2. Looking into the abyss. The analytical tool of planetary boundaries

2.1 The concept of planetary boundaries

How much strain can we put on the earth's ecosystem without risking its permanent collapse in essential parts? This is the question that an international research group from top-level institutes has been asking since 2009 (Johan Rockström et al. 2009a and 2009b). Their goal was and is to define a "safe operating space" for the further development of human societies. Whereas previous environmental research had named local or regional stress limits, the research collective is venturing towards the planetary level. This is extremely ambitious and demanding, and certainly the results have some uncertainties. But tackling this task is a must because the earth as a whole is indeed at risk.

In a first step, the research group therefore looked for a concept of "planetary boundaries" that is as simple and precise as possible. For the authors, a planetary boundary is not a tipping point at which the earth's ecosystem would abruptly collapse, and consequently it is not an absolute limit, the crossing of which would clearly and immediately trigger a catastrophe. Rather, the planetary boundaries are set well below the tipping points so that global society still has enough time to react and adopt countermeasures before it is really too late. For this reason, the authors have determined a "zone of uncertainty" for each boundary, at the uncertain end of which there is a considerable probability that the earth's ecosystem will tip over. The further the transgression of the zone of uncertainty progresses, the more likely the overturning becomes. The uncertain end is thus determined by the considerable probability of the objective overturning of the previous physical, chemical and ecosystem processes and is therefore primarily determined by natural science. The safe end of the "zone of uncertainty", on the other hand, is essentially defined by people's general (inter-) subjective need for security and traditional standards of democratic societies in dealing with risks. It is therefore determined more by the human sciences than by the natural sciences.

In total, three areas will be surveyed:
- The area in which the processes are definitely out of control and the tilting of the earth's ecosystem has considerable probability (beyond zone of uncertainty).
- The area in which human action is highly risky because the processes become out of control (zone of uncertainty, cf. Johan Rockström et al. 2009a, Fig. 2).
- The area in which human activity is relatively safe (safe operating space).

The aim of the analysis is primarily to identify this third area and to motivate all those responsible to take measures to return to this relatively safe area or not to leave it in the first place.

2.2 *The nine borders and their meaning*

In the second step, the research group looked for a manageable, but as representative as possible set of planetary boundaries. First, those processes that significantly control the ecosphere had to be identified and then aggregated in a simplified way to a single measurable boundary. The result is nine planetary boundaries, which I will briefly describe below. The order of these boundaries is arbitrary. There is no hierarchy between them; they are all equally original and equally significant, and neither are they derivable from each other despite their many interactions. The order of presentation chosen by the research group has changed in the course of their work. I follow the more recent chart shown below (Will Steffen et al. 2015, 736) and the clockwise order there, starting at 1 o'clock.
- *Chemical pollution and the introduction of novel substances and organisms*: Humans emit a large number of toxic substances that are very persistent. These include, for example, synthetic organic pollutants, heavy metal compounds and radioactive substances. These can have irreversible effects on both living organisms (e.g. reduced fertility or genetic damage) and the physical environment (e.g. atmospheric processes and climate). These effects can be severe and occur far from the source of the pollution. Damage from different substances can also add up and act synergistically.
- *Ozone depletion in the stratosphere*: The ozone layer in the stratosphere filters out ultraviolet radiation from the sun. If this layer decreases, more and more UV rays reach the earth's surface. This can lead to permanent damage to biological systems and more frequent occurrence

of skin cancer in humans. With the Montreal Protocol, which was adopted in 1987, has been ratified by all member states of the United Nations since 2009 and prohibits the production and emission of so-called "ozone killers", humanity seems to have found an effective instrument against ozone depletion.
- *Charging the atmosphere with aerosols*: An aerosol is a mixture of suspended solid or liquid particles in a gas. The particles float because their weight in relation to their surface area is so low that air resistance cannot be overcome by gravity. Aerosols in the atmosphere influence the earth's climate because they reflect and absorb sunlight, and the global circulation of water in the air. If inhaled by living beings, they can seriously affect their health. Humankind increases the number of aerosols in the atmosphere directly by emitting exhaust gases and indirectly through land use changes that increase the natural release of dust and smoke into the air.
- *Ocean acidification*: About a quarter of the carbon dioxide emitted by humans into the atmosphere dissolves in the oceans in the long term. There, it forms carbonic acid and lowers the pH value of the surface water. The increased acidity reduces the amount of carbonate ions available. Carbonate, however, is an essential building block for the shell and skeleton formation of many species living in the ocean. Its decline reduces the ability of organisms such as corals, shellfish and plankton to grow and survive. The loss of these species could, in turn, lead to a drastic reduction in fish stocks.
- *Biogeochemical material fluxes, especially of nitrogen and phosphorus*: Biogeochemistry is essentially concerned with material fluxes between the individual ecosystems of the earth. Besides water and carbon, which are already considered in some of the nine planetary boundaries, nitrogen and phosphorus in particular play a major role. Their biogeochemical cycles are radically altered by humans through industrial and agricultural processes. As they are essential conditions for plant growth, fertiliser production and use are the main problem. Human activity currently converts more atmospheric nitrogen into reactive forms than all of earth's natural processes combined. Much of this nitrogen is not absorbed by plants but emitted into the atmosphere. Similarly, only a small proportion of phosphorus fertiliser is absorbed by food crops. A large proportion ends up in water systems where algae and other plants grow excessively. From there, nitrogen and phosphorus eventually enter the sea and can cause marine ecosystems to topple.

- *Freshwater consumption and the global water cycle*: For almost all living creatures, water is the most precious resource (next to light). On the one hand, the freshwater cycle is strongly affected by climate warming and land use changes. But the dominant driver of serious changes is human water consumption. Water is becoming increasingly scarce. By 2050, about half a billion people are expected to suffer from water scarcity.
- *Land use change*: All over the world, land areas are being converted for human use. (Rain) forests, meadows and wetlands are primarily being turned into agricultural land. These land use changes are a driving force in the reduction of biodiversity and have an impact on the cycles of water, carbon, nitrogen and phosphorus as well as on the concentration of aerosols in the atmosphere.
- *Integrity of the biosphere (at the level of diversity of species and ecosystem diversity)*: Humanity's enormous demand for food, water and natural resources has led to a severe loss of species diversity as well as ecosystems and their services. The sciences speak of the sixth great mass extinction of species in the history of the earth.
- *Global warming*: Since the beginning of industrialisation, mankind has, on the one hand, emitted gases that intensify the natural greenhouse effect of the earth's atmosphere and, on the other hand, destroyed so-called "carbon sinks" such as rainforests or peatlands that bind carbon from the atmosphere. This has led to a noticeable warming of the earth's atmosphere, which will continue at an ever faster rate if humanity does not implement decisive countermeasures.

2.3 Measured variables and measurement of the limits

The research group has thus compressed the greatest threats to planet earth into these nine boundaries. Now two tasks remain: On the one hand, it is necessary to find a meaningful parameter for each boundary that can be used to determine whether it has been exceeded or not. And on the other hand, two threshold values must be specified for each of these variables in order to delimit the "zone of uncertainty" upwards and downwards. By comparing them with the actual values measured, it can then be said in which of the three areas humanity is currently located: in the safe space of action, in the zone of uncertainty or beyond the zone of uncertainty.

