	Maximum monthly withdrawal as a percentage of mean monthly river flow: Low-flow months: 25% (25–55%) Intermediate-flow months: 30% (30–60%) High-flow months: 55% (55–85%)	
Atmospheric aerosol loading (Rockström et al. 2009: same)	*Global* Aerosol Optical Depth (AOD), but much regional variation		
	Regional AOD as a seasonal average over a region; South Asian monsoon used as a case study	South Asian monsoon as a case study: anthropogenic total (absorbing and scattering) AOD over Indian subcontinent of 0.25 (0.25–0.50); absorbing (warming) AOD less than 10% of total AOD	0.30 AOD, over South Asian region
Introduction of novel entities (Rockström et al. 2009: Chemical pollution)	*No control variables currently defined*	*No boundary currently identified, but see boundary for stratospheric ozone for an example of a boundary related to a novel entity (CFCs)*	

2.8 A New Paradigm for Development

"Climate change, demographics, water, food, energy, global health, women's empowerment - these issues are all intertwined. We cannot look at one strand in isolation. Instead, we must examine how these strands are woven together."
UN Secretary-General, Ban Ki Moon, at COP 17
(Ban, 2011)

The United Nations' Sustainable Development Goals (SDGs) unanimously adopted in September 2015 at the UN General Assembly in New York mark a turning point in human development. The resolution on "Transforming our world: the 2030 Agenda for Sustainable Development" (UN GA, 2015) acknowledges, for the first time, that developed nations must act rapidly to protect the resilience of the Earth system while developing nations need to achieve a just and safe future for all with dignity and equity.

The 17 SDGs fully acknowledge the scientific advances of the last three decades: "*The survival of many societies, and of the biological support systems of the planet, is at risk*" (UN GA 2015) The goals, based on the largest consultation in UN history and underpinned by Planetary Boundaries thinking, provide the vision for a grand transformation of societies. They provide an aspirational and holistic narrative for achieving the desired future and normative human development goals – a world free from hunger, injustice and absolute poverty, a world with universal education, health and employment with inclusive economic growth, based on transparency, dignity and equity. They also explicitly call for protection of the Earth system. It is in this sense that the goals are holistic and inclusive leaving no externalities outside the scope of transformative development.

The SDGs are indivisible and integrated (UN GA, 2015). They are also cumulative as the effort to achieve the 2030 Agenda must be sustained and this effort needs to be perceived as being irreversible. An accumulation of knowledge, capital, stable institutions and governance, and infrastructures is needed for the achievement of the 17 SDGs. So, there is a certain (implicit) organizing framework in the SDGs that indicates a fundamental paradigm shift in thinking about development (*Figure 16*), in which the economy and society are clearly articulated as being dependent upon sustainable stewardship of the Earth system (Rockström and Sukhdev, 2016). The SDGs acknowledge that based on current socioeconomic trends and technology use, the long-term stability of the Earth system is at risk. Put another way, the Earth system can no longer be viewed as an economic or social externality.

Achieving one SDG may contribute to achieving others, conversely there are many trade-offs. For example, achieving SDG 7, the energy goal, could jeopardize goals related to water, health and climate, but tackled in harmony these goals can support one another. In other words, all of the 17 aspirational goals should be achieved, for example, in such a way as to maximize synergies and minimize investment costs among many other salient considerations. A comprehensive scientific assessment of how this can be achieved and implemented is currently lacking. There are many interactions and the scope of these is unknown. This renders holistic policy making difficult. The goal of the new scientific initiative "The World in 2050" *(Box 1)* is to provide the fact-based knowledge to support the policy process and implementation of the 2030 Agenda.

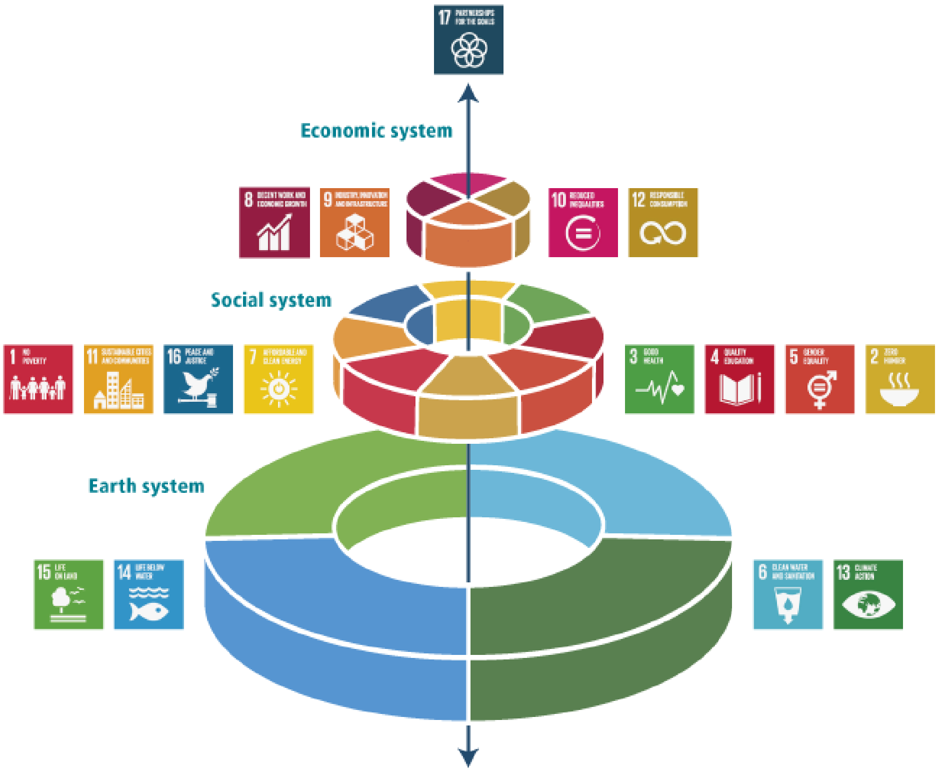

Figure 16 Categorization of the Sustainable Development Goals into three spheres: Earth system preconditions for development; social and economic systems as core means for delivery. Adapted from Rosktröm and Sukhdev, 2006.

BOX 1 The World in 2050 initiative.

The World in 2050 (TWI2050) is a partnership between science and policy that aims to develop equitable pathways to sustainable development within safe Planetary Boundaries. TWI2050 was launched by the International Institute for Applied Systems Analysis (IIASA), the Sustainable Development Solutions Network (SDSN), and the Stockholm Resilience Centre (SRC). It brings together leading policymakers, analysts, and modeling and analytical teams to collaborate in developing pathways toward sustainable futures and the policy frameworks required to achieve the needed transformational change.

TWI2050 aims to address the full spectrum of transformational challenges related to achieving the 17 Sustainable Development Goals (SDGs) and the Paris Agreement on Climate Change by using an integrated and systemic approach. The objective is to provide the science and policy for achieving SDGs in an integrated manner so as to avoid potential conflicts among the 17 goals and reap the benefits of the potential synergies of achieving them in unison. For example, there would be clear health benefits from a reduction in indoor and outdoor air pollution from global decarbonization if the two objectives were implemented in a manner that generates synergies and thereby also lowers costs. This kind of approach can in principle be generalized for achieving all 17 SDGs simultaneously.

