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Planetary Boundaries for SD

From an international perspective to national applications

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Planetary Boundaries for SD

From a conceptual perspective to national applications

by

[Umberto Pisano](#) and [Gerald Berger](#)

This ESDN Quarterly Report (QR) provides an overview of the planetary boundaries concept and related framework. In addition, it seeks to reflect on possible links between planetary boundaries with sustainable development as well as on chances and opportunities for its approach to be considered by the policy-making world in the context of international governance for sustainable development, but also at the national and regional level.

In the first chapter, we provide a comprehensive overview of the concept of ‘planetary boundaries’. Firstly, we look at how the concept has been developed. Secondly, we describe the scientific basis in a very concise way and with the help of several visual and descriptive tools. Finally, we briefly consider the topic in light of the sustainable development discourse, also looking at it from a social and equity perspective.

The second chapter provides an overview on the responses that the planetary boundaries framework has received, especially with an eye on the policy-making world. We look at different angles, from the global sphere (such as the United Nations), the supra-national perspective of the European Union, and also the national viewpoints from eight European countries (i.e. Belgium, Finland, France, Germany, Italy, Switzerland, The Netherlands, United Kingdom), always keeping in mind the sustainable development context. In so doing, we explore whether chances and opportunities can be found, particularly in terms of application and implementation, of the planetary boundaries framework. With this intention, we summarise and present a research study commissioned by the Swedish Environmental Protection Agency (SEPA), which represents the first attempt to comprehend the feasibility of using planetary boundaries as a framework for understanding national contributions to the transgression of the planetary boundaries.

Finally, the concluding chapter presents the main arguments explored in the report and provides several reflections that we consider interesting and potentially stimulating for furthering the planetary boundaries framework’s uptake, especially in the policy-making world.

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1 The concept of ‘planetary boundaries’

In this chapter of the Quarterly Report, we provide a comprehensive overview of the concept of ‘planetary boundaries’. Firstly, we will look at how the concept has been developed. Secondly, we describe the scientific basis in a very concise way and with the help of several visual and descriptive tools. Finally, we briefly consider the topic in light of the sustainable development discourse, also looking at it from a social and equity perspective.

1.1 Brief history of the concept

From Earth-system dynamics to planetary boundaries

In 2008, an interdisciplinary group of scientists started the discussions about **‘planetary boundaries’** in a workshop convened by the Stockholm Resilience Centre, the Stockholm Environment Institute and the Tällberg Foundation¹. They were looking for insights into Earth-system dynamics to characterise the conditions needed for our planet to continue in a state, such as the Holocene. For the past ten thousand years (ca.), this state of the Earth has been supportive of the human civilization progresses providing humans with a stable climate.

A safe space for humanity

In 2009, one year after this workshop, a group of 29 internationally renowned scientists identified and quantified a set of **nine planetary boundaries** within which humanity can continue to develop and thrive for generations to come² - the so-called **‘safe space for humanity’**. They believed that transgressing these boundaries could generate abrupt or irreversible environmental changes. On the contrary, respecting them would instead reduce the risks of human activities from causing unacceptable and undesirable environmental change (Rockström et al., 2009a; Rockström et al. 2009b).

Inter alia, researchers involved in the study stressed that the approach does not offer a complete roadmap for sustainable development but also that the **identification of critical planetary boundaries could provide one important element that can inform society’s decisions about sustainability**.

After 2009, the concept of ‘planetary boundaries’ has gained **strong interest** not only throughout the scientific community but also within the world of policy-making (e.g. UN Secretary-General Ban Ki-moon has often referred to this concept³) and civil society (e.g. OXFAM on social and equity issues and the planetary boundaries).

¹ <http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries/planetary-boundaries/background.html>

² <http://www.stockholmresilience.org/planetary-boundaries>

³ See for instance: <http://www.un.org/apps/news/story.asp?NewsID=39627#.Ulu4YlBmiSo>

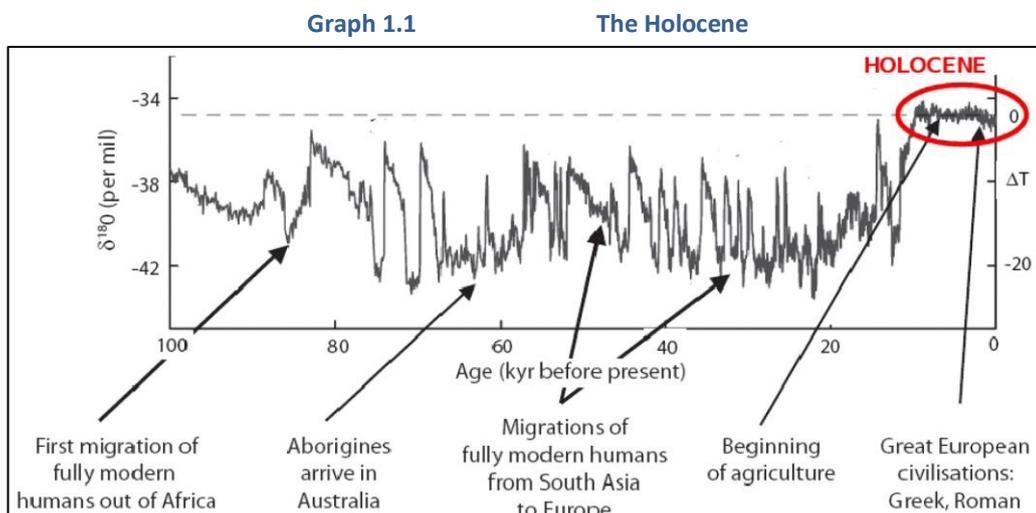
1.2 Welcome to the Anthropocene

A new geological era

Although not formally recognized yet⁴, a large number of scientists are convinced⁵ that the Earth – including the human population – has entered a new geological epoch, which has been defined by Nobel prize winner Paul J. Crutzen as ‘**the Anthropocene**’ (Crutzen, 2002). Already recognised in 1873 by the Italian geologist Antonio Stoppani, who saw in humanity a “new telluric force which in power and universality may be compared to the greater forces of earth”, the Anthropocene dates back to the Industrial Revolution around 1800 (ibid.), especially with the “enormous expansion in the use of fossil fuels” (Steffen et al. 2007). In fact, Crutzen defined the Anthropocene as such, considering the escalation of the effects on the global environment provoked by humanity; furthermore he pointed out that because of the “anthropogenic emissions of carbon dioxide, global climate may depart significantly from natural behaviour for many millennia to come” (Crutzen, 2002).

The Holocene

In contrast, the precedent era - **the ‘Holocene’** - has permitted human civilizations to thrive, especially because it guaranteed a stable warm period (for 10,000 years ca.) without dramatic variations, which is not usual in the history of humans’ appearance on the Earth (Rockström et al., 2009a; Rockström et al. 2009b; Steffen et al., 2011a). The Holocene has been the only stable accommodating environment and the “only state of the Earth System that we know for sure can support contemporary society” (Steffen et al. 2011a, p.739): for instance, it allowed the development of agriculture and the creation of complex civilizations (**Graph 1.1**).



The Anthropocene

As very well defined by Steffen et al. 2011b, the Anthropocene is revealed by two main features:

