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Human prosperity requires global sustainability

- a contribution to the Post-2015 agenda and the development of Sustainable Development Goals

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Summary

This discussion paper has been commissioned by the Swedish Government Office and developed by Stockholm Resilience Centre for the Nordic environment ministers meeting in Jukkasjärvi 7th February, 2013. The paper provides the scientific evidence in support of the conclusions from the Rio+20 UN Earth Summit that global sustainability is now critical for human development in the world. The planetary boundaries concept is presented as a possible framework to define global sustainability criteria in a post 2015 agenda as part of defining Sustainable Development Goals.

Planetary boundaries defines a science-based safe operating space for human prosperity in a world with growing development needs and rising environmental risks. This safe operating space for the human enterprise on Earth offers ample room for growth and human wellbeing, while providing fundamental biophysical boundaries that need to be respected in order to avoid dangerous and costly environmental impacts. A world transition to a world that meets sustainable development goals defined by universal goals of poverty eradication and planetary boundaries will require major innovation and policy changes, while offering large opportunities for individual wellbeing and national prosperity.

The urgency of recognising global sustainability as an integral part of individual, societal and world development, rests on the scientific evidence that humanity over the past decades has entered a new geological epoch, the Anthropocene, in which human actions have become the main driver of global environmental change. Human activities may now push the Earth system outside the stable environmental state of the past 10,000 years that enabled the development of modern societies, with consequences that are detrimental or even catastrophic for large parts of the world. To meet the challenges scientist have proposed a framework based on 'planetary boundaries' that define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes.[1]

Nine planetary boundaries have been identified, namely climate change, biodiversity loss, change to the nitrogen and phosphorus cycles, freshwater use, land system change, ocean acidification, stratospheric ozone depletion, chemical pollution and aerosol loading. Out of the nine planetary boundaries identified, three boundaries are currently being exceeded: climate change, biodiversity loss and nitrogen emissions. The effects on human well-being are severe. According to Stern Review on the Economics of Climate change tackling climate change is the pro-growth strategy; ignoring it will ultimately undermine economic growth. The Economics of Ecosystems and Biodiversity (TEEB) estimates we lose land-based ecosystem services worth 50 billion every year starting in 2000. The accumulated welfare loss of these annual losses by 2050 is equivalent to 7% of the prospected annual consumption in 2050.

In the comparison between planetary boundaries and existing International Environmental Agreements, IEAs, boundaries have partly been addressed. The planetary boundaries framework does not really introduce new issues on the policy agenda as such but rather suggests measurements for boundaries, based on recent scientific evidence on harmful thresholds, and there are also a number of new institutional issues raised by the planetary boundary concept - the IEAs has not managed complex threshold effects and interactions between planetary boundary issues.

[1] Rockström, J., Steffen, W., Noone, K., et al. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14, 32. http://www.ecologyandsociety.org/vol14/iss2/art32/main.html.

In the development of the Post 2015 and goals and targets a number of issues are recommended that influence individual human-wellbeing:

- To recognise the new challenge of meeting the twin universal challenge of poverty alleviation and human wellbeing on the one hand, and global sustainability on the other. Global sustainability being an overarching precondition for human prosperity.
- To recognise that a stable planet is a necessary condition for human prosperity in the world, and that a Post-2015 development agenda should consider defining a science-based safe operating space defined by global sustainability criteria such as the planetary boundaries.
- To consider a secure social and economic foundation resting on principles of individual, societal and Earth resilience, recognising the risks of abrupt changes, often with irreversible consequences, where conventional economic assessment of costs and benefits no longer work.
- To recognise that human and natural systems are interdependent, coupled social-ecological systems.
- To consider the importance of adaptive governance, process oriented targets, an inclusive process and to stimulate innovation.
- To consider already agreed commitments and processes such as under the IEAs.

1. Introduction

This discussion paper has been commissioned by the Swedish Government Office and developed by Stockholm Resilience Centre for the Nordic environment ministers meeting in Jukkasjärvi 7th February, 2013. The paper introduces the planetary boundaries concept for global sustainability and seeks to exemplify how this concept relates to the post 2015 agenda and the development of Sustainable Development Goals. An in-depth analysis is undertaken of three boundaries that are assessed to be exceeded: climate change, biodiversity loss and nitrogen emissions. We will describe:
- How critical Earth system processes relates to human well-being and the possibilities and opportunities for individuals and society's future development.
- International Agreements already available to address these Earth system processes and how they relate to the on-going discussions on a post-2015 agenda, and
- How the post-2015 agenda can incorporate the scientific insights provided by Earth system and Resilience science and what its impacts may be on people.

2. Environmental Changes at the Global Scale

Environmental pressures resulting from human activities have increased so much that humans are now a force of change at a global scale. Research is showing that these human pressures on the planet are increasing and are already leading to undesired planetary impacts (Table 1).

Table 1: Some recent international scientific assessments of global change issues

Climate change	IPCC synthesis assessments 1990, 1995, 2001, 2007	www.ipcc.ch
Ecosystem degradation	Millennium Ecosystem Assessment 2005 Global Biodiversity Outlook 2010	www.maweb.org http://gbo3.cbd.int
Human-environment interactions	Global Environment Outlook 1997, 2000, 2002, 2007	www.unep.org/geo
Poverty and environmental inequity	Human Development Reports 1990-2011	http://hdr.undp.org

The human induced changes are so far-reaching that this epoch in the history of the planet has been proposed to be given its own geological term "Anthropocene"[2]. For the past ten thousand years the climate and environment have been relatively stable on Earth, making it possible for humans to develop agriculture and civilisations (Figure 1).

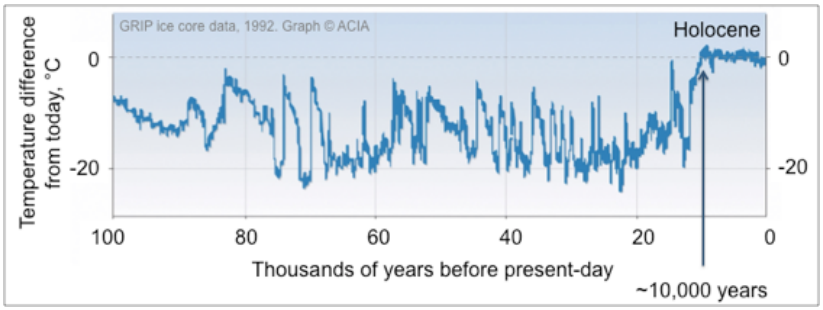


Figure 1. The relative climatic stability of the Holocene. This stable period made it possible to develop agriculture and civilizations.

This stable state of the planet, known as the Holocene, is the only planetary state we know that can support world development. In the Anthropocene, humanity is threatening this stability and exposing itself to unprecedented environmental conditions and the risk of abrupt and extreme changes. We now have a world of seven billion people, committed to nine billion people by 2050, of which all have a right to development and aspire to improved living conditions. To avoid the risk of environmental shocks and ensure the future wellbeing of human societies, it will be necessary for nations in the world to collaborate with the Earth system, and explore novel ways of ensuring required growth and achieve human wellbeing within the safe operating space of the planet.

