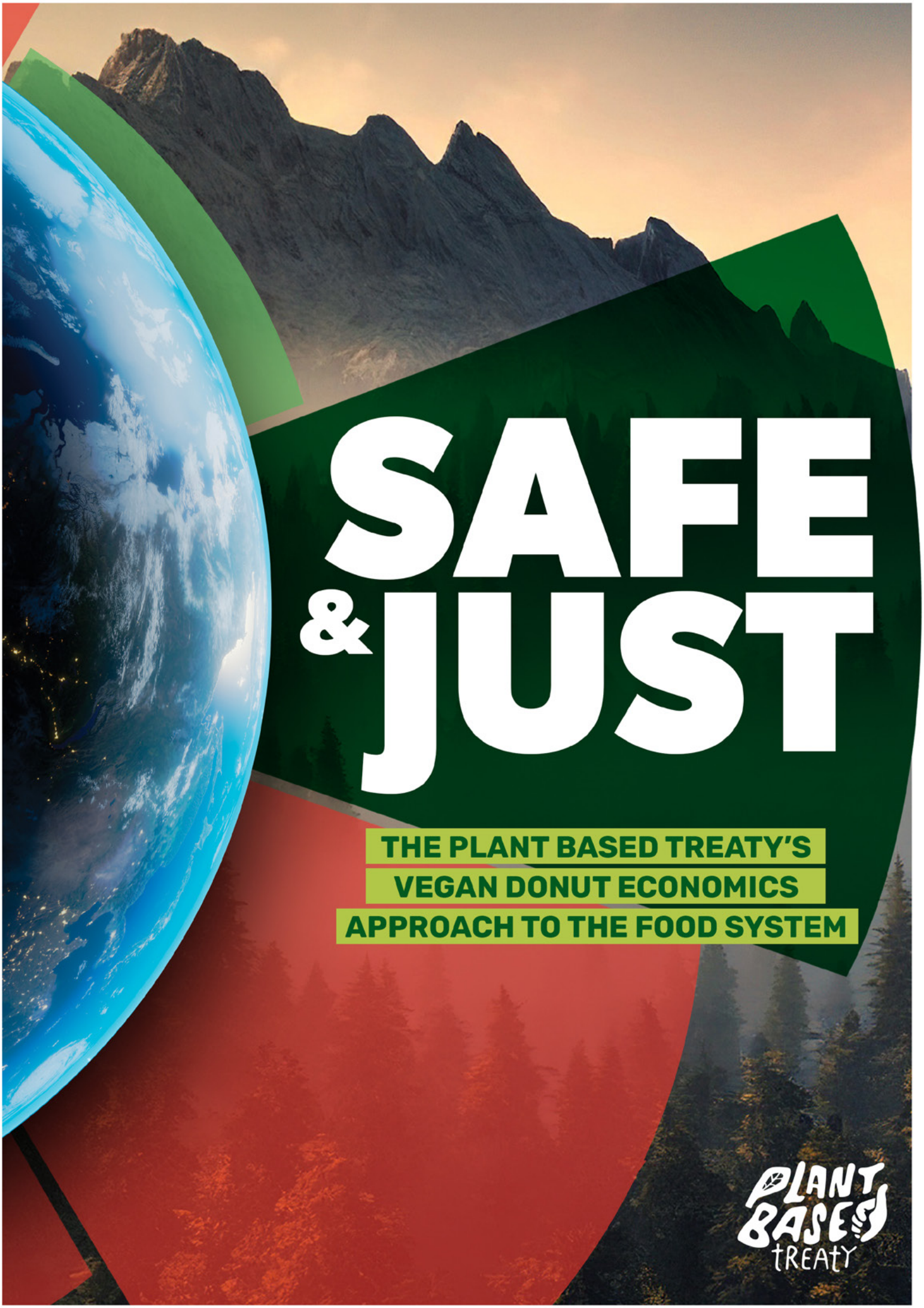
SAFE
& JUST
THE PLANT BASED TREATY'S
VEGAN DONUT ECONOMICS
APPROACH TO THE FOOD SYSTEM
PLANT BASED TREATY

Acknowledgements

Co-authors and contributors: This inaugural report begins with a scientific literature review and assessment of animal agriculture's impact on the planetary boundaries in the donut's outer rim penned by Steven George, Joy van Breda, and Elise van Breda, followed by sections on the donut's social boundaries on the inner rim and city actions co-authored by Anita Krajnc, Nicola Harris, James O'Toole and Enric Noguera. We are grateful for the research and contributions by Natasha Maria, Nilgün Engin, Hoshimi Sakai, Aprajita Ashish, Rajeshwar Singh, Lea Goodett, Jason Fonger, Max Weiss, Alice Pais Basilio, Erika Xananine Calvillo and Gülbike Mirzaoglu; copy editing by Jennifer O'Toole and Anne Casparssan; design assistance from Esra Ozalp and Fede Callegari, and daily inspiration from activists and changemakers worldwide.