1. Earth is now moving out of its current geological epoch (the Holocene); and,

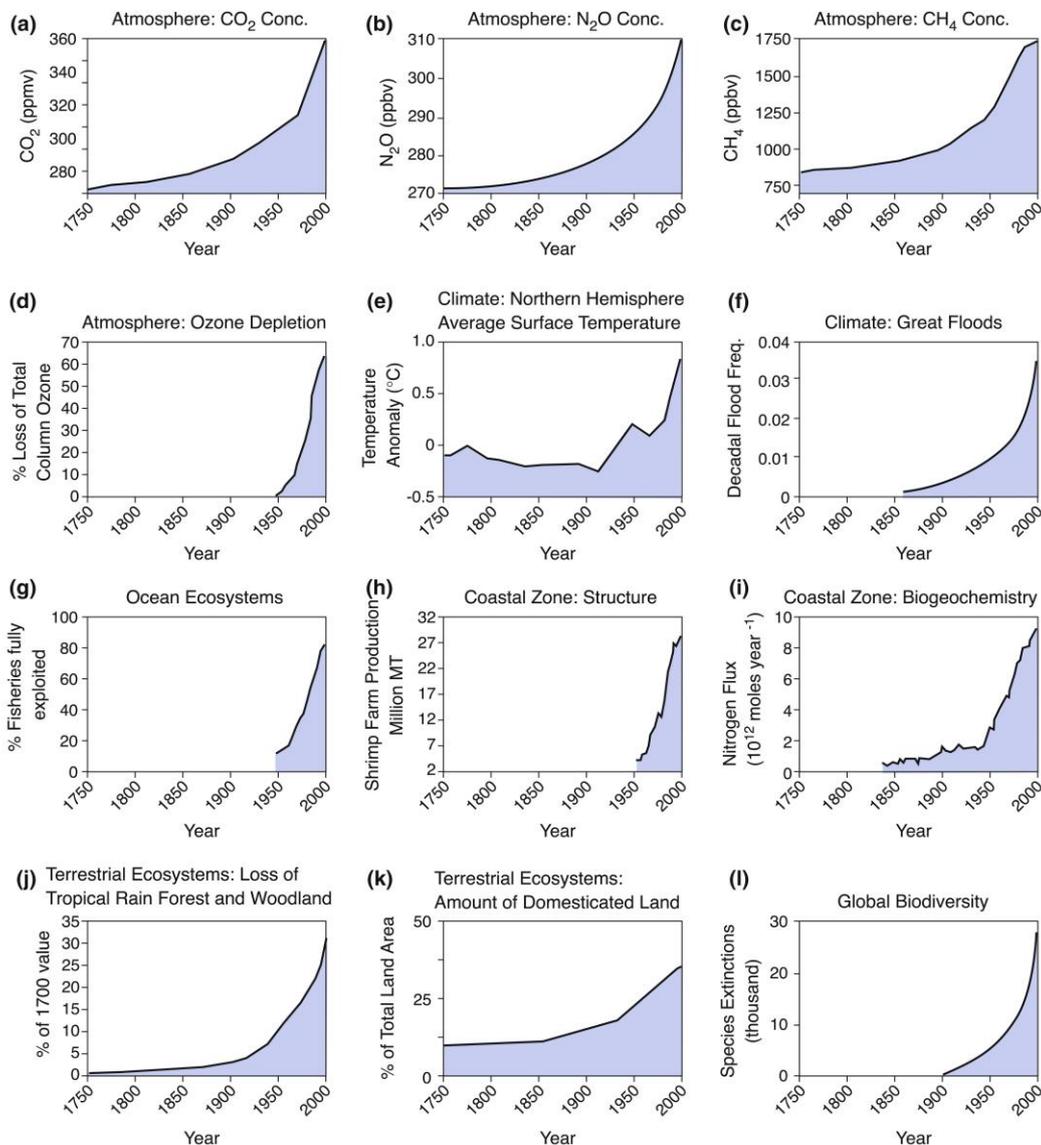
⁴ The argument is under serious analysis: a proposal to formalise the 'Anthropocene' is being developed [by the 'Anthropocene' Working Group for consideration by the International Commission on Stratigraphy](#), with a current target date of 2016. However, the 'Anthropocene' has emerged as a **popular scientific term** used by scientists, the scientifically engaged public and the media to designate the period of Earth's history during which humans have a decisive influence on the state, dynamics and future of the Earth system. It is widely agreed that the Earth is currently in this state.

⁵ See for instance: Steffen et al., 2011b

2. Human activity is largely responsible for this exit from the Holocene (therefore, recognizing that humankind has become a global geological force in its own right).

The Anthropocene started around the beginning of 1800 with the Industrial Revolution in England and concluded its first stage after WWII in 1945. This period has been characterized mainly by an enormous expansion in the use of fossil fuels, first coal and then oil and gas (Steffen et al., 2007). The second stage, referred to as ‘**the Great Acceleration**’ and characterized by a dramatic increase in human activities (Steffen et al., 2011a), started in 1945 and is coming to an end in these very years. This great acceleration of the human impact is well described in the next figure (Fig. 1.1), which looks at the global-scale changes in the Earth- system as a result of the dramatic increase in human activity.

Fig. 1.1 The great acceleration



Source: Steffen et al., 2011a

The 3rd stage At the moment, the Anthropocene has lived already through its first two stages. It is believed (Steffen et al. 2007; Steffen et al., 2011a), humankind finds itself in the third stage which is meant to start with the **recognition by decision makers of the role of human activities in “affecting the structure and functioning of the Earth System as a whole”** (ibid.). However, now, it is up to humanity to decide what the 3rd phase will be like: continuing in a “business-as-usual” trajectory or striving to become “Stewards of the Earth”?

1.3 Nine thresholds humanity should not surpass

The 9 planetary boundaries As mentioned above, in 2009, Johan Rockström together with other 28 scientists developed “A safe operating space for humanity”, the framework of the **“planetary boundaries”**. The authors identified the nine planetary boundaries among Earth System processes that should be put under serious control and whose thresholds should not be exceeded in order to avoid the disruption of the Earth-system stability, namely:

- 1) Climate Change;
- 2) Rate of Biodiversity Loss;
- 3) Interference with the Global Phosphorus and Nitrogen Cycles;
- 4) Stratospheric Ozone Depletion;
- 5) Ocean Acidification;
- 6) Global Freshwater Use;
- 7) Land-system Change;
- 8) Atmospheric Aerosol Loading;
- 9) Chemical Pollution.

Unfortunately, **humanity has already transgressed at least three planetary boundaries** (*rate of biodiversity loss, climate change, and human interference with the nitrogen cycle*), whilst some are at risk of being surpassed (*freshwater use, land-system change, and ocean acidification*).

Interactions among the boundaries

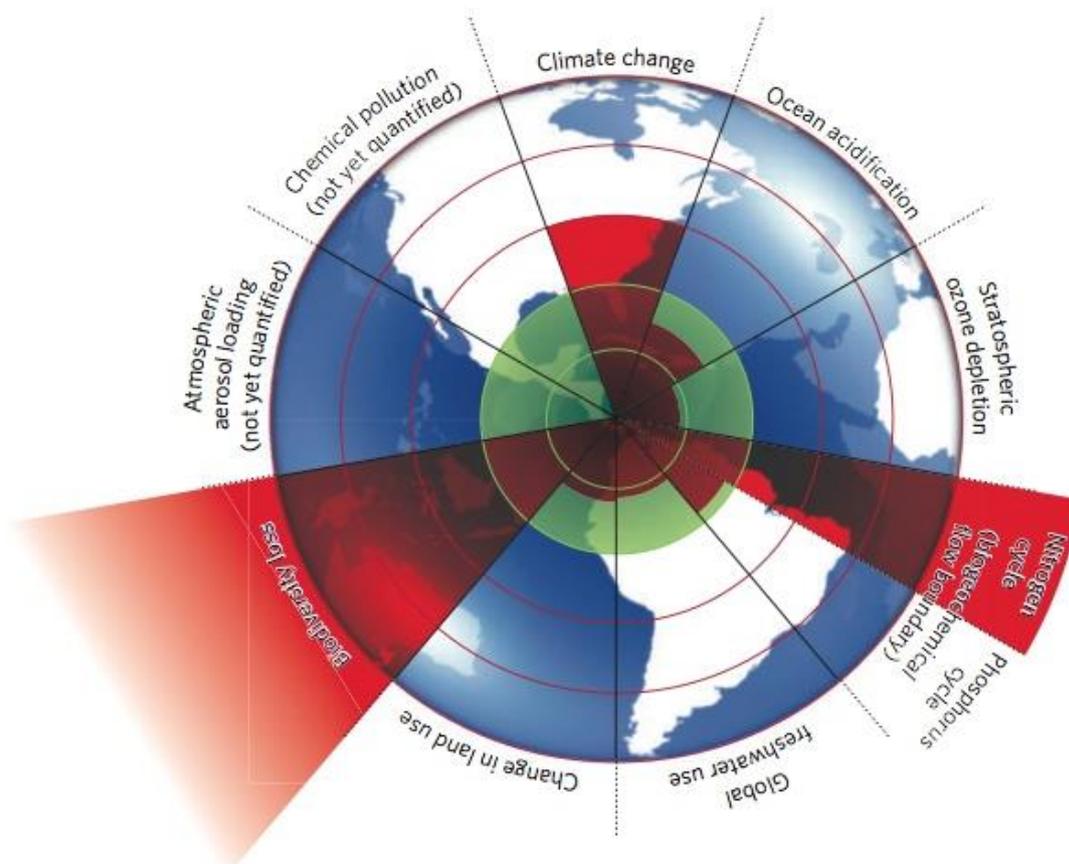
An important statement by Rockström et al. (2009b) needs particular consideration in our discourse:

“Interactions among planetary boundaries may shift the safe level of one or several boundaries, which we have provisionally set under the (strong) assumption that no other boundaries are transgressed. In reality, what may appear as a physical boundary with a clearly defined threshold may change position as a slowly changing variable (...) exceeds its boundary level.”