If the variables measured are defined as described and compared with the actual values, the following picture emerges:

- For one limit, no variables or global limit values can be given at present, namely the aerosol charging of the atmosphere (for which, however, regional variables and values are available).
- Three limits are currently still being undershot, i.e. we are still in the safe operating zone, at least from a global perspective: ozone depletion in the stratosphere, ocean acidification and freshwater consumption. However, in all three cases, there are clear regional transgressions and associated problems. Over Australia, for example, the ozone layer is very thin; on some coasts such as the Great Barrier Reef the acidification of the seawater clearly exceeds the acceptable level, which is why the coral reefs there are dying; and, of course, there are regions of the world where the anthropogenic freshwater shortage is dramatic. Moreover, the dynamics are favourable only for ozone depletion: as already mentioned, the 1987 Montreal Protocol ensures that the "ozone killers" are no longer produced and that the stratospheric ozone layer can therefore recover slowly but steadily. For the other two boundaries, however, where the earth is currently in the green zone, the dynamics are leaning towards deterioration. The zone of uncertainty could soon be reached.
- Two boundaries are already being crossed into the realm of uncertainty, namely land use change and global warming. However, if we look at their dynamics, the destruction of forest areas is currently accelerating rather than being slowed down—especially in the rainforest zone. Greenhouse gas emissions are also not decreasing but continuing to grow.
- Finally, three boundaries have already been crossed far beyond the range of uncertainty: the material flows of phosphorus and nitrogen, the introduction of novel substances and organisms, and the integrity of the biosphere.

Summarised in a table and a chart, it all looks like this:

Table: Measured variables and measured values (target/actual) of the planetary boundaries (according to Will Steffen et al. 2015, 734–735)[2]

Dimension		Measured variable	Zone of Uncertainty (from–to)	Measured value 2015
1 Introduction of novel substances		Several complementary metrics, trend observation		
2 Ozone depletion in the stratosphere		Ozone concentration in the stratosphere (Dobson Units = DU)	275–260 DU	450–220 DU
3 Aerosol charging of the atmosphere		Aerosol optical thickness (without unit)	No global limit defined	?
4 Ocean acidification		Mean global aragonite saturation in surface water (omega units)	2,75–2,40 Ω	3.03 Ω
5 Biogeochemical material flows	Phosphorus cycle	Phosphorus input into oceans (teragram/ year = Tg/ a)	11–100 Tg/ a	22 Tg/ a
		Phosphorus input into freshwater systems (Tg/ a)	6.2–11.2 Tg/ a	14 Tg/ a
	Nitrogen cycle	Industrial and intentional biological fixation of nitrogen (Tg/ a)	62–82 Tg/ a	150 Tg/ a
6 Freshwater consumption and the global water cycle		Global consumption of surface and groundwater (cubic kilometres/year)	4000–6000 km^3/ a	2600 km^3/ a
7 Land use change		Still preserved part of the original forest area	75–54 %	62 %
8 Integrity of the biosphere	Genetic diversity	Extinction rate (number of species extinct per million species per year = E/ MSY)	10–100 E/ MSY (long-term 1 E/ MSY)	100–1000 E/ MSY
	Functional diversity	Biodiversity Intactness Index	90–30 %	84% for Southern Africa

Dimension	Measured variable	Zone of Uncertainty (from–to)	Measured value 2015
9 Global warming	CO_2 concentration in the atmosphere (ppm) *or*	350–450 ppm	398 ppm
	Radiative forcing (W/m^2)	1.0–1.5 W/m^2	2.3 W/m^2

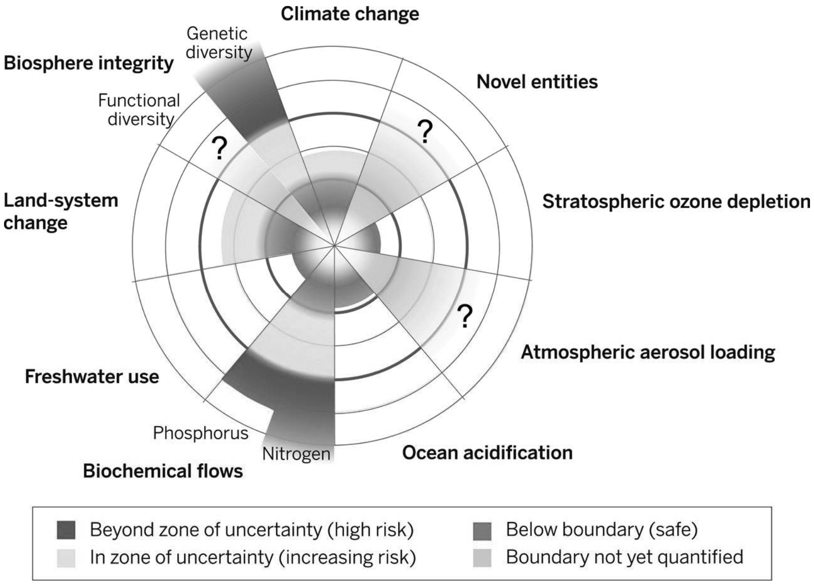


Chart: Status of Planetary Boundary control variables in 2021 (from: Will Steffen et al. 2015, 736; the update of the boundary crossing for novel substances based on Linn Persson et al. 2022 has not yet been incorporated).

In relation to the necessary question of the causes of this, one central aspect must be kept in mind from the outset: The activities of agriculture and food processing are single-handedly responsible for exceeding three

2 The current figures for the last column of row 9 Global Warming can be found here: Earth System Research Laboratories, Trends in Atmospheric Carbon Dioxide, in: https://www.esrl.noaa.gov/gmd/ccgg/trends/ and Annual Greenhouse Gas Index, in: https://www.esrl.noaa.gov/gmd/aggi/aggi.html (retrieved 10.10.20). For the other eight indicators, there are no continuous updates yet. The assessment for the introduction of novel substances draws on Linn Person et al. 2022.

of the five boundaries transgressed: biogeochemical fluxes (phosphorus, nitrogen), land use change and biosphere integrity; they still contribute 37% to the fourth transgression, global warming (Toni Meier 2017, 69). The great challenges facing the planet cannot therefore be solved without a radical change in agriculture. At the same time, it is possible in principle to feed a world population of 9 or 10 billion people without damaging the planet (Dieter Gerten et al. 2019). The frequently voiced claim that consistent greening of agriculture would leave countless people starving is simply wrong. Rather, whether or not the path to environmentally friendly development can be followed will depend on a fundamental reform of global agriculture.

2.4 Key problem 1: Global warming

Among the nine planetary boundaries, two stand out, according to the research group, because, on the one hand, they have the largest impact on the planet and, on the other hand, they are the most interconnected with the other planetary boundaries as well as with each other: global warming and biosphere integrity. These two will therefore be presented in more detail below.

In contrast to weather, *climate* refers to long-term average (mean) constellations of temperature, precipitation and other weather phenomena. While the current weather has an effect for a few days or weeks at most, climate determines periods of years or decades. Which plants and animals thrive in a region, how high a river overflows its banks, how much water it carries all year round—these are all questions that depend on the climate. Climate is therefore of central importance for the living conditions of living creatures, including humans.

Now the earth's climate is fluctuating constantly. This is caused by changes in the earth's orbit around the sun, rising or falling solar activity, and large volcanic eruptions whose ash remains in the earth's atmosphere for long periods of time. Climate changes are therefore completely natural and unavoidable. Living things have to adapt accordingly—often by migrating from one climate zone to another—or become extinct. This also applies to humans. Humankind has inhabited the earth for about 3 million years and has experienced some climate fluctuations during this time. As long as they lived nomadically, they could cope with it relatively well—continuous migration was part of their lifestyle. After settling down in the Neolithic period about 11,000 years ago and the associated development of agriculture, however, humankind became very vulnerable to climate-induced migratory pressures.