The SDG credo, “leave no one behind” provides the framework for a new international social contract for the grand transformation of humanity to achieve a sustainable future. We conclude that this also means that no SDG should be left behind. While the goals are very ambitious, tackling them together will help humanity make rapid progress and enter a new era of human societies and Earth systems. The SDG process, as well as the Paris Agreement, showcase what institutional international governance is able to achieve with joined forces. We have entered a new era of global governance which has done away with mere top-down policy making in the goal-setting process. It also acknowledges the complexity and connectivity of human development and the Earth system by addressing global challenges. This is also the type of system we need during policy implementation on the ground to achieve the SDGs.

The SDGs and the 2030 Agenda have shown that all countries of the global community have come to a common understanding of the key global challenges, priorities and responsibilities for humankind. With this and their moral call for "global citizenship and shared responsibility," the SDGs provide the legitimacy for a new notion of global commons when they "*reaffirm that planet Earth and its ecosystems are our common home...*" (UN GA, 2015).

3 The Global Commons in the Anthropocene

"What is needed, in effect, is an agreement on systems of governance for the whole range of so-called 'global commons'."
Pope Francis in Encyclical Letter, *Laudato Si*, 2015

As Earth reaches the limits of Earth system boundaries for interglacial equilibrium we argue that a narrow concept of the global commons is no longer sufficient. We consider also that all components of the planetary system not only interact with each other, but are also collectively affected by aggregate or cumulative impact from industrial societies – the Anthropocene Effect.[2]

At the heart of this discourse is *planetary resilience*. This new worldview is a necessary precondition for long-term abundance, equity and prosperity within Planetary Boundaries. Decisions and actions made now relating to, for example greenhouse gas emissions, will have far-reaching implications tens of thousands of years from now on the Earth system. Individuals, businesses, cities and nations have a new responsibility to consider the functioning and resilience of ecosystems and biomes across the entire planet as integral to their own long-term wellbeing and that of future generations. International approaches to problems and solutions must address the new reality. Without major economic, technological and political transformations Earth will leave the stability of the Holocene with deleterious consequences for many societies and even our global civilization. This is new knowledge established over the last three decades. This knowledge changes everything.

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[2] In 1987, the World Commission on Environment and Development, chaired by then Norwegian prime minister Gro Harlem Brundtland, published "Our Common Future," which argued that "*The traditional forms of national sovereignty are increasingly challenged by the realities of ecological and economic interdependence. Nowhere is this more true than in shared ecosystems and in 'the global commons' – those parts of the planet that fall outside national jurisdictions*" World Commission on Environment and Development (1987) *Our Common Future*. Available at: http://www.un-documents.net/our-common-future.pdf..
International law identifies four global commons: the high seas; the atmosphere; Antarctica; and outer space, which are recognized as the common heritage of humankind IUCN, UNEP and WWF (1980) *World Conservation Strategy. Living Resource Conservation for Sustainable Development* International Union for Conservation of Nature (IUCN), United Nations Environment Program (UNEP), World Wide Fund for Nature (WWF), UNEP Division of Environmental Law and Conventions *Global Commons*: UNEP. Available at: http://www.unep.org/delc/GlobalCommons/tabid/54404/ (Accessed: 28 July 2016.. In this context, the term "global" is taken to mean the human sphere or world and discussion focuses on exploitation rights.

We must now consider the Global Commons more than ever.

The Global Commons in the Anthropocene is a resilient and stable planet. This is our common heritage and every child's birthright. This is now at risk.

In the Anthropocene, Global Commons are an integral part of the Earth system and can no longer be considered to be exogenous to human development and prosperity. The resilience of critical biomes, for example the Amazon rainforest and the Arctic, which are at risk of reduced functionality or changing state within the next few decades, must be protected. This is a fundamentally new perspective. We all depend on a stable and resilient Earth system for our wellbeing, from individual households, communities and cities to nations and regions. This resilience can no longer be taken for granted.

In *Table 3* we describe some of the most significant Global Commons in the Anthropocene – the biomes, biodiversity, and biogeochemical cycles that combine to form a dynamic equilibrium at the planetary scale. All commons are shared resources in which each stakeholder has an equal interest. Common-pool resources are resources where one person's use subtracts from another's use and where it is often necessary, but difficult and costly, to exclude other users outside the group from using the resource (Ostrom, 1990). Local commons are, for example fishing grounds, grazing areas, irrigation systems, agriculture and forests. Global commons, for example include the atmosphere and high seas, areas that are recognized as falling beyond national jurisdiction. In the Anthropocene, we have to recognize the importance of the stability, resilience and functioning of the entire Earth system. Other commons are also important, such as microbial resistance and the global knowledge system, and the Anthropocene puts these in a new perspective, but they are beyond the scope of this analysis.

Commons such as the oceans, the atmosphere and Antarctica are not externalities of the global economic system; they are its foundation. Based on the proposal herein, in the Anthropocene, we can no longer consider Global Commons as *external* to our wellbeing and development. They are *internal* to human development.

This reflects a new worldview and puts the world in a better position to deliver global environmental sustainability, which is crucial for the Paris Agreement on Climate Change, as well as the implementation of Aichi Targets of the Convention on Biological Diversity and other international environmental agreements. This concept lies at the heart of the SDGs and the 2030 Agenda, namely the achievement of inclusive social and economic development, and even of peace and security. It also illustrates our common responsibility to ensure that we have a resilient planet and resilient people. We argue that a broadly shared worldview acknowledging the Global Commons in the Anthropocene can support economic and governance transformations toward global sustainability

The Global Commons in the Anthropocene implies that all nation states have a domestic interest in safeguarding the resilience and stable state of all Global Commons, as this forms a prerequisite for their own future development, because losing the functions (e.g., carbon sinks, moisture feedback, biodiversity) of one can generate feedback that undermines the quality and function of critical systems, for example collapse of forests and ice sheets undermines regional and global climate systems). . Every nation should demand the right to shield critical biomes from external exploitation for the sake of providing the Earth system with the ability to remain resilient and generate ecosystem functions and services for development.

Table 3 Global Commons in the Anthropocene.

Global Commons in the Anthropocene	Description	Importance for Earth resilience	Importance for societal resilience
Biodiversity			
• Biodiversity	Condition critical: average rate of vertebrate species loss over the last century is up to 100 times higher than the background rate (Ceballos 2015)	Regulates key Earth-system processes	Essential for ecosystem services, e.g., pollination, food security, water purification, wellbeing, health
Biogeochemical cycles			
• Carbon	Condition critical: changing at a rate not seen for possibly 65 million years	Regulates climate system and thereby Earth system	Impact on climate stability, translating into social shocks and undermining of livelihoods
• Water	Finite and key to sustainment of all Earth-system functions and social systems. Rising variability, rising scarcity, rising pollution, undergoing rapid change	Essential for living biosphere and for functioning of Earth (upholds negative feedback like natural carbon sinks in oceans and on land)	Non-negotiable basic component of human development, for food, health, energy, materials, social stability
• Nitrogen	Changing at a rate not seen for possibly 2.5 billion years	Regulates ocean and biosphere stability	Essential for agriculture
• Phosphorus	Released into Earth system at unprecedented rate causing regional-scale state changes	Regulates ocean and biosphere stability	Essential for agriculture
Critical biomes			
Rainforests		Risk of shift in feedback from negative (carbon sink) to positive (carbon source)	
• Amazon	Reduced resilience: ability to store carbon is diminishing	Critical for carbon sinks, biodiversity, moisture feedback for regional rainfall, and climate system teleconnections across continents	Community livelihoods, food, largest genetic diversity on Earth, bioresources, tourism
• South Asia	Condition critical: under severe threat		
• Africa	Reduced resilience: under increasing threat		
Boreal forests		Risk of shift in feedback from negative (carbon sink) to positive (carbon source)	
• North Europe	Healthy, resilient, and providing global ecosystem services	Critical for carbon sinks, biodiversity, and moisture feedback at regional scale (between upwind/downwind nations)	Energy, bioresources, recreation
• North Asia	Healthy, resilient, and providing global ecosystem services		
• North America	Healthy, resilient, and providing global ecosystem services		
Cryosphere		Risk of feedback shift in Albedo from negative (cooling) to positive (warming)	
• Antarctica	Parts of West Antarctic ice sheet may have destabilized. Critical threshold: 3°C	Sea-level rise, disruption of ocean circulations and global carbon cycle	Sea level rise will affect coastal zones
• Arctic	Stability of Greenland ice sheet, permafrost and summer sea ice now in question	Sea-level rise, Arctic ecosystem collapse, disruption of ocean circulations and global carbon cycle – positive carbon feedback amplifying warming	Risk of collapse of indigenous pastoral reindeer societies. Regional societal impact, plus teleconnected impact through trade
• Mountain glaciers	Mountain glaciers worldwide are retreating, threatening water supply	Global water cycle, amplification of warming through positive climate feedback	Regional water supplies