In other words, interactions among boundaries are crucial and need to be monitored constantly: these interactions may be able to provoke or induce changes to other planetary boundaries levels, and consequently push them to go beyond the respective limits. In this regard, Rockström et al. suggest *extreme caution, particularly when approaching or transgressing any individual planetary boundary*.

As shown in the following figure (**Fig. 1.2**), inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable (Rockström et al., 2009a; Rockström et al., 2009b). Rockström et al. pointed out that they were able to quantify with confidence only three out of nine boundaries; four are represented by tentative suggestions (best guesses based on the current state of knowledge), whilst two boundaries still need to be determined (Atmospheric Aerosol Loading; Chemical Pollution).

Fig. 1.2 Planetary boundaries for a safe operating Earth system



Source: Rockström et al., 2009a

Motive and descriptions

A more punctual and in-depth description for each of the nine planetary boundaries follows below where we try to summarise the comprehensive work done by Rockström et al. in 2009, also utilizing the resources of the Stockholm Resilience Centre's website⁶, especially for its effort in synthesizing a very complex matter.

⁶ <http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html>

(1) Climate Change

Description:

Recent evidence suggests that the Earth, now passing 387 ppm CO₂ in the atmosphere, has already transgressed the planetary boundary and is approaching several Earth system thresholds. For instance, we have already reached a point at which the loss of summer polar sea-ice is almost certainly irreversible. This is one example of a well-defined threshold above which rapid physical feedback mechanisms can drive the Earth system into a much warmer state with sea levels metres higher than present. A major question is how long we can remain over this boundary before large, irreversible changes become unavoidable. There is a growing convergence toward a “2°C guardrail” approach, which would contain the rise in global mean temperature to no more than 2°C above the preindustrial level.

Planetary boundary: a dual approach is proposed to defining the planetary boundary for climate change, using both atmospheric CO₂ concentration and radiative forcing as global-scale control variables. Values of **350 ppm CO₂** and **1 W m⁻² above the pre-industrial level, respectively, are suggested.**

(2) Rate of Biodiversity Loss

Description:

Local and regional biodiversity changes can have pervasive effects on Earth System functioning and interact with several other planetary boundaries. The current and projected rates of biodiversity loss constitute the sixth major extinction event in the history of life on Earth. Since the advent of the Anthropocene, humans have increased the rate of species extinction by 100–1000 times the background rates that were typical over Earth’s history, resulting in a current global average extinction rate \geq of 100 E/MSY. In the last 20 years, about half of the recorded extinctions is primarily due to land-use change, species introductions, and increasingly climate change. These large rates of ecosystem damage and extinction can be slowed by judicious projects to enhance habitat and improve build appropriate connectivity between ecosystems, while maintaining the high agricultural productivity that humanity needs. The primary reason for including biological diversity as a planetary boundary is its role in providing ecological functions that support biophysical sub-systems of the Earth, and thus provide the underlying resilience of other planetary boundaries.

Planetary boundary: extinction rate should be decided at **10 E/MSY** (therefore, within an order of magnitude of the background rate)⁷. However, it is also suggested to set an uncertainty range of 10–100 E/MSY.

(3) Interference with the Global Phosphorus and Nitrogen Cycles

Description:

The biogeochemical cycles of nitrogen and phosphorus have been radically changed by humans as a result of many industrial and agricultural processes (i.e. fertilizer production and application). Nitrogen and phosphorus are both essential elements for plant growth. Human activities now convert more atmospheric nitrogen into reactive forms than all of the Earth’s terrestrial processes combined. Much of this new reactive nitrogen is emitted to the atmosphere in various forms rather than taken up by plants. When it is rained out, it pollutes waterways and coastal zones or accumulates in the terrestrial biosphere. Similarly, a relatively small proportion of phosphorus fertilizers applied to food production systems is taken up by plants; much of the phosphorus mobilized by humans also ends up in aquatic systems. A significant fraction of the applied nitrogen and phosphorus makes its way to the sea, and can push marine and aquatic systems across ecological thresholds of their own.

Planetary boundary: (i) for **Nitrogen (N)**: it should be set at 25% of its current value, or to about 35 Mt N yr⁻¹; (ii) for anthropogenic **Phosphorus (P)** inflow to the oceans, it is tentatively placed at <10 times (<10×) the natural background weathering flux of P, with an uncertainty range (<10×–<100×).

⁷ E/MSY = extinctions per million species per year

(4) Stratospheric Ozone Depletion

Description:

The stratospheric ozone layer in the atmosphere filters out ultraviolet (UV) radiation from the sun. If this layer decreases, increasing amounts of ultraviolet radiation will reach ground level. This can cause a higher incidence of skin cancer in humans as well as damage to terrestrial and marine biological systems. The appearance of the Antarctic ozone hole was a textbook example of a threshold in the Earth System being crossed—completely unexpectedly.

Planetary boundary: it is proposed a <5% decrease in column ozone levels for any particular latitude with respect to 1964–1980 values.

(5) Ocean Acidification

Description:

Ocean acidification poses a challenge to marine biodiversity and the ability of oceans to continue to function as a sink of CO₂ (currently removing roughly 25% of human emissions). The atmospheric removal process includes both dissolution of CO₂ into seawater, and the uptake of carbon by marine organisms. Addition of CO₂ to the oceans increases the acidity (lowers pH) of the surface seawater. Many marine organisms are very sensitive to changes in ocean CO₂ chemistry. Furthermore, globally, the surface ocean aragonite saturation state (Ω_{arag}) is declining with rising ocean acidity. Aragonite under-saturation means that these waters will become corrosive to the aragonite and high-magnesium calcite shells secreted by a wide variety of marine organisms. The large-scale depletion of aragonite-forming organisms would be a major disturbance in marine ecosystems, the consequences and impacts of which are highly uncertain. Ocean acidification may have serious impacts on coral reefs and associated ecosystems; similarly, marine plankton are also vulnerable, presumably with ripple effects up the food chain. Losses of these species would change the structure and dynamics of ocean ecosystems and could potentially lead to drastic reductions in fish stocks.

Planetary boundary: oceanic aragonite saturation state is maintained at 80% or higher of the **average global pre-industrial surface seawater Ω_{arag} of 3.44**. Recognizing that carbonate chemistry can be variable over diel and seasonal timescales, we suggest that the typical diel and seasonal range of values of aragonite saturation state be incorporated into this boundary (i.e., >80% of the average surface ocean, pre-industrial aragonite saturation state \pm diel and seasonal variability).

(6) Global Freshwater Use

Description:

Human pressure is now the dominant driving force determining the functioning and distribution of global freshwater systems. Global manipulations of the freshwater cycle affect biodiversity, food, and health security and ecological functioning, undermining the resilience of terrestrial and aquatic ecosystems. Water is becoming increasingly scarce: it is thought that by 2050 about half a billion people are likely to be subject to water-stress, increasing the pressure to intervene in water systems. For instance, an estimated 25% of the world's river basins run dry before reaching the oceans due to use of freshwater resources in the basins.

Planetary boundary: it should be set at **~4,000 km³ yr⁻¹** of consumptive blue water use (with a zone of uncertainty of 4000–6000 km³ yr⁻¹).

(7) Land-System Change

Description:

Land is converted to human use all over the planet. Forests, wetlands and other vegetation types have primarily been converted to agricultural land. This land-use change is one driving force behind the serious reductions in biodiversity, and it has impacts on water flows and on the biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements. Conversion of forests and other ecosystems to agricultural land has occurred at an average rate of $0.8\% \text{ yr}^{-1}$ over the past 40–50 years and is the major global driver behind loss of ecosystem functioning and services. While each incident of land cover change occurs on a local scale, the aggregated impacts can have consequences for Earth system processes on a global scale. A major challenge with setting a land use boundary is that it needs to reflect not just the absolute quantity of unconverted and converted land but also its function, quality and spatial distribution.

Planetary boundary: no more than 15% of the global ice-free land surface should be converted to cropland.

(8) Atmospheric Aerosol Loading

Description:

Through their interaction with water vapour, aerosols play a critically important role in the hydrological cycle affecting cloud formation and global-scale and regional patterns of atmospheric circulation (i.e. the monsoon systems in tropical regions). They also have a direct effect on climate, by changing how much solar radiation is reflected or absorbed in the atmosphere. Humans change the aerosol loading by emitting atmospheric pollution, and also through land-use change that increases the release of dust and smoke into the air. Shifts in climate regimes and monsoon systems have already been seen in highly polluted environments. A further reason for an aerosol boundary is that aerosols have adverse effects on many living organisms. However, the behavior of aerosols in the atmosphere is extremely complex: while many relationships between aerosols, climate and ecosystems are well established, many causal links are yet to be determined.

Planetary boundary: no specific threshold value for global-scale effects identified yet.

