Scientific definition of sustainability

Internal report

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1. Introduction

Eso-x is a worldwide community which aims at helping to create a sustainable world more effectively than ever before. This is done by creating a large community of concerned world citizens that are willing to spend their money as sustainable as possible. eso-x drives sustainable development by providing this community knowledge on how to spend their money with the most impact, and with opportunities such as collective deals.

This knowledge is generated in four steps:

1) defining a sustainable world and society and setting criteria

2) modeling the dynamics and current state of the world and society

3) finding the most effective pathways from the current state towards a sustainable state

4) identifying the companies that invest the most in line with the obtained pathways, and encouraging them further by sharing our knowledge and providing them with customers from the eso-x community.

This report is focused on the first step of this process, defining what a sustainable world and society are, in a measurable way. At the moment, the goal is to obtain a set of criteria that are suitable for making a well-supported choice for the first topic that eso-x will provide knowledge on: energy in the Netherlands (initially electricity contracts with suppliers, but later also heat pumps, solar panels, home storage, etc.). It is fully expected that this set of criteria will be revisited, expanded, and detailed further in the near future.

2. Method

Both a definition of sustainable development, and a set of measurable criteria have been identified based on the most relevant available scientific literature. Argumentation is given on why specific literature was used, and how they are used in relation to other used literature in this work. Where needed, commentary is provided on the interpretation of the literature.

3. Definition of sustainable development

For the definition of sustainable development we use the definition from Our Common Future by the Brundtland Commission [1], as it is the most established definition available:

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

We, however, propose an alternative formulation of this same definition:

"Development within the limits where humanity can safely operate."

This definition has the same meaning, but connects more directly to a technical interpretation of sustainable development or sustainability. This interpretation, from a human centric perspective, is as follows: when the earth, and human society with it, is viewed as a system, the earth-system, then sustainability means that this system is in a state where human society can continue to exist indefinitely. Sustainable development then means that the earth-system is in a state where human society can continue to develop indefinitely. The notion of our planet as the earth-system, which can have different states (as e.g. encountered in different geological epochs), is a concept that is crucial to understanding the criteria for a sustainable world formulated below.

Note that multiple sustainable states can in theory exist, which may each be more or less desirable for different reasons outside the scope of this definition (e.g. a world in which biodiversity is largely lost and humanity survives in giant greenhouses might be sustainable, but not necessarily desirable). Also note that the only earth-system state which is currently proven to support the present human population is the Holocene state, which is the most recent geological epoch.

Given this system view of the Earth, the criteria listed below must be viewed as limits, or boundaries, within which the sudden transition to another state is extremely unlikely. Note that the above definition refers to "limits" in general. This is logical as we must stay within all relevant limits (e.g. not just environmental limits).

4. Global criteria for a sustainable world

A set of criteria is defined that is presented in table 1. The criteria are based on the work of J. Rockström and W. Steffen [2] [3] [4], and E. Holden [5]. The criteria can be divided into two categories: biophysical criteria, and societal criteria, which are presented in section 4.1 and 4.2 respectively.

4.1. Biophysical criteria

Criteria 1 through 9 are the planetary boundaries, as proposed by Rockström and W. Steffen [2] [3] [4], see figure 1. Within these boundaries the earth-system is and should remain in a state that we know from experience can support human society as it is today. In other words, the climate and ecosystem should remain constant and similar to how they were in the past 11.6 thousand years, i.e. the Holocene. If the boundaries are exceeded, we risk that the earth-system transitions into another state, which is less certain to support human society and therefore might cause mass extinction.

Currently, the 2 out of 9 boundaries are exceeded, criteria 2 and 5: Humanity introduces too much reactive phosphorus and nitrogen into the environment (predominantly as fertilizers), and the species extinction rate is too high to be maintained. Two other boundaries are close to being exceeded: in the dimensions of land system change and climate change (atmospheric CO_2 levels and global temperature increase) we are currently in the uncertainty range. This means that the earth system in these dimensions is beyond the safe zone (where risk of transitioning towards another state is relatively low), but thresholds beyond which a transition takes place are not yet definitely exceeded (these are often uncertain to some degree). In other words, we are at increased risk of transition, but not yet at high risk.