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Graphs: Lucía Sierra

Citation: Plant Based Treaty, 2023. Safe and Just: The Plant Based Treaty's vegan donut economics approach to the food system.

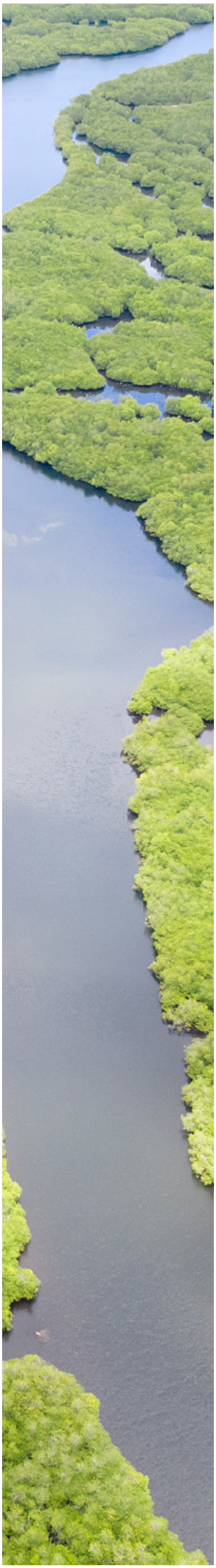
> The *Safe and Just* Report is an eye-opening statement clearly illustrating what must be done – on an individual, institutional, and global scale – if we want a safe and sustainable food system, and a planet capable of supporting future generations. Please share this crucial report with every who wants to build a better world."
>
> - **Naomi Hallum**, CEO of GenV

> Food emissions are the silent contributors to climate change. The Plant Based Treaty's report highlights the urgent need to shift to plant-based solutions for the sake of our planet and future generations."
>
> - **Sada Sayed**, Indian actress

> The *Safe and Just* report is all we need to know about what's going on with the crisis happening. I personally find the Donut Economics Approach to the Food System a great visual tool to understand quickly how serious we need to change our behavior. It's a political choice, it's a personal consumer choice but it must be done by all humanity and fast now. The entire sustainability of Life as we know it depends on those decisions."
>
> - **Louis-Philippe Loncke**, World Class Explorer and Adventurer, Jane Goodall Institute Ambassador (Belgium)

> The role of sustainable plant-based food is the missing piece of the puzzle in environmental action. Plant Based Treaty's *Safe and Just* report, shows how cities can promote and increase access to plant-based food, helping communities thrive whilst respecting our planetary limits. In Edinburgh, we are proud that the Council has signed the Plant Based Treaty and is developing an ambitious action plan to see the aims and ambitions of the treaty come to life on the ground for people across the city."
>
> - **Ben Parker,** Scottish Green Party Councillor (The City of Edinburgh Council)

> Plant Based Treaty's *Safe and Just* report details the widespread degradation and impacts of expanding animal agriculture on our planetary boundaries. It also offers us hope and a pathway to a more sustainable, ethical food system that would benefit the health of Earth and those who call it home."
>
> - **Henry Smith**, Member of British Parliament



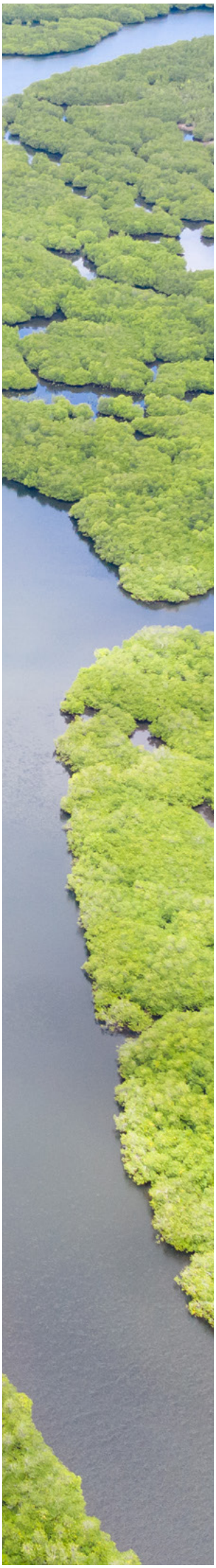
Foreword

A donut that's actually good for us?

2023 is on track to be the hottest year on record, and 2024 could be even hotter. On roughly a third of days in 2023, the average global temperature was at least 1.5°C higher than pre-industrial levels, exceeding the Paris Agreement target. Food emissions account for a third of greenhouse gas emissions, and yet the two-part solution of transitioning to a plant-based food system and rewilding (Plant Based Treaty's motto is "Eat plants, plant trees") hasn't yet translated into meaningful time spent on this topic at climate negotiations or in advocacy work, media coverage and policy making. We need information sharing and massive organizing for the imperative of dietary change to be front and centre at climate talks and local actions.