Today, we have ample evidence of the great acceleration of human environmental change resulting in an exponential growth of pressures. The past 40 years have seen a rapidly growing scientific advancement of knowledge about how the Earth system operates. There are growing insights about the risks of crossing environmental tipping points, with potentially catastrophic implications for human development. Today we have robust evidence indicating that humanity may be reaching the ecological capacity of planet Earth in several critical areas. We can no longer exclude the possibility of large, abrupt and irreversible changes to living conditions on Earth (Steffen et al., 2011; Nobel Ambio).

A new approach to human prosperity in the Anthropocene

Science indicates that *global* sustainability is a prerequisite for human wellbeing at the *local* level – the individual household, community, region or nation. Policy has started to acknowledge the new challenge facing humanity at this "globalised stage" of environmental change. The UN Secretary-General's High Level Panel on Global Sustainability highlighted this in their report to the Rio+20 Earth Summit in June 2012[3]. This new juncture for human development has led to renewed scientific efforts to introduce improved frameworks to guide human development.

Many of these scientific approaches to steer sustainability, and inform policy and regulation are routinely applied in environmental decision-making tools. Examples include the critical load concept, the application of the precautionary principle, risk and hazard assessment approaches, standard-setting frameworks, global resource use

[2] Steffen, W., P. Crutzen, et al. (2007). "The Anthropocene: are humans now overwhelming the great forces of Nature?" Ambio 36: 614-621.
[3] UNGSP (2012) Resilient Planet, Resilient People – the Future We Choose

forecasting models and so on. Another widely applied approach is to develop scenarios depicting possible futures (e.g., the IPCC SRES scenarios[4], and the 2005 Millennium Ecosystem Assessment), but these are usually applied as a means to address uncertainty about future options, rather than setting out intended pathways for sustainability.

The concept of planetary boundaries (Figure 2) builds on the last decades of scientific advances, by combining an integrated approach to global sustainability with understanding of the importance of Earth resilience for world development. It constitutes a natural scientific evolution from recent advancements including climate tipping elements, climate guardrail analyses, ecological carrying capacities and critical loads assessments (Rockström et al. 2009 Supplementary Information). It introduces a way to facilitate scientific, social and political dialogues about a safe operating space for humanity in the context of these global biophysical changes, drawing on a wealth of knowledge about Earth system processes.

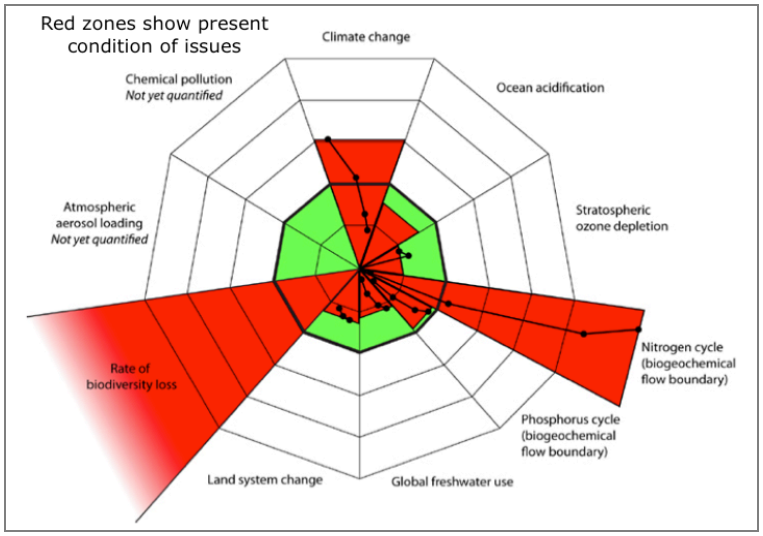


Figure 2: The planetary boundaries (from Rockström and colleagues, 2009[3]). Green zone represents the biophysical 'safe operating space' for human development. Since our knowledge of the complex social-environmental interactions of the Earth system is not complete, the planetary boundaries concept takes a precautionary line.

Outlining the 'safe operating space for humanity' is a highly challenging project. While there are areas of scientific uncertainty, as well as strong disagreement among political actors about how to best grapple with these, few global change scholars question the claim that humanity has entered a new era of rapid environmental change.

The human enterprise has radically changed Earth's climate dynamics, fundamentally modified marine and land-based ecosystems at very large scales, and even changed the course of biological evolution. These changes, combined with insights about how complex systems behave, pose extremely challenging risks at unprecedented temporal and spatial scales.

The planetary boundaries framework suggests a planetary safe operating space within which human development can occur. It thereby associates itself closely with recent analyses of the need for a new sustainable growth paradigm, such as the "Growing

[4] Nakicenovic et al. 2000 and Fisher et al. 2007

within Limits" report to the 2009 Global Assembly of the Club of Rome[5], and the Tolerable Windows Approach[6] developed by the German Advisory Council on Global Change.

Nine planetary boundaries have been identified.[7] They include the Earth system processes that regulate Earth resilience providing the basis for the human entreprise, namely climate change, biodiversity loss, change to the essential nutrient cycles of nitrogen and phosphorus, freshwater use, land system change, ocean acidification, stratospheric ozone depletion, chemical pollution and atmospheric aerosol loading. In Annex 1, all nine boundaries are presented, including their control variables.

These different boundaries are all interconnected. Climate change influences a broad range of processes including biodiversity, biogeochemical cycles, ocean acidification, freshwater flow and aerosol dynamics. Land-use change is a key driving force behind reductions in biodiversity and it influences water flows as well as biogeochemical cycles of carbon, nitrogen and phosphorus. As an example, significant land-use changes in the Amazon could influence water resources as far away as Tibet[8].

Transgressing these boundaries has direct consequences for human wellbeing. Generally, this is already well-recognised at the local level; the planetary boundaries concept simply highlights the global extent of the impacts and their interactions. The planetary boundaries concept does not set economic boundaries. Rather, it seeks to focus attention on emerging risks, and establish a safe space for economic growth, social development and innovation.

It thereby provides a foundational definition of global sustainability – an overarching sustainable development goal – within which individual, societal and world prosperity can evolve.

Human wellbeing and the Planetary Boundaries

Of the nine planetary boundaries identified, three boundaries are currently being transgressed: climate change, biodiversity loss and nitrogen emissions. Exceeding these global sustainability criteria places humans and humanity at risk of large social and economic impacts, some of which are described below.

Climate Change

Climate change is the most well-understood planetary boundary. Policy has already made an attempt to avoid dangerous climate change, by setting a "safe boundary" for global average temperature increase at 2°C. The climate system is a global system, associated with global risks such as the amplification of warming (a "runaway feedback") as polar ice-melt decreases Earth's albedo, and also with regional risks, such as the collapse of large biomes like rainforests and coral reef systems. Science indicates that catastrophic thresholds are more likely to be crossed as concentrations of CO_2 rise. The uncertainty range for many of these risks is 350 – 550 ppm. Applying a precautionary approach, the safe boundary for climate change is 350 ppm CO_2. With atmospheric concentrations already at ~390 ppm CO_2 – and rising – humanity has transgressed the safe boundary, and has reached a global climate danger zone. Evidence

[5] Growing within Limits. A Report to the Global Assembly 2009 of the Club of Rome, Netherlands Environmental Assessment Agency (PBL), Bilthoven, October 2009

[6] WBGU 1995; Toth et al. 2002; Füssel et al. 2003.