During this phase of the last 11,000 years, however, the earth's climate was more stable than on average. Compared to the world mean temperature of 15 degrees Celsius, it fluctuated by a maximum of one degree up or down. This was quite different in previous warm periods: during the Eemian warm period (about 126,000 to about 115,000 years ago) the climate fluctuated by 2 to 2.5 degrees Celsius, and during the Pliocene warm period (about 5.3 to about 2.6 million years ago) even by 3 to 3.5 degrees Celsius. But even the fluctuations of the last 11,000 years have had enormous social consequences. Thus, the rise of the Roman Empire would not have been conceivable without the "Roman Climate Optimum", and its downfall would not have occurred without the "Migration Cold Period" (Kyle Harper 2020). The entire history of the world has had to be rewritten in recent decades against the background of climate science. Since sedentarisation, the well-being of human societies has depended more than ever on climate.

There is also a so-called "*natural greenhouse effect*". As early as 1824, Joseph Fourier (1768 near Auxerre–1830 Paris) postulated it in an essay in which he calculated that the temperature on earth would be much lower without such an effect. And indeed: if the earth were not surrounded by a thin layer of various gases, the mean world temperature would be minus 18 instead of plus 15 degrees Celsius. The gases in the earth's atmosphere act like a glasshouse and cause significant warming. This is because they allow energy-rich, short-wave solar rays to shine onto the earth's surface. There, part of their energy is absorbed, so that longer-wave, less energetic rays are reflected upwards. Because of their low energy and long wavelength, the greenhouse gases reflect some of them so that they hit the earth's surface again, and some of them are released back into space. In this way, the earth heats up more than if it did not have a gas envelope.

However, if the degree of global warming depends on the type and quantity of greenhouse gases, the earth's mean temperature will inevitably change as soon as human activity causes the greenhouse gases to change. It was precisely this man-made, "*anthropogenic greenhouse effect*" that the later Nobel Prize winner for chemistry Svante August Arrhenius (1859 Vik–1927 Stockholm) predicted for the greenhouse gas carbon dioxide in 1896. In view of this early prediction, it is surprising that the first United Nations "World Climate Conference" (WCC-1) did not take place until

1979 in Geneva. Apparently, time had to mature for global initiatives to take effect.

What are the main *causes of the anthropogenic greenhouse effect*? First of all, this is the direct emission of greenhouse gases

- Carbon dioxide (CO_2, approx. 60% of the anthropogenic greenhouse effect),
- Methane (CH_4, approx. 20% of the anthropogenic greenhouse effect),
- Nitrous oxide (N_2O, approx. 7–8% of the anthropogenic greenhouse effect),
- Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (together accounting for about 10% of the anthropogenic greenhouse effect),
- Sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) (minor contribution to the anthropogenic greenhouse effect).

In addition to the direct emissions of greenhouse gases, there is the indirect effect from the removal of so-called natural "greenhouse gas sinks", which bind certain greenhouse gases and reduce their concentration in the atmosphere. A hundred-year-old spruce, for example, binds the carbon from about 2.6 tonnes of carbon dioxide, a hundred-year-old beech from even about 3.5 tonnes. A wooden house built from hundreds of tree trunks accordingly binds the carbon from hundreds of tonnes of carbon dioxide. If large sinks such as the tropical rainforest or large peatlands are now destroyed, this massively reduces the capacity of the global ecosystem to extract carbon dioxide from the earth's atmosphere and convert it into carbon and oxygen.

The emission of greenhouse gases and the removal of their sinks make up the anthropogenic greenhouse effect. In 2001, the Intergovernmental Panel on Climate Change (IPCC), composed of about 3000 climate researchers and commissioned by the state governments of all countries, states in its Third Assessment Report that, even taking into account remaining uncertainties, most of the global warming since 1950 can almost certainly be attributed to such human activities (IPCC 2001, 398–399). The Fourth Assessment Report 2007 then considers the influence of humans on the climate system as clearly proven (IPCC 2007, 104–106). Since that time at the latest, claims to the contrary have no longer been able to invoke scientific consensus.

But what are *the consequences of anthropogenic global warming*? Compared to pre-industrial levels, the world mean temperature has already risen by about one degree Celsius and the sea level by about 25 centimetres. If humanity continues to behave as it has in recent decades ("business as usual"), the world mean temperature could rise by 7 degrees Celsius (IPCC

2014, Fifth Assessment Report). This is more than the 6 degrees that the IPCC predicted in 2000 and twice what it predicted in 1995. The forecasts are thus becoming more and more dramatic, which on the one hand has to do with the ever-increasing greenhouse gas emissions by humans, and on the other hand with the feedback effects of individual climatic processes that are becoming more and more apparent. The IPCC predicts that sea levels will rise by a further 80 centimetres by 2100, assuming business as usual. Moreover, sea levels will continue to rise for a long time even if the world mean temperature does not increase any more.

Year by year, the IPCC's calculations become more precise and accurate. The so-called "climate sensitivity", i.e. the sensitivity of the climate to greenhouse gases, was still estimated relatively inaccurately in the IPCC's Fifth Assessment Report of 2014. Global warming was calculated to be between 1.5 and 4.5 degrees Celsius if the concentration of greenhouse gases in the atmosphere doubled. That still left a lot of room for speculation. A new calculation narrows this estimation corridor considerably. With a doubling of the greenhouse gas concentration in the atmosphere, one now assumes 2.5 to 4.0 degrees of global warming (Steven Sherwood et al. 2020). The broad direction of the earlier estimate is thus confirmed, but has been considerably refined and made more precise.

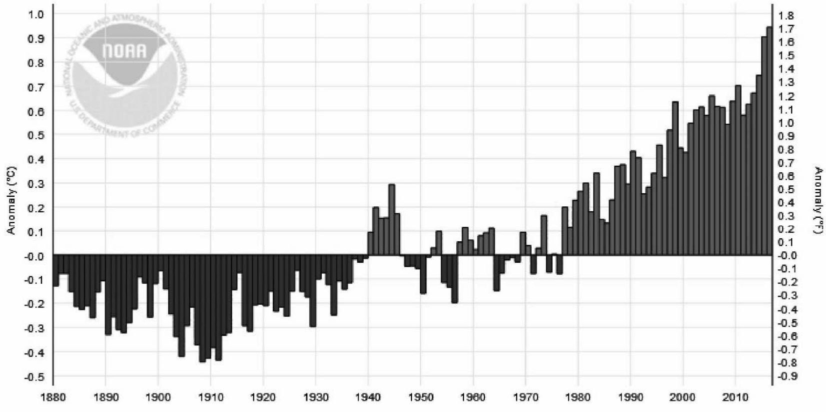


Chart: Deviations of global annual mean temperatures from 1881 to 2016 compared to the 20th century mean (Source: National Oceanic and Atmospheric Administration NOAA 2017)

We must therefore expect a dramatic increase in the earth's mean temperature. However, even if it is possible to limit it to 1.5 degrees Celsius above pre-industrial levels, as agreed at the 2015 World Climate Conference in Paris, the local and regional consequences will be significant, "including an increase in extreme temperatures in many regions (high confidence), increases in the frequency, intensity and/or amount of heavy precipitation in some regions (high confidence), and an increase in the intensity or frequency of droughts in some regions (medium confidence)." (IPCC 2018, 11). "Sea levels will continue to rise well beyond 2100 (high confidence)." (IPCC 2018, 11) "Out of 105 000 species studied ... 6% of insects, 8% of plants and 4% of vertebrates ... will lose more than half of their climatically determined geographic range" (IPCC 2018, 12).

We have been able to observe some of these changes in Central Europe for years. Storm disasters are on the increase, years of extreme drought have put a strain on agriculture and forestry. The glaciers in the Alpine region, which according to the World Glacier Monitoring Service in Zurich lost a quarter to a third of their area between 1975 and 2000 alone, are continuing to recede dramatically and will, for the most part, disappear completely, which will lead to a summer water shortage in the rivers of the Alpine region and cause temperatures in the Alpine valleys to rise far above average because they lack the cooling provided by the glaciers.