There are numerous environmental reasons to shine additional spotlights on the precarious food system. Reducing greenhouse gas emissions is only one piece of the food puzzle. When Johan Rockström and his colleagues rang the alarm bells in 2023 that six of nine planetary boundaries had been breached, it hammered home the significance of environmental impacts of the food system putting our future at risk. Fossil fuels have contributed to one of the planetary boundary breaches, namely, climate change. Global per capita meat, dairy and egg consumption has steadily risen since the 1950s, contributing to the breach of five planetary boundaries, specifically climate change, land-use change, biodiversity, phosphorus and nitrogen, and water use. In addition, the ocean acidification boundary is rapidly reaching the danger zone. This "carbon tunnel vision" fails to address the interrelated planetary crises driven by animal agriculture.

We released ***Safe and Just: The Plant-Based Treaty's vegan doughnut economics approach to the food system*** to provide a holistic, ecological, systems-thinking response to scientists' clarion call to fast-track action on food systems during this critical decade. We must also listen astutely to philosophers, social scientists, and artists if we are to re-enchant the world and adopt principles of interspecies, intergenerational, and intragenerational justice. Otherwise, our self-defeating worldviews and business-as-usual behavior may, in this century, lead to unimaginable food insecurity, water scarcity, billions of people living outside the climate niche, and environment-induced wars and conflicts. In Leo Tolstoy's moral tale "Esarhaddon, King of Assyria", a king recognizes his self-centeredness and cruelty to other human and nonhuman animals and afterwards "went about as a wanderer through the towns and villages, preaching to the people that all life is one, and that when men wish to



harm others, they really do evil to themselves." When will we learn these simple lessons about empathy, simplicity, and the unity of life? Aside from being a great writer, Tolstoy was an ethical vegetarian, a count who dropped his title and dawned peasants' garb to plow the land, and a peace, environmental, land reform, and anti-imperialist advocate who inspired Mahatma Gandhi.

Enter onto centre stage Kate Raworth, a brilliant Oxford economist and human rights advocate who adopted veganism in 2021. Our vegan adaptation of her Doughnut Economics model is concerned with finding ways to live in the green 'safe and just' space within ecological limits while allowing communities to thrive through food security and justice, Indigenous protection, ending live export, financing plant-based food, public education campaigns to close the awareness gap on food emissions and benefits of plant-based diets, greener cities, restoring and rewilding ecosystems, equitable land distribution, and more!

We hope to make it easy for individuals, communities, businesses, and policymakers to get involved. We need to improve ecoliteracy, bear witness to the severe environmental impacts and climate injustice, and design and implement commensurate restorative, plant-based solutions. We invite you to draw on the report's findings, learn about success stories and champions like New York City Mayor Eric Adams' commitment to a plant-based revolution. Like King Esarhaddon, Mayor Adams went on a mission to spread whole foods, plant-based programs across the city after promising to help his constituents with his discovery that he became "healthy at last" and reversed his type 2 diabetes through healthy living. It's time to put meat on the climate agenda and get it off our menus. Eat plants. Plant trees. Endorse the Plant Based Treaty!