It must be noted that although these criteria are called "planetary boundaries", not all of them must be evaluated as a single global threshold. For example: atmospheric CO_2 levels are assessed globally, and should globally not exceed the set limit of 350 PPM. Biochemical flows such as nitrogen from fertilizer, however, should also locally stay within the boundary. A local excess of nitrogen can lead to a chain reaction: reduced growth of plants, increasing local temperatures, less natural availability of freshwater, leading to less plant and animal life, and again the need for more fertilizer. In such a way, locally exceeding the planetary boundaries can also lead to global transgressions. Assessing only the global average is therefore not enough in this case.

Table 1: Overview of the criteria for sustainability as compiled by eso-x, based on literature. The biophysical criteria are the latest version of the planetary boundaries [4]*, the societal criteria are taken and adapted from* [5]*. Colors denote whether a criteria is currently exceeded (red), fulfilled (green), in the uncertainty zone (yellow), or unknown (white).*

Dimension	Indicator	Threshold	Current value
Biophysical criteria – Planetary Doundaries			
1. Climate change	Atmospheric CO2 concentration, ppm	350 ppm CO2 (350–450 ppm)	Closely approaching 420 ppm [6]
	Energy imbalance at top-of-the-atmosphere, W/m2	+1.0W/m2 (+1.0 to + 1.5W/m2)	+2.3W/m² (+1.1 to +3.3 W/m²)
2. Change is biosphere integrity	Genetic diversity, extinction rate E/MSY	<10 E/MSY (10 to 100 E/MSY). Goal should be 1 E/MSY, which is equal to the background rate (E/MSY means extinctions per million species years).	100 to 1000 E/MSY
(Note: these are interim control variables until more appropriate ones are developed.)	Functional biodiversity, Biodiversity Intactness Index (BII)	Maintain BII at 90% (90% to 30%) or above, assessed geographically by biomes/large regional areas (e.g. southern Africa), major marine ecosystems (e.g. coral reefs) or by large functional groups	84%, applied to southern Africa only

3. Stratospheric ozone depletion	Stratospheric O3 concentration, DU	<5% reduction from preindustrial level of 290 DU (5% to 10% reduction), assessed by latitude	Only transgressed over Antarctica in Austral spring (~200DU)
4. Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	≥80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (>80% to >70%)	~84% of the pre-industrial aragonite saturation state
5. Biochemical flows: P and N cycles	Global: P flow from freshwater systems into the ocean	11 Tg/yr (11 to 100 Tg/yr)	~22 Tg/yr
	Regional: P flow form fertilizers to erodible soils	6.2 Tg/yr mined and applied to erodible (agricultural) soils (6.2 to 11.2 Tg/yr). Boundary is a global average but regional distribution is critical for impacts.	~14 Tg/yr
	Global: Industrial an intentional biological fixation of N	62 Tg/yr (62 to 82 Tg/yr). boundary acts as a global 'valve' limiting introduction of new reactive N to Earth System, but regional distribution of fertilizer N is critical for impacts.	~150 Tg/yr
6. Land-system change	Global: area of forested land as % of potential forest	Global 75% (75 to 54%) values are a weighted average of the three individual biome boundaries and their uncertainty zones	62%
	Biome: Area of forested land as % of potential forest	Biome: Tropical: 85% (85% to 60%) Temperate: 50% (50 to 30%) Boreal: 85% (85% to 60%)	
7. Freshwater use	Global: maximum amount of consumptive blue water use (km3/yr)	Global: 4000 km3/yr (4000 to 6000 km3/yr)	~2600 km3/yr
	Basin: Blue water withdrawal as % of man monthly river flow	Basin: maximum monthly withdrawal as a percentage of mean monthly river flow. For low flow months: 25% (25% to 55%); for intermediate flow months 30% (30% to 60%); for high flow months: 55% (55% to 85%)	
8. Atmospheric aerosol loading	Global Aerosol Optical depth (AOD), but much regional variation		
	Regional: AOD as a seasonal average over a region. South Asian	Regional: (South Asian Monsoon as a case study): anthropogenic total (absorbing and scattering) AOD over Indian subcontinent of 0.25 (0.25 to	0.3 AOD, over South Asian region