As already mentioned, climatic changes have always had major *impacts on human societies*. This is also the case in the most favourable conceivable case of a temperature increase of only 1.5 degrees Celsius by 2100: "Climate-related risks to health, livelihoods, food security and water supply, human security and economic growth will ... increase" (IPCC 2018, 13). Thus, in 2015, the renowned medical journal "The Lancet" appointed a commission that annually assesses the health consequences of global warming under the name "The Lancet Countdown". Their forecasts are already dramatic, on the one hand with regard to the direct consequences of greater heat on the heart, circulation, kidneys and brain, and on the other hand with regard to indirect consequences through the greater increase in and spread of infectious germs (Nick Watts et al. 2019). Almost all medical disciplines are thinking intensively about how to prepare for the consequences of global warming. The economic side is similar: Munich Re, which acts as a reinsurer, measured four times more natural disasters and 15 times greater damage caused by them for the decade from 1985 to 1995 than in the decade from 1960 to 1970. Rich industrialised countries have meanwhile implemented adaptation measures such as dikes or flood protection walls. Poorer countries, however, cannot afford this.

If sea levels rise by one metre, about 18 per cent of Bangladesh's land area will be under water, and 38 million people will lose their homes and become climate refugees. In the Nile Delta, 8 million people will become homeless, and 12.5 per cent of Egypt's agricultural land will be destroyed. The Maldives will sink completely, as will the island nation of Tuvalu, the fourth smallest member state of the United Nations, whose 11,000 inhabitants already left the country in 2002 and emigrated to New Zealand. Millions and millions of environmental refugees will take flight (IPCC 2007), so much so that the US Department of Defence already warned in 2004 that environmental policy is the best defence policy. We cannot imagine the impact of global warming on our human lives dramatically enough.

2.5 Key problem 2: The loss of biodiversity

Although the second key issue of biodiversity enjoys far less attention than climate protection, it is even more serious and pressing. The term was first used by Thomas E. Lovejoy (1980, 327) in the Global 2000 Report to US President Jimmy Carter. While Lovejoy understood biodiversity there to mean only species diversity, the term was later defined more broadly. Today, the definition of the Biodiversity Convention is mostly adopted: "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems." (United Nations 1992, Art. 2) Accordingly, biodiversity is understood as the diversity of life forms in all their forms (genes, species, ecosystems and landscapes, which are often added as a fourth) and their relationships to each other. Each level of diversity is analysed under the three aspects of its composition, structure and function.

In itself, evolutionary history is a process towards increasing diversity of both genes and species and ecosystems. Nevertheless, in the course of earth's history, there have also been phases of drastic destruction of diversity, so-called "mass extinctions". The cause was usually dramatic climate change, and in the case of the fifth and, so far, last mass extinction, the impact of a huge meteorite.

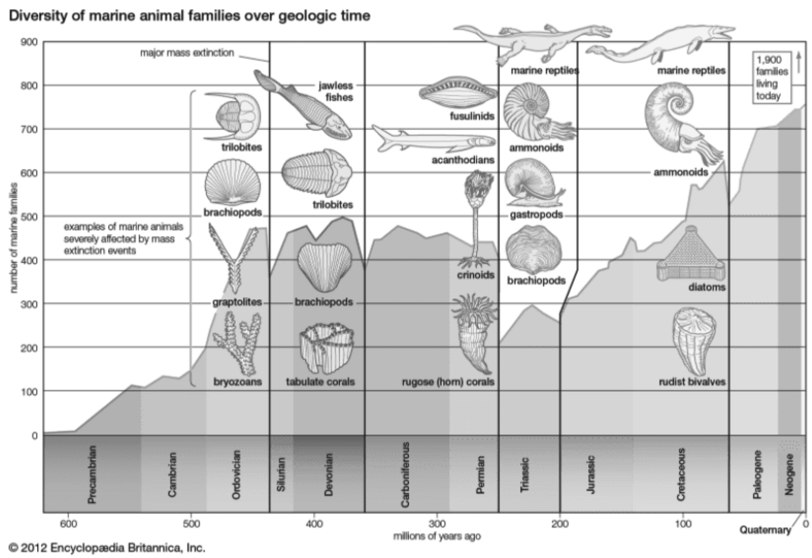


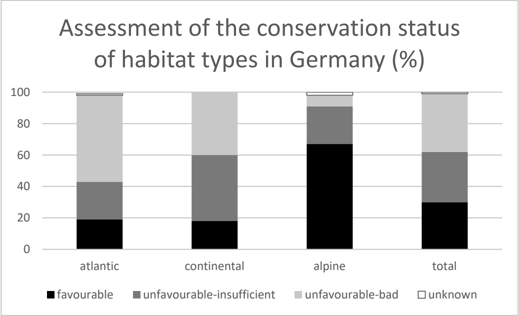
Chart: Number of families of marine fossils over the course of earth's history. They are a good indicator of the overall species diversity on earth. (from: Encyclopædia Britannica, https://www.britannica.com/science/mass-extinction-event#/media/1/368208/74659 (12.5.2022).

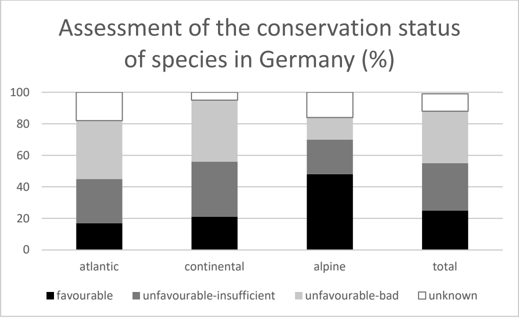
In addition to the temporary mass extinctions, there is a barely noticeable but very *natural extinction of species* that is constantly taking place. 99% of all species in the history of the earth are now extinct. And yet there are currently so many species that humans know only a small proportion of them. About 60% of them belong to insects, 11% to fungi, 2–3% to green plants and only 0.4% to vertebrates, including 0.0003% to mammals.

However, the industrialisation of modernity has ushered in a dramatically opposite development. Globally, one of the most extensive species extinctions in earth's history is underway, the "sixth extinction", as Elizabeth Kolbert titled it in 2016. For example, the German Federal Agency for Nature Conservation rates the conservation status of 37% of all habitat types in Germany as poor and that of 32% as insufficient in 2020. The conservation status of all species living in Germany is only slightly better—here 32% are in a poor condition and 30% in an inadequate condition. A large part of our biodiversity is threatened with extinction.

According to the current report by the European Environment Agency (EEA), 79% of the habitats assessed in Austria are not in a good ecological condition—Austria thus ranks 18th out of 28 EU states, while Germany still manages to rank 10th due to more favourable conditions in the south of the country (EEA 2020, 44). The situation is even worse for species: Around 70% of the species assessed in Germany and as many as 83% of those in Austria have a poor to bad status, putting Germany in 21st place and Austria in 27th place out of 28 EU states (EEA 2020, 50).

The extinction of the smallest species, especially insects, is particularly significant. 40% of all insect species worldwide are threatened with extinction in the coming decades, with annual declines of 1 to 2% of species and 2.5% of biomass (Francisco Sánchez-Bayoa/ Kris A.G. Wyckhuys 2019, 8 and 15–17). Insect mass in Germany has declined by two-thirds to three-quarters since 1990, and everything points to comparable values for Austria (Caspar A. Hallmann et al. 2017, 1; Fritz Gusenleitner/ Martin Schwarz 2019, 33). This means that birds, reptiles and small mammals lack food. And if these decline, the larger predators also lose their food source. The creatures of the biosphere are so strongly dependent on each other that they will be threatened one after the other like a row of dominoes.