[7] Rockström, J., Steffen, W., Noone, K., et al. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society* **14**, 32. www.ecologyandsociety.org/vol14/iss2/art32/main.html.

[8] Snyder, P. K., Foley, J. A., Hitchman, M. H. & Delire, C. J. Geophys. Res. Atmos. 109, D21 (2004).

that this assessment is correct is today seen in the extreme melting of Arctic summer sea-ice and continental ice in Greenland in recent years.

Climate change affects people. According to WHO, climatic changes already are estimated to cause over 150,000 deaths annually[9]. The expected changes will continue to influence people worldwide, both directly and indirectly through impacts on food producing systems and the availability of water resources.

There is ample scientific evidence that a 2°C rise in global average temperature would cause major adaptation problems for people across the world. It is thus associated with large global risks for individuals across the world to exceed the global boundary for climate change. Unfortunately, as things stand today, the world is largely committed to a 2°C, due to cumulative historic emissions, and as recently shown in a scientific synthesis by the World Bank, 'Turn Down the Heat' (World Bank 2012), the world is current heading towards a significant (20 %) risk of reaching 4°C warming, within this century. Such a future would, with little scientific uncertainty, be devastating for a significant proportion of the world population: the inundation of coastal cities; increasing risks for food production potentially leading to higher under- and malnutrition rates; many dry regions becoming dryer, wet regions wetter; unprecedented heat waves in many regions, especially in the tropics; substantially exacerbated water scarcity in many regions; increased intensity of tropical cyclones; and irreversible loss of biodiversity, including coral reef systems; potential collapse of rainforests. This could lead to large-scale displacement of populations and consequences for human security and economic and trade systems. Moreover, adverse effects of a warming climate are "tilted against many of the world's poorest regions" and likely to undermine development efforts and global development goals, says the study.[10]

Moreover, it is likely that the warming would not stop at 4°C, as such large warming would trigger positive (reinforcing) feedbacks that would propel the planet to warming that could reach 6 – 8°C (melting of ice that leads to higher absorption of heat from the sun; release of stored carbon and methane in soil and ocean sediments).
In 2012, according to the German Insurance company Munich Re, natural disasters caused $160 billion in overall losses and $65 billion in insured losses worldwide.

According to UK's Stern Review on the Economics of Climate Change, tackling climate change is the pro-growth strategy; ignoring it will ultimately undermine economic growth. The Review estimated that global climate risks could be equivalent to 20% of GDP or more. In contrast, the costs of action to reduce greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1% of global GDP each year. The benefits over time of actions to shift the world onto a low-carbon path could be in the order of $2.5 trillion each year. The shift to a low-carbon economy will also bring huge opportunities. Markets for low-carbon technologies will be worth at least $500bn, and perhaps much more, by 2050 if the world acts on the scale required. According to the report tackling climate change is the pro-growth strategy; ignoring it will ultimately undermine economic growth.[11]

Regarding mitigation of climate change, more than one third of all greenhouse gas emissions are related to agriculture and forestry. The contribution from deforestation alone is approximately 20 per cent (more than the entire transport sector which

[9] www.who.int/heli/risks/climate/climatechange/en/
[10] Turn Down the Heat: Why a 4°C Warmer World Must be Avoided, November 2012, A Report for the World Bank. by the Potsdam Institute for Climate Impact Research and Climate Analytics

contributes about 14 percent)[12]. Reducing deforestation is the most cost-effective way of reducing CO_2 emissions.

Biodiversity

Scientific analysis clearly show that the current rate of biodiversity loss is unsustainable, risky for human societies, and transgresses the safe boundary at a planetary scale. This has been recognised by the UN Convention for Biological Diversity (CBD), raising deep concerns over the risks humanity face by causing such rapid loss of the genetic library in the world and the basis for ecosystem resilience in the world's landscapes.

This boundary is measured in terms of the extinction rate (number of species per million species per year). The proposed boundary is 10 species/million species/year, while the current status is over 100 species/million species/year, and the preindustrial value was 0.1–1. The level of species extinctions today is comparable to major mass die-off periods in the history of earth.

Overwhelming evidence, including the Millennium Ecosystem Assessment (MA 2005)[1], has clearly demonstrated that humans have changed ecosystems more rapidly and extensively in the last 50 years than in any other period in history. This has contributed to substantial net gains in human well-being and economic development, but at the cost of large and increasing degradation of the majority of ecosystem services. This degradation of ecosystem services is increasingly jeopardizing human well-being, including possibilities of achieving the Millennium Development Goals (MDGs).

Biological diversity underpins ecosystem functioning and the provision of ecosystem services essential for human well-being. It provides for food security, human health, the provision of clean air and water; it contributes to local livelihoods, and economic development, and is essential for the achievement of the Millennium Development Goals, including poverty reduction. In addition it is a central component of many belief systems, worldviews and identities.

Maintenance and improvement of ecosystems services is important for upholding economic, social and cultural rights, such as the rights to health and an adequate standard of living, freedom from hunger and cultural freedom and experience has demonstrated that exclusionary approaches to natural resource management can undermine those rights[13]. People are most likely to become involved in sustainable management when they have clear rights to resources and are confident of future access to these resources[14]. Security of tenure is a critical component in determining how rural people can secure their livelihoods and alleviate poverty. Analysis is always needed that reveals who derives which benefits from ecosystems, and how such benefits contribute to the well-being of the poor[15].

The Economics of Ecosystems and Biodiversity (TEEB) estimates we lose land-based ecosystem services worth 50 billion every year starting in 2000. The accumulated welfare loss of these annual losses by 2050 is equivalent to 7% of the prospected annual

[12] Stern Review: The Economics of Climate Change, 2006

[13] Rights-based approaches: Exploring issues and opportunities for conservation, Campese, J.; Sunderland, T.C.H.; Greiber, T.; Oviedo, G.; eds. CIFOR/IUCN

[14] Ostrom Elinor *Governing the Commons The evolution of Institutions for Collective Action*. Political Economy of Institutions and Decisions p 90 and following

[15] Daw, Tim, Katrina Brown, Sergio Rosendo, and Robert Pomeroy. 2011. "Applying the Ecosystem Services Concept to Poverty Alleviation: The Need to Disaggregate Human Well-Being." Environmental Conservation 38 (04): 370-379. doi:10.1017/S0376892911000506.

consumption in 2050[16]. Competition between highly subsidized industrial fishing fleets coupled with poor regulation and weak enforcement of existing rules has led to over-exploitation of most commercially valuable fish stocks, reducing the income from global marine fisheries by US$ 50 billion annually, compared to a more sustainable fishing scenario (World Bank and FAO 2009). Green products and services represent a new market opportunity - Global sales of organic food and drink have recently been increasing by over US$ 5 billion a year, reaching US $46 billion in 2007 (Organic Monitor 2009); the global market for eco-labelled fish products grew by over 50% between 2008 and 2009 (MSC 2009); and ecotourism is the fastest-growing area of the tourism industry with an estimated increase of global spending of 20% annually (TIES 2006).[17]

Ecosystem based adaptation suggests a number of possible win-win options, related to increasing the flow of ecosystems services and helping disadvantaged groups deal with future impacts of climate change - strategies that can lead to risk reduction and can also contribute to attempts to promote a transition to sustainable poverty alleviation in rural communities[18]. For examples see box 1.