Anita Krajnc

Plant Based Treaty's Global Campaign Coordinator

Steven George

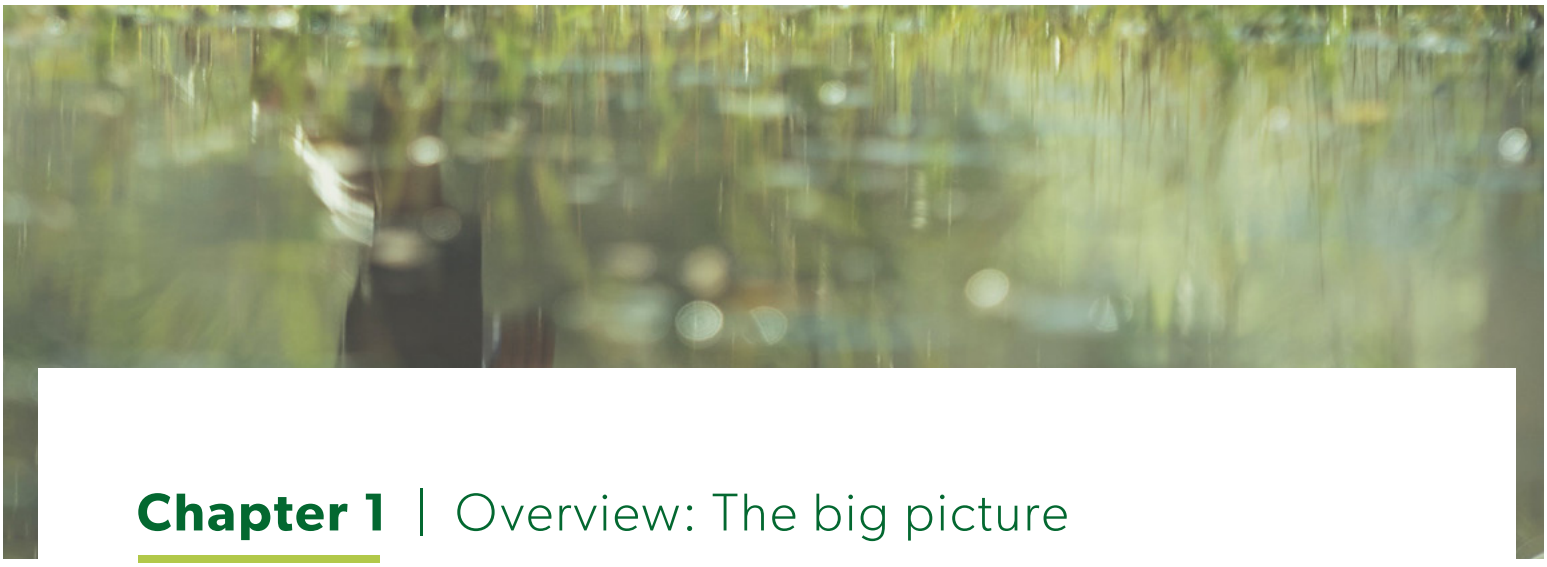
Plant Based Treaty Science Ambassador

Contents

Executive Summary

Plant Based Treaty's COP28 report, ***Safe and Just: The Plant Based Treaty's vegan donut economics approach to the food system***, tells the story of the interconnected relationship we share with the biosphere while urgently advocating for an integrated, systems-thinking approach. The report is largely inspired by the principles of Kate Raworth's Doughnut Model and the planetary boundary framework led by Johan Rockström from the Potsdam Institute for Climate Impact Research (PIK).

As we stand at the intersection of urgency and hope, the global food system must become a future carbon sink and fundamental agent in regenerating and strengthening our biosphere's innate resilience. The Plant Based Treaty acts as a compass, leading us to a safe and just future where *interspecies justice* and *Earth system stability*, *intergenerational justice*, and *intragenerational justice* (i.e., the three justice criteria or the 3Is) are intertwined. Through systems thinking, we can tap into Plant Based Treaty's 40 detailed proposals in order to freeze the expansion of animal agriculture, promote a shift towards plant-based diets through policy change and education, and restore and rewild ecosystems. We must design and implement a Plant Based Treaty globally and locally for a safe and just food system that operates within the planetary boundaries.



Chapter 1 | Overview: The big picture

As we leave the stable Holocene epoch, we find ourselves at a pivotal moment facing an unpredictable climatic future. The Holocene, which spanned the past ~12,000 years, marked a period where the human species witnessed the emergence of modern civilisations, all adapted to a specific climate niche. This climate niche also played a key role in shaping our food systems, ensuring reliable food production attuned to the prevailing conditions.

However, rapid anthropogenic changes are pushing us beyond this equilibrium. The shifting in our climate niche affects not just humans, but also other animals, ecosystems and the reliability and predictability of food systems that have evolved alongside it. As the world confronts a rapidly depleting carbon budget and urgent need for action this decade, the elephant - or rather, the 'cow in the room' remains largely ignored. The world's food and agriculture system, deeply embedded into our biosphere, stands as one of the most environmentally damaging industries and must transition into being a carbon sink in the next two decades if we are to address the multifaceted challenges of our time.

How can we reshape and restore our fragile food system to be ecologically safe and socially equitable? We need a radical reimagining and adoption of a holistic model that considers the connection between ecosystems and human systems and ultimately steers the global food system away from animal-based food sources.In the quest for a sustainable future, the Plant Based Treaty is a landmark international initiative to put food systems at the heart of combating the multifaceted planetary and humanitarian crises.

The most immediate steps must be to halt the widespread degradation of critical ecosystems caused by animal agriculture, promote a shift to more healthy, sustainable plant-based diets, actively reverse the damage done to Earth systems, and restore vital ecosystem functions and biodiversity. In this approach, we advocate for a holistic systems-thinking approach that ensures the well-being of citizens, Indigenous Peoples, climate migrants, farmers and animals as we navigate our global food system's safe and just transition.

Climate tipping points

- Five climate tipping elements are already in a danger zone within a 1.1-1.5°C temperature threshold and a further five are at risk under the Paris Agreement's 1.5-2.0°C warming limit. Surpassing these thresholds may trigger reinforcing feedback mechanisms, causing their collapse, which in turn could lead to runaway impacts and destabilize the entire Earth system. This implies that, as Johan Rockström points out, *"The 1.5°C threshold is a physical limit, not a political target."*
- Our global food system, with animal agriculture as a central issue, affects all nine planetary boundaries, significantly contributing to five breaches.

Global warming and carbon budget

- Earth has already experienced 1.2°C of global warming, and we are quickly depleting our 1.5°C carbon budget, using up 3 per cent each month. To have a 67 per cent chance of staying under 1.5°C, the estimated carbon budget is 150 Gt CO_2, which will likely be used by 2026. For a 50 per cent chance, the budget is 250 Gt CO_2, expected to be exhausted by 2029, based on an annual emission rate of 41 Gt CO_2.

- Current trends suggest a rise in global temperatures of +0.23°C per decade, potentially reaching an average increase of 1.5°C by 2034. Due to an intensifying El Niño event, the World Meteorological Organization (WMO) predicts a temporary breach of the 1.5°C threshold within the next two years, entering potentially dangerous uncharted territory.