continued

Table 3 *continued*

Global Commons in the Anthropocene	Description	Importance for Earth resilience	Importance for societal resilience
Atmosphere			
Climate system (atmos component)	Stability of climate system at risk. Regional weather patterns are altering with complex teleconnections	Carbon cycle, water cycle	Extreme weather, and weather unpredictability bringing vulnerability and adaptation challenges
Air quality/urban (cross scalar implications)	Regional challenges particularly in Asia, with global implications	Radiative forcing implications, impacts on regional rainfall patterns (e.g., monsoon)	Severe respiratory problems and increased mortality, particularly in Asia and Africa
Ozone layer	Stabilizing with full recovery due around 2100	Essential for life	Skin cancers and other harmful effects
Hydrosphere			
Oceans			
• Ocean conveyor belt	Early signs of possible disruption	Global heat redistribution	Regional climate variability, particularly in Europe, potential amplification of extreme climatic events (e.g., El Niño)
• Coral reefs	Condition critical for majority of warm water corals due to combined threats of temperature, acidification, pollution, and overfishing	Significant for marine diversity	Economic, social, and cultural value
• Fisheries	Majority of fisheries are fully exploited	Altering marine food chain	Essential source of protein; critical for feeding a world population of nine to ten billion within Planetary Boundaries
• Ocean pH	Rate of change unprecedented for possibly 300 million years. Major threat to marine life	Carbon cycle, ocean biome, critical influence on ocean carbonate chemistry and shell-growing organisms	Potentially substantial economic impacts

The critical biomes *(Figure 17)* that regulate regional energy flows, hydrological flows, and carbon, nitrogen and phosphorus cycles and provide stable habitats for living species are under threat. These biomes are interconnected with each other – moisture feedback from the Amazon rainforest affects the temperature and function of the tropical monsoon system, which in turn may interact with the global climate system. Critical biomes play a decisive role in regulating the overall status of the life-support system on Earth, that is, how well Earth can support world development. Significantly, the resilience of ecosystems, critical biomes, and the biosphere as a whole determines the degree of feedback (negative or positive, weak or strong) to the climate system, which regulates the degree of global warming, which in turn, generates a direct feedback to the biosphere, affecting all ecosystems. All Earth's biomes are now influenced by human pressures (Barnosky et al., 2012, Williams et al., 2015, Lenton et al., 2007, Lenton and Williams, 2013) indeed, more than three quarters of the terrestrial biosphere has been transformed into what might be called anthromes – or anthropogenic biomes (Ellis 2013). In particular, the world's grasslands and savannas have been transformed by human pressures, particularly agriculture, with severe impacts on biodiversity and other Earth system functioning. The management of these anthromes will be critical for long-term planetary stewardship.

We acknowledge the transient nature of definitions and that each concept is a child of its time. Here we have built upon existing concepts and hope that the Global Commons in the Anthropocene will provide a solid base for the next iteration. Humanity might decide to expand the concept to "Planetary Commons", as the common heritage of humankind and include "socioeconomic commons." Also, as more knowledge becomes available and as human activities push further toward Planetary Boundaries, more commons may be identified.

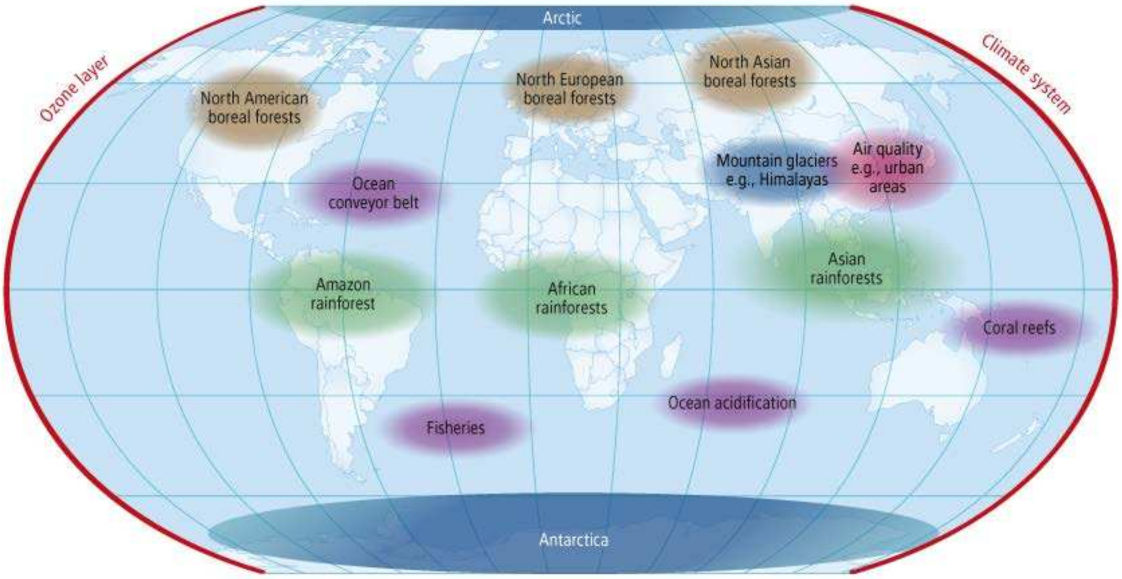

Figure 17 Critical biomes that play a decisive role in regulating the overall status of the life-support system on Earth, i.e., how well Earth can support world development. Rainforests (green), boreal forests (brown), atmosphere (red), cryosphere (blue), hydrosphere (purple).

4 Solutions for a Planet under Pressure

The following is an overview of the transformative nature of the changes needed to implement the proposed Global Commons in the Anthropocene, rather than detailed actions.

4.1 New Principles for Governing Global Commons in the Anthropocene

The responsibility of the Anthropocene, and the new world view it implies, demands a new set of principles to govern our thinking of the Global Commons. We set out three new overarching principles to inform transformative solutions that cross scales and regions: inclusivity, universality and resilience. Together these provide a system-wide perspective to enhance the resilience of Earth and its interlinked subcomponents.

Principle 1: The Inclusivity Principle

The Global Commons in the Anthropocene are not external to human activity; they are internal to development at all scales and need to be treated inclusively.

