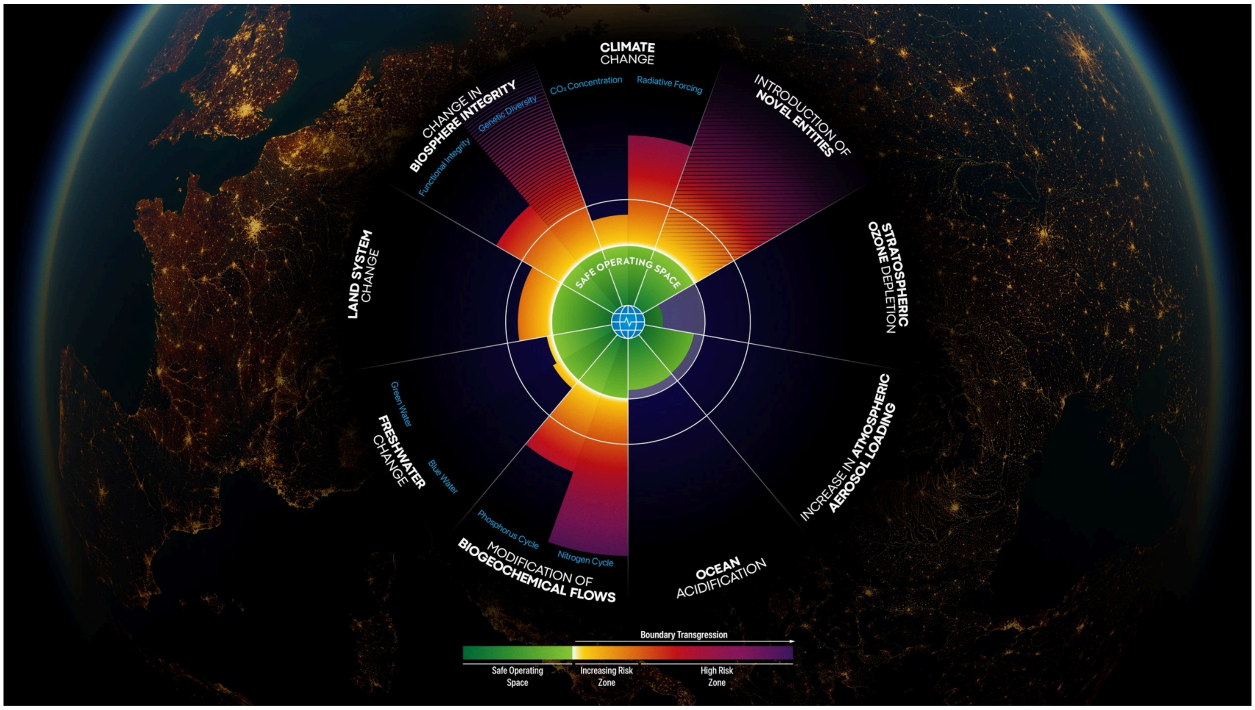
By Aashna Raghu Sankar, 18th December 2024

Understanding Planetary Boundaries

A Framework for Assessing Global Environmental Limits and Sustainability Risks



Introduction

Climate change...biodiversity loss...plastic pollution. These are big words, with a worldwide impact. But how can we quantify this impact? How can we understand it? How can we represent this data in a way that can drive action? The planetary boundaries are a framework designed to do just that. To quantify and represent what seems to be unquantifiable and unrepresentable: nature.

Why Do We Need Planetary Boundaries?

The planetary boundaries framework was first proposed by Johan Rockström and his team in 2009. It identifies nine key Earth system processes that are crucial for maintaining a stable and resilient planet. By defining these boundaries, the framework provides a set of scientific thresholds that, if crossed, could lead to irreversible damage to the Earth's ecological systems and threaten the well-being of humanity.

Using this framework, different stakeholders like scientists, policy-makers and innovators can evaluate whether we are operating within a safe operating space for the entire planet. This framework also gives a structured way for anyone to compare their individual activities to a global framework, enabling shared responsibility and more scope for structured change.

So what are these planetary boundaries?

The 9 Planetary Boundaries

Ocean Acidification: Safe Zone

Oceans act as natural carbon sinks by absorbing excess carbon dioxide from the atmosphere, helping to regulate atmospheric CO2 levels. The subsequent excess of carbonic acid in the water increases the acidity of the waters, which could potentially lead to weak and dissolving skeletons, shells and even a severe impact on the biological structure of coral reefs, thus destroying the entire marine ecosystem.

Biogeochemical Flows: Danger Zone

These are the cycles of different chemical elements and compounds crucial to life: nitrogen, phosphorus, carbon, sulfur and water. These cycles map the flow of these substances between the abiotic ecosystem and living matter too. With the advent of industrialisation, human activities have disrupted these cycles vastly, especially through the processes of artificially producing fertilisers (increased nitrogen and phosphorus created), fossil fuel combustion (rapid movement of carbon to atmosphere) and much more. This disrupts ecosystems, reinforces feedback loops that lead to climate change and can also create human health risks too.