- Even if fossil fuel emissions ended today, global food emissions alone would make the 1.5°C limit impossible and even the 2°C target difficult to realize.

Climate niche

- As we leave the safe and stable conditions of the Holocene epoch, more and more people are being displaced from their climate niches. Presently, around 9 per cent of the world's population, which amounts to over 600 million individuals, reside in areas outside of their climate niche. Current policies could lead to global warming of approximately 2.7°C by 2080-2100, leaving an additional one-third of the world's population (22 per cent to 39 per cent) outside their temperature niche. A reduction of 0.3°C in end-of-century warming could reduce exposure to extreme heat by 4.3 per cent, impacting around 410 million people.

- There is also a risk that existing climate policies may not be implemented, leading to a return to fossil fuel use as per the SSP5-8.5 scenario, potentially causing global warming of around 4.4°C. Under this scenario, over 55 per cent ± 7 per cent of the global population (about 5.3 ± 0.7 billion people),, could be displaced from the human climate niche.

Methane opportunity

- Around 0.5°C of the total 1.1°C (as of 2021) global warming is attributed to methane (CH_4) emissions, highlighting the significance of addressing CH_4 emissions for effective short-term mitigation of global warming. In 2021, the global food system contributed to over54 per cent of anthropogenic methane emissions, with 36 per cent from animals raised for food, 10 per cent from crop production (mainly rice cultivation), and 8.2 per cent specifically from food waste. Methane's GWP of 80.8-82.5 and 12.4-year atmospheric lifespan means that mitigating these emissions can quickly slow the rate of global warming, buying us essential time for rapid decarbonization of our societies. This mitigation effort begins with the elimination of animal agriculture, as it is the single largest source of anthropogenic methane emissions. The Climate and Clean Air Coalition (CCAC) and the United Nations Environment Programme (UNEP) estimate that a 45 per cent reduction in methane emissions by 2030 could prevent a 0.3°C temperature rise by 2045.

- Transitioning away from animal agriculture creates time to decarbonize the energy sector, transform global food systems into a carbon sink, and restore degraded land to regenerate the biosphere's resilience. Therefore, a plant-based food system with low methane emissions offers a significant opportunity to slow global temperature rises.

Rapid decarbonization

- To address climate change effectively, emissions must reduce by 50 per cent every decade to achieve net zero emissions by 2050. Key to this strategy is the transformation of agriculture into a major carbon sink (anticipated to happen in the next two decades, according to assumptions made in the IPCC Models) and the preservation and restoration of both land and ocean-based carbon absorption systems. However, there is currently no significant discussion or global agreement surrounding this much needed transformation.

- Restoring degraded lands is critical for reducing carbon emissions and stabilizing global temperatures

within safe limits. Land-based strategies are projected to contribute over 30 per cent of the required emission reductions by 2050 to keep global warming below 2°C.

The urgency for a systems approach to food

- Our global food system has a pivotal role — both as a future carbon sink and as a fundamental agent in regenerating and strengthening the biosphere's innate resilience. Earth's terrestrial ecosystems store a vast amount of carbon, about 60 times the yearly human-induced greenhouse gas emissions, with soil containing roughly 70 per cent of this (1500–2400 Gt C). Oceans are even larger carbon stores, containing around 38,000 Gt of carbon, emphasizing the importance of marine and land ecosystems as key carbon sinks historically aiding climate stability.

- The focus on carbon emissions, or "carbon tunnel vision," overshadows other interconnected planetary crises, particularly rapid biodiversity loss, which is integral to Earth's systems, influencing feedback mechanisms in oceans and land capable of reducing or intensifying global warming effects.

- Farming practices such as monoculture and pasture-based agricultural systems, which simplify and standardize ecosystems, diminish the resilience and ability of the biosphere to perform vital ecosystem functions. Animal agriculture is the primary driver of this trend.

The Plant Based Treaty's donut approach

- **The traditional global economy and food system, guided by classical economic principles emphasizing growth and profit, frequently neglect factors such as human welfare, ecological sustainability, and community health.** Alternative models like Doughnut Economics propose fresh approaches for aligning economies with contemporary needs, providing insights that are pertinent to reforming the global food system. Embracing a systems-thinking perspective is essential in transforming the global food system and enhancing the resilience of the biosphere.

- The Plant Based Treaty, inspired by the concept of safe and just Earth system boundaries and now Kate Raworth's Doughnut Economics, underscores the global food system's role in maintaining ecological limits and supporting various stakeholders, including communities, Indigenous peoples, climate migrants, farmers and animals.

- The Plant Based Treaty advocates for the application of holistic systems thinking and the Doughnut Model to foster care for the biosphere, especially within the context of the global food system. It acknowledges the rights of non-human entities and emphasizes our collective coexistence within the shared biosphere.

Chapter 2 | Plant Based Treaty's Vegan Donut Model

A food system within Earth's boundaries

It is widely recognised that a profound transformation of our food system is needed to achieve global food security and nutrition while aligning with climate, biodiversity, and health targets. Food choices, along with, how, and where it is produced, and the extent of waste and losses have profound effects on both human and planetary well-being.