The stability of the remaining rainforests, the temperate forest ecosystems and the Arctic sea ice is now of importance not only to local communities, but also to all nations because these systems regulate conditions on the planet, for example the global climate, regional rainfall and pollution. All the negative and positive effects that result from the use of each one of the global commons, all the externalities, are considered *a priori* as inherent to the commons. Continuing to adhere to the concept of externalities would mean a prolongation of old global commons thinking. If we make the transition to the concept of Global Commons in the Anthropocene, the idea of externalities loses its validity, independently if there exists a market for them or not. The historical concept of externalities has contributed to the upcoming collapse we are now facing and has led us into the Anthropocene.

Inclusivity lies at the core of the human predicament in the Anthropocene. Humanity has essentially put so much pressure on and exploited so many resources, ecosystems and environmental processes that human interference with the Earth system can no longer be conceived as "external." Rather, everything – from air pollution to GHG emissions and plastic pollution – has direct or indirect implications for the functioning of the Earth system as a whole and thereby affects the lives of our neighbors from other countries/cultures/societies, as well as our own lives. What are the universal implications and moral obligations associated with cutting down trees or emitting GHGs when the climate system is at a tipping point?

Economic discourses that categorize the stability of the Earth system as an externality of the economic system are obsolete in the Anthropocene. New approaches that recognize the Earth system as a foundation of economic development must be adopted. We live in a globalized world where everything is connected and therefore a differentiation between the external and internal is no longer plausible.

Principle 2: The Universality Principle

Managing the Global Commons in the Anthropocene requires a paradigm shift in human worldviews toward planetary stewardship.

Universality refers to the ethical, equality and justice dimensions of social-ecological integration for all humans and societies on Earth.

Everybody needs to be aware of their broader responsibility to the Earth system, which reaches beyond city limits and national jurisdictions. The impacts of our actions are often invisible, taking place on the high seas or in distant inaccessible places such as rainforests and Arctic tundra.

Societal transformation often starts with the evolution of a new worldview that percolates through a society's political, economic and cultural life, beginning with early adopters. The new worldview can be catalyzed by, for example new technology, scientific knowledge or adoption of ideas from other cultures. But this is not enough. We need to spark the evolution of new goals, rules and information flows among actors in a sector or society to drive behavioral change that is aligned with the new worldview.

The Anthropocene is the defining concept of our age. The most significant implication for life in the Anthropocene is the urgent need to shift to a new worldview that encompasses the idea of planetary stewardship for the Global Commons, thereby delivering global benefits. Effective planetary stewardship can be defined as the sum total of societal and individual activities that generate long-lasting prosperity for all and enhance the resilience of the Earth system. To achieve this aim will require a shift in worldviews at all scales, from local community to nation and from regional to global.

This shift in worldview is already underway. The concept of sustainable development is evolving toward "global sustainability" and from "thinking globally and acting locally", as postulated by the "Rio Declaration" (UN GA, 1992) and "Our Common Future" (World Commission on Environment and Development, 1987), to "acting and thinking globally and locally" – simultaneously.

Worldviews evolve slowly over time. The challenge and urgency in the Anthropocene is to transition to a new worldview with unprecedented rates of change. The challenge for the scientific community is threefold: to understand the resilience of critical biomes and communicate this knowledge effectively; to identify a safe and just operating space for humanity; and to provide intellectual support for a transition to this new worldview.
Equality is an essential component of planetary stewardship. Increasingly, research shows that equality and sustainability are linked (Steffen and Stafford Smith, 2013, Wilkinson and Pickett, 2009, Wilkinson et al., 2010). We have an ethical responsibility to share resources in a just manner. It has been shown that in more equal societies, environmental awareness and social cohesion are higher than in less-equal societies (with regard to income distribution). Equality is conducive for resilience. Societies with less inequality are more willing to act as stewards of a resilient planet, and they also tend to have high levels of innovation, probably as a result of enhanced social mobility, which allows these societies to adapt rapidly.

Principle 3: The Resilience Principle

Planetary stewardship of the Global Commons in the Anthropocene is fundamentally about safeguarding social-ecological resilience, from local communities to Earth stability.

We define resilience as the capacity of a social-ecological system, for example wetlands, farmlands, financial systems or the Earth system, to deal with changes while maintaining structure and function. Resilience includes three key properties, which apply for all systems at all scales:

- Persistency – the ability to remain in a given state or equilibrium while avoiding collapse or the crossing of thresholds (tipping into a new state due to shifts in feedback from negative (dampening any change) to positive (reinforcing the shift to a new state).
- Adaptability – the ability to adapt to changing conditions while remaining in a current state.
- Transformability – the properties required to be able to transform a system – ecosystem or social system – after having crossed a tipping point (for example, the ability to rise out of a poverty trap or a decertified state in an ecosystem) to a new stable state.

Several principles on understanding and governance that are related to the resilience of social-ecological systems have been proposed recently (Biggs et al., 2012):

- <u>Principle one: Maintain diversity and redundancy</u>
  Diverse ecosystems and social systems with many species and cultural groups are generally more resilient than systems with few components. Aiming for high rates of efficiency by removing any redundancy in a system could backfire. Redundancy means some components in the system can step in to compensate for the loss or failure of others. Redundancy is even more valuable if the components providing the redundancy also react differently to change and disturbance, which is known as response diversity.
- <u>Principle two: Manage connectivity</u>
  Connectivity can be both a good and a bad thing. Well-connected systems can overcome and recover from disturbances quickly, but conversely connectivity may also lead to the rapid spread of disturbances – contagion. In ecological systems, landscape connectivity through the creation of wildlife corridors can help maintain biodiversity.
- <u>Principle three: Manage slow variables and feedback</u>
  The phosphorus in the sediment of a freshwater lake can build slowly over time as fertilizer from farms is washed into the lake. The slow buildup may not affect the drinking quality of the water. Up to a point. However, beyond a certain threshold, eutrophication occurs, which is then difficult to reverse. Managing slow variables is critical to ensure that ecosystems produce essential services. Changes within a system can be amplified or dampened by feedback loops. For example, white Arctic sea ice reflects heat into space, but as it melts it exposes more of the dark ocean that absorbs heat, leading to more melting. An example of negative feedback is the body temperature within mammals which is carefully controlled; if body temperature rises or falls, the body adopts measures to bring the temperature within a strict range.
- <u>Principle four: Foster complex adaptive systems thinking</u>
  Social systems can be dominated by rigid constraints to maintain order. This can reduce resilience to large shocks. Social-ecological systems can be more resilient if management approaches accept unpredictability, uncertainty and ranges of movement rather than rigid control.
- <u>Principle five: Encourage learning</u>
  Social-ecological systems are in a constant state of flux, thus a process of continuous learning is required to enable adaptation to change. This learning process does not end.
- <u>Principle six: Broaden participation</u>
  Trust and shared understanding are essential elements of managing resources (Ostrom, 1990). Broad participation enhances legitimacy and expands the depth and diversity of knowledge.
- <u>Principle seven: Promote polycentric governance</u>
  Formal, monolithic, hierarchical governance systems are often inflexible to changing needs. By comparison, polycentric governance where multiple governing institutions overlap and interact in complex ways to enforce rules can seem inefficient, but it provides the essential adaptability and flexibility to promote resilience. Polycentric governance is considered to enhance the resilience of ecosystem services in six ways: it provides opportunities for learning and

experimentation; enables broader levels of participation; improves connectivity; creates modularity; improves potential for response diversity, and builds redundancy that can minimize and correct errors in governance. In addition, in polycentric governance systems, traditional and local knowledge stand a much better chance of being considered.