(9) Chemical Pollution

Description:

Emissions of toxic compounds such as heavy metals, synthetic organic pollutants and radioactive materials, represent some of the key human-driven changes to the planetary environment. These compounds can persist in the environment for a very long time, and their effects are potentially irreversible. Chemical pollution qualifies as a planetary boundary because it can influence Earth System functioning (i) through a global, ubiquitous impact on the physiological development and demography of humans and other organisms with ultimate impacts on ecosystem functioning and structure, and (ii) by acting as a slow variable that affects other planetary boundaries.

Planetary boundary: no comprehensive single planetary boundary has been found yet.

In the following table (**Fig. 1.3**), we offer a comprehensive list of the planetary boundaries. Please note that the third planetary boundary (Interference with the Global Phosphorus and Nitrogen Cycles) has been subdivided in two parts since the Nitrogen cycle boundary has already been surpassed.

Fig. 1.3 Description of the nine planetary boundaries⁸

Earth-System process	Parameters (Control variable)	Explanation of Threshold avoided or influenced by slow variable	Proposed Boundary	Current Status	Pre-industrial Value
(1) Climate change	(i) Atmospheric Carbon Dioxide (CO ₂) concentration (Parts per million by volume, ppm)	<ul style="list-style-type: none"> Loss of polar ice sheets; Regional climate disruptions; Loss of glacial freshwater supplies; 	350 (ppm)	387 (ppm)	280 (ppm)
	(ii) Change in radiative forcing (Watts per meter squared)	<ul style="list-style-type: none"> Loss of glacial freshwater supplies; Weakening of carbon sinks 	1 (W m ⁻²)	1.5 (W m ⁻²)	0 (W m ⁻²)
(2) Rate of Biodiversity Loss	Extinction rate (number of extinctions per million species per year (E/MSY))	<ul style="list-style-type: none"> 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)	>100 (E/MSY)	0.1-1 (E/MSY)
(3a) Nitrogen Cycle (part of a boundary with the phosphorous cycle)	Amount of N ₂ removed from the atmosphere for human use (Million of tonnes per year, Mt N yr ⁻¹)	<ul style="list-style-type: none"> Slow variable affecting overall resilience of ecosystems via acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems. 	35 (Mt N yr ⁻¹)	121 (Mt N yr ⁻¹)	0 (Mt N yr ⁻¹)
(3b) Phosphorous Cycle (part of a boundary with the nitrogen cycle)	Quality of P flowing into the oceans (Million of tonnes per year, Mt N yr ⁻¹)	<ul style="list-style-type: none"> Avoid a major oceanic anoxic event (including regional), with impacts on marine ecosystems 	11 (Mt N yr ⁻¹)	8.5-9.5 (Mt N yr ⁻¹)	-1 (Mt N yr ⁻¹)
(4) Stratospheric ozone depletion	Concentration of Ozone (Dobson Unit, DU)	<ul style="list-style-type: none"> Severe and irreversible UV-B radiation effects on human health and ecosystems. 	276 (DU)	283 (DU)	290 (DU)
(5) Ocean acidification	Global mean saturation state of aragonite in surface sea water (Ω_{arag})	<ul style="list-style-type: none"> 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. 	2.75 (Ω_{arag})	2.90 (Ω_{arag})	3.44 (Ω_{arag})
(6) Global freshwater use	Consumption of freshwater by humans (km ³ per year)	<ul style="list-style-type: none"> 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 	4000 (Km ³ yr ⁻¹)	2600 (Km ³ yr ⁻¹)	415 (Km ³ yr ⁻¹)
(7) Change in Land Use	Percentage of global land cover converted to cropland	<ul style="list-style-type: none"> 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%	11.7%	Low
(8) Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	<ul style="list-style-type: none"> Disruption of monsoon systems; Human health effects; Interacts with climate change and freshwater boundaries. 	To be determined		
(9) Chemical pollution	For example, amount emitted to or concentrations of persistent organic pollutants (POPs), plastics, endocrine disruptors, heavy metals, and nuclear waste in the global environment or the effects on the ecosystem and functioning of Earth system thereof	<ul style="list-style-type: none"> 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		

⁸ Table modified using the following sources: Steffen et al., 2011c; Rockström et al., 2009b and <http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries/about-the-research/quantitative-evolution-of-boundaries.html>

1.4 Planetary boundaries for Sustainable Development

In May 2013, Johan Rockström and Jeffrey D. Sachs prepared a Background paper for the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda, as part of a global initiative for the UN called '[Sustainable Development Solutions Network](#)' launched by United Nations Secretary-General Ban Ki-moon (Rockström and Sachs, 2013). In this paper, scientists proposed the Planetary Boundaries framework in the context of SD to provide a safe space for innovation, growth and development in the pursuit of human prosperity, clearing the misconception that these boundaries would place a cap on human development. Nonetheless, Rockström and Sachs pointed at a so-called '**Sustainable Development Trajectory**' built upon six major structural transformations:

An 'SD trajectory'

1. **Energy Transformation**, especially through the shift towards a low-carbon economy;
2. **Food Security Transformation**, mainly with a multi-faceted agro-ecological intensification of food production that needs to be decoupled from unsustainable use of water, energy, fertilizers, chemicals and land;
3. **Urban Sustainability Transformation**, for instance with resource-efficient investments and an upgrade to resilient cities;
4. **Population Transformation**, particularly towards slowing population growth as much as possible;
5. **Biodiversity Management Transformation**, for example, by developing strategies for managing the world's species that will operate at local and regional scales where the species live or through strategies for preserving the six critical biomes that constitute key "global regulating systems" of concern for humanity as a whole;
6. **Private and Public Governance Transformation**, *inter alia* by recognising that public policy decisions must be made on the basis of scientific evidence, or that multi-national companies must be made accountable for their actions.

While seeking effective solutions for living sustainably, Steffen et al. (2011c) identified the right approach in the **holistic and integrated approach** provided by the planetary boundary framework. In this sense, they precisely suggested that "within the boundaries of the planetary playing field, there is an infinite number of strategies, tactics, and trade-offs that humanity can deploy as it continues to strive to improve well-being", also because, they added, "respecting the boundaries means respecting the global commons" (i.e. the atmosphere, the oceans, the ecosystems).

Humans as stewards of the Earth System

In this context, humanity needs to decide about its role in the new epoch of the Anthropocene (Steffen et al., 2011a; Rockström et al., 2009b; Steffen et al. 2007). Therefore, reconnecting human development and progress to the capacity of the biosphere and essential ecosystem services is to be sustained while humans become active stewards of the Earth System as a whole (Folke et al. 2011). Sustainable development has a crucial role in this discourse and, furthermore, should recognise it as a strong ‘prerequisite for long-term human wellbeing’ (Berkes and Folke, 1998; Ostrom, 2009; Chapin et al., 2011).

Redefining sustainable development

In other terms, as suggested by Griggs et al. (2013), the definition of sustainable development should take into serious consideration the planetary boundary framework and be redefined indeed as “**development that meets the needs of the present while safeguarding Earth’s life-support system, on which the welfare of current and future generations depends**” (p. 306).

