earthwatch learning | Planetary Boundaries

Introduction

We're going to take you on a journey that describes how recent human development has impacted the health and well-functioning of our planet, and to provide a guide for future development in the Anthropocene – the age of humans.

An international team lead by scientists from the Stockholm Resilience Centre led by Johan Rokström have set out several 'planetary boundaries' critical to the health of our planet, and therefore critical to us all. This model has been recognised and endorsed by the United Nations, and updated regularly. In designing this model, the scientists made an expert assessment of the intrinsic biophysical processes that regulate the stability of Earth's whole system.

For Earth to remain in a stable state these Planetary Boundaries need to remain in what is called the safe operating space. This safe operating space is marked in the model by the picture of the Earth, and once the planets' boundary is crossed we have moved beyond the known safe operating space and into a much less stable state.

But what do we mean by a 'stable state'? This describes the state our planet has been in over the last 10,000 years or so – the Holocene period. During this time humans have harnessed our environment and the resources our natural world provides. If we move out of the safe operating space into a zone of uncertainty, we are increasingly likely to cross tipping points, and where they're crossed we risk a sudden and irreversible change in the Earth's whole system and significant areas of the planet becoming uninhabitable.

1800 – 1950

We will start at where there has been negligible impact by humans (a little after the kickstarting of the industrial revolution) , in 1800. The years before 1800 are often referred to as pre-industrial times). This section covers the period from 1800 to 1950.

- The world population in 1800 is 1 billion
- This period saw the industrial revolution, and since this time the world has witnessed a period of staggering economic growth
- Plastic is invented in 1869 and goes on to become one of the world's most robust and widely-used materials
- Global Gross Domestic Product (GDP) increases 23-fold from 1800 to 1950
- At this point in time, we have data for 5 of the planetary boundaries.

Climate Change

Burning of fossil fuels and changes in land-use are emitting greenhouse gases, mainly carbon dioxide, methane and nitrous oxide, into the atmosphere.

Greenhouse gases remain in the atmosphere for a considerable period and are responsible for trapping the sun's heat, thereby increasing global average temperature.

Freshwater use

70% of all freshwater use is for agricultural production; about 20% is used by industry and the remaining 10% for households.

Severe droughts and unpredictable, more intense, rainfall patterns lead to crop failure. Flooding and storm damage can lead to contaminated drinking water supplies.

Agricultural use around the world is depleting groundwater aquifers.

Nitrogen Flow

Plants need the nutrient nitrogen for healthy growth.

Most plants absorb nitrogen from the soil. Consequently, intensively farmed land is soon depleted of its nutrients and artificial fertilisers are then used at a rate far exceeding the actual need.

The application of nitrate fertiliser has also resulted in an increased concentration of nitrous oxide in the atmosphere, a powerful greenhouse gas.

Phosphorus Flow

Similar to nitrogen, plants also need phosphorus for healthy growth.

Overuse of phosphorus & nitrogen rich fertilisers can result in them entering waterways polluting rivers, lakes and coastal waters.

Fertiliser run-offs into water systems lead to eutrophication — when the waters become enriched with nutrients, massively increasing the amount of plant and algae growth.

This also starves them of oxygen creating massive 'Kill Zones' with such low oxygen levels they are unable to sustain aquatic life

Land System Change

Forests play a vital role in storing carbon, protecting soil and reducing flood risks.

Commercial agriculture — such as cattle ranching, soy cultivation and oil palm plantations — drives 40 percent of deforestation worldwide. Mining, infrastructure and urbanisation are also key culprits.

Deforestation impacts 1.6 billion rural people worldwide who rely on forests for their livelihoods — most live in extreme poverty.

Land use change is the main cause of ecosystem damage and a decline in wildlife diversity and abundance.

By 1950 this is the extent of the impact on the environmental system processes. They all remain within the safe operating space.

By the 1850s: Smoke pollution from coal-fired factories is affecting the health of a disproportionate number of poor people, a problem greatly aggravated by the Industrial Revolution

1856: Eunice Newton Foote was the first person to demonstrate that carbon dioxide is a greenhouse gas, and to suggest that an atmosphere containing high levels of carbon dioxide would lead to a warmer earth.