Box 1. Potential of ecosystems for climate change adaptation

- Agriculture: Maintaining diversity of local varieties, crops and agricultural systems contributes to risk distribution, decreased vulnerability, and increases the ability of the agricultural system to adapt. Increased levels of organic matter in soil contribute to increased harvests and improved ecosystem services, such as nutrient cycling and water retention, and it also sequester large amounts of CO2.
- Coastal zones: Conservation of mangrove forests and coral reefs is a cost-efficient measure to protect coastal zones against weather-related catastrophes (storms and typhoons). It also benefits biodiversity and fisheries since spawning grounds for fish are preserved, and it is favourable for tourism.
- Forested mountain areas are important as water sources, but also for their capacity to absorb and moderate the consequences of flooding (and increased water flows from glacial melting).
- Wetlands have a buffering effect (e.g. against drought and flooding), as well as a rich species diversity, and also contribute to other ecosystem services such as removal of nitrogen from agricultural runoff. [19]

Biodiversity loss affects people. Loss of biodiversity affects human wellbeing and individuals in many ways, such as regarding economic opportunities, food security, nutrition and health, and is linked to issues as equity and rights to resources, which demands good governance and well functioning institutions. Regulations and incentives measures for biodiversity and ecosystem services affects individuals and companies, through opportunities such as Payment for Ecosystem Services schemes as green agriculture subsidies and possibilities regarding green markets, and regulations for Environmental Impact Assessments and taxes. Tools to assess business risk and opportunities from ecosystem change has been also been developed and applied[20].

Investing in resilience - the capacity to deal with change and continue to develop - can be seen as insurance against future shocks. By safeguarding critical resources and

[16] TEEB (2008) The Economics of Ecosystems and Biodiversity: An Interim Report. European Comission. Brussels.

[17] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

[18] Closing the Gaps p.17; Commission on Climate Change and Development 2009

[19] Climate change and ecosystem services, Fact sheet from SwedBio, no 2, 2007

[20] The Corporate Ecosystem Services Review: Guidelines for Identifying Business Risks & Opportunities Arising from Ecosystem Change, 2012, WRI,

ecological functions, the chances of 'riding through' shocks – such as extreme events – increase. This is of critical importance considering future uncertainty and limited understanding of the vulnerability generated by anthropogenic change.

Biogeochemical Cycles of Nitrogen and Phosphorus

The perturbation of the globally important nutrient cycles of nitrogen and phosphorus is another of the boundaries that has been exceeded. The biogeochemical cycles of nitrogen and phosphorus regulate a range of life-supporting processes. Human activities have greatly increased the mobilisation of these elements in the environment, both deliberately through the use of agricultural fertilizers and inadvertently, mainly through combustion processes (in the case of nitrogen) and sewage and wastewater processing (in the case of phosphorus). Much of the reactive nitrogen and phosphorus end up in soils and waterways; nitrogen is also implicated in air quality problems.

Nutrient overload (eutrophication) caused by enhanced nitrogen and phosphorus levels in rivers, lakes and seas causes algal blooms. Nuisance and toxic blooms are increasingly widespread problems with local economic and health implications, but algal blooms also cause oxygen depletion when aquatic bacteria consume the algae. This leads to severe regional problems, as in the Baltic Sea, where bottom waters become "dead zones" incapable of supporting fisheries, with direct impacts on the income of fishermen and the economic viability of their communities. Eutrophication of freshwaters is also a global-scale problem[21], evident in more than half of the lakes in Europe and Asia.

Of the two cycles, the global nitrogen cycle is better understood, and is also better addressed in policy. Its planetary boundary is defined in amount of N_2 removed from the atmosphere for human use. The proposed boundary is 35 million tonnes per year and the current status is 121. Human activities now convert more atmospheric nitrogen into reactive forms than all of the natural terrestrial processes combined. Excess nitrogen in the environment costs the European Union (EU) between €70 billion (US$100 billion) and €320 billion per year.[22]

Because nitrogen and phosphorus are both essential in food production, rules and regulations to control them have the greatest impacts on people and their businesses that apply them. Subsidies that encourage the application of these nutrients in the environment are problematic. There is thus a growing demand for enhanced agricultural efficiency and alternatives such as closed production systems.

3. International policy moves towards global sustainability

Over time, sustainable development has emerged at several different levels, where responsive action can be taken – businesses[23], communities (Local Agenda 21) and nations, and international agreements has been developed for example the three Rio Conventions adopted at the 1992 Earth Summit in Rio de Janeiro, the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and The Convention to Combat Desertification. The Brundtland Commission[24] stated that *"sustainable development aims to promote harmony among human beings and between humanity and nature".* Social issues and equality lie at the core of this pillar, between

[21] Carpenter, S. and E. Bennett (2011).
[22] Sutton,M.A.etal.(eds)TheEuropeanNitrogen Assessment (Cambridge Univ. Press, 2011); available at http://go.nature.com/5n9lsq
[23] An early approach to 'triple bottom line' auditing was Spreckley, F. (1982) *Social Audit – a management tool for Cooperative Working*, Beechwood College, Wales. Many organisations now exist advocating a better balance of economic, social and environmental issues, notably the World Business Council for Sustainable Development, www.wbcsd.org.
[24] World Commission on Environment and Development (1987) *Our Common Future*, A/42/427. ("The Brundtland Report") Chapter 2 - The concept of Sustainable Development. www.un-documents.net/ocf-02.htm.

men and women, as well as the rights of ethnic minority groups and indigenous peoples. The second aim, environmental sustainability, involves a broad range of environmental issues. In terms of economic development, there are a number of challenges ahead. These different "pillars" of sustainability do not exclude the other, but are interlinked. By addressing the implications of each of the environmental issues for the continued working of the Earth system the planetary boundaries concept also has relevance to the Brundtland definition of sustainable development: *meeting the needs of the present without compromising the ability of future generations to meet their own needs*.

The preamble of the Rio Principles already emphasizes to: *Protect the integrity of the global environmental and development system.* Examples of Rio Principles for guiding sustainable development:

7: Conserve, protect and restore the health and integrity of the Earth's ecosystem.

9: Improving scientific understanding through exchanges of scientific and technological knowledge

10: Encourage public awareness by making information widely available

11: Enact effective environmental legislation; priorities should reflect the environmental context […]

12: Economic system that better addresses environmental degradation. Environmental measures addressing transboundary or global environmental problems should be based on consensus.

15: Precaution - where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

18: Notify of any natural disasters or other emergencies that are likely to produce sudden harmful effects on the environment.

19: Prior and timely notification and relevant information of transboundary environmental problems

25: Peace, development and environmental protection are interdependent and indivisible

Tackling World Poverty: the MDGs and the Post-2015 Agenda

In year 2000, the UN adopted the Millennium Development Goals (MDGs). The eight MDGs address different issues including poverty and hunger, universal education, gender equality, child health, maternal health, HIV/AIDS, environmental sustainability and global partnership. Each goal has targets that should be achieved by 2015. Although the prime focus of the MDGs has been on the social aim of sustainability, the 'Environmental Sustainability' goal in the MDGs already recognises several critical environmental issues explicitly, with individual targets for climate/CO_2, ozone depletion, land and water use, and biodiversity losses.