Charts: Assessment of habitat types and species in Germany 2020 (from: Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit/ Bundesamt für Naturschutz (hg) 2020, 5–6)

What are the *causes* of this dramatic development (cf. Francisco Sánchez-Bayoa/ Kris A.G. Wyckhuys 2019, 20; Martha J. Groom et al. (eds.) 2006[3], 64–68)? The lion's share is contributed by industrialised intensive agriculture (see LS 34). In arable farming, it uses sprays on a large scale, killing not only "pests" but also many "beneficial insects"—causing huge collateral damage. Pastures are intensively fertilised, which drastically reduces the diversity of plants to those that absorb many nutrients, and consequently offers insects less food diversity. The intensively fertilised pastures are also mown more often, so that the plants often no longer flower and are consequently not available as a food source for insects. Marginal woody plants in fields and meadows are removed, so that many creatures lose their habitat. Finally, agriculture is responsible for numerous land use changes that also limit biodiversity: the draining of wetlands, swamps and bogs in Europe (LS 39) as well as the clearing of rainforests in Latin America and Asia (LS 32; 38).

But there are also other causes of the loss of biodiversity: natural areas are being increasingly cut through by traffic routes, so that they become too small a habitat for many animals (LS 32; 34–35). Rivers are straightened, dammed and diked, so that many creatures no longer find a home there. The environmental media soil, air and water are polluted with harmful substances (LS 34) and thus impair the health and reproductive capacity of plants and animals. Certain species are overexploited through hunting, fishing or wild plant exploitation (LS 40). Global warming is changing the living conditions of many ecosystems to such an extent that not all plant and animal species living there can survive (LS 24; 41). And the spread of so-called invasive species and pathogens through human mobility can put ancestral species under severe pressure.

The *consequences for nature and humans* are dramatic. From an ecological point of view, highly developed creatures, including humans, are largely dependent on habitats with high diversity. In layman's terms, we became aware of this when the bee mortality of recent years made us realise how dependent agriculture is on bees and other insects. Economically, biodiversity is invaluable. The destruction of ecosystems and biodiversity costs humanity two trillion US dollars a year—more than the financial crisis of 2008/09—and that is annually, not just once (TEEB 2010, 29). However, this is only the economically noticeable value of the so-called "ecosystem services", also referred to as "natural capital". This does not even include the positive health, aesthetic, psychological and spiritual effects of diverse nature on humans and its indirect effects on the tourism industry, for example (TEEB 2010, 46).

As with limiting global warming, there has been little progress in biodiversity conservation for thirty years. On the contrary, in some areas there has been regression. The tenth Conference of the Parties (COP-10) to the United Nations Convention on Biological Diversity, which took place in Nagoya in Aichi Prefecture in Japan in 2010, had defined twenty strategic goals for 2020, the so-called "Aichi Biodiversity Targets". In 2020, an evaluation of the targets took place—with alarming results (Secretariat of the Convention on Biological Diversity 2020, 12–17):

- half a target was overachieved,
- 1.6 targets were met,
- some progress was made on 11.82 targets, but the targets were clearly not reached,
- no progress was made on 3.53 targets and therefore the targets were not achieved,
- for 1.83 targets, the situation has even worsened, so one has gone in the opposite direction, and
- for 0.7 targets, their achievement could not be determined.

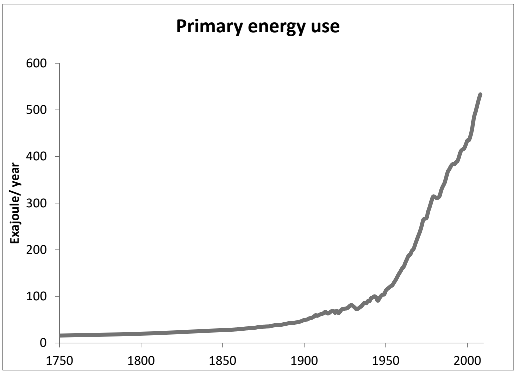
The drama becomes even clearer when one looks at the content of the targets set: Even such simple targets as target 1, to make the population of one's own country aware of the value of biodiversity, have only been achieved by slightly more than a third of the world's population. No progress at all was made on target 3.1, the complete dismantling of subsidies and support for actions that destroy biodiversity. This, too, should actually be an easily achievable goal. Target 5.3, to slow down the fragmentation and degradation of valuable ecosystems, has not only not been achieved, but on the contrary, fragmentation and degradation have accelerated. Similarly, target 8.2, to reduce fertiliser application in agriculture to a harmless level, has not only not been achieved, but the situation has worsened. The targets that have been achieved are mainly those that are the responsibility of the sciences, namely target 9.1 to identify invasive species and target 19.1 to improve knowledge about biodiversity and its functions. Target 17.1, to develop a national biodiversity strategy, was also achieved, but so far it exists only on paper in most countries. Overall, therefore, the picture is bleak. The protection of biodiversity has not made any progress for decades.

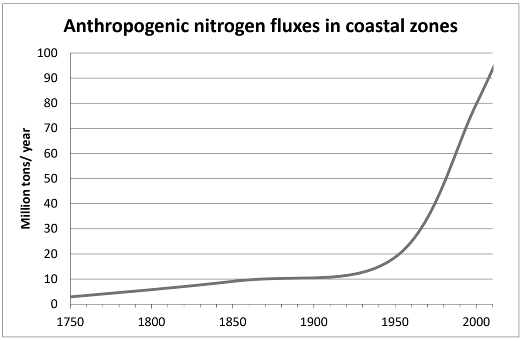
2.6 The great acceleration

So far, we have considered the two key problems of global warming and biodiversity loss—representative of the five transgressed planetary boundaries—more or less in a snapshot. However, they become much more acute when the development over the last few decades or centuries is taken into account. This is exactly what the International Geosphere-Biosphere Programme (IGBP) did in a research project that was completed in 2015. As a representative example, the research group examined twelve socio-economic and twelve ecological indicators and determined their globally aggregated data for the years 1750 to 2010 (Wendy Broadgate et al. 2014).

- The 12 socio-economic indicators are: (total) population; real gross domestic product (GDP); foreign direct investment; urban population; primary energy consumption; fertiliser consumption; large dams; water use; paper production; transport; telecommunications; international tourism.
- The 12 ecological indicators are: carbon dioxide; nitrous oxide; methane; stratospheric ozone; surface temperature; ocean acidification; marine fish catch; shrimp aquaculture; nitrogen in coastal waters; rainforest loss; human-designed land areas; degradation of the terrestrial biosphere.

The data obtained were finally entered into diagrams whose X-axis depicts time (Will Steffen et al. 2015a). The unsurprising yet impressive result is that practically all curves look more or less the same: Until 1950 they undergo a rather low, flat course; from 1950 onwards they rise steeply. In other words: since 1950, the socio-economic standard of living has been rising steeply globally—but with it, almost to the same extent, the destruction of the environment. And despite all the climate and biodiversity summits, there is still no sign of a reversal in this trend. So, we are buying social standards at the expense of the environment and our fellow human beings, and we are doing so ever faster and more intensively. The time for a reversal is running out faster and faster!





Charts: Primary energy use (socio-economic indicator) and anthropogenic input of nitrogen into coastal waters (ecological indicator) from 1750 to 2010 (Source: Will Steffen et al. 2015).

2.7 Regional inequalities. The World Risk Index

Now, the burdens of planetary boundary transgressions are very unequally distributed globally. And just as unequally distributed are the abilities of individual societies to manage the risks they face in such a way that they remain manageable overall. In order to draw attention to this problem, the Institute for International Law of Peace-Keeping and International Humanitarian Law (IFHV) at Ruhr University in Bochum has been producing an annual World Risk Report (https://weltrisikobericht.de/) on the basis of the World Risk Index since 2018. It is published on behalf of the "Bündnis Entwicklung hilft" (Alliance Development Helps), in which nine German development aid organisations, including several of the two large Churches, have joined forces. The concept of the World Risk Index was developed together with the Institute for Environment and Human Security at the United Nations University (UNU-EHS).