1912: The burning of coal and resulting Carbon Dioxide emissions were already being posited as having impacts on the climate

1950-1970s

Now we are going to look at the changes that take place from 1950 and into the early 1970s.

- The world population increases from 2.5 billion in 1950 to 3.7 billion in 1970
- 1950 is described as the beginning of the 'great acceleration' where many human activities reach take off points and sharply accelerate.
- December 1952: A killer smog hits London, causing an estimated 4,000 to 12,000 deaths

Here we can introduce a new planetary boundary – Ozone Depletion.

Ozone Depletion

Having been discovered in 1913 by the French physicists Charles Fabry and Henri Buisson, a standardised method of monitoring ozone was established between 1928 and 1958, which continue to operate to this day

- High in the Earth's upper atmosphere is a diffuse layer of ozone gas.
- The ozone layer filters out 97-99% of harmful ultraviolet radiation from the sun, which can cause a higher incidence of skin cancer in humans, as well as damage to terrestrial and marine plankton – the very foundation of the food chain.
- In 1976 the appearance of the Antarctic ozone hole was shown to be proof of concentrations of ozone-depleting chemicals causing damage.

During this period, climate change, freshwater use, land system change, nitrogen and phosphorus flow all increased too.

The green revolution from the 1940s to the 1960s leads to increasingly high yields of wheat and rice worldwide, particularly in the developing world

Essential minerals are often a limiting factor in crop production but phosphorus is being heavily mined and energy is used to extract nitrogen from the atmosphere to make fertilisers

The post WWII 'Great Acceleration' saw increased living standards and life expectancy for many across the globe, which also created a massive increase in manufacturing, pollution, resource extraction and unsustainable consumption patterns.

1970s-1990s

Let's continue with a look at the changes that take place in the following approximately 25 years, from 1970 and into the 1990s.

- The 1980s sees a rapid growth in urban populations. People who once farmed have moved in search of better lives or have been forced to move because of falling incomes.
- Fertiliser use rapidly expands worldwide, but especially across Southern Asia and Eastern Europe.

During this period, Climate change, Freshwater use, Land system change Nitrogen and Phosphorus flow and Ozone Depletion all increased too.

Note that we have now crossed two boundaries into the extremely high risk area

1990s – the Present Day

Many of the planetary boundaries are interconnected, with changes to one impacting one or more others, and during this period we start to see more and more effects of this interconnectedness.

So now we are going to look at the changes that take place in just 30 years from the early 1990s to the present day.

- Emerging economies such as Brazil, India and China now account for 60% of carbon emissions -but the US is still the largest cumulative emitter.
- Plastic pollution is found in every ecosystem on the planet - from Mt Everest (the highest) to the Mariana Trench (the deepest). Only 9% of plastic is recycled.
- Increasingly warm and acidic oceans threaten coral reefs and marine life. With a temperature rise of 1.5° between 70-90% of coral reefs will die
- Dry vegetation and excess temperatures lead to regular wildfires burning in summertime across Europe, North America, Siberia and Australia. 90% of California's largest wildfires have burned in the last 20 years.

We are now able to introduce some other boundaries where we have relatively recently been able to measure the impacts.

Novel entities and Chemical pollution

These are human-made and include microplastics, heavy metal compounds, and additional radioactive materials.

These compounds can persist in the environment for a very long time, and their effects are potentially irreversible.

Even when non-lethal, uptake of chemical pollution can cause reduced fertility and the potential of permanent genetic damage across species, which can have severe effects on ecosystems and the ecosystem services on which all life relies.

Atmospheric Aerosol Loading

Aerosols are airborne droplets and particles, including soot or droplets of sulphates from burning fossil fuels.

Naturally occurring particles come from pollen and salt from ocean spray.

Aerosols impact Earth's climate system, affecting cloud formation and also altering the amount of solar radiation that is reflected or absorbed in the atmosphere.

We don't have any baseline data on this and have not been able to calculate a safe operating threshold. But we recognise that Aerosol Loading can have a serious impact on the function of the whole-earth system.