The global food system stands as the world's largest contributor to greenhouse gas emissions and is a leading driver of biodiversity loss, terrestrial ecosystem degradation, excessive freshwater use, and waterway pollution from nitrogen and phosphorus overuse. It exerts a significant influence on Earth's stability and the future of humanity.

The conversion of natural ecosystems into farmlands and pastures, alongside the repercussions of agricultural pollution, severely threatens vital ecosystem functions that underpin agriculture itself. A complete transformation is necessary, involving changes in production, landscape management, and the entire food system. This is because all food system activities, from agriculture, through processing, logistics and retail, to consumption, affect planetary boundaries, and thereby offer multiple opportunities for mitigation. There is a critical need to scientifically define and move back to "the safe operating space" within planetary boundaries for the food system. Therefore, we will assess the impact of the current food system on all nine planetary boundaries.

Climate Change

- Agriculture ranks among the most significant human activities driving the climate crisis, primarily due to land-clearing (slash-and-burn practices and biomass burning), animal farming (enteric fermentation and manure management), and crop production (fertilisers and emissions from land and paddies), that contribute to the global greenhouse effect.

- The global food system is the single largest GHG-emitting sector in the world, responsible for more than a third of the global GHG emissions (CO_2eq). Animal agriculture is responsible for approximately 58 per cent of global food emissions, and the share of plant-based foods is approximately 29 per cent. This means that the emissions from animal-based foods are twice those of plant-based foods, while only providing 18 per cent of calories and 37 per cent of protein compared to plant-based foods.

- Forests and natural ecosystems are crucial carbon sinks, absorbing vast amounts of carbon and playing an integral role in stabilising the Earth's climate. The land-clearing for agriculture is accelerating global warming and rapid biodiversity loss and ecosystem functions that are both vital for climate regulation. A global shift to plant-based food systems could potentially free up 75 per cent of agricultural land, which would both reduce food emissions and opportunity costs.

- Climate change has reduced the extent of global agricultural productivity growth, so there is a danger that hunger will escalate in the absence of immediate climate action.

Land-system Change

- Agricultural ecosystems cover more than 40 per cent of the global land surface, making agricultural land the largest terrestrial biome on the planet, with animal agriculture taking up 83 per cent of it. In the past 300 years, a staggering 55 per cent of all ice-free land has been converted into croplands, pastures and rangelands, leaving only 45 per cent for natural or semi-natural ecosystems.

- Since the 1960s, the rise in global population and consumption has intensified land use. The conversion of forests and other ecosystems to agricultural land has occurred at an average rate of 0.8 per cent per year in the past decades, and approximately 90 per cent of all deforestation is cause by agricultural expansion.

- Halting the expansion of agriculture and protecting intact ecosystems is necessary to halt the loss of biodiversity and to mitigate climate change. Currently, 15 per cent of converted lands need to be restored and reforested to reverse the transgression of the Land-system change boundary. To do so could avoid 60 per cent of expected species extinction and help provide vital ecosystem functions, such as sequestering 30 per cent of the total CO_2 increase in the atmosphere since the Industrial Revolution.

- Moving to a diet without animal products has transformative potential, reducing food's land use by approximately 3.1 billion ha (a 75 per cent reduction), which is crucial if we want to mitigate the climate crisis, restore biosphere integrity, and provide healthy food for all.

Biosphere Integrity

- Both functional integrity and genetic diversity have been in rapid decline since the late 19th century, and this is primarily driven by land- and sea-use change (expansion of agriculture into ecosystems and exploitation of marine ecosystems), direct exploitation of organisms (primarily fishing), climate change, pollution and invasion of non-native species. The current rapid loss could disrupt the services and functions we all depend on.

- The available natural Net Primary Production (NPP) of plants is greatly reduced by human appropriation through harvesting, alteration, and elimination. The loss in 2020, was approximately 30 per cent, which is much more than the 10 per cent scientists say the biosphere can handle for functional integrity.

- The growing pressure on ecosystems to supply us with food, water, land and energy is resulting in biodiversity loss and increased species extinction. The current rate of 100 extinctions per million species per year is much higher than the rate at which new species are evolving, and this is expected to increase tenfold by the end of this century.

- With current negative trends in biodiversity, we are not going to be able to feed the human population. Approximately 70 per cent of the world's crop species rely to some extent on insects for pollination, but with the expansion of intensive monoculture agriculture and heavy reliance on chemicals such as insecticides, herbicides and pesticides, insect populations have drastically declined.

- It's imperative to keep at least half of the ecosystem area intact to conserve 80 per cent of species. Restoring an additional 10 per cent to 15 per cent is needed to avoid 60 per cent of species extinction. Targets to retain at least 10-20 per cent of natural area per km2 have been proposed in agricultural policy, but many agricultural ecosystems fall below this threshold.