The World Risk Index indicates the disaster risk from extreme natural events for 180 countries around the world. It is calculated per country by multiplying exposure according to vulnerability. *Exposure* represents the natural threat posed to a country by earthquakes, hurricanes, floods, droughts and rise in sea-level. Apart from earthquakes, all these phenomena are linked to the anthropogenic greenhouse effect and are at least exacerbated by it, and in some cases even generated by it in the first place. *Vulnerability* maps societal vulnerability and is made up of three components that are weighted equally in the calculation:

- *Vulnerability* describes the structural characteristics and framework conditions of a society and denotes the probability of it suffering damage in the event of an extreme natural event.
- The category of *coping* includes various capacities of societies to minimise the negative impacts of natural hazards in the short term and directly through actions and available resources.
- *Adaptation* is understood as the measures and strategies of societies to deal with the negative impacts of natural hazards that lie in the future. In contrast to coping, adaptation is understood as a long-term process that also includes structural changes.

The result shows that the individual countries represent very different typologies. Some countries have

- a *very low risk* (< 3.3%) due to low exposure and very low vulnerability: these countries include, for example, Germany (exposure E = 11.5%, vulnerability V = 22.8%, risk R = E x V = 2.6%), Austria (E = 13.2%, V = 23.2%, R = 3.1%) and Switzerland (E = 9%, V = 23.2%, R =2.2%). The German-speaking region is thus privileged in every respect, and yet the storms of recent decades are making life increasingly difficult for the forestry sector and the dry summers for forestry and agriculture, and in the mountain valleys there is an increasing threat of mudslides and avalanches due to climate warming. Locally and sectorally, even the privileged countries are facing enormous challenges.
- a *very low risk* due to very low exposure despite medium vulnerability: an example is Mongolia (E = 6.9%, V = 43.2%, R = 3.0%). Although it is not among the world leaders in socio-economic terms, its risk is exceptionally low because the country is not threatened by any major natural hazards.
- a *high risk* due to very high exposure, despite very low vulnerability (between 7.59% and 10.75%): A striking example is Japan (E = 38.7%,

V = 24.9%, R = 9.6%). The country is located in a zone that is extremely prone to earthquakes and tsunamis. Therefore, despite its highly developed industry and great prosperity, it is exposed to high risks. Not least the meltdown at the Fukushima power plant in 2011 due to a tsunami demonstrated this impressively.

– a *very high risk* due to very high exposure and vulnerability (between 10.76% and 49.74%): This applies to a number of African countries, e.g. Cameroon (E = 20.3%, V = 63.8%, R = 13.0%). But the Philippines (E = 42.3%, V = 49.6%, R = 21.0%) also belong to this category. They are massively disadvantaged in terms of both natural conditions and societal resilience and must therefore bear the greatest burden of planetary boundaries despite their low carrying capacity.

Overall, Europe and North America have a low risk, while Central America, Africa and Southeast Asia have a high risk. It is therefore precisely those countries that contribute less to global warming that, with a few exceptions, are exposed to a particular risk and have very little resilience to deal with the consequences of natural disasters. This is true even if one excludes earthquakes as not being caused by global warming.

In contrast to the World Risk Index, the Climate Risk Index by Germanwatch (https://germanwatch.org/de/kri) measures the frequency and the extent of economic damage caused by climate-related natural disasters. Looking at the period from 1999 to 2018, the following countries top the rankings: 1 Puerto Rico, 2 Myanmar, 3 Haiti, 4 Philippines, 5 Pakistan, 6 Vietnam, 7 Bangladesh, 8 Thailand, 9 Nepal. One can quickly see that the overall result converges with the World Risk Index: The particularly poor countries are especially affected by global warming, which, however, is mainly caused by the rich countries. This imbalance will have to be taken into account in the assessment and in the development of solutions.

2.8 The two central causes: Economic activity and lifestyle

How far can we put a strain on the earth's ecosystem without risking its permanent collapse in essential parts? Looking at the earth in terms of this question is, on the one hand, focused on the consequences for humanity and thus anthropocentristic, and on the other hand, within this framework, focused on the functional benefits. It is a classic technocratic approach. It ignores the beauty of the planet as well as the needs of non-human creatures. The concept of planetary boundaries is thus hardcore economically oriented. On the one hand, this is its methodological limitation, but on the other hand it is its enormous opportunity, because it offers the prospect of convincing hard economists, for a large part of current ecological problems are economically induced and can therefore only be improved through reform of the economic system.

The economy has exploded in industrialised countries and now also in emerging countries within a century. We rightly speak of an "industrial revolution", just as we refer to the sedentarisation of humankind as the "Neolithic revolution". This revolution has overtaken the societies concerned in many respects. Above all, their cultures and lifestyles have changed dramatically. But human impact on the environment has also been revolutionised. The pre-industrial "ecological footprint" of humanity was tiny compared to the industrial one. Environmental ethics were therefore only necessary to a very modest extent, for example to limit local water pollution, to prevent regional deforestation or to equitably share grazing on communal lands.

The *social* upheavals triggered by the economic explosion of industrialisation have now been contained or even reversed in many democracies. The concept of the social market economy has been enforced, which places limits on the economy where it wants to shed its social responsibility. However, national social market economies are on shaky ground as the market has become globalised and undermines many social achievements of nation states. Migrant and temporary workers from poorer countries often do not participate in the social standards of richer countries. Suppliers and entire manufacturing sectors are located abroad anyway, where low wages and a lack of social protection are the order of the day. Many social problems have not been solved but only externalised. From a global perspective, the social containment of the economy has not yet achieved its goal.

In any case, the *ecological dislocation* triggered by the economic explosion of industrialisation was not recognised until much later. While the beginnings of social legislation date back to the 19th century, environmental legislation only took off in the 1970s. And just as in the 19th century it was the labour movement, in the second half of the 20th century the environmental movement was the decisive driving force. With the Fridays for Future protests, it has gained unprecedented strength since 2018. However, it remains to be seen whether this will be sufficient for effective ecological structural change.

What do we learn from these very fundamental considerations? Ecology must be thought of even more globally than social issues. For goods and services, national borders are already not a decisive obstacle. The US–Chinese trade war of the last few years will do little to change this. The environment, more than anything else, does not adhere to national borders. All nine planetary boundaries have planetary impacts by definition. Of course, they impact in different ways regionally. But they do so according to their own laws. Creation ethics must therefore look for concepts that are globally implementable and acceptable.

A second insight is that we must not play ecology and social issues off against each other. This insight was already shaped by the UN Conference for "Environment and Development" (UNCED) in Rio de Janeiro in 1992. In his encyclical Laudato si' in 2015, Pope Francis also attributed a central role to it. Ecological and social justice are interdependent in many ways. Ultimately, the poorest people always suffer the most from environmental disasters because they have the fewest resources to protect or safeguard themselves against them. And vice versa, pursuing social policy at the expense of the environment and understanding it in such a way that every person should have his or her own car, his or her annual flight on holiday and his or her portion of meat with every meal will not add up. Taking social and ecological requirements into account together is not trivial. But playing them off against each other is fatal in every case.