1.5 A Social and Equity perspective

Planetary boundaries and human development

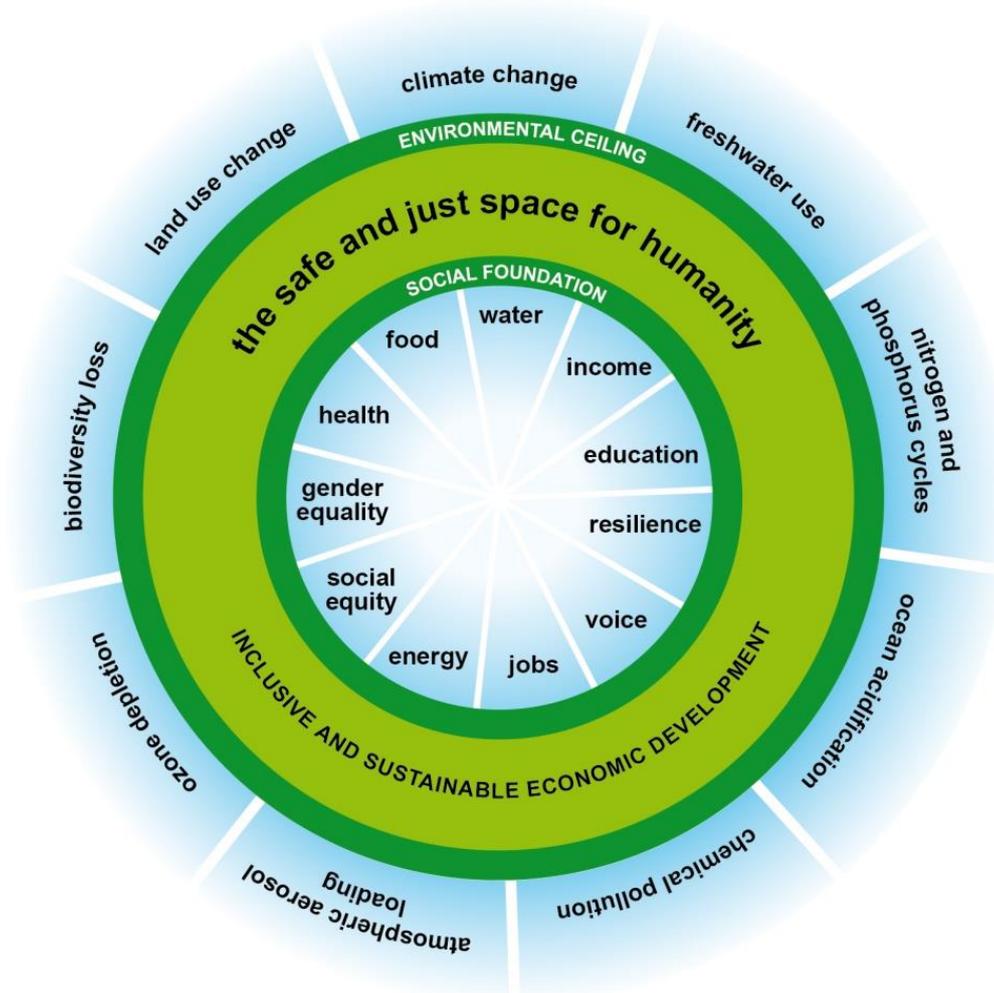
Whilst the planetary boundaries framework represents – at first look – an environment-oriented concept, it is also true that its premises are definitely ‘socially’ well-embedded in the sustainable development discourse, we believe at least for two reasons. Firstly, the nine planetary boundaries have been set with the intention to safeguard the Earth-system functioning in a state as similar as possible to the only Earth stable state we know that helped human development (the Holocene), and therefore to continue guaranteeing a ‘safe space for humanity’. Secondly, by recognizing the role of humankind in the development of the era of Anthropocene, Rockström and colleagues acknowledge the importance of the modes of human development for the sustainability of the human race.

Social boundaries

In February 2012, an interesting discussion paper by Oxfam (Raworth, 2012) advanced the idea of **combining the framework of planetary boundaries with a complementary concept of social boundaries**, taking into consideration main human deprivations.

The paper sets out a visual framework for sustainable development – shaped like a doughnut (see the following **Fig. 1.4**) – that outlines a safe and just space for humanity to thrive in an inclusive and sustainable economic development.

Fig. 1.4: A safe and just space for humanity to thrive in



Source: Raworth, 2012

The Doughnut

As presented by Raworth, the figure has an inner boundary (**the social foundation**) that contains eleven dimensions based on governments' priorities for Rio+20. The **environmental ceiling** forms an outer boundary made of the nine planetary boundaries set out by Rockström and his co-authors. Between the two circles lies an area – shaped like a doughnut – which represents an **environmentally safe and socially just space for humanity** to thrive in. It is also the space in which inclusive and sustainable economic development takes place:

“The framework brings out a new perspective on sustainable development. Human-rights advocates have long highlighted the imperative of ensuring every person’s claim to life’s essentials, while ecological economists have emphasised the need to situate the economy within environmental limits. The framework puts the two together, creating a closed system that is bounded by both human rights and environmental sustainability.” (Raworth, 2012, p.5)

The Equity dimension

Following the line of thought of the ‘Doughnut’ argument, Steffen and Stafford Smith (2013) also proposed to integrate ‘social equity considerations’ to the management of the biophysical planetary boundaries, especially through the identification of synergies between both the environmental and social dimensions. Therefore, they argue that this combination would represent at least a *necessary condition* towards fostering sustainable development. In fact, they reflected on the often heterogeneous spatial distribution of the planetary boundaries among countries, which has clear implications on the social and economic pillars of SD and, hence, on the improvement of human well-being of developing countries. Furthermore, they argue that a more spatially equitable world (especially, in terms of incomes and resource use) would not only be in the interests of developing nations but also of wealthy countries.

A very interesting example of their work and argument is provided in the next figure, which offers a first analysis of how spatial social equity considerations might be included in the management strategy for various planetary boundaries: in the figure, for each boundary (column 1) that has a regional expression with global significance (column 2), Steffen and Stafford Smith (2013) identified at least one aspect of its management which requires a consideration of spatial distribution (column 3) and note how this could also contribute to social equity (column 4).

Fig. 1.5 Synergies between planetary boundaries and spatial social equity considerations

Planetary boundary	Regional impacts with global implications if boundary is transgressed	Managing the boundary's control variable through distribution of technology, resources and ecosystem services	Synergistic effects that can reduce social inequities between and within countries
Phosphorus/nitrogen cycles	Widespread eutrophication of freshwater and coastal seas → freshwater PB → changes in global hydrological cycle [17*,37]	Redistribution of P and N application around the world to reduce eutrophication while maintaining or enhancing total agricultural productivity	Increase in regional food security, especially in nutrient-poor regions
Land system change	Deforestation of the Amazon basin, with teleconnections to global climate [18,19]	International community paying fully for global-scale ecosystem services	Increased income flows into regional economies dependent on natural resources
Aerosols	Aerosol loading over Indian sub-continent that triggers flip of Indian monsoon and influences Asian monsoon circulation [20,38]	Technology transfer to reduce aerosol emissions from industry, transport and cooking (e.g. deliver universal local energy sources for cooking)	New industries and economic development; improved health; more time for education and social participation by women
Freshwater	Human diversion of water vapour (green water) flows, disrupting climate regulation [39,40] and liquid (blue) water flows, inducing collapse of aquatic ecosystems [41]	Transfer of water management expertise and technology to reduce water demand and improve water quality; globalised economy paying fully for ecosystem services (e.g. reduced deforestation)	Improved health outcomes from better water quality; increase in regional food security via more reliable water resources; increased income flows into regional economies
Chemical pollution	Levels of pollutants (especially POPs) that damage health or disrupt ecosystem functioning over large areas [42,43]	Technology transfer to reduce chemical pollution	Increased health and social equity; enhanced provision of ecosystem services
Biodiversity	Loss of diversity at continental/ocean basin scales at levels that disrupt important ecosystem services (e.g. N/P cycling) or reduce resilience of major ecosystems (e.g. tropical forests) towards disturbance [44]. There is also evidence for a single, global-scale tipping point for biodiversity [45]	Globalised economy to pay fully for ecosystem services; direct actions that enhance biodiversity conservation	Increased income flows into developing countries; new industries built around tourism and conservation

Source: Steffen and Stafford Smith (2013)

2 Chances and opportunities for application of the PBs framework at different levels

This chapter provides an overview on the responses that the planetary boundaries framework has received, especially with an eye on the policy-making world. We look at different angles, from the global sphere (such as the United Nations), the supra-national perspective of European Union, and also the national viewpoints from eight European countries (i.e. Belgium, Finland, France, Germany, Italy, Switzerland, The Netherlands, United Kingdom), but always keeping in mind the sustainable development context. In so doing, we explore whether chances and opportunities can be found, particularly in terms of application and implementation, of the planetary boundaries framework. With this intention, we summarise and present a research study commissioned by the Swedish Environmental Protection Agency (SEPA), which represents the first attempt to comprehend the feasibility of using the PBs as a framework for understanding national contributions to the transgression of the planetary boundaries.

2.1 The international level

'Planetary boundaries' gains momentum

The planetary boundaries framework, the Anthropocene and how to create a "safe operating space for humanity" are concepts that are **increasingly gaining momentum**: numerous policy makers and world's leading scientists on global sustainability are now jointly working to take the message to the highest decision-making level⁹.

United Nations

Indeed, in several¹⁰ occasions, the UN Secretary General Ban Ki-moon has referred to planetary boundaries in the context of sustainable development. Also in other international situations, he **urged leaders to show greater commitment**; for instance, during climate negotiations¹¹, Ban Ki-moon affirmed:

*"I appeal to you; help us to achieve success in Durban. Use every ounce of your experience, skills, and influence to advance action on climate change. Help us defend the science that shows we are destabilizing our climate and stretching **planetary boundaries** to a perilous degree."*

In 2012, the UN published a report, entitled "**Resilient people, resilient planet**" by the High-Level Panel on Global Sustainability. While proposing its long-term vision for "*A Future Worth Choosing*" (page 6), the Panel points at eradicating poverty, reducing inequality, making growth more inclusive, and production and consumption more sustainable, while combating climate change and **respecting a range of other planetary boundaries**. Also in their recommendations (page 13), while affirming the need to strengthen the interface between science and policy, the

⁹ <http://www.stockholmresilience.org/21/research/research-news/9-30-2011-planetary-boundaries-research-gains-further-momentum.html>

¹⁰ See also UN news, for instance: (1) http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=1812#.UjgvWsZmiSo; (2) http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=1538#.UjguScZmiSo; (3) http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=1668#.UjguRsZmiSo; (4) http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=1135#.UjgvFsZmiSo.