	Monsoon used as a case study	0.50); absorbing (warming) AOD less than 10% of total AOD.	
9. Introduction of novel entities	No control variable currently defined	No boundary currently identified, but see boundary for stratospheric ozone for an example of boundary related to a novel entity (CFCs)	
Societal criteria			
10. Basic human needs	National: Human Development Index (HDI)	The aim should be to lift the population in all countries into the third quartile (low: < 0.550, medium: 0.550–0.699, high: 0.700–0.799, very high: 0.800)	119 out of 189 countries >0.7 in 2019 [7]
11. Intra-generational equality	Global: Gini Coefficient	World GINI coefficient < 0.4	Estimated at 0.68 [8]

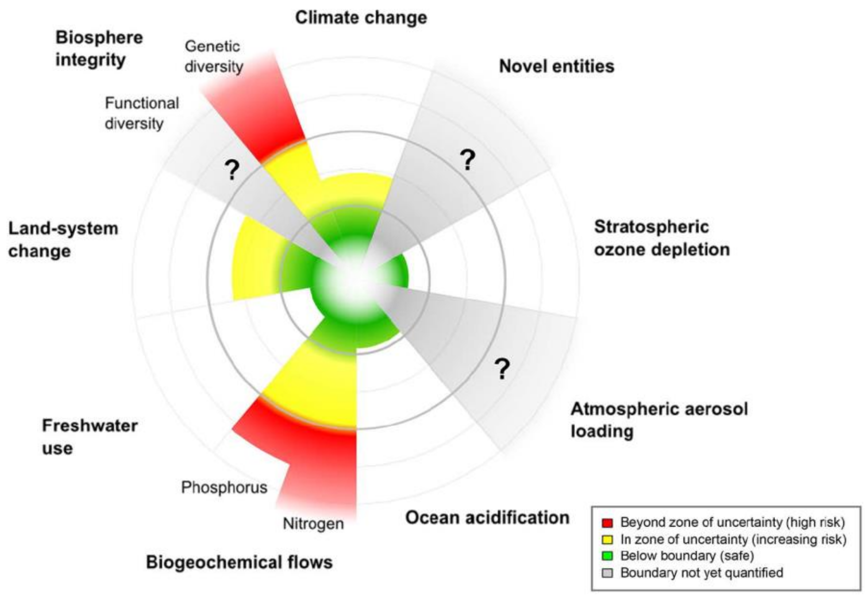


Figure 1: Visualization of the planetary boundaries proposed from [4].

4.2. Hierarchy in biophysical criteria.

A two-level hierarchy among the boundaries can be observed. In [4] it is pointed out *that "climate change and biosphere integrity – are highly integrated, emergent system-level phenomena that are connected to all of the other PBs"*. Therefore, *"climate change and biosphere integrity should be recognized as core planetary boundaries through which the other boundaries operate. The crossing of one or more of the other boundaries may seriously affect human well-being and may predispose the transgression of a core boundary(ies) but does not by itself lead to a new state of the Earth system".*

Note that despite this hierarchy, it is still necessary to consider all dimensions of the planetary boundaries when assessing the sustainability of a policy, industry, product, or anything else. This is simply because as quoted, the second level boundaries can cause transgression of the core boundaries.

4.3. Societal criteria

When it comes to the societal criteria, proof for their necessity is not as hard as it is for the biophysical criteria. However, it is important to include them if a comprehensive set of criteria is to be obtained. Examples of societal goals can be found in the widely known Sustainable Development Goals (SDGs, e.g. goal 1: ending poverty). In this work we will base ourselves on the work from [5] instead of the SDGs, since it offers more concrete and concise societal criteria, which are more useful in practice.

First, a minimum level of human development is required for a stable society, and therefore a sustainable Earth-system (after all, in the current epoch of the Anthropocene humanity is the dominant influence on our planet). As a metric for human development it is opted to use the widely used Human Development Index (HDI), published yearly by the United Nations Development Programme (UNDP). The HDI is a country based composite index based on life expectancy at birth, expected years of schooling, mean years of schooling, and the gross national income per capita. It appears there is a correlation between HDI and the awareness, acknowledgement, and the willingness and ability to act on common global issues. For example, only when a country's HDI is high (<0.7) is there a majority that accepts human activity as the cause of climate change, see box 2.5 in [9]. Therefore a minimum HDI can indeed be said to be required, and based on [9] and [7] it is decided to increase the minimum level of HDI to "high", larger than 0.7, rather than use the proposed value from [5].