Earth system science, climate science and Planetary Boundaries research increasingly show, convincingly, that resilience must now be applied at the global scale. Earth resilience is defined as the capacity of the integrated Earth system to persist in a Holocene-like state, that is, to maintain the environmental conditions on Earth that can support world development in the Anthropocene.

The new principles are designed as foundational principles to inform economic and political decisions at all scales from local to global. For example, criteria for investment decision making would incorporate the fundamental question: how does this investment affect Earth's resilience? This approach goes beyond the development agenda and should be applied to all governance and investment decisions. We acknowledge the principles of "interdependence," "universality," and "solidarity" in the UN 2030 Agenda that guide the world in pursuing the SDGs. They complement the new principles, set forth above, which are specifically for managing the Global Commons in the Anthropocene

4.2 A Grand Transformation

The three principles described above provide the underpinning for a new social contract for planetary stewardship. The SDGs together with the Paris Agreement depict a normative, common understanding of the future of the world. With these goals in mind, a scientific, moral and political discourse is necessary to establish how to get there. A slight change in worldviews has occurred at the highest level and can guide us. "Anthropocene Governance" and "Anthropocene Economics" provide a toolbox for a grand transformation.

Incremental changes, which we are already experiencing in some areas, are useful but will not suffice as we have waited too long (Schellnhuber et al., 2016). In line with Schumpeter's "gales of creative destruction" (Schumpeter, 1942) new ways are required to implement a grand transformation and fundamentally change energy, food, water and urban systems. Old industries, such as coal power plants, and old ways of thinking have to be replaced to make space for new technologies. These new technologies, such as electric mobility, need space and time to thrive. This is a well-proven cycle. Policymakers must refrain from the temptation to save the old industries and ignore fear of change. Rather, we can actively shape the transformation through policies, for example no combustion engines by 2025, disinvestment in coal power, etc., to bring about and accelerating disruptive change – with clear-cut solutions. In this sense, disruptive change joins the incremental advances that have been ongoing, and we can consciously steer it.

A grand transformation (*Figure 18)* goes beyond a solely technology-centered view of the world and the substitution of one technology by the next. It encompasses technological, social and behavioral changes. We have shaped the planet and now we have to change our socioeconomic system in such a way that we not only stay within the Planetary Boundaries but do not infringe them. We, all citizens on Earth, are the stewards of this planet. We have to take collective action at all scales from local to global. This action needs to be guided by the new Global Commons in the Anthropocene thinking. The urgently needed grand transformation has at its heart new principles and new worldviews (WBGU, 2011). The idea might seem utopian, but we have seen that scientific evidence underscores the basic necessity of this shift toward planetary stewardship. With the SDGs we already have a globally agreed-upon vehicle to achieve this. This is the starting point.

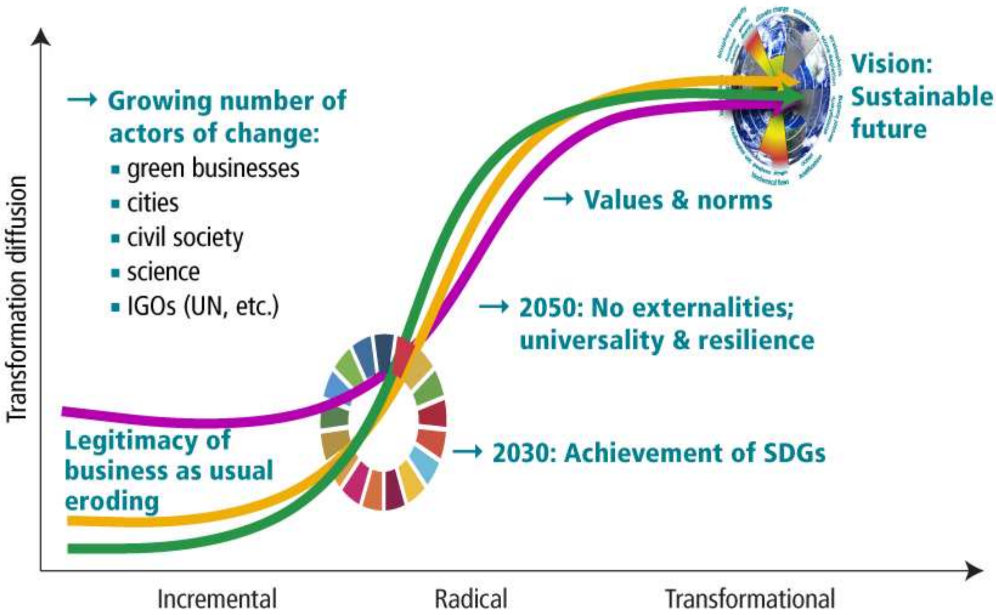

Figure 18 Sustainability transformation – temporal dynamics and action levels. The goal of the transformation is a low-carbon society. A sustainable path manages the transition from a high-carbon to low-carbon society over time. Adapted from WBGU, 2011.

4.3 Governing the Global Commons in the Anthropocene

"The treasured resources for the whole [of] mankind are threatened by the very technological capabilities that we have mastered during … recent years."
Elinor Ostrom (Gaffney and Pharand-Deschênes, 2012)

Governance of the Global Commons in the Anthropocene has two objectives:

- To safeguard the capacity of ecosystems to generate services for the wellbeing of all humans;
- To safeguard a stable and resilient Earth system for long-term global sustainability.

Governance in the 21st century will require a great transformation of societies and new political and economic theories that are suitable for life in the Anthropocene. This will necessarily entail a deep understanding of user rights (*Box 2*) and effective governance of common resources across scales, as well as insights from resilience and global sustainability science.

BOX 2 User rights and charges in the context of Global Commons in the Anthropocene.

The need to manage common goods and common-pool resources – animals, grazing lands, forests, waters, fisheries – is probably as old as humanity itself. Hunting-and-gathering societies had to share these common resources. This changed through the Neolithic revolution and emergence of agriculture, then city states. These new ways of organizing societies led to goods and resources falling into private ownership. Yet some goods and resources common to all were impossible to appropriate, such as the air that we breathe.

The term "commons" derives from the traditional English legal term for common land. It means belonging to all, held or shared by all and derives from the Latin *"communis"* meaning "common property" or "commonwealth" (Etymonline, 2016). Today, the term commons refers to the cultural and natural goods and resources that are accessible to all, including natural materials such as air, water, ecosystems and planetary processes. Some of these resources are held in common, not owned privately (Bollier, 2002).

Stewardship of Global Commons in the Anthropocene requires rules of good practice to assure livable and safe planetary conditions for humanity. As with other common-pool goods and resources, there is a danger of over-exploitation of planetary support systems. The gaps in international regulatory regimes, especially where property rights cannot be duly established, generally lead to over-exploitation because the users do not necessarily bear the full social costs of their actions. Another issue is that users have little understanding or knowledge of the state of the resource. These *"common goods would thus need to be administered in trust by the international community. It is at this point that the concept of user charges comes into play."* (WBGU, 2002)

The term "user charge" is an economic and public finance term that refers to the use of an asset or right that is linked to the payment of a sum of money for the conferral of the right, in contrast to property rights that relate to ownership. In the case of global common goods and resources, the payment creates user awareness of the costs of its provision and its scarcity including the non-renewability or stock nature of the good or resource (WBGU, 2002, Birk and Eckhoff, 200).