Three targets: on poverty, slums and water, have been met three years ahead of 2015. But projections indicate that in 2015 more than 600 million people worldwide will still lack access to safe drinking water, and almost one billion will be living on an income of less than $1.25 per day. Hunger remains a global challenge. Lack of safe sanitation is hampering progress in health and nutrition and greenhouse gas emissions continue to pose a major threat to people and ecosystems. [25]

Towards global sustainability - the SDGs

Sustainable development goals (SDGs) were originally proposed by the Governments of Colombia and Guatemala and discussed during the Rio+20 conference. Colombia, together with other countries, identified a suite of priority issues that constituted the basis for initial discussions:

- Food security: production, access and nutrition
- Integrated water management for sustainable growth
- Energy for sustainable growth
- Sustainable and resilient cities

[25] The Millennium Development Goals Report 2012, http://www.undp.org/content/undp/en/home/librarypage/mdg/the-millennium-development-goals-report-2012/

– Healthy and productive oceans
– Sustainable consumption and production patterns (SCP)
– Enhanced employment and livelihood security
– Human health (which is related to ecosystem health)
– Education for productive lives.

Nations are now working to define what such goals should be, through a multitude of initiatives being developed by diverse stakeholders worldwide. The outcome document from Rio+20 states that sustainable development goals should be action-oriented, concise and easy to communicate, limited in number, aspirational, global in nature and universally applicable to all countries while taking into account different national realities, capacities and levels of development and respecting national policies and priorities.

A key initiative in this emerging global sustainability agenda is the UN Sustainable Development Solutions Network (SDSN)[26]. SDSN supports dialogues to develop a framework for these goals and inform the UN Secretary-General's High-Level Panel of eminent persons on the Post-2015 Development Agenda. In this context, the framework being developed by Colombia (outlined in Annex 2) is an important conceptualization of sustainability.

International environmental related agreements, planetary boundaries and the post-2015 agenda

For the development of the post-2015 agenda it is relevant to take stock of how existing international environmental agreements (IEAs) and/or policy targets that can be used, to what extent they address global sustainability goals, and how they relate to critical Earth system processes such as the nine planetary boundaries.

In the comparison between planetary boundaries and existing IEAs, boundaries have partly been addressed (see Table 2 below). In some cases existing targets do not fully address the Planetary Boundary, but only partial aspects, such as certain geographical locations or selected drivers of the problem (e.g. land system change, biogeochemical cycles). In other cases, there is a clear policy gap in that there is no sufficient target or it has inadequate level of ambition (e.g. ocean acidification, freshwater consumption). In some cases the problem is rather an implementation gap (e.g. climate change). The clear success story coming out of this comparison is, as often noted, the Montreal Protocol and its effect on limiting emissions of ozone-depleting substances. One conclusion from this initial comparison is that existing IEAs and institutions can be utilized more effectively in order to calibrate policy targets in relation to the scientific evidence on global environmental thresholds. To the extent that policy-makers wish to use this evidence to inform new policy, including the formulation of post-2015 goals and Sustainable Development Goals, one approach could focus on reducing implementation deficits and/or increase the level of ambition of existing targets.

The policy context of the planetary boundaries is examined further in a forthcoming research report by SEI and SRC for the Swedish EPA in which a methodology for measuring national performance on planetary boundaries is developed (expected

[26] SDSN involves scientists, engineers, business and civil society leaders, and development practitioners for practical, science-based problem solving. Thematic Groups will support SDSN as well as the UN High-Level Panel on the post-2015 development agenda. The thematic groups focus on key questions in sustainable development including planetary boundaries, ecosystem services, food production, low-carbon energy, efficiency in resource use, population dynamics, poverty eradication, cities, fragile regions, business, pollution, global rules, gender, in-equalities, human rights, childhood, education and health.

publication February 2013).[27] Another relevant stocktaking of global environmental goals has recently been concluded by UNEP.[28]

These preliminary results can be considered to be consistent with the "Environment Scorecard" coming out of UNEP's stock-taking, where comparison is made with environmental goals themselves and not with planetary boundaries. The message these two reports combined can send to the post-2015 and SDG debate is that a range of environmental goals and targets already exist (accompanied with indicators and monitoring systems), but there are significant implementation deficits. A more detailed comparison of planetary boundaries and targets agreed under IEAs needs to consider several aspects; how relevant the target is to the Planetary Boundary, its coverage (in terms of both scope and number of Parties), its level of ambition, whether the target is legally binding, whether a strong compliance mechanism exists, and whether the target has so far been successfully achieved.

The planetary boundaries framework does not introduce new issues on the policy agenda as such but rather suggests metrics for boundaries, based on scientific evidence on harmful thresholds. However, a number of new institutional issues are raised by the planetary boundary concept. IEAs are not equipped to manage complex threshold effects and interactions between these global and cross-scale issues, which are hard to deal with through static targets.

Table 2. Comparison of planetary boundaries and existing International environmental agreements and targets that could be relevant for the post 2015 agenda – an overview

Planetary boundary, from Rockström et al. (2009):	**IEA, with relevant quantified targets**	**Comment**
Climate change - Atmospheric CO2 concentration not above 350 ppm - Change in radiative forcing limited to +1 W m^{-2}	The United Nations Framework Convention on Climate Change , UNFCCC -"Stabilisation of greenhouse gases concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Art 2) -"To hold the increase in global average temperature below 2 degrees Celsius" (Decision 1/CP.16)	While the Convention objective and 2 degree target have comparable level of ambition as the PB, neither the Kyoto Protocol and pledges made for a post-2015 agreement match this level.
Ocean acidification - Global mean saturation state of aragonite in surface sea water not below 2.75	No specific IEA yet developed, but issue raised under CBD and UNFCCC.	The main policy recommendation is to limit anthropogenic GHG emissions. The CBD Aichi Biodiversity Target 10 deals with pressure on vulnerable ecosystems such as by ocean acidification.
Stratospheric ozone depletion - Concentration of ozone no less than 276 DU	Montreal Protocol -Various binding bans and phase-out schedules adopted for relevant ozone depleting substances	Relevant and quantified phase-out targets have been set and several of these have been achieved. The PB is less ambitious than these targets, considering that humanity is no longer transgressing this boundary.
Perturbed biogeochemical flows - Amount of N2 removed from the atmosphere for human use, no more than 35 million tonnes per year - Quantity of P flowing into the oceans, no more than 11 million tonnes per year	No IEA with global coverage exists, but various (binding and non-binding) regional agreements to reduce nutrient inputs to regional seas (e.g. HELCOM, OSPAR) (see UNEP Regional Seas Programme). In Europe, the Water Framework Directive was a key piece. The Convention on Long-Range Transboundary Air Pollution (CLRTAP) aims to reduce eutrophication and the atmospheric emission of gaseous nitrogen compounds. CBD includes measures, e.g. Aichi Target 8. UNFCCC sets out policies for the emissions of nitrogenous greenhouse gases and the environmental impact of carbon sequestration	The cumulative global effects of regional eutrophication have not been addressed and the regional pollution problems have not been effectively mitigated. Nitrogen has been briefly reviewed in the 2010 European Nitrogen Assessment [29]. Scientists call for global nitrogen assessment.