Second, limited degree of inequality is required for a stable society. Excessive inequality, and a struggle for resources, can lead to armed conflict as studied in e.g. [10], and should therefore be avoided. As a worst case, a world war between upcoming and existing economic powers is deemed a significant risk by some, such as global health expert Hans Rosling [11]. A world war would have a direct catastrophical impact as well as an indirect one, as it will impede our ability to fulfill the biophysical criteria of sustainability.

5. Discussion

5.1. Practical considerations

First, it should be noted that the scientific fields from which the above criteria come are all very much active. Insight is still advancing, and therefore it should be expected that these criteria will change and improve in correctness and accuracy. Moreover, the Earth-system itself is in motion, because we are transgressing planetary boundaries, and because humanity itself is changing. Millions of people are slowly rising out of poverty, capabilities are increasing, and morals are changing. Therefore, again, the criteria laid out in this review report should not be regarded as final, but rather as the starting point for eso-x future activities. These criteria should be regularly reconsidered.

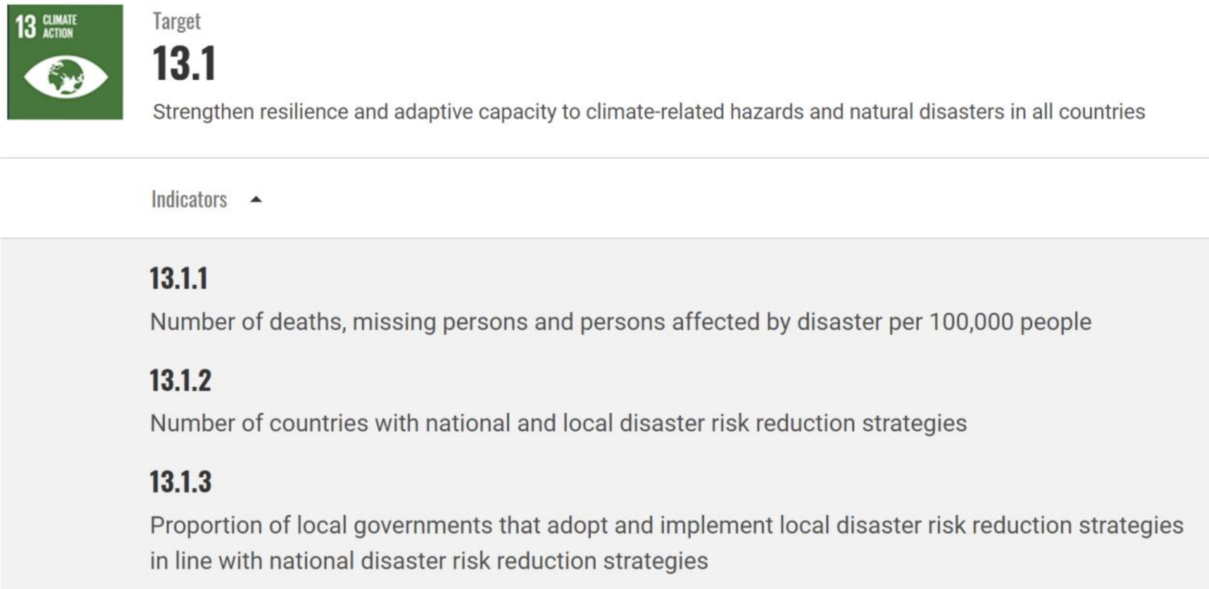
Second, the author of this report would like to point out that staying within the criteria for a sustainable world, does not mean that all growth is limited. Human curiosity should be expected to advance both our capability to realize a sustainable world, and to change the current set of criteria. As the Brundtland Report states: "The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization." [1].