In addition to social and ecological dislocation, the economic explosion of industrialisation has also triggered *economic dislocation*, which is often overlooked. It is not uncommon for successful companies to be ruined because they act too ecologically or too socially—or simply because they make too little profit compared to the expectations of investors. It is not a question of companies making losses or mismanaging, but of well and solidly run businesses that are not able to cope with the harshness of unbridled competition. The fact that such companies disappear from the market is counterproductive, at least from an economic point of view. Moreover, and this is the idea behind the concept of planetary boundaries, ecological processes also trigger economic consequences. A functioning environment is the prerequisite for successful economic activity. So, when the earth's ecosystem reaches its limits, the economy cannot be indifferent to it.

The economic upheavals make it particularly clear that the world economy is a system, a functional unit that runs according to its own rules. Those who want to change it must therefore change the system and not be content with individual ethical appeals to individual economic actors. Environmental ethics needs individual and socially ethical considerations in equal measure. Only when these complement each other can the path to an ecological and social economy be opened up. We will consider this specifically in chapter 8.

At the same time, however, the tempting tendency to shift all ecological and social responsibility onto "politics" and "the economy" must be resisted. The enormous dynamism that the economy has acquired since the industrial revolution did not only come from the economy itself. Rather, it also came about because it made possible a standard of living that was tempting for most people. Beyond the subsistence level, no one is forced to run on the hamster wheel of the economy. And yet that is exactly what most people have done over the last two centuries. The economy does not force people to join in, but lures, seduces, awakens the desire for more and more... and most people let themselves be taken by surprise by its temptations.

Thus, without the question of creation-compatible lifestyles, which I discuss in chapter 9, ethics of creation are also inconceivable. In pre-industrial times, this question was meaningless for most people because they were fighting for their very existence. In industrial and post-industrial times, however, this question becomes the key to the future: How much consumption of material goods is good for us? How much do we really need? How can we live well without overusing the earth? In the face of these questions, we are admittedly faced with a considerable problem: "we cannot claim to have a sound ethics, a culture and spirituality genuinely capable of setting limits and teaching clear-minded self-restraint." (LS 105) So again we come back to the problem of limits, this time not so much from a scientific as from an anthropological and ethical point of view: What significance do limits have for the success of life?

2.9 Boundaries in an anthropological and ethical perspective

Limitations are highly suspect in modern discourse on freedom because they are understood primarily, often even exclusively, as a restriction of freedom. Therefore, modernity tries to overcome limits altogether. But is that possible at all? And if it were possible, would it make sense?

In the encyclical Laudato si', the reference to limits plays a not insignificant role. First of all, the Pope refers to the concept of planetary boundaries when he writes: "The exploitation of the planet has already exceeded acceptable limits and we still have not solved the problem of poverty." (LS 27). In the further course of the text, however, Pope Francis then shows that the concept of planetary boundaries contains much more potential, anthropologically and ethically speaking, than it immediately indicates: Deliberately anthropocentristic in conception for strategic reasons, it leads beyond anthropocentrism[3] because humans, animals and plants benefit together when the ecosystem's stress limits are respected, and suffer together when they are exceeded. For strategic reasons, it is deliberately benefit-focused and transcends the benefit perspective because behind the quantitative metrics, qualitative values and notions of good living shine. The concept of planetary boundaries thus overcomes modern industrial society and its technocratic logic with its own weapons and opens up a view of larger contexts.

But these larger contexts need to be opened up. "The time has come to pay renewed attention to reality and the limits it imposes; this in turn is the condition for a more sound and fruitful development of individuals and society." (LS 116). In ecological ethics, limits have received significant attention from the beginning. For example, the first report of the Club of Rome in 1972 was entitled "The Limits to Growth". The ecumenical assemblies of Stuttgart (EAS) in 1988 and Dresden (EAD) in 1989 in the framework of the conciliar process for justice, peace and the integrity of creation also work with the concept of limits at central points, in contrast to the first European Ecumenical Assembly in Basel (EEA) in 1989, in which the idea plays no role[4]. So, what might the outlines of an anthropology of the limits look like?

First of all, a *creation-theological or existential-anthropological* insight comes into play: limits are constitutively part of being a creature and thus also of being human: Every human being is a finite creature (EAD 1/(42)) —spatially, temporally, but also in terms of its possibilities. All forms of earthly existence gain their identity from limitation (Aristotle, Metaphysics V, 17, 1022a 8ff: πέρας, limit). If they were limitless, they would not be "definable" at all, literally: not containable. Therefore, "identity is a formula for limit" (Hanna-Barbara Gerl-Falkowitz 1996, 67).

Dealing with limits is therefore a central moral task because it creates and determines identity. Ultimately, this is the moment that elevates the human being to the status of subject: "The human being experiences him-

3 I use the terms anthropocentrism/anthropocentristic as distinct from anthropocentrics/anthropocentric. The differentiation and definition of these terms is given in the introduction to chapter 5.

4 The texts of the three ecumenical assemblies are documented together in: Michael Rosenberger 2001, 309–498. Further places of publication for the individual texts are also mentioned there.

self precisely as a subjective person, insofar as he brings himself before himself as the product of what is radically foreign to him.... It is precisely this being brought before himself, this confrontation with the wholeness of all his conditions, this conditionality, that shows him to be more than the sum of his factors." (Karl Rahner 1976, 40). The self-development of the human being takes place in the free, responsible acceptance of his or her own radically limited and limiting future. The principled affirmation of limits is therefore an indispensable component of the affirmation of one's own existence. Only this makes true humanity possible (EAS 242, EAD 1/(42)) as well as true freedom (EAD 8/(1)).

Boundaries are, at the same time, the enabling condition of community: "Only in such a way that one is not everything and lives everything is common life possible." (Eberhard Schockenhoff 1993, 46). From modern identity theory we know that identity grows out of relationships, but relationships are only possible on the basis of an already existing identity. Identity and relationality are mutually dependent and constituted.

Boundaries will always also remain painful, especially when we think of limitation through illness and death. So, they must not be transfigured one-sidedly. Limits are not an end in themselves. Nevertheless, they offer a great opportunity, for they activate people and motivate them to help shape a world that takes away as much of the horror of limits as possible (EAD 1/(42)). Their denial, on the other hand, paralyses and hinders the development of the human being, for example in the direction of more ability to experience and care (EAS 242), creativity and understanding (EAD 10/(12)). In this context, the acceptance of limitations is not to be understood as pure passivity or acceptance of external processes as a matter of fate, but as creative shaping, sometimes also shifting or eliminating limitations where it makes sense and is possible. But just as boundaries are not an end in themselves, neither is their removal. Rather, it is about their considered and orderly integration into one's own reality of life so that it can be fruitful and fulfilled.

Ethically, various attitudes of the critically reflective acceptance of limits follow from this existential-anthropological fundamental consideration: humility as the free affirmation of one's own limitedness (EAS 181), moderation as self-limitation for the sake of others, and willingness to renounce as self-limitation for the sake of a greater hoped-for "gain" (EAS 230). In the course of this study, we will reflect on such attitudes in detail (chapter 9). However, it should not be overlooked that attitudes always need the support of framework conditions (EAS 206, EAD 12/(11)) and of the community (EAD 8/(7)).

In the previous sub-chapter, we saw that well-founded ethics of creation cannot do without considering its *economic dimension.* This also applies to reflection on the meaning of limits. Economics assumes that human desires are in principle limitless. However, they are confronted with narrowly limited material resources for satisfaction—a realisation that is still highly insufficiently taken into account in the current concepts of economic growth and even more so in public discussion (cf. on the following chapter 8.4). Thus, the Ecumenical Assemblies of 1988 and 1989 state that the belief in unlimited quantitative economic growth and technical progress without end is a socially established form of denial of our limits (EAS 181 and EAD 1/(42)). Pope Francis also criticises the "idea of infinite and limitless growth, which so excited economists, financial experts and technologists. But this growth presupposes the lie concerning the unlimited availability of the planet's goods, which leads to 'squeezing' it to the limit and beyond." (LS 106).