User rights can thus serve to incentivize sustainable use of Global Commons in the Anthropoceneas well as provide financial resources for innovation and other measures and policies for their preservation including alternative sources of provision. A good case in point is the decarbonization of the global economy to both limit climate change and provide sustainable energy and food services for all. Without user charges, a "tragedy of Global Commons in the Anthropocene" would result from over exploitation endangering planetary systems that would ne analogous to the overuse of other commons (Hardin, 1968, Ostrom, 1990).

The concept of user charges needs to be distinguished from other ways of internalizing negative external effects, such as the "Pigouvian tax" (Pigou, 1920), which levies charges on undesired negative consequences with the aim of accounting for all social costs, such as air pollution, from the production or use of goods and resources. Thus, one of the principles we propose is that of "inclusivity" in the sense of Pigou as well as the establishment of user rights and charges to avoid a tragedy of Global Commons in the Anthropocene (Hardin, 1968, Ostrom, 1990, Stiglitz, 2006) through extraction and overuse in order to assure a stable and resilient planet for the sustainable development of humanity.

Toward the end of her career, Ostrom not only considered the risks societies were taking with the global commons, but also how to manage those commons. Ostrom and colleagues arrived at a consensus on approaches for resilient governance and the establishment of user rights (Ostrom et al., 1999).

First, the resource, either a physical resource or a dumping ground for our waste – must continue to be useful. That is, on the one hand, exploitation cannot be so complete as to have left the resource drained – a forest of tree stumps or a sea without fish is of no value. Nor can the resource be so little used that the benefits of managing the resource are slight. In the case of the Global Commons in the Anthropocene, it is essential to identify at an early stage the biomes, biogeochemical cycles and other resources that are under stress and provide expert information on the scale of exploitation. One difficulty is that in the

Anthropocene, resource use may be increasingly geographically dislocated from exploitation. This distances the user from the resource-exacerbating issues.

Secondly, resource users find it easier to assess the benefits when they have accurate knowledge of external boundaries with reliable indicators of the resource conditions [and accurate knowledge of their own resource use and that of others]. However, they also require accurate knowledge of the internal microenvironments and need to have reliable and valid indicators of resource conditions.

Thirdly, management is easier when the resource flow is predictable. In the case of the Global Commons in the Anthropocene, the resource flow may in some circumstances be relatively predictable, for example fossil-fuel use, fishing and deforestation. However, the impact of resource use may be distant, for example a collapsing ice sheet in Antarctica and collapsing fish stocks in the high seas.

Fourthly, if resource users depend on the resource for their livelihoods and can act autonomously to create their own access rules, they are more likely to see benefits from their own sacrifice. Critically, the users in this scenario need to "share an image" of how the resource works and how their actions affect one another. Ultimately, resource users must see how the potential benefits of maintaining a sustainable resource outweigh the cost of doing so. Resource users need to learn to accurately calculate group benefits and costs, not just personal costs.

Finally, effective conflict resolution systems need to be developed – starting with investing in trust that provides a low-cost method for managing common resources – and supplemented by monitoring and sanctions (Ostrom, 1990).

In the Anthropocene, our generation must also learn to cooperate with future generations. This is a novel concept, but research indicates that it is possible (Hauser et al., 2014). Failure to cooperate with the future is primarily driven by a small minority of "free riders" who always act selfishly. The system of majority voting is the most successful approach to ensure that resources are available for future generations because the majority of people can be categorized as either "cooperators" or "conditional cooperators." Conditional cooperators only agree to using resources sustainably if they know that the free riders are restrained (through majority voting where decisions are binding), which thus reassures the conditional cooperators that their efforts are not in vain.

Based on our assessment of these considerations, we can see that the building blocks for governance of the Global Commons in the Anthropocene are beginning to emerge organically. The Planetary Boundaries framework provides an estimate of the key Earth system parameters that indicate the state of the resources at a planetary scale. The framework is now being adopted at not only a regional, but also a national scale as in the case of South Africa and China (Dearing et al., 2014).

For resource users, the SDGs provide a new set of goals that emphasize the need to remain within the Planetary Boundaries, particularly at the nation-state level, but the goals are also applicable to individuals, cities, businesses and institutions. The SDGs emerged from the biggest consultation in UN history and provide a legitimate framework that goes beyond GDP as a measure of development. The Paris Agreement on Climate Change is a recognition of the extreme risks posed by stepping beyond the 2°C threshold and provides the binding rule-system necessary, though it needs to go much farther.

Accurate and reliable information on the state of the resource for *all users* is critical. So too is actionable information on alternative approaches to reduce resource use. Global and regional assessments relating to biodiversity, climate and other issues provide accurate, reliable information, but often not in an actionable form for all stakeholders. Moreover, these must be complemented by new knowledge on building resilience into a system. Critically, resource users – individuals, families, businesses, cities, nation states and institutions – do not "share an image" of how the Earth system functions, nor how their actions affect it on aggregate or cumulatively.

How far do we need to travel to arrive at this destination? In the Holocene, international political systems largely evolved to prevent conflict, minimize friction between states, encourage trade and promote economic stability. These systems have had remarkable success for six decades. However, these systems have not been designed to enhance planetary resilience in the face of climate change, biodiversity loss and other global threats. They are not fit for the Anthropocene. The UN system and associated organizations are evolving to keep pace with the scale of the changes. Currently, the UN system provides the only decision body that adequately represent the global public. However, it is widely recognized that key areas need fundamental overhauls. The SDGs and the Paris Agreement provide the first signs that the international political system recognizes the new worldview. We are shifting toward the right direction institutionally.

"Anthropocene Governance" however, will be broader and involve more, and especially more-diverse, stakeholders than the type of governance we have been used to. So, who are these stakeholders who will shape Anthropocene Governance? For Anthropocene Governance to be successful, we need innovators and pioneers of change at various levels and in diverse roles. These innovators can be entrepreneurs, engineers, policy makers or activists. In this regard the UN 2030 Agenda and preceding consultative process serve as an indication that governance approaches are already changing.

This also ties into the important aspect of education, knowledge and empowerment. Stakeholders need adequate knowledge and awareness of the issue in order to participate effectively in governance processes. We have a plethora of knowledge at hand, and we need new ways to synthesize, integrate and share it to use its full potential. Here also, science is asked to become more active and leave its ivory tower to engage more intensely with other stakeholders. Science is one of the strongest voices of the environment in terms of governance. The environment is not a constituent in international negotiations; it is at most a concern. It usually becomes an agenda item when it is linked to the economy. Science does not have a formal say either.

However, in Anthropocene Governance, decisions are based on scientific evidence. This new worldview acknowledges the environment, if not as an actor, through genuine awareness of its state and its relationship with humanity. Then again, we are all stewards of this planet. We cannot rely only on institutions to fix the problem; each and every one of us has to contribute to safeguarding Earth resilience.

4.4 Anthropocene Economics for a Transformation to Global Sustainability

The existing dominant economic models are pre-Anthropocene. They were developed in the Holocene under the assumption that resources are infinite and the Earth has the buffering capacity to absorb shocks from the socioeconomic system. This worldview no longer applies. The Anthropocene itself is an artifact of the dominant economic models.

Innovations often create at least one unintended consequence. In the Anthropocene, if unintended consequences scale at a rate greater than one, then planetary scale problems emerge very quickly, for example CFCs and ozone, or GHGs and climate, or air and water pollution and waste. Exponential growth now means the aggregate and cumulative impacts of industrial societies have Earth system repercussions. The three principles outlined above – inclusivity, universality and resilience – provide a new foundation for economic thinking in the Anthropocene in support of the Global Commons.