Third, the criteria in this report are formulated on the global level, and must next be translated to the local level. Namely, it is already clear that some of the planetary boundaries must inherently be enforced on the local level. Part of the envisioned activities of eso-x are also foreseen to take place on the local level (modeling the dynamics and current state of the world and society, finding the most effective pathways from the current state towards a sustainable state, identifying the companies that invest the most in line with the obtained pathways and encouraging them further). The actions that companies will be encouraged to take will be local actions by definition. Therefore, local criteria for sustainable development must be formulated next, for the regions where eso-x will operate first.

5.2. Comparison to other literature

Asides from the literature on which the above criteria are based, other works exist that are not used here, but that should be mentioned.

First and most famous are the UN Sustainable Development Goals, or SDGs. The SDGs are not used directly in this work because they are in fact not concrete goals, but rather they are intended as "an urgent call for action by all countries – developed and developing – in a global partnership" [12]. To illustrate the difference with the criteria set in this report, the first target and indicators used in SDG 13, climate action, are shown in figure 2. The SDGs and the criteria in this report are, however, clearly related.


Target
13.1
Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Indicators

13.1.1
Number of deaths, missing persons and persons affected by disaster per 100,000 people

13.1.2
Number of countries with national and local disaster risk reduction strategies

13.1.3
Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies

Figure 2: Example of the SDGs from [12]. Goal 13, climate action.

Second, the concept of ecological footprint should be mentioned, which is also used in [5] and elaborated on in [13]. The concept of ecological footprint seeks to quantify our impact on our environment by expressing it in global hectares, and comparing to the available land on Earth. Also productivity of the land is taken into account. Although this concept is useful to assess ones personal impact, it not as useful as the planetary boundaries when seeking to quantify the stability limits of the earth-system.

Third, the model of Dougnut Economics should be mentioned [14]. The model defines a suitable operating space for humanity between two limits: A societal foundation, which represents the basic needs of a society (food, water, energy, etc.); and, an ecological ceiling, which is in fact quantified by the planetary boundaries used in this report. So, the model of Doughnut Economics in fact uses a very similar definition as is used here. The main differences being that the Doughnut model emphasizes on a visual style (the two different limits are visualized as a donut), and that the societal criteria in this report are more concise than the societal foundation used in the Doughnut model.

Fourth and last, the definition and criteria from this report should not be confused with current policy targets. Government may for example have specific targets to reduce CO_2 emissions by a certain percentage within a certain time. Although such targets maybe concrete and measurable, they are not the definition and criteria for sustainable development, rather they are approaches to fulfill them. Also, one should be cautious of the fact that policy targets do not always accurately reflect scientific insights. For example, more and more CO_2 emission targets exist. This addresses the core planetary boundary dimension of climate change. For this dimension the indicator of atmospheric CO_2 levels in in the uncertainty zone, see table 1. Meanwhile, for biodiversity, the other core planetary boundary dimension, indicators are far into the danger zone! Yet, far less policy is made to address this.

5.3. Philosophical and ethical considerations

Finally, for a full understanding of the definitions and criteria of sustainability, two philosophical remarks must be made, as well as one ethical remark.

First the philosophical remarks: The pursuit of sustainability, as defined in section 3, is arbitrary. The Earth, and likely life, will continue to exist without humanity. It is however logical that humanity should seek its own preservation, and therefore pursue a sustainable society. In addition, the remark must be made that true sustainability is unobtainable. There will always be risks that threaten humanity, which are beyond our control. A relevant example of this would be the risk of a meteorite impact.

Secondly the ethical remark: The pursuit of a sustainable society can be said to be about more than just self-preservation of the human race. In particular, the societal criteria from section 4.3 are partly motivated by ethical beliefs. To support this point, the Brundtland Commission report states: *"The Commission believes that widespread poverty is no longer inevitable. Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes."* [1]. The authors of this report agree with this statement. In other words, we believe that it is in itself good to abolish poverty as much as possible, and strive for a world in which all can thrive.

6. Conclusions

A clear set of criteria for sustainable development is formulated. These criteria are formulated on the global level. However, several of the formulated criteria must be also satisfied on a local level.

These criteria are based on science under development, and must therefore be regularly kept up to date.

Further growth of human society, with the bounds formulated here, is possible.

To carry out eso-x's envisioned future steps, local criteria for sustainable development must be formulated next, for the regions where eso-x will operate first.

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