One, if not the central paradigm of modern economic theories, the growth paradigm, is thus fundamentally called into question by the identification of ecological capacity limits. This does not necessarily mean that it must be abandoned, but it does at least require fundamental correction. This applies analogously to the central paradigm of modern social theories, the *freedom paradigm*. Boundaries are highly suspect in modern discourse on freedom because they are understood primarily, in radical constructivist approaches even exclusively, as a constructed and thus unnecessary restriction of freedom. Now, it cannot be denied at all that the questioning and overcoming of limits has brought enormous progress to humanity—technically as well as socially. A renaissance of the pre-modern tendency to accept limitations unquestioningly and be resigned to fate would therefore be completely misguided. Nevertheless, Pope Francis is right in saying that many wounds in the social sphere and in nature "are ultimately due to the same evil: the notion that … human freedom is limitless." (LS 6)

In ethical terms, freedom means—as paradoxical as it sounds—self-limitation through morality. Freedom means "finding the law which alone is capable of necessarily determining it [the will, MR]" (Immanuel Kant, Critique of Practical Reason AA V 29). It is "independence of the will from every other except the moral law alone" (Immanuel Kant, Critique of Practical Reason AA V 94). Freedom therefore means binding oneself to the law of reason out of insight. He who follows ethical principles is free, for only he can want all people to act as he does, as Kant says in his famous categorical imperative: "Thus a will to which the mere legislative form of the maxim can alone serve as a law is a free will." (Immanuel Kant, Critique of Practical Reason AA V 29). This is a significantly different understanding of freedom than the societally dominant one.

Such an understanding of morally determined freedom needs limits, if only because this is the only way to realise the freedom of all and not only of a few: "To ensure economic freedom from which all can effectively benefit, restraints occasionally have to be imposed on those possessing greater resources and financial power." (LS 129). However, this justification of the limitation of human freedom with social considerations must always be accompanied by justification using human bondage to nature: a blind person does not have the freedom to see; a paralysed person does not have the freedom to walk; a child does not have the freedom to drive a car, and neither does a person with dementia. Freedom therefore sometimes means being able to do and not do what one intuitively does not want to do but sees as necessary due to natural limitations. Society can and should try to reduce such natural barriers as much as possible, through guidance systems for the blind, electric wheelchairs and other aids. But this is only possible to a limited extent. And no human being can overcome the hardest limit, death. Free then is not who decides to want to live on forever, but free is who can accept death as a "sister" like Francis of Assisi.

In Europe, from 1945 until the coronavirus pandemic, the majority of people hardly had to experience permanent limitations due to nature. Unlimited freedom seemed possible. And wherever resistant phenomena such as the dramatic loss of biodiversity or global warming became apparent, they were successfully suppressed and literally nothing was done. This has strengthened many in the false attitude of claiming absolute freedom. Yet freedom is not the overcoming of all limits, but their fair and prudent shaping, which makes them open to fulfilment and happiness. Almost 100 years ago, Romano Guardini (1925, 208) already formulated: "To the conditio humana belongs precisely the modesty in the limit which is set to its cognition. This drawing of boundaries, far from being a torturous pruning and barrier, is ultimately the conditio sine qua non for the perfection of the human being: We must not deny the limits. We cannot transcend them. But we are to overcome them by freely affirming and completing them, thus making them the law of perfection."

2.10 A New Age: The Earth in the Anthropocene

Man has taken the earth almost completely into his service. There are practically no natural areas left that have not been significantly changed and shaped by him. This is the core thesis behind the term "Anthropocene" (Paul Crutzen/ Eugene F. Stoermer 2000). Literally, it means "the humanly [made] new" (from Greek ἄνθρωπος, human, and καινός, new). Linguistically, Crutzen and Stoermer are thus following on from the term "Holocene", "the completely new" (from Greek ὅλος καινός), which describes the post-glacial epoch of the last ten to twelve thousand years, i.e. the period since the Neolithic Revolution, and which probably became established at the Third International Geological Congress in Berlin in 1885[5] . In terms of content, they claim that a new Earth Age began with the Industrial Revolution, whose start they place roughly at the invention of the steam engine by James Watt in 1784 (Paul J. Crutzen/ Eugene F. Stoermer 2000, 17)—a striking thesis that has since gained wide scientific acceptance. Talk of the Anthropocene has been widely received, both in specialist literature and in government documents, even if the "International Commission on Stratigraphy", which is officially responsible in this respect, has not yet recognised the term as a new geological epoch.

Humans have become one, possibly the most important factor influencing the earth's biological, geological and atmospheric processes. The term "Anthropocene" could therefore also be translated as "human age". Paul Crutzen and Christian Schwägerl write: "For millennia, humans have rebelled against the superpower we call 'nature'. In the 20th century, however, new technologies, fossil fuels and a rapidly growing population have led to a 'great acceleration' of our own capabilities. We are taking control of the realm of nature, from climate to DNA, albeit clumsily (...) Today we live in human systems in which natural ecosystems are embedded. The barriers between nature and culture that have been maintained for a long time are breaking down... (...) It is no longer 'us against nature'. Instead, today we decide what nature is and what it will be in the future. (...) we live in the Anthropocene, which highlights the high degree of responsibility of humanity as stewards of the earth. (...) Imagine our descendants in the year 2200 or 2500. They might compare us to aliens who treated the earth as if it had merely been a stopover for refuelling. Or, even worse,

5 Crutzen and Stoermer locate the congress in Bologna, many others in London. All agree that it was the third International Geological Congress in 1885, but that one was held in Berlin. The second congress was held in Bologna in 1881, and the fourth in London in 1888, cf. The International Geological Congress (A Brief History), in: http://iugs.org/uploads/images/PDF/A%20Brief%20History.pdf (retrieved: 20.2.2018). The term "Holocene" was first used by Charles Lyell in 1833, so it took more than half a century before it was officially recognised. In this respect, the term "Anthropocene" still has some time left.

they might call us barbarians who plundered their own home. (...) Consider: in this new age, we are nature." (Paul J. Crutzen/ Christian Schwägerl 2011)

These are just a few of the plausible examples that Crutzen and Stoermer cite for the Anthropocene hypothesis: At present, farm animals bred by humans have more biomass worldwide than wild animals; humans are responsible for more than half of quite a few biogeochemical substances in the earth's atmosphere, such as methane, nitrogen and phosphorous; almost half of the land area has been transformed by humans (Paul J. Crutzen/ Eugene F. Stoermer 2000, 17).

So, there is no question that there is practically no "untouched nature" left today. There is also no question that humanity can only overcome the problems of its own making with a combination of retreat (degrowth, i.e. reduction of resource consumption in the economy and consumption as well as reduction of the world's population) and design (environmental management, environmental technologies). For this second aspect, however, Crutzen and Schwägerl propose such controversial technologies as carbon capture storage, i.e. the injection of carbon dioxide into underground cavities, and geoengineering, i.e. large-scale interventions in geochemical or biogeochemical cycles of the earth by technical means (Paul J. Crutzen/ Christian Schwägerl 2011). This is rightly criticised by many colleagues in the environmental ethics debate. However, one does not have to go as far as Eileen Crist, who rejects the concept of the Anthropocene as such along with the proposed solutions (Eileen Crist 2020, 136–138).

One is the question of solutions—we will deal with them later in this book—the other is the question of analytical tools. As far as the latter is concerned, the classification of the present age as the Anthropocene is quite suitable. The term makes clear the totality of human influence on nature. We humans decide today "what nature is and what it will be in the future" (Paul J. Crutzen/ Christian Schwägerl 2011). This imposes on us an enormous responsibility that we can never fully fulfil.