Ocean Acidification

Around a quarter of CO2 emissions is ultimately dissolved in the oceans. Here it forms carbonic acid, and has caused marine ecosystems to rapidly become more acidic.

Acidity has risen by 30%.

Rising acidity threatens marine life including plankton, corals and shellfish by making it harder for them to form their protective shells.

Freshwater use

Until now, the water boundary had been considered to be within the limits of a relatively safe zone. Recently however it has become clear that it was needed to be split into 2; Blue water and Green water.

Green water

The original freshwater boundary only focused on extraction of water in rivers, lakes, and groundwater – known as 'blue water.

Green water is the water available in the soil for plants and soil microorganisms. It is the water absorbed by roots, used by plants, and released back to the atmosphere through the process of transpiration. This life depends on soil moisture for their survival.

The latest scientific analysis shows how humans might be pushing 'green water' well outside of the safe zone.

There is evidence that parts of the Amazon are drying out and losing soil moisture because of climate change and deforestation.

Ozone

During this period climate change, land system change and biochemical flows have all increased. But there is good news. Notice that Ozone Depletion has stepped back slightly. Why the positive move?.

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer was a landmark agreement that has successfully reduced the global production, consumption, and emissions of ozone-depleting substances. These substances are also greenhouse gases that contribute to climate change.

However, even under the initial Montreal Protocol, (and subsequent London (1990) amendment), reduction controls and targets would have been too relaxed to have resulted in an absolute reduction of emissions.

The Copenhagen revision in 1992 and its subsequent revisions greatly increased controls and ambition in global commitments, leading to a peak in stratospheric concentrations in the early 2000s and projected declines in the decades to follow.

This is another example of the vital importance of international cooperation and frameworks in preventing the potentially catastrophic impacts of environmental change.

Biosphere integrity and Biodiversity loss

The disappearance of wildlife species is perhaps the most pressing and serious of all environmental problems. A sixth global mass extinction is under way, comparable to the extinction of dinosaurs.

Recent attention has been paid to insect pollinators which are in sharp decline due to habitat loss, use of toxic pesticides and the effects of climate change.

Wild species are not only beautiful but provide a wide range of essential and economically valuable benefits.

You can see in this graphic just what is meant by "pressing and serious".

- The world is demonstrably getting hotter. Surface temperatures have risen almost 1.2C on average across the globe, leading to (among other massive impacts) melting polar ice sheets, melting glaciers and continuing sea level rise which will impact 500million people over the next 10-15 years.
- The world population is 8 billion today, expected to reach 8.5 billion by 2030
- CO2 concentration is now 420 parts per million
- We see multiple interconnected boundaries of Biodiversity, Freshwater Use, Land-System Change and Climate change: Due to deforestation, freshwater depletion, droughts, floods and land clearance for farming, 12 million hectares of land are lost to desertification globally each year, leading to habitat loss and declining biodiversity.
- The last male Northern White Rhino died in March 2018, effectively condemning the species to extinction through human activity, and more than 1 million species are now threatened with extinction.

In Summary

- It has been suggested that we have entered a new epoch – the Anthropocene.
- Human activity has overtaken natural systems and has become the main driver of planetary change.
- As you have seen the scale and speed of this change within a single lifetime is extraordinary.
- The boundaries are complex and interconnected – impact on one can undermine another and changes can become non-linear and hard to predict.
- There is a major question of how long we can remain over a threshold before huge, irreversible changes become unavoidable.

The Planetary Boundaries framework has been adopted by decision makers to help steer us towards change. (For example The World Business Council for Sustainable Development)

There is clearly a conflict between human aspirations for unending economic growth (based on outdated and unsuitable singular measures such as GDP), and staying within the safe operating space for humanity.

Johan Rockström warns that 'business as usual' is not an option and that humanity must find a sustainable development trajectory. It IS possible to support stable and equitable growth, increased health and wellbeing, and the restoration of the natural systems we rely upon for our very existence.

Indeed, research has shown that "The cost of global warming in the most conservative scenario is higher than the mitigation cost in the most pessimistic scenario. Investment spending is not a cost, but will boost activity."

And as the Intergovernmental panel on Climate Change (IPCC) has clearly stated, "The scientific evidence is unequivocal. Any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future"