Freshwater Change

- Agriculture, particularly crop production for feed and food, is responsible for more than 70 per cent of global freshwater withdrawals. When including evapotranspiration from crops and water returned to rivers and groundwater, agriculture's share of water use is much higher - irrigated agriculture makes up 84 to 90 per cent of all human blue water consumption.

- Land-use change, from intact nature to cropland or land for grazing, decreased evapotranspiration by 5.6 per cent and increased water run-off by 6.8 per cent globally. Approximately 40 per cent of irrigation water extracted from surface water sources negatively impacts environmental flows, and around 20 per cent of irrigation water is currently depleting groundwater reservoirs, highlighting that 50-60 per cent of current global irrigation practices are unsustainable.

- The global food system is the primary driver of the changes in the hydrological cycle and freshwater reserves, leading to increased extremes in precipitation and river flow in northern latitudes and increased drought frequency and severity in the tropics and subtropics.

- A global transition to plant-based dietary patterns could reduce diet-related freshwater use by 21 per cent for blue water and 14 per cent for green water, making diet change a key solution to reverse the transgression of the freshwater change boundary.

Biogeochemical flows

- The global nitrogen and phosphorus cycles are primarily disrupted by agriculture due to high demands and low use-efficiencies in the production of meat, dairy and crops for animal feed and food. Anthropogenic use of nitrogen and phosphorus in the form of fertilisers consumes approximately 86 per cent and 96 per cent of global stocks, respectively, and this has raised many environmental concerns.

- Major losses occur during food production, where more than half of the total extracted phosphorus, and more than two-thirds of anthropogenic nitrogen are lost to the environment through runoff, leaching, erosion and emissions. The excessive use of fertilisers is leading to soil and air pollution, biodiversity loss, terrestrial and aquatic pollution and eutrophication, and increases in emissions that lead to the depletion of the ozone layer.

- The food industry is responsible for approximately 32 per cent of global terrestrial acidification and 78 per cent of eutrophication, more than half of which is caused by the production of animal-based foods. Therefore, it's estimated that a global transition towards plant-based diets would reduce eutrophication and terrestrial acidification by 49 per cent and 50 per cent, respectively.

- Efforts to limit nitrogen and phosphorus pollution are crucial, and this can be achieved through the restoration of natural elements on and around agricultural lands. Better farming practices and improved prediction of fertiliser requirements, timing and placement, along with strategies to recover and recycle losses, can all greatly reduce agriculture's impact on the environment. Minimising food waste throughout the entire production and supply chain is essential to reduce agriculture's need for fertilisation, and can, at the same time, lower emissions, land use and water consumption.