¹¹ http://www.un.org/apps/news/story.asp?NewsID=39627&Cr=climate+change&Cr1=#.Ukq_QIZmiSp

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panel urges for a common definition of planetary boundaries through science (UN, 2012). In this sense, another important report by UN, which will be published soon (end of 2013) with the title of “[Global Sustainable Development Report 2013](#)”, endorses the science behind the planetary boundaries (UN, 2013).

At UN level, important work is also done towards the definition of sustainable development goals (SDGs), in particular under the coordination of the UN Secretary General Ban Ki-moon – as agreed by the world’s governments at the Rio+20 Summit. Ban Ki-moon has put into motion several high-level processes to help devise the SDGs: (i) a large outreach of global discussion being led by the UN itself; (ii) intensive negotiations among governments; and, (iii) a High-Level Panel of political leaders.

Among these activities, the Sustainable Development Solutions Network (SDSN), an international initiative launched by the Secretary General as a collaboration between top scientists, technologists, businesses, and development specialists, has recently delivered its report ‘**An Action Agenda for Sustainable Development**’ and represents a “critical input to the work (...) to shape an ambitious and achievable post-2015 agenda” (SDSN, 2013). In its report, the SDSN has identified **10 priority challenges of sustainable development** that could form the basis for the SDGs that would apply to all countries during the years until 2030:

1. End Extreme Poverty Including Hunger;
2. *Achieve Development within Planetary Boundaries*;
3. Ensure Effective Learning for All Children and Youth for Life and Livelihood;
4. Achieve Gender Equality, Social Inclusion, and Human Rights for All;
5. Achieve Health and Wellbeing at All Ages;
6. Improve Agriculture Systems and Raise Rural Prosperity;
7. Empower Inclusive, Productive and Resilient Cities;
8. Curb Human-Induced Climate Change and Ensure Sustainable Energy;
9. Secure Ecosystem Services and Biodiversity, and Ensure Good Management of Water and Other Natural Resources;
10. Transform Governance for Sustainable Development.

The second priority challenge proposed – **Achieve Development within Planetary Boundaries** – takes in serious consideration the ‘planetary boundaries’ framework by suggesting that “all countries have a right to development that respects planetary boundaries, ensures sustainable production and consumption patterns, and helps to stabilize the global population by mid-century” (SDSN, 2013, p. ix).

This goal is then further defined by three targets:

- a. Each country reaches at least the next income level as defined by the World Bank;
- b. Countries report on their contribution to **planetary boundaries** and incorporate them, together with other environmental and social indicators, into expanded GDP measures and national accounts;
- c. Rapid voluntary reduction of fertility through the realization of sexual and

reproductive health rights in countries with total fertility rates above [3] children per woman and a continuation of voluntary fertility reductions in countries where total fertility rates are above replacement level.

2.2 A European perspective

From the viewpoint of the European Union, the concept of the ‘planetary boundaries’ is increasingly considered. Three examples are presented here: (a) the 7th EAP; (b) the EU Commission’s standing position on the post-2015 agenda; and, (c) the recent Council Conclusions of the Council of the European Union of the 25th June 2013.

The 7th EAP and the evidence of planetary boundaries

The EU Commission’s proposal for the **7th Environment Action Programme (7th EAP)** recognises the planetary boundaries concept when it affirms that “there is **evidence** that planetary boundaries for biodiversity, climate change and the nitrogen cycle have already been transgressed” (European Commission, 2012, paragraph 7, p.11). The 7th EAP also refers to the concept in the Priority Objective 5: To improve the evidence base for environment policy” where again mentions it as “**available evidence** [that] fully warrants precautionary action” requesting further research into planetary boundaries in order to “support the development of the most appropriate responses” (ibid., paragraph 69, p. 27).

EU Commission’s standing ground

In February 2013, in its Communication “**A DECENT LIFE FOR ALL: Ending poverty and giving the world a sustainable future**”, the EU Commission called for a *unified policy framework* for post-2015 “to mark out a path from poverty towards prosperity and well-being, for all people and all countries, with progress remaining within planetary boundaries” (European Commission, 2013, p.2). Furthermore, it also proposed that the EU pursues a number of principles in its discussions on the post-2015 overarching framework. Among these principles, the Commission underpinned the importance of a framework that:

- is universal in aspiration and coverage,
- with goals for all countries, applying to all of humanity,
- is focused on the eradication of poverty in all its dimensions, wherever it is found, and
- is promoting prosperity and well-being for all people, **within planetary boundaries**.

Council of the European Union

On June 25, 2013, the Council of the European Union released its Conclusions on the topic of **the Overarching Post 2015 Agenda**, taking into consideration the concept of planetary boundaries. In paragraph 10, the Council commits the EU and its Member States towards an “inclusive and equitable green economy in the context of sustainable development and poverty eradication” (Council of the European Union, 2013, p.4) as one of the important tools available for achieving sustainable development. Then, in this context, the Council not only welcomes the previously mentioned EU Commission Communication, but also affirms the necessity “to

respect planetary boundaries, tackle the unsustainable use and management of natural resources, ecosystem degradation, biodiversity loss, pollution, climate change and natural disasters, as well as to address inequalities, resilience to stress and external shocks and to promote social inclusion, social protection floors and decent work for all” (ibid. p.4). Again then, it advances a post-2015 framework that needs to “work towards sustainable development to eradicate poverty in all its dimensions (...) and to ensure sustainable prosperity and well-being of all people **within planetary boundaries**” (ibid. para.16, p.6).

2.3 Points of view from eight European countries

Contributions from ESDN countries

With the intention of providing a more ‘on-the-ground’ overview of how the planetary boundaries framework is perceived in national policies, we asked ESDN Members from several European countries (in most cases those responsible for the national SD strategy) to provide us with their perspectives on the issue. Additionally, we asked them about past, present and future initiatives or actions on planetary boundaries. To do so, we prepared a short questionnaire with three open questions:

1. What is your institution’s perspective on the concept of “Planetary Boundaries”?
2. Are you aware of any past/current initiative on this issue in your country?
3. Are you planning any future actions on “Planetary Boundaries”?

Eight European countries’ viewpoints are presented and we offer hereby a summary of the analysis of their contributions; namely from: Belgium, Finland, France, Germany, Italy, Switzerland, The Netherlands, and United Kingdom.

Results of the survey

First of all, apart from the **United Kingdom** that still finds itself in the process of developing its own position on the concept of the Planetary Boundaries, ***all countries surveyed find the concept useful and important*** at the same time. Although in **Italy** it seems that the concept did not reach yet the political/decision-making level, “the issue is very well taken on board by Ministries and Director Generals in their speeches (in particular when delivered in international and European arena)”. This been said, the rest of the countries participating in our survey acknowledge the concept. In **Belgium** and in **France**, the “planetary boundaries” is seen a fruitful concept *to address limits to development*. In **Germany**, the BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) considers the PB concept to be “potentially very important for putting the social and economic condition of sound ecological systems on the scientific and political agendas”; moreover, they say, “its scientific grounding combined with its intuitive rationale makes it highly attractive”. In the **Netherlands**, the concept is particularly seen as a strong communication tool, visualizing the main challenges, especially in the early stages of policy formulation (agenda-setting).

More prominently in **Switzerland**, ‘*respecting planetary boundaries*’ has been recognised as one of the five principles in Switzerland’s Position on a Framework for

Sustainable Development Post-2015¹² (see the box below).

Swiss position on a Framework for Sustainable Development Post-2015 and Planetary Boundaries

The overarching objective of a new framework for post-2015 should be: Achieving Sustainable Development and eradicating extreme poverty while respecting planetary boundaries as well as fostering peace and security, in fulfilment of human rights obligations and commitments.

Respective goals and targets should provide a coherent and comprehensive response to global challenges until 2030, with a longer-term vision until 2050 for transformative change towards Sustainable Development in order to ensure prosperity for current and future generations.