Ozone Layer Depletion: Safe Zone

The ozone layer is where ozone molecules are concentrated in the stratosphere. This layer absorbs excess radiation, especially UVB radiation which is notorious for the skin cancers and health issues it causes. However, industrial activities like the production of aerosol propellants, refrigerators, air conditioning units and more resulted in a steep hike in the release of particles like chlorofluorocarbons which can easily destroy and decompose these ozone molecules. Gradually, a giant hole in the ozone layer appeared above the poles. With a failing and depleting ozone layer, human health and planetary health were both at risk, which is why nations came together in the Montreal Protocol of 1987 to ban such emissions and bring this earth system back within safe operating space again.

Introduction to Novel Entities: Danger Zone

Novel entities are substances that did not geologically exist before and have been artificially manufactured by humans, and have the potential to induce a large-scale impact on the earth systems as we know them. There is a threshold up to which the ecosystem can withstand degrading chemicals like plastics, genetically engineered properties, and even radioactive materials beyond which it could disrupt the planet's stability. While some of these substances have actually been studied and evaluated, a vast majority of them have not, and hence the quantification of this boundary is still underway.

Climate Change: Danger Zone

This is the process by which the increasing emissions of greenhouse gases are enhancing the greenhouse effect, raising the overall global temperature that has a cascading effect on the entire earth system. Experts say that if we overshoot 350 parts per million in the carbon dioxide concentration, we would have breached this boundary and could soon be on a path of no return. That breach has already happened, in fact, it happened in 1988. The continual use of unrenewable energy and various industrial processes have continued to exacerbate this issue, and while innovations in fields like renewable energy and carbon sinking are underway, the situation remains stark.

Biodiversity Loss: Danger Zone

This planetary boundary encompasses the degradation of biodiversity and ecosystems, and it is by far the most local and regional. A wide variety of human activities can cause a rapid rate in biodiversity loss, from the most obvious ones like urbanisation and deforestation to the more nuanced ones like the propagation of invasive or genetically modified species.

This boundary is one of the most vital ones, for each organism in an ecosystem contributes to the stability of the planet, and the moment that one goes extinct the ecosystem destabilizes and becomes more vulnerable to issues like climate change and ocean acidification, thus pushing these boundaries into an unsafe operating space too.

Global Freshwater Systems: Danger Zone

We need water for our daily needs of washing, drinking, cleaning and more. With our rapidly rising population and our increasingly consumerist culture, we are demanding rising freshwater. It is predicted that this demand with 40% excess the supply of freshwater by 2030 according to the World Economic Forum. And where is all this water coming from? The water cycle is a natural one, that keeps waters of different forms constantly moving in the environment. We harvest freshwater before it reaches the oceans, using dams, reservoirs and various other infrastructure, depriving other ecological cycles, biodiversity and habitats with that water as a result. It also impacts us, as the rain patterns become unpredictable, causing floods, droughts and by extension creates a risk to health and food security too.

Land-Systems Change: Danger Zone

This boundary primarily involves the shifts in the systems of the land and soil which today are heavily influenced by current agricultural practices, urbanisation and construction and deforestation and habitat loss. The major impacts of the changes in this underlying system lies in the hydrological cycle, further hastening climate change through phenomena like the urban heat island effect, destroying biodiversity and also compromising diverse and rich terrains and habitats like mountains and wetlands.

Atmospheric Aerosol Loading: Safe Zone

The term aerosols refers to tiny particles of pollutants suspended in the air. These have been produced at a dramatic scale since the industrial revolution (more than doubling the aerosol concentration compared to pre-industrial times). These particles play a role in climate change as they act as extra heat sources and also impact the Earth’s radiation reflectivity to increase the global temperature. They also pose a hazard to human health as they have been linked to respiratory illnesses, thereby making it one of the most deadly and the toughest to quantify boundaries in the framework.

Conclusion

The planetary boundaries framework offers a powerful lens through which we can understand and measure the Earth's capacity to support life. While each of the nine boundaries may seem distinct, they are deeply interconnected, with changes in one often influencing others in a cascade of impacts. Whether it's the rise in ocean acidity affecting marine life or the loss of biodiversity exacerbating climate change, the systems of the Earth are delicately balanced—and we are now operating outside of that balance in critical areas.

This framework not only highlights the precariousness of our planet's ecological systems but also serves as a wake-up call: we are living in an age where the risk of irreversible damage to the Earth's life-support systems is greater than ever. Yet, it also presents an opportunity. By understanding and respecting these boundaries, we can redefine our development pathways and shift toward a more sustainable and resilient future. Whether through innovations in renewable energy, changes in agricultural practices, or stronger international collaborations, we have the tools and knowledge to act. And trust me, it is time to act—before it's too late.

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