When we talk about Global Commons in the Anthropocene, the neoliberal arguments of market efficiency and privatization are no longer applicable (Stiglitz 2006, Farley 2015). We need new economic models suitable for life in the Anthropocene. These models position Earth resilience as a fundamental for economic development, not as an externality as it is viewed today: this is "Anthropocene Economics."

Anthropocene Economics will involve production systems that work to improve the resilience of the Earth system by enhancing biodiversity, enlarging carbon sinks, and minimizing any detrimental by-products of human consumption. In Anthropocene Economics, productivity and efficiency in both production and consumption are key, and wastage will reach zero across all resource domains, removing the pressures on Earth resilience. Here too, diversity and resilience are as important as in ecosystems. Production and consumption will minimize detrimental by-products of human consumption. Food waste, from the point of production, throughout transportation and at the end user, will be minimized. Anthropocene Economics will shift the food system based on agricultural intensification toward a system focused on ecological intensification for food security for all. Fishing – both wild and managed – will be based on scientifically validated maximum yields and the price will include the full cost to the biosphere. Anthropocene Economics will put the full force of the market behind rapid decarbonization of the global economy. It will entail radical new approaches to, for example taxation. Traditionally, labor tax is a primary tool for governments. In the Anthropocene it is more appropriate to develop tax approaches based on resource use.

4.5 Systemic Approaches

In the Anthropocene we will have to follow system-wide approaches if we want to achieve transformational outcomes and benefits beyond the direct results of an intervention.

Insights from resilience thinking and effective management of common resources allow a framework to emerge to support system-wide approaches to investment. Such an approach must work across industry sectors and levels of governance from local to global. Moreover, Earth system research and international agreements relating to climate, biodiversity and SDGs provide a legitimate prioritization, as has been shown under the mega drivers for:

- decarbonization of the global energy system,
- resilient food,
- water for healthy people and a healthy planet and
- sustainable cities.

For all of these systems, the following guiding questions can help decision makers when deciding on each investment:

Implementing the big picture

- Changing worldviews – does the investment contribute to changing worldviews toward planetary stewardship?
- Internalizing externalities – does the investment internalize environmental externalities?
- Information flows – does the investment enhance information flows on the state of the Global Commons?
- Does the investment enhance dialogue with all stakeholders and build trust?
- Cultural diversity and ecological diversity are linked and enhance one another – does the investment support both aspects of diversity?

System-wide impact

- Does the investment take an integrated, resilience-centered approach to solutions?
- No incrementality – emissions reductions in all sectors at +5% per annum are required to meet global climate targets. Does the investment drive emissions down across relevant sectors where the investment is being applied and beyond? In the long term will the investment lead to zero carbon emissions?
- To meet the 2–1.5°C targets will require new carbon sinks on the scale of the world's oceans. Does the investment help resilience in existing/creating new sinks?
- Biodiversity loss must halt. Does the investment enhance biodiversity and intensify ecosystem resilience in line with Aichi targets?
- The resilience of all critical biomes must be enhanced through improved social-ecological governance at all scales

4.6 Implementing Solutions

Here we introduce some strategic solutions in the context of planetary stewardship for global sustainable development. As set forth, it is crucial to understand the links between the human sphere and the Global Commons in the Anthropocene. We provide exemplary solutions for each proposed action area, based on the mega drivers, which we test against the newly defined principles.

The following action areas have been selected on the basis of their critical and decisive role in determining the possibility of attaining a global sustainable future for humanity:

- Food, the world's single largest user of fresh and underground water, and the single largest reason for transgressing Planetary Boundaries on nitrogen/phosphorus, land, and biodiversity, is a sine qua non for global sustainable development in a stable and resilient Earth system, particularly as the world will require more than a 50% increase in food production to meet dietary demands of a world population of nine to ten billion by 2050 (and those of the approximately 700 million malnourished people today).

- Decarbonization of the global energy system is now of critical importance for a 1.5–2°C future global temperature increase line with the Paris Agreement.
- Water, the source of life, is under severe pressure, and water stress and scarcity are increasing in many parts of the world.
- Soon, 75% of the world's population will live in urban areas. This global shift requires a major focus on transformation to sustainable and livable urban environments, transportation and a circular economy.

Table 4 provides a preliminary overview of the solutions.

Food System

The guiding actions for the food system are sustainable intensification, no expansion and the landscape approach. Through behavior change, such as shifting to a vegetarian diet or decreasing the protein intake from meat, future pressure to convert forests to cropland or pasture can be decreased (Erb et al., 2016), and if followed through, already converted land can even be released for other purposes. This supports resilience and universality. Through payments for ecosystem services, the "inclusivity" principle can be achieved.

More than a third of food is wasted in distribution and end use. Improvements to efficiency throughout the system, including the supply, would reduce the pressure on land use and the needed water and energy. Furthermore, yield increases through better practices and stewardship of land would improve the efficiency of land use. More controversial is the issue of genetically modified crops. Their use is diffusing rapidly throughout the world. For example, some 80% of soya bean cultivation, especially in the Americas, is genetically modified. The use of genetically modified crops furthers the spread of monocultures.

The monoculture approach to the production of food or energy is in contrast to the landscape approach that aims to reflect the connectivity between the local and global spheres. Reforestation to maximize carbon sinks through monoculture would be against the three principles. In contrast, afforestation that respects the landscape and provides sufficient biodiversity is not only good for resilience, but also brings benefits to universality.

Table 4 Potential application of the new principles.*

	Principle 1 No externality	Principle 2 Universality	Principle 3 Resilience
Energy system and end-use			
Decarbonization	Not exceeding the global carbon budget (GCB) for 1.5–2°C climate stabilization	Just distribution of GCB across countries, regions and income groups	Flexible approaches with multiple options of technologies and behaviors (e.g., mobility)
Efficiency	Regulatory frameworks to enable scaling of sustainable efficiency solutions and eliminating externalities	Reduces pressure across sectors, supply and end use	Increases technology options (e.g., mobility) and reduces pressures at all scales
Access (if done right)	Local access to modern renewable resources an internal affair for all economies	Universal access to modern technologies/ leapfroggingtechnology evolution	Diversity and local adaptation of access systems
Food system			
Sustainable (ecological) intensification	Ecosystem services	Sustainable production and demand (e.g., diet shift, organic products, food quality, reduction of food waste across the value chain, precision farming systems, irrigation–climate smart agriculture, etc.). Assure fair distribution of remaining, finite, global budgets for carbon, nitrogen and phosphorous	Innovations and integration (e.g., conservation tillage, water harvesting and ecological sanitation)
No expansion of agriculture	Safeguard critical biomes as new global commons for global sustainability	Virtual water and virtual protein trade	Safeguarding biodiversity and ecological functions
Landscape approach to sustainable farming systems	Understand global and local connectivity – invest in management practices locally (e.g., farm or forest development) that interlinks with global changes and interdependencies (e.g., moisture feedback for rain from forests upwind)	Collective action integrating land- and seascape units across national borders, for water, carbon, energy, pollution, etc.	Enhancing carbon sinks; ensuring water flows; sustaining ecological function
Water system			
Water productivity (water use efficiency)	Management of water locally interconnects with hydrological cycle and biosphere functioning across scales (e.g., drying out of local wetlands can generate methane and moisture feedback at regional to global scales)	Water availability among all inhabitants in river basins and regions	Technological flexibility and ecological diversity (enabling environmental water flows and a minimum degree of "wetness" in landscapes)
Water quality	Pollution from chemicals, nutrients, plastic, and antibiotics transcend scales and have an effect globally through freshwater systems and oceans – and are thereby internal to all citizens on Earth	The right to good quality freshwater is universal, and dependent on universal principles of water use (e.g., for food, bioenergy)	Important for marine and terrestrial ecological functions and thereby for land- and seascape resilience (e.g., sediments suffocating coral reefs causing environmental degradation and loss of coastal resilience)
Stable water systems	Biome-scale interventions to safeguard moisture feedback and water flows to sustain regional and global hydrological cycle	Universal right to reasonable stable freshwater supply at Holocene variability level, not at Anthropocene variability level	Maintain ecological and social resilience to enable freshwater systems – like meandering rivers and glacial "water towers" – to be sustained and adaptive (ability to deal with shocks without crossing tipping points)