Switzerland considers **five principles** as necessary underlying elements to address the global challenges of the post-2015 era. They shall provide the foundation of an inclusive and rights-based agenda for achieving a better life for all human beings while respecting the planet's limited resources:

- i. Human Rights
- ii. **Respecting Planetary Boundaries**
- iii. Social Inclusion and Justice
- iv. Universality
- v. Policy coherence

Also in **Finland**, the FNCSD has used the concept in the process of preparing the *new society's commitment to sustainable development "The Finland we want by 2050"*¹³; at the same time, it was found useful as an illustrative framework to draft the strategic framework of the Finnish SD policy.

Vision: A prosperous Finland within the limits of the carrying capacity of nature

"In 2050, every person in Finland will be a valuable member of society. Finland will be an affluent society that lays the foundation for sustainability and provides its citizens, communities and companies with the conditions they need to operate sustainably. The **carrying capacity of nature is not exceeded** and natural resources are used in a sustainable manner. Finland will promote peace, equality and justice and offer practical and sustainable solutions to the world's problems."

Past initiatives

In terms of initiatives backed by ministries, not much has been organised 'on the ground' by the national institutions we contacted. For instance, in Germany so far, there have not been any initiatives implemented with explicit reference to the concept of PBs. However, the German climate protection targets (e.g. reduction of GHG emissions by at least 80% by 2050) are based on the internationally agreed 2 degree target.

Anyway, as already mentioned, in Switzerland and Finland the concept has been used, especially in strategy and policy formulation. Also in Belgium, at the federal level, this concept was introduced in the definition of SD in the law establishing a federal strategy for SD; additionally, it has been recalled in the recently approved

¹² See also: <http://www.post2015.ch/post2015/en/home.html>

¹³ See also: [http://www.ym.fi/en-US/Latest_news/News/Proposal_for_societys_commitment_to_sust\(17497\)](http://www.ym.fi/en-US/Latest_news/News/Proposal_for_societys_commitment_to_sust(17497))

long-term vision for SD of the Federal Government.

Future actions

At the moment, it seems that the majority of countries are not planning any immediate future action with regard to the topic of 'planetary boundaries'. Interesting exceptions are represented by Finland and Germany. Finland is going to organize a workshop together with UNEP on planetary boundaries in next future. Additionally, the Finnish scientific community – especially the social sciences – is going to organize workshops on the issue (social policy within the planetary boundaries) in late October 2013. Concerning activities in Germany, the federal ministry (BMU) is working on an integrated environmental programme which is supposed to define the main issues and environmental objectives of the German environmental policy in the long-term perspective of 2030 and beyond. According to the current status of the project, the concept of planetary boundaries could play a relevant role within the programme. However, it seems that at present it is not yet clear how its role will be exactly defined; central questions remain unanswered, such as: (How) can planetary boundaries be formulated and interpreted on national scale? How can it be used for defining national environmental goals and targets?

Another example comes from Belgium where, although no specific actions on “planetary boundaries” are foreseen in the near future, it seems that the next Federal Plan for SD (which is currently in preparation) will take this concept into account. Nevertheless, in early 2014, there will be conferences with stakeholders on how to translate long term goals – including planetary boundaries and social norms – in urgent public policies in the short term.

2.4 An example of application from Sweden

The first example of a national application

At the moment, **Sweden** seems to be the only country that has considered more concretely applying the planetary boundaries framework in its national context. The Swedish Environment Protection Agency commissioned a study with the intention, among others, to understand the feasibility and applicability of the planetary boundaries framework on the national level and, in this context, look at the national environmental objectives and their performance. In June 2013, “**National Environmental Performance on Planetary Boundaries - A study for the Swedish Environmental Protection Agency**” was published and made publicly available by the Agency (Nykvist et al., 2013).

In this section, firstly, we offer a brief outlook of this study where we summarise the main results, the methodology used and the challenges faced by the authors, with special consideration of the application/implementation point of view. Secondly, we provide a summary of two ‘on-the-ground’ interviews we conducted with **Björn Nykvist**, first author of the study (Stockholm Environment Institute and Stockholm Resilience Centre), and **Ulrik Westman**, Head of International Cooperation of the Swedish Environmental Protection Agency.

The study

The study **tested and evaluated the relevance of developing national boundaries based on the Planetary Boundaries framework** in order to:

- assess the relative and absolute performance of countries on the key global environmental challenges, and
- understand how these could reflect the international dimension of Sweden's national environmental quality objectives.

Although uncertainties remain in the original planetary boundaries framework (as developed by Rockström et al.), the authors concluded that the approach followed in the study was both **useful and relevant especially for policy-makers**, as it developed per capita and absolute national boundaries that can be used by them in order to compare performance. The study **directly downscaled boundaries for four of the originally proposed PBs** to national boundaries, either as absolute or per capita measures of the global safe operating space (see next table):

- climate change,
- nitrogen cycle,
- land-use change, and
- freshwater use.

Table 1.1 Four downscaled boundaries for Sweden

Planetary Boundary	Per capita (current population)		Absolute	
	Territorial performance	Consumptive performance	Per capita * national population	Country-dependent (relative to national resource base)
Climate Change	2 t CO₂ / capita / y UNEP (2007)		Eg., Sweden: 18 Mt CO₂ / y	n/a
Nitrogen cycle	5 kg / capita / y Rockström et al. (2009) divided by world population		Eg., Sweden: 45,000 t N / y	Not yet quantified, but suggestion is WPL<1
Freshwater use	585 m³ / capita / y Rockström et al.(2009) divided by world population		Eg., Sweden: 5.5 km³ / y	40% water withdrawal, eg., Sweden: 73 km³ / y
Land use	0.3 ha / capita Rockström et al. (2009) divided by world population		Eg., Sweden: 2.7 Mha	15% land use, eg., Sweden: 6 Mha

Source: Nykvist et al., 2013

Additionally, the report describes the performance of 61 countries on these boundaries and on other indicators. For three of the globally quantified PBs (*Stratospheric Ozone Depletion, Biodiversity Loss, Phosphorous Cycle*), the study found a number of limiting factors – that we will not touch here – but that “*made it currently not possible to downscale the planetary-level boundaries to the national level in a meaningful way*” (p.57). For the remaining boundaries, further developments are expected in the future.

Although related to the Swedish context, two things seem to be most interesting to be generalised here: firstly, the study is the **first of its kind to explore, and then perform the downscaling of the planetary boundaries to the national level**. This means that this work can be optimistically taken up already by other countries, which could use it, discuss it and advancing it further in the effort of adopting such a framework.

Moreover, in this way, this method could develop into a more generalised approach to environmental protection, but also as an instrument for guiding policy-makers in international agreements and international cooperation among countries towards regressing from already surpassed planetary boundaries, keeping track of those we are in proximity, and possibly ensuring ‘a safe operating space for humanity’. Secondly, the study performed an analysis of the PB framework’s ability to understand whether efforts to achieve domestic environmental objectives cause increased environmental and health problems beyond national borders. The study found that **consumption-based indicators on performance for several boundaries** can be particularly relevant and useful for:

- capturing the environmental effects of an economy not just domestically but also abroad,
- while being able to portray a “fairer comparison than territorial emissions and use of global environmental resources” (p.88).

2.4.1 A double point of view

In this section, we offer the summary of two interviews we undertook with **Ulrik Westman** (Swedish Environmental Protection Agency) and **Björn Nykvist** (Stockholm Resilience Centre and Stockholm Environment Institute), the main author of the study we presented above on ‘downscaling’ planetary. The questionnaires we used included seven open questions, defined as follows:

1. What was the **main driver** for undertaking this study?
2. Was there any **political or policy-oriented priority** behind the study?
3. What was the **main challenge** you faced in elaborating this study?
4. What was the **main opportunity** you saw in it?
5. Are you aware of any **other attempt in the application/implementation** of the ‘planetary boundary’ concept in your countries or anywhere else?
6. What is the greatest challenge to consider when **down-scaling/implementing the planetary boundaries concept**?
7. Are you planning any **future action** on “Planetary Boundaries”?

Main drivers

The **main driver** and interest of the Swedish Environmental Agency to conduct the study was in the definition of the linkages between national environmental performance and relevant global environmental issues; as Mr. Westman put it, the Agency “wanted to test whether the concept of planetary boundaries in different ways could reflect the international dimension of Sweden’s national environmental quality objectives”. Therefore, as Mr. Nykvist confirmed, the **feasibility** of using the PBs as a framework for understanding national contributions to the transgression of the Planetary Boundaries was crucial in the study.

A political priority behind?

Both the interviewees agreed on the absence of any **political or policy-oriented priority** behind the study. In fact, Mr. Nykvist emphasized that he and the other scientists were asked to **openly explore** what type of science and policy relevant analysis could be suggested in case they confirmed the feasibility of using the PBs framework at the national scale. Interestingly, SEPA also wanted to improve the

pedagogical approach in the process of communicating national environmental performance and its relationships to global environmental challenges.