[27] For more information, contact Åsa Persson, SEI.
[28] UNEP (2012) Measuring Progress: Environmental Goals and Gaps. Nairobi, UNEP. http://www.unep.org/geo/pdfs/geo5/Measuring_progress.pdf
[29] Chapter 25 in M.A. Sutton, C.M. Howard, J.W. Erisman, G. Billen, A. Bleeker, P. Grennfelt, H. van Grinsven and B. Grizzetti, eds. (2011) *The European Nitrogen Assessment*. Cambridge University Press.

Global freshwater use -Consumption of freshwater by humans no higher than 4,000 km3 per year	UNECE Water Convention -Recently opened to all UN member states -"To ensure that transboundary waters are used with the aim of ecologically sound and rational water management, conservation of water resources and environmental protection" (Art 2.2 b) Various bilateral and regional agreements on freshwater resources	Until very recently, no IEA with global coverage existed. Unclear to what extent targets in regional agreements refer to freshwater consumption levels as opposed to e.g. transboundary water pollution, and to what extent they add up to the planetary boundary proposed.
Land system change - Percentage of global land cover converted to cropland no more than 15%	CBD -Several of the Aichi Targets address conservation and sustainable management of land (e.g. target 5, 7, 11, 14, 15)	Certain functions of forested areas addressed under UNFCCC (REDD, LULUCF, CDM) and CBD (Aichi targets for habitat loss) UNCCD (UN Convention to Combat Desertification) deals with land use patterns, management of water resources, soil conservation, forestry, agricultural activities and pasture and range management.
Biodiversity loss - Extinction rate no higher than 10 species per million species per year	The Convention on Biological Diversity, CBD, main goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources -The Aichi Targets, see Annex 2, are partly quantified targets and relates to the biodiversity boundary and address various drivers and pressures on biodiversity loss, and also define desirable state. A comprehensive work is undertaken regarding indicators for follow up of the Targets and for biodiversity and ecosystem services in general, such as under Biodiversity Indicators Partnership (see e.g. app for indicators at www.bipindicators.net/resources/aichipassport) Several other IEAs address aspects of biodiversity loss, e.g. CITES, Ramsar, Bonn Convention	Previous global biodiversity targets have not been achieved. An example of a regional strategy is EU biodiversity strategy to 2020. MDGs, the Goal 7: Ensure environmental sustainability has the target: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss, which relates to work undertaken by CBD.
Chemical pollution -For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disruptors, heavy metals and nuclear waste, in the global environment, or the effects on ecosystem and functioning of Earth system thereof, boundary TBD	Several IEAs exist (e.g. the Basel, Rotterdam and Stockholm Conventions and the voluntary SAICM), but not covering all potentially harmful substances nor their cumulative global effect.	PB tbd, no comparison possible.
Atmospheric aerosol loading -Overall particulate concentration in the atmosphere on a regional basis, boundary TBD	A global WHO guideline on particulate matter concentration exists and various regional agreements on transboundary air pollution (e.g. CLRTAP, Malé Declaration)	PB tbd, no comparison possible. Existing agreements based on human health rather than climate change/environmental concerns.

As explored by Galaz and colleagues (2012) however, a focus on formal international agreements alone gives a too simplistic perspective on the features of global environmental governance. They propose that insights from current scientific work on planetary boundaries, also highlight the need to consider flexible multilevel forms of state and non-state collaborations and partnerships; the importance of legitimate and inclusive international and regional scientific assessments; the important role played by international organizations; and the need for international policies that support social-ecological innovation (Olsson and Galaz 2012, Westley et al 2012 Ambio). [30]

Surely international agreements and national enforcement matters, but these should not be decoupled from local and regional adaptive forms of ecosystem stewardship as these

[30] Galaz, V., F. Biermann, B. Crona, C. Folke et. al. (2012). "Planetary Boundaries – Exploring the Challenges for Earth System Governance", Current Opinion in Environmental Sustainability 4(1):80-87.
Olsson, P. and V. Galaz (2012). "Social-ecological innovation and transformation", in Social Innovation: Blurring Sector Boundaries and Challenging Institutional Arrangements. A. Nicholls and A. Murdoch (eds). Palgrave MacMillan.

have been proven to be critical in dealing with key features of global change: uncertainty, surprise, and change.[31]

Many countries have far reaching sustainability and environmental goals. Sweden has for example the 16 national environmental quality objectives to be met by 2020– adopted by the Parliament in 1999 and 2005, e.g. on Reduced Climate Impact, Zero Eutrophication, Sustainable Forests, and Biodiversity "A Rich Diversity of Plant and Animal Life" (although all of the goals relates to biodiversity to some extent).

6. Conclusions: Formulating Sustainable Development Goals in the Post 2015 Agenda – within planetary boundaries

Among the important global issues that will follow in the post-2015 era, the concept of sustainable development is emerging as a central theme. The move towards internationally agreed Sustainable Development Goals (SDGs) brings stewardship of the environment into focus. To ensure society enjoys ecological integrity, social equity, and economic stability, and the well-being of the individual human being, among issues recommended to consider when developing goals are:

- *To recognise the new challenge of meeting the twin universal challenge of poverty alleviation and human wellbeing on the one hand, and global sustainability on the other. Global sustainability being an overarching precondition for human prosperity.*

The scientific conclusion is that this is the new situation facing the world: the stability of the Earth system and therefore its ability to support human prosperity in the future, is now at stake. Global sustainability goals must therefore be defined in support of human development. The reason is obvious. We know that the life support systems provided by a resilient Earth – all ecosystems and natural resources - constitutes the basis upon which human well being and poverty reduction efforts and sustainable development are built. All people depend on natural capital, a stable local environment and energy resources for their livelihoods and wellbeing. It is widely recognized that recent and ongoing global shocks - food, fuel, economy, climate change – are connected to environmental risks associated with the way we govern and manage ecosystems and our global commons, such as the climate systems, the global hydrological cycle, and our oceans.

- *To recognise that a stable planet is a necessary condition for human prosperity in the world, and that a post-2015 development agenda should consider defining a science-based safe operating space defined by global sustainability criteria such as the planetary boundaries.*

The planetary boundaries approach can potentially fill a critical gap in the pursuit of sustainable development, by providing global sustainability criteria for a safe operating space for human prosperity. Global sustainability criteria must then be operationalised within economic sectors, and in societies at regional to local scales. Our conclusion is that Sustainable Development Goals focusing on food security, poverty alleviation, equity, energy security etc, must be achieved within the confines of global sustainability goals, in order to safeguard that social accomplishments are resilient to last many generations in the future. Clearly, there are uncertainties. Global sustainability needs to embed the precautionary principle. This involves normative decisions that reflect people's different risk preferences.

[31] Folke et al. AMBIO (2011) 40:719–738, Reconnecting to the Biosphere

- *To consider a secure social*[32] *foundation, and economic foundation resting on principles of individual, societal and Earth resilience, recognizing the risks of abrupt changes, often with irreversible consequences, where conventional economic assessment of costs and benefits no longer work.*

In the Rio+20 outcome document "The Future We Want", and under the Millennium Development Goals, the world has agreed on critical social foundations, based on human rights, poverty alleviation and equity aspects, that the post-2015 agenda obviously could build on.