continued

Table 4 *continued*

	Principle 1 No externality	Principle 2 Universality	Principle 3 Resilience
Urban system			
Integration between natural and human capital	65% of world population in urban environments by 2050, all of whom depend on biosphere for livelihoods, requires social–ecological integration and internalization of natural and human capital	The right of access to – and moral responsibility of using – natural and human capital	Social and ecological diversity of capital forms builds resilience
Hinterland approach	Increasing resource efficiency		Harnessing local resources
Closed metabolism	Circular economy, city planning (e.g. mobility)	Recycling and job creation	Diversifying pathways to circular social–ecological approaches to development

* *Disclaimer* This table highlights prime examples and is not exhaustive; there are many other solutions that seek to address both the principles and the systems. The aim of including this table is to provide a basis for discussion and joint reflection.

Energy System

The three key items to address with regards to the energy system are decarbonization, efficiency and energy access.

There are two ways of achieving decarbonization. One is to shift to zero-carbon energy options such as a portfolio of renewables. Another is to capture and store carbon from fossil energies. Both of these options have potential negative externalities. As renewables are more modular and granular they are likely to have lower externalities even at large-scale deployment, for example on water use. In contrast, carbon capture and storage could potentially have large negative environmental externalities. While all of the components of the necessary technology to decarbonize exist today, large-scale deployment has not yet been realized. As we know from the history of technology, it is too early to assess all the possible impacts. Both of the decarbonization options are good for the principles of inclusivity and of universality as long as they stay within the global carbon budget (GCB) and there is a fair sharing of the burden. Yet, for resilience it would be good to have a full portfolio of all the options (including carbon capture and storage and where acceptable nuclear) indicating the trade-off between resilience and inclusivity.

If energy access for those excluded is done right, all three of the new principles will be achieved. For example, externalities will be reduced because introducing clean cooking fuels reduces air pollution and deforestation. People with access to clean energy will be empowered to be planetary stewards, enhancing Earth resilience. Conversely, today's lack of energy access for all makes it a challenge to remain within Planetary Boundaries.

By efficiency we refer to reducing the amount of energy needed to provide a given service, which means doing more with less. This can lead to a so-called "rebound effect" where the lower cost leads to increased use. Efficiency is clearly beneficial to access, and we assume that appropriate policies would be put in place to avoid rebound. Efficiency with the previous conditionality reduces externalities and contributes to universality and resilience. The latter especially requires further explanation as it is an indirect effect; the more efficient an energy system is the easier it is to have a wider portfolio of technology options and more sustainable behaviors which inherently provides a buffer against disturbances.

Water System

With regard to water, water quality, water productivity and stability are at the core of all discussions. Neither water nor energy are consumed, they are just transformed from one state to the other with increasing entropy. However, we would like to make a distinction between water consumption/transformation and water use where water is returned to the system (albeit in changed quality).

Similar to the energy system, improved efficiency, if accompanied by the right measures to avoid rebound effects, reduces externalities and also contributes to universality and resilience. The use of underground water rather than rainfall for agriculture generally depletes the water resource at rates well above replenishment. This is especially applicable for the interactions of the water system with the other nexus systems – food and energy. Increasing water-use efficiency in agricultural production improves resilience and reduces externalities, similar to energy production.

As for water quality and stability, analogies can be drawn with terrestrial ecosystems in the food system. Ecosystem services and biodiversity contribute to resilience, universality and reduced externalities. Reduced water demand on all levels, be it direct or indirect, contributes to universality. A reduction in pollution, such as plastic waste, is similar to the notion of decarbonization in the energy system where the externalities will be reduced if pollution can be controlled. The management of our water system is weak, especially in the case of transboundary freshwater bodies and oceans. Our seas provide a very good example of the challenge of protecting the Global Commons in the Anthropocene.

Urban System

As the majority of the world's population will be living in cities and urban areas, cities will have to close their metabolism sooner rather than later. Cities account for 80% of GHG emissions. Initiatives such as Zero Carbon Cities and Smart Cities provide promising examples of how to address this issue. The exchange with the hinterland which provides essential resources to the cities cannot be neglected either. Cities have to reduce the pressure on the hinterland by increasing the share of resources harnessed within the urban area, such as renewable energy, and follow a circular economy approach with reuse and recycling at its core. Clearly, waste cannot be reduced to zero, but recycling and reuse are important measures to reduce the pressure of the urban areas on the hinterland and the environment at all scales. As in the other systems, increasing resource efficiency as a first step will be key as a closed metabolism will not be achieved as soon as needed.

The challenge of urbanization has many facets. One is that 800 million live in informal settlements and if unabated this figure will reach two billion by 2050. The other is that, according to most studies, essentially everybody will end up living in urban areas, which means that those areas will have to be planned for the people.

A particularly important example is mobility in urban areas and transportation in general. Here too, a fundamental decarbonization and reductions in noise and congestion are high priorities. Norway has set an important example by announcing a ban on internal combustion engines in individual modes of transportation by 2025. Clearly, this would be beneficial only in combination with decarbonized sources of electricity as is the case in Norway. A systems perspective is needed in all sectors, foremost in transport and mobility.

5 Concluding Remarks – the Road to Planetary Stewardship

With this paper we set out to examine the global commons in light of evidence that Earth has now entered the Anthropocene. This analysis has led us to the conclusion that the traditional notion of the global commons fails to capture the common heritage of humankind – a stable and resilient Earth system. The scientific evidence is clear. At the saturation point we have reached in the Anthropocene – with real, dangerous human-induced global environmental risks, and with interactions, feedback and tipping points connecting every ecosystem and biome – it is now necessary to recognize that human wellbeing in one place requires planetary health. In every nation today, we all depend on the stability and functioning of the Earth system.

The Global Commons in the Anthropocene recognizes a new relationship between people and planet. Humanity has crossed the Rubicon. There is no going back. Exponential growth characterized by the Great Acceleration means we are now pushing up against Earth system limits. The notion of Global Commons in the Anthropocene refers to the support systems for human development during the unique period in the evolution of the Earth called the Holocene. The Holocene has provided a stable and resilient space for humanity to develop. It is the great success of humanity through the Neolithic and industrial revolutions that has expanded our niche on the planet to the degree that this is now paradoxically endangering the very basis of further sustainable development.

It is now essential that industrialized societies embark on a grand transformation to achieve global sustainability, and that industrializing countries do so without further jeopardizing the stability of the Earth system. Stewardship of the Global Commons in the Anthropocene, with its three central principles of inclusivity, universality and resilience, is an essential prerequisite to guide national and local approaches in support of the Sustainable Development Goals for generations to come. We must now find new institutions, new governance arrangements and, as Mary Robinson, former president of Ireland and UN Ambassador says, “new Guardian Angels” for the Global Commons in the Anthropocene.

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