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Section I

The Planet: Caught between Biogeophysical Knowledge and the Uncertainty of Our Adventure

Nathanaël Wallenhorst and Christoph Wulf

There is an abundance of scientific studies on the current environmental situation, all of which are very alarming. Let us start by reviewing the key results of the last few years which offer a good interpretation of the current situation and the speed with which it has evolved (Wallenhorst, 2019, 2020a, 2020b, 2021, 2022; Wallenhorst & Wulf, 2022; Kamper & Wulf 1989, 1994; Gil & Wulf, 2015; Wulf, 2022).

2009–2022: *planetary boundaries*. In 2009, the Swedish environmentalist Johan Rockström and his 28 colleagues published “*A Safe Operating Space for Humanity*” (Rockström et al., 2009) in *Nature*. They identify nine planetary boundaries, the crossing of which would render our planet clearly less propitious for human life. The nine boundaries of nine processes of the Earth system which guarantee that humans evolve within a safe operating space. In 2009 three planetary boundaries were crossed: climate change, the erosion of biodiversity and the changing of the biogeochemical cycle of nitrogen.

To put this more simply: the boundaries are estimated within a safe operating space from the threshold (or “systemic tipping point”) into dangerous consequences for human life in society. This article presents with great clarity what all Earth system researchers know full well, that the earth functions as a system consisting of numerous sub-systems, which are characterised by reacting in an abrupt, non-linear way where the boundaries are closely intermeshed. Climate and biodiversity have a very singular systemic power in this ensemble – crossing one of these two boundaries is enough to set the whole Earth system into a mode of completely reorganising

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itself which will complicate the very way that we are able to coexist on Earth. In 2015 the same authors continue their work in *Science* (it is noteworthy that the two most important scientific reviews ratify the existence of planetary boundaries that must not be crossed). A few years on and the situation is now considerably worse. The boundary of biogeochemical cycles has been crossed twice (from now on the boundary of the nitrogen cycle is crossed more than that of phosphorus which was already crossed) and a further boundary has been crossed, that of land-system change. In 2022 we were informed by an international team of 14 researchers, led by Linn Persson, a chemist at the Stockholm Environment Institute, that a fifth planetary boundary had been crossed, which threatens to destabilise the Earth system – the boundary of chemical pollution. In 2022 again, another team of 15 researchers led by Lan Wang-Erlandsson and Johan Rockström showed that a sixth boundary, the boundary of freshwater consumption, has been crossed.

2011. The American biologist Anthony Barnosky and eight of his colleagues pull the alarm cord. We are in the process of causing a new mass extinction of species (2011). Over its entire history the Earth has known five large episodes of extinction of life, which, according to palaeontologists, resulted in the loss of 75% of animal and plant diversity (on Earth and in the oceans) in less than two million years. This article, “*Has The Earth’s Sixth Mass Extinction Already Arrived?*” leaves us in no doubt – we are in the middle of a catastrophe, a sixth mass extinction, caused by the only human species and in record time, despite the fact that coexistence with other species is fundamental to our own existence.

2014. Luciana V. Gatti, physicist and chemist in the field of atmosphere, and 16 other researchers published a “carbon balance” of the Amazon in *Nature* (2014). Up until then it was understood that a tree, through photosynthesis, captured CO₂ and replaced it with O₂. The trees, which decarbonised the atmosphere were considered our best friends – they functioned as carbon filters. The tropical forests absorbed about a quarter of the carbon gas released into the atmosphere by human activities. This is what caused the Amazon rainforest to be called the “lungs of the planet”. But is that still what it is? Their conclusion was that photosynthesis of the trees in the Amazon lessened in the dry year (2010, in comparison with 2011, a very wet year), with the trees releasing more carbon than they absorbed. Conclusion: the Amazon is approaching a point of no return – and the deforestation that is currently taking place is aggravating the situation still more. Vegetation can change from being our best friend to being our worst enemy depending on climatic conditions which themselves are dependent on the activities of humans.

2017. We learn from the Mexican biologist Gerardo Ceballos and two of his American colleagues that the situation is much more concerning than it first appeared in the analysis of Anthony Barnosky in 2011. Published in the great American review *PNAS*, their article paints a picture of “biological annihilation” unprecedented in the history of the Earth. Their research is focused on the populations, on the occurrence of vertebrates (amphibians, reptiles, birds, mammals), rather than on species (Ceballos et al., 2017). The result? The number of populations threatened with extinction is huge and not commensurate with the number of

their species. The researchers concluded that, in terms of numbers and speed, the phenomenon surpasses everything that we have known so far.

2017. A study published in *Environmental Research Letters*, led by the French climatologist Margot Bador et al. (2017). What will the heatwaves and the extreme summer temperatures in France be like in the year 2100, they ask, if global greenhouse gas emissions are not drastically cut? They predict increases of between +6 °C and +13 °C, depending on region, compared to the heatwave which we experienced in 2002, which they used as a point of comparison. The peaks in temperature could easily go higher than 50°, temperatures which are customary in the desert, and could reach 55 °C in Eastern France in the year 2100.