Main challenges From the perspective of the researchers, the **main challenge** was found in *how to conceptually downscale the PBs per se*, especially if considering that many different approaches are possible, each of them containing “very tricky conceptual questions”. In addition, they felt challenging to delimit the work either in terms of depth of analysis for each planetary boundary to downscale and in terms of the prioritisation of the policy analysis within the given limited time. On the other hand, without touching upon methodological issues, Mr. Westman pointed out several challenges connected to the ‘downscaling’ of the planetary boundaries to the national level: among others, he mentioned how crucial it is to consider that through international trade, the environmental impacts of our consumption are often caused elsewhere. Therefore, he pointed at the need to consider those measurements and environmental impacts that devise policy responses not only in relation to national borders. Additionally, Mr. Westman further remarked another challenge linked to the fact that the study took as a starting point “the control variables and boundary values proposed in the original planetary boundaries framework”. Following this rationale, he said that they “did not look for a wider set of relevant indicators around a planetary boundary, but only those which best matched the original control variable”, therefore, subjecting the developed methodology “to the same criticisms of individual boundary definitions that have previously been voiced”.

Opportunities In terms of **opportunities**, Mr. Nykvist said that he and his colleagues were able to finally find a “concentrated amount of time” to develop ideas not yet explored, such as for instance, “developing a better understanding how Swedish national environmental policy is matched by, or, rather, addresses the same issues as the PBs, and if and how, the international dimension of Swedish environmental policy could be better understood and measured with the help of the PBs framework. And, if the range of footprint-methods now available could be used to illustrate national contributions to the transgression of PBs.” From the perspective of SEPA, the main opportunity they saw was to provide a first attempt to translate the planetary boundaries into a corresponding set of national boundaries, therefore, investigating “whether the planetary boundaries framework provides a scientifically grounded approach to addressing problems of international environmental policy and comparing performance”.

Other attempts and future initiatives As from our interviews, it seems that, at the moment, not many **other attempts have been made in the application/implementation** of the planetary boundaries concept at a national scale: for instance, Mr. Nykvist mentioned an attempt in Oxford (UK) to look at South Africa in more detail, while Mr. Westman mentioned that the Stockholm Resilience Centre (SRC) was undertaking research on the overarching theme of global dynamics.

In terms of **future initiatives** in this context, Mr. Nykvist mentioned a research in the process to start at the Stockholm Environment Institute with a “small project looking at PBs at the EU level”. On the other hand, SEPA will consider if the methodology developed in the study on National Environmental Performance on Planetary Boundaries will be useful for improving “the way we monitor and evaluate our achievements towards to overall Generational goal in Sweden”. Finally, Mr Westman also pointed to a workshop to be held in Geneva together with the Nordic countries and UNEP on planetary boundaries in relation to sustainable development and the post 2015 agenda.

3 Reflections and conclusions

In 2009, a group of 29 internationally renowned scientists identified a set of **nine planetary boundaries**, which could, if respected, offer to humanity a ‘**safe space**’ to continue living and developing: they believe that transgressing these boundaries could generate abrupt or irreversible environmental changes. On the contrary, respecting them would instead reduce the risks of human activities from causing unacceptable and undesirable environmental change. Although the researchers involved in the study did not aim at offering a complete roadmap for sustainable development, they stressed that the **identification of critical planetary boundaries could provide one important element that can inform society’s decisions about sustainability**.

A large number of scientists are now convinced that the Earth – including the human population – has entered a new geological epoch (the **Anthropocene**). This new era might develop in a different way if compared to the precedent geological era (the Holocene: approximately 10,000 BC to 1800 AD), which guaranteed a stable warm period and represented therefore the only stable accommodating environment that we know for sure can support contemporary society. In contrast, the Anthropocene started around the beginning of the 1800s with the Industrial Revolution in England and the enormous expansion in the use of fossil fuels and saw, since 1945, a ‘**Great Acceleration**’, characterized by a dramatic increase in human impacts on Earth-System processes.

The framework of the planetary boundaries finds itself in these discussions. Nine planetary boundaries have been identified among Earth System processes that should be put under serious control and whose thresholds should not be exceeded in order to avoid the disruption of the Earth-system stability, namely: 1) Climate Change; 2) Rate of Biodiversity Loss; 3) Human Interference with the Global Phosphorus and Nitrogen Cycles; 4) Stratospheric Ozone Depletion; 5) Ocean Acidification; 6) Global Freshwater Use; 7) Land-system Change; 8) Atmospheric Aerosol Loading; 9) Chemical Pollution.

Unfortunately, **humanity has already transgressed at least three planetary boundaries** (*Climate change, Rate of biodiversity loss, and Human interference with the nitrogen cycle*), whilst some are at risk of being surpassed (*Freshwater use, Land-system change, and Ocean acidification*). Rockström et al. (2009) pointed out that they were able to quantify with confidence only three out of nine boundaries; four are represented by tentative suggestions (best guesses based on the current state of knowledge), whilst two boundaries still need to be determined (*Atmospheric Aerosol Loading; Chemical Pollution*). Another crucial element regards **interactions among boundaries**: scientists advise to constantly monitor them, especially because these interactions may be able to provoke or induce changes to other planetary boundaries levels, and consequently push them to go beyond the respective limits.

The planetary boundaries approach could provide the right **holistic and integrated approach** that could help humanity following a sustainable development trajectory while respecting the global commons. In this context, humanity needs to decide about its role in the new epoch of the Anthropocene. Therefore, reconnecting human development and progress to the capacity of the biosphere and essential ecosystem services should be promoted: humans need to become **active stewards of the Earth System** as a whole. In this context, it might be crucial to redefine sustainable development including planetary boundaries in the effort of safeguarding Earth’s life-support system. Other researchers also proposed to integrate ‘social equity considerations’ to the management of the

biophysical planetary boundaries, especially through the identification of synergies between both the environmental and social dimensions, arguing that this combination would represent at least a *necessary condition* towards fostering sustainable development.

Since 2009, the planetary boundaries framework has received **growing interest and consideration by numerous policy makers and the world's leading scientists** on global sustainability that are now jointly working to take the message to the highest decision-making level. Indeed, on several occasions, the UN Secretary General Ban Ki-moon has referred to planetary boundaries in the context of sustainable development. Additionally, UN reports and the work done to inform the post-2015 agenda as well as the sustainable development goals (SDGs) is now suggesting in various ways to integrate the planetary boundaries framework.

From the viewpoint of the European Union, the concept of the 'planetary boundaries' is increasingly considered. Recent examples are the EU Commission's proposal for the 7th Environment Action Programme, EU Commission's Communication "A DECENT LIFE FOR ALL: Ending poverty and giving the world a sustainable future", and the Conclusions of the Council of the European Union on the "Overarching Post 2015 Agenda".

Almost all **the countries surveyed in this QR find the concept useful and important** at the same time (Belgium, Finland, France, Germany, Italy, Switzerland, and The Netherlands). More prominently, in Switzerland, '*respecting planetary boundaries*' has been recognised as one of the five principles in Switzerland's Position on a Framework for Sustainable Development Post-2015; in Finland, the FNCSD has used the concept in the process of preparing the *new society's commitment to sustainable development* "The Finland we want by 2050", also finding it useful as an illustrative framework to draft the strategic framework of the Finnish SD policy. However, at the moment, it seems that the majority of countries are not planning any immediate action with regard to the topic. In terms of implementation, **Sweden** seems to be the only country that has considered more concretely applying the planetary boundaries framework in its national context. The Swedish Environment Protection Agency commissioned a study – the first of its kind – with the intention, among others, to understand the feasibility and applicability of the planetary boundaries framework on the national level.

Several questions might help reflecting and stimulating the further debate on the planetary boundaries' role in the context of the governance for sustainable development:

1. Why is a decision on humankind's role in the Anthropocene so important? What is 'at stake'? Are we able to see ourselves as 'Stewards of the Earth'?
2. How crucial is for us to fully comprehend 'planetary boundaries' and their interactions? What role does Planetary Boundaries play in the context of sustainable development (SD)?
3. To what extent are 'planetary boundaries' applicable in the transition towards SD? What are the challenges and how should governance for SD 'govern' planetary boundaries?
4. What roles might social and economic aspects play in the 'planetary boundaries' discourse? To what extent do trade-offs occur and how should they be addressed?
5. What role can 'planetary boundaries' play for a post-2015 development agenda? What links can be foreseen with the SDGs? Would it be 'safe' or precautionary to include them in the development of the SDGs?
6. How is the EU reflecting on 'planetary boundaries' in general? Is there a road foreseen for 'European' planetary boundaries?
7. What are the challenges for 'national' planetary boundaries? Can they be downscaled and translated at national or even local level?

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