- *To recognise that human and natural systems are interdependent, coupled social-ecological systems.*

Social-ecological systems are interdependent and linked systems of people and nature that are nested across scales. In essence this reflects that people are part of ecosystems and shape them, from local to global scales, from the past to the future and are at the same time fundamentally dependent on the capacity of these systems to provide services for human wellbeing and societal development. A social-ecological systems (SES) approach provides two underlying principles that can guide the development of SDGs; the need to recognize multiple interdependencies at and across scales in the SES, and the need to design institutions that are flexible and adaptive in order to deal with unexpected outcomes and feedbacks. The SDGs should go beyond a disciplinary division of socio-economic and environmental goals, and avoid becoming a collection of single issue-based objectives as was partly the case with the MDGs. SDGs should be designed in ways that enhance the awareness of and focus on the role of natural resources and ecosystem services within (not alongside) economic development and poverty reduction objectives. Similarly, targets for SDGs focused on the environment need to be formulated not only in favour of preserving the biosphere, but also to ensure continued societal development. [33]

For examples of sustainability frameworks that partly consider Social-Ecological Systems and Resilience, see Annex 3.

- *To consider the importance of adaptive governance, process oriented targets, an inclusive process and to stimulate innovation.*

Insights from studies on social-ecological systems suggest that human activity will likely trigger unexpected and non-linear changes (Scheffer et al 2001; Lenton et al 2008). To be congruent with this type of complex, dynamic behaviour, SDGs need to be embedded in an adaptive governance context that allows for recursive adjustments of goals and strategies. A central characteristic of such adaptive governance is collaborative, flexible and learning-based issue management across different scales. Investments in real-time data-collecting and reporting systems for SDGs alongside institutions that foster learning and allow rapid feedback to decision-makers can provide further adaptive capacity to shift SDGs when approaching thresholds or should catastrophic change occur. [34]

The process of developing SDGs needs to stem from a broad and inclusive vision and common analysis of what to achieve. While MDGs focused on developing countries, an achievable and shared set of SDGs must inspire public support and need to be universal in nature and will require a buy-in from all nations. There is an unprecedented opportunity to build a highly energized network that engages the world's governments, scientific communities, business and civil society for inclusive, global-scale collaboration

[32] Kate Raworth (Oxfam) has been developing ideas linking the planetary boundaries concept with global equity, ahead of the Rio+20 conference. An accessible version of her work is on www.oxfamblogs.org/fp2p/?p=7237
[33] Norström et al, Three necessary conditions for establishing effective SDGs, (In Review)
[34] Ibid.

around formulating and identifying sustainable development goals, and the pathways needed to reach them. Achieving any suite of SDGs will require innumerable forms of social change at multiple social scales. Our understanding of how social change occurs, from individual behaviour to institutional reform will therefore be needed to provide important guidelines, which could help determine the success or failure of SDGs.[35]

Knowledge rich collaborative learning platforms between policymakers, practitioners and scientist offer solutions also for local and national level development and implementation of SDGs. Combining knowledge systems for learning is essential in adaptive ecosystem stewardship.

Technological novelties and social innovations in the form of new sets of rules and norms, new ways of thinking, new processes for action and decision making, and novel designs for behaviour are important to understand and stimulate. Such value-driven 'responsible innovation' can assist in a transition of human societies towards a more sustainable future. [36]

- *To consider already agreed commitments and processes such as under the IEAs.*

To be cost effective goals should be developed in synergy with commitments and already undertaken work with international goals, targets and indicators such as under International Environmental Agreements, IEAs, e.g. UNFCCC and CBD and also FAO to not repeat what is already developed and under development. Goals need to be measurable so as to allow for monitoring and assessment of progress; and this measurability should be considered in their initial design. The possibility for follow up increases with collaborations with the IEAs. Science-Policy Panels and Platforms such as Intergovernmental Panel on Climate Change (IPCC) and Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) can further contribute to the knowledge generation necessary for understanding of sustainability and goal setting.

[35] Ibid.
[36] Ibid.

Annex 1. Planetary boundaries, control variables and some effects[37]

Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Climate change	Atmospheric CO_2 concentration, ppm; Energy imbalance at Earth's surface, W m^{-2}	Loss of polar ice sheets. Regional climate disruptions. Loss of glacial freshwater supplies. Weakening of carbon sinks.	Atmospheric CO_2 concentration: 350 ppm (350-550 ppm) Energy imbalance:+1 W m^{-2} (+1.0 – +1.5 W m^{-2})	1. Ample scientific evidence. 2. Multiple sub-system thresholds. 3. Debate on position of boundary.
Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	Conversion of coral reefs to algal-dominated systems. Regional elimination of some aragonite- and high-magnesium calcite-forming marine biota Slow variable affecting marine carbon sink.	Sustain ≥ 80 % of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80 % - ≥70 %)	1. Geophysical processes well-known. 2. Threshold likely. 3. Boundary position uncertain due to unclear ecosystem response.
Stratospheric ozone depletion	Stratospheric O_3 concentration, DU	Severe and irreversible UV-B radiation effects on human health and ecosystems.	<5% reduction from pre-industrial level of 290 DU (5 - 10 %)	1. Ample scientific evidence. 2. T hreshold well established. 3. Boundary position implicitly agreed and respected .
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	Disruption of monsoon systems. Human health effects. Interacts with climate change and freshwater boundaries.	To be determined	1. Ample scientific evidence. 2. Global threshold behaviour unknown. 3. Unable to suggest boundary yet.
Biogeo-chemical flows: interference with P and N cycles	P: inflow of phosphorus to ocean, increase compared to natural background weathering N: amount of N_2 removed from atmosphere for human use, Mt N yr^{-1}	P: avoid a major oceanic anoxic event (including regional), with impacts on marine ecosystems. N: slow variable affecting overall resilience of ecosystems via acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems.	P: < 10× (10× - 100×) N: Limit industrial and agricultural fixation of N_2 to 35 Mt N yr^{-1}, which is ~ 25% of the total amount of N_2 fixed per annum naturally by terrestrial ecosystems (25- 35%)	P: (1) Limited knowledge on ecosystem responses; (2) High probability of threshold but timing is very uncertain; (3) Boundary position highly uncertain. N: (1) Some ecosystem responses known; (2) Acts as a slow variable, existence of global thresholds unknown; (3) Boundary position highly uncertain.
Global freshwater use	Consumptive blue water use, km^3 yr^{-1}	Could affect regional climate patterns (e.g., monsoon behaviour). Primarily slow variable affecting moisture feedback, biomass production, carbon uptake by terrestrial systems and reducing biodiversity	< 4,000 km^3 yr^{-1} (4,000 - 6,000 km^3 yr^{-1})	1. Scientific evidence of ecosystem response but incomplete and fragmented. 2. Slow variable, regional or subsystem thresholds exist. 3.. Proposed boundary value is a global aggregate, spatial distribution determines regional thresholds
Land system change	Percentage of global land cover converted to cropland	Trigger of irreversible & widespread conversion of biomes to undesired states. Primarily acts as a slow variable affecting carbon storage and resilience via changes in biodiversity and landscape heterogeneity	≤ 15% of global ice-free land surface converted to cropland (15 – 20%)	1. Ample scientific evidence of impacts of land cover change on ecosystems, largely local and regional. 2. Slow variable, global threshold unlikely but regional thresholds likely. 3. Boundary is a global aggregate with high uncertainty, regional distribution of land system change is critical.
Biodiversity loss	Extinction rate , extinctions per million species per year (E/MSY)	Slow variable affecting ecosystem functioning at continental and ocean basin scales. Impact on many other boundaries – C storage, freshwater, N and P cycles, land systems. Massive loss of biodiversity unacceptable for ethical reasons.	< 10 E/MSY (10 – 100 E/MSY)	1. Incomplete knowledge on the role of biodiversity for ecosystem functioning across scales. 2. Thresholds likely at local and regional scales 3. Boundary position highly uncertain.
Chemical pollution	For example, emissions, concentrations, or effects on ecosystem and Earth system functioning of persistent organic pollutants (POPs), plastics, endocrine disruptors, heavy metals, and nuclear wastet.	Thresholds leading to unacceptable impacts on human health and ecosystem functioning possible but largely unknown. May act as a slow variable undermining resilience and increase risk of crossing other threshold.	To be determined	1. Ample scientific evidence on individual chemicals but lacks an aggregate, global-level analysis. 2. Slow variable, large-scale thresholds unknown. 3. Unable to suggest boundary yet.