2018. The US chemist Will Steffen and six other scientists (including Swedish environmentalist Johan Rockström, British oceanographer Colin Summerhayes, American biologist Anthony Barnosky and German physicist Hans Joachim Schellnhuber), stress the fact that the data forecasting the temperature of the Earth are worse than previously envisaged (2018). They study the major risk to be addressed – the possibility that a series of chain reactions, or the domino effect, is pushing the Earth system towards an increase of average temperature that will settle at +5 °C, a threshold that is incompatible with human life in society in most regions of the world. If we are to avoid the planet irrevocably becoming a “Hothouse Earth” for the thousands or tens of thousands of years to come (without the possibility of any reversal) we have two decades left to *radically* change the way we live.

2020. 11,000 scientists from 150 countries all over the world, from the fields of the geosciences and life sciences, co-sign a statement in *Bio Science*, invoking the moral obligation under which they find themselves. The seriousness and the acceleration of the climate crisis are “threatening the destiny of humanity”. “We declare clearly and unequivocally that planet Earth is facing a climate emergency. To secure a sustainable future, we must change how we live” (Ripple et al., 2020).

Etc.

To sum up, the countdown has started. In the view of Johan Rockström, we have ten years left before this system crosses different systemic boundaries and the planet becomes irrevocably unfavourable for the human adventure in society. Ten years in which to decarbonise industry, energy, transportation and habitats. Ten years to transform agriculture, which should be storing, and not releasing, CO₂. An indisputable conclusion which necessitates a radical change in how we live (Rockström, 2020). Why? Because humans have become a geological force, having the same impact as other natural forces. Because they pose a threat to their own survival in society.

From now on this threat has a name – Anthropocene. Or the title of the geological epoch in which we live. The consequences for our civilisation are considerable. In fact, the emergence of civilisations was due to the stable and predictable climate of the interglacial period of the Holocene which began 11,700 years ago. If *Homo sapiens*, who had been there for about 350,000 years, hadn't planted seeds and put a few animals in an enclosure during his first 340,000 years, it's not that he didn't

think of it. It quite simply wasn't possible. It is the stability of the Holocene that allowed *Homo sapiens* to control the ecosystem in order to build up agricultural surplus, which then allowed some people to do different things, rather than just engage in subsistence farming. This allowed the emergence of our complex societies. Our societies are built on the bedrock of a favourable, stable climate. The question of their collapse is a result of the current changes in this bedrock that enabled them to emerge. The climate is not to be taken lightly. It is directly related to the way in which we coexist, the way in which we all live together as humans – and will be able to continue to do so. The climate is closely connected to biodiversity. If the climate changes it alters the resilience of this solid tissue that is life. However, the erosion of biodiversity reinforces climate change and rising temperatures on Earth.

As mentioned in the general introduction, there is no doubt that the Anthropocene is the concept of the twenty-first century. It is the name of a new geological epoch in which we find ourselves, in view of the impact of humans on the Earth system. The term is part of a tradition that has been taking place over more than 150 years, during the course of which the idea of humanity as a geological force has emerged, as numerous scientific publications have reported for several decades how human activity has brought about changes in the biosphere. Coined informally to begin with in February 2000 at a scientific conference, this term gradually went on to find scientific acceptance and has come to crystallise the magnitude of the human footprint on the Earth as a whole.

The Anthropocene is as simple as it is complex. The simple thing about it is that we have changed the trajectory of the Earth system. Simpler still, from the point of view of the human adventure, is that we might summarise the situation like this: “The situation is serious”. From the perspective of the adventure of life as a whole, no panic, living tissue is solid, resilient and creative. Although it severely affected, it will manage to get through the upheavals of the Anthropocene – it has been through others.

The Anthropocene is also complex. As we will discover in the different articles in this *Handbook of the Anthropocene*, it is at the crossroads of many scientific disciplines: geology and stratigraphy, palaeontology, geography, biochemistry and geochemistry, anthropology, social and political sciences ... The Earth and its biosphere have left the various fields where they were up until now (climate, chemical composition of the oceans, extinction of animal and plant species, etc.), and which allowed the possibility of human life in society.

Human activity has changed the habitability conditions of the Earth for all living creatures. Human life in society finds itself jeopardised at this very moment in certain parts of the world, and it will be even more so in the decades to come. The first thing to do is to bring an awareness of the Anthropocene to people's attention. At the present time, where we sometimes find it hard to distinguish between what is true and what is “fake”, it is important to reach agreement on the facts, without which we risk sliding towards a totalitarian regime, as the German philosopher Hannah Arendt clearly demonstrated. It is this in particular that is addressed by the articles

in this first section, where scientific knowledge of how the Earth system works is often counter-intuitive. There are very many aspects of the Anthropocene that we must try and understand (with all its new terms and concepts).

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Part I
The Earth as a System