* State of knowledge regarding three factors: 1. Basic understanding of Earth system process. 2. Existence of threshold behaviour 3. Position of the boundary

[37] Rockström et al, 2009, Planetary Boundaries: Exploring the safe operating space for humanity, Ecology and Society

Annex 2. Strategic Plan for Biodiversity 2011-2020, From: COP 10 Decision X/2

VISION

The vision of this Strategic Plan is a world of "Living in harmony with nature" where "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."

THE MISSION OF THE STRATEGIC PLAN

The mission of the Strategic Plan is to "take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication. To ensure this, pressures on biodiversity are reduced, ecosystems are restored, biological resources are sustainably used and benefits arising out of utilization of genetic resources are shared in a fair and equitable manner; adequate financial resources are provided, capacities are enhanced, biodiversity issues and values mainstreamed, appropriate policies are effectively implemented, and decision-making is based on sound science and the precautionary approach."

STRATEGIC GOALS AND THE AICHI BIODIVERSITY TARGETS

The Strategic Plan includes 20 headline targets for 2015 or 2020 (the "Aichi Biodiversity Targets"), organized under five strategic goals. The goals and targets comprise both: (i) aspirations for achievement at the global level; and (ii) a flexible framework for the establishment of national or regional targets. Parties are invited to set their own targets within this flexible framework, taking into account national needs and priorities, while also bearing in mind national contributions to the achievement of the global targets. Not all countries necessarily need to develop a national target for each and every global target. For some countries, the global threshold set through certain targets may already have been achieved. Others targets may not be relevant in the country context.

Strategic goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Target 1: By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

Target 2: By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

Target 3: By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

Target 4: By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

Strategic goal B. Reduce the direct pressures on biodiversity and promote sustainable use

Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 6: By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

Target 9: By 2020, invasive alien species and pathways are identified and prioritized, priority species

are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Target 10: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

Strategic goal C. Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Target 11: By 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 12: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services

Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Target 16: By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.

Strategic goal E. Enhance implementation through participatory planning, knowledge management and capacity-building

Target 17: By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

Target 18: By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

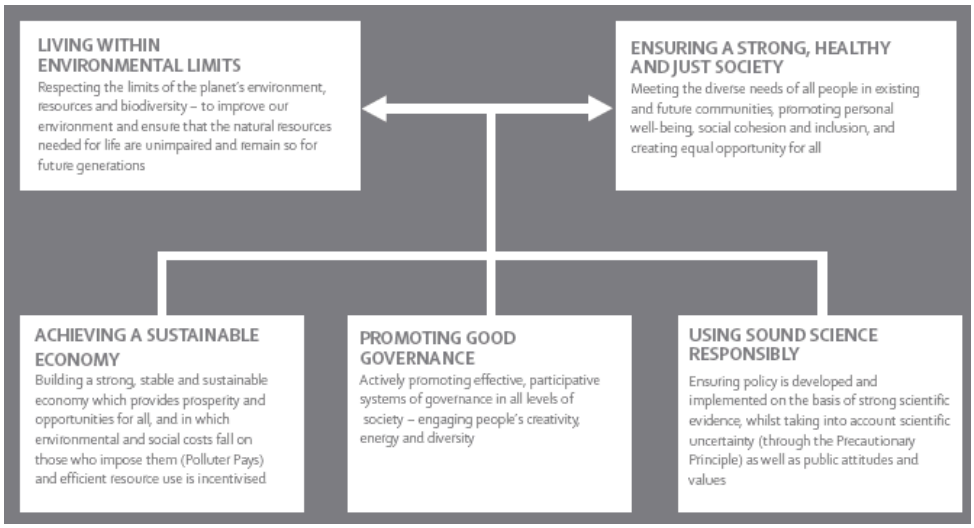
Target 19: By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

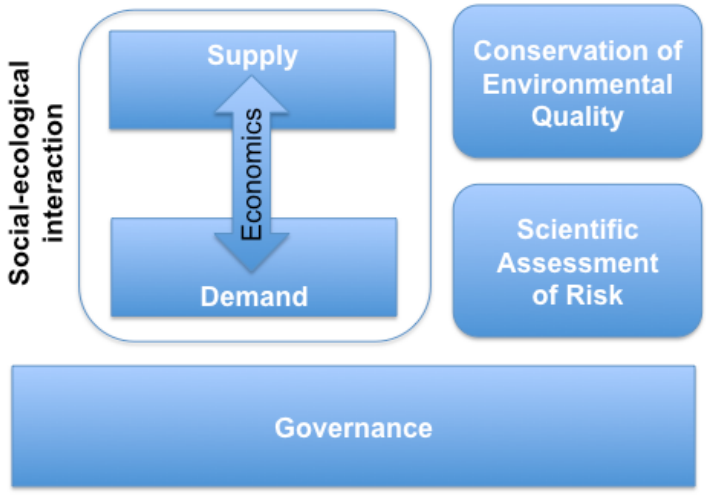
Target 20: By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

Annex 3. Examples of Sustainability Frameworks

Shared features of the UK Sustainable Development strategy framework[38] (top figure) and tentative framework from the Ministry of Environment and Sustainable Development Colombia (bottom figure):

- Essentially the same elements – partly embeds a resilience perspective through the explicit treatment of the social and environmental sub-components (top boxes in UK diagram, top left-hand in Colombian diagram).
- Tacitly (but not yet explicitly) recognize that environmental quality ('supply') underpins or constrains social activity ('demand').
- The economy is a means for mediating resilient interaction between social and environmental dimensions. Colombia's framework potentially allows for clarity about the 'economic development within limits' (where demand does not exceed supply), while the UK framework remains at 'environmental limits' more detached from the economic component.
- Both recognize the underpinning importance of governance for sustainability.
- Both recognize the need to use best available knowledge to minimize risk.





[38] Defra (2005) Securing the Future: the UK Sustainable Development Strategy. The Stationery Office. London, UK. www.sustainable-development.gov.uk/publications/uk-strategy/uk-strategy-2005.htm