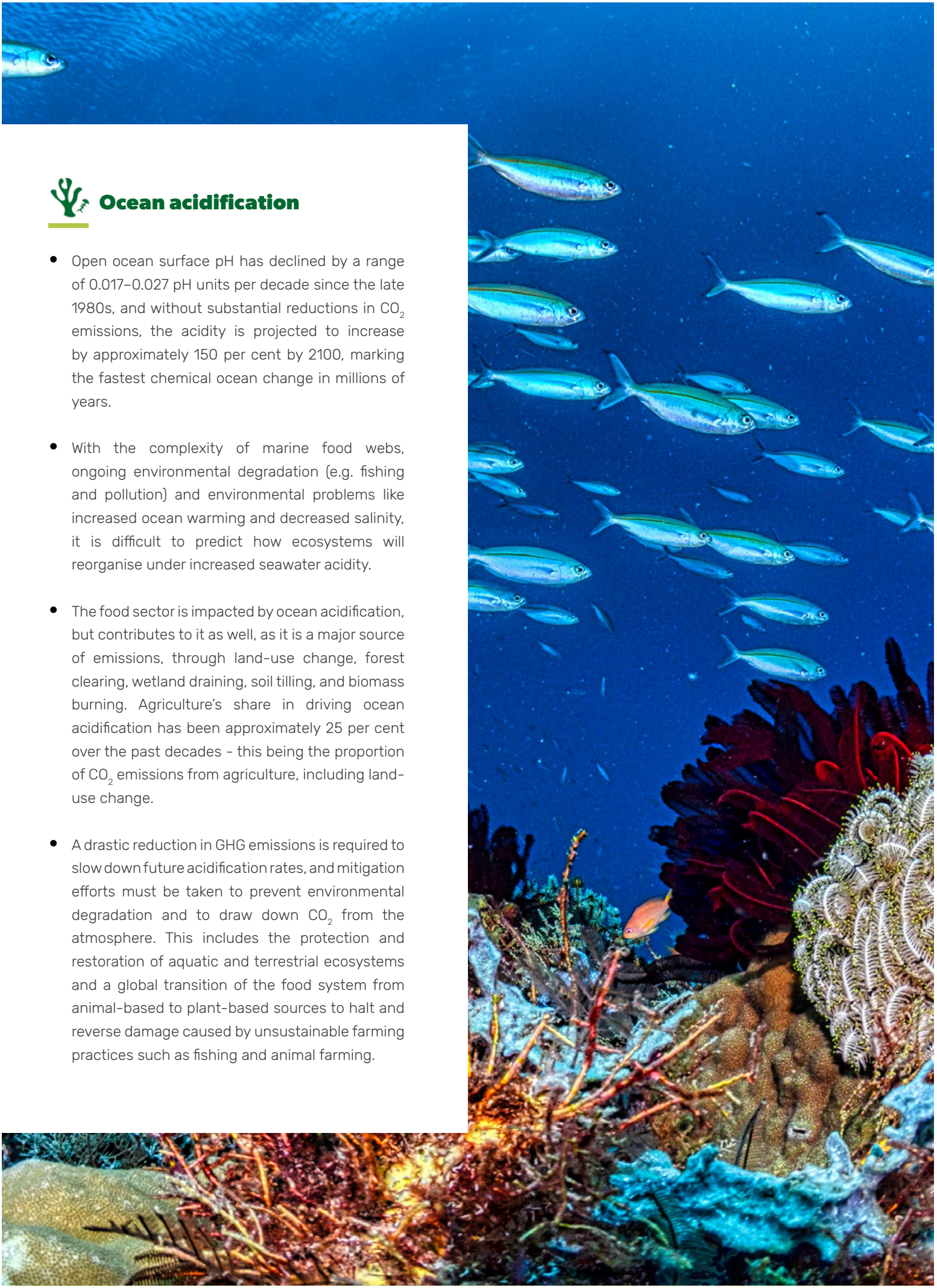
Ocean acidification

- Open ocean surface pH has declined by a range of 0.017–0.027 pH units per decade since the late 1980s, and without substantial reductions in CO_2 emissions, the acidity is projected to increase by approximately 150 per cent by 2100, marking the fastest chemical ocean change in millions of years.

- With the complexity of marine food webs, ongoing environmental degradation (e.g. fishing and pollution) and environmental problems like increased ocean warming and decreased salinity, it is difficult to predict how ecosystems will reorganise under increased seawater acidity.

- The food sector is impacted by ocean acidification, but contributes to it as well, as it is a major source of emissions, through land-use change, forest clearing, wetland draining, soil tilling, and biomass burning. Agriculture's share in driving ocean acidification has been approximately 25 per cent over the past decades - this being the proportion of CO_2 emissions from agriculture, including land-use change.

- A drastic reduction in GHG emissions is required to slow down future acidification rates, and mitigation efforts must be taken to prevent environmental degradation and to draw down CO_2 from the atmosphere. This includes the protection and restoration of aquatic and terrestrial ecosystems and a global transition of the food system from animal-based to plant-based sources to halt and reverse damage caused by unsustainable farming practices such as fishing and animal farming.



Stratospheric ozone depletion

- Recovery of the ozone layer highly depends on the chemical and climate effects of GHGs such as CO_2, CH_4 and N_2O. Increasing concentrations of CO_2 and CH_4 will increase ozone levels beyond the natural level last observed in the 1960s. Increasing N_2O emissions, on the other hand, will cause ozone depletion.

- Agriculture's share in stratospheric ozone depletion is increasing, partly because of increased N_2O gases due to rising global food demand and a reduction in other ozone-depleting substances. Unlike many ozone-depleting substances, N_2O is not regulated and is now the single most important ozone-depleting emission.

- Sustainable agricultural practices, such as optimised fertiliser use on cropland, are highly effective approaches to mitigate anthropogenic N_2O emissions. Limiting these emissions not only supports the recovery of the depleted ozone layer but is also beneficial to the climate system.

Atmospheric aerosol loading

- The high concentration of aerosol pollution and land use changes in the Northern Hemisphere are causing a temperature asymmetry that shifts tropical precipitation southward, reducing global land monsoon precipitation and water availability.

- Agriculture contributes to aerosol loading directly and indirectly through fossil fuel combustion, land clearing (slash-and-burn practices), biomass burning, and the application of fertilisers and chemicals (e.g. pesticides, herbicides, and insecticides) on land.

- Agricultural-related emissions are the dominant source of fine particulate matter in some densely populated areas, and agricultural burning and fertiliser usage contribute approximately 3 per cent and 11 per cent of the global aerosol loading, respectively.

- Implementing bans on open burning of agricultural waste and slash-and-burn practices, and adopting more efficient fertiliser practices could effectively mitigate aerosol loading and would be beneficial for human health, ecosystems and the climate system.

Novel entities

- The impact of novel entities on the Earth system is multifaceted. These substances can pose risks to biosphere integrity, human health, and overall ecological balance. Evidence on the diverse risks of novel entities is growing, yet, there are still gaps in our understanding of their full impact on Earth system functioning, human health, and food security.

- It remains a scientific challenge to determine the extent to which the Earth's system can handle novel entities before an irreversible shift takes place. But with hundreds of thousands of synthetic chemicals now being produced and released into the environment, without first considering the health of the environment and living organisms, this boundary is clearly transgressed.

- From discarded fishing gear to biocides, and from antibiotics to GMOs, there is no doubt that the global food system is responsible for the introduction of novel entities in the environment. The adverse impacts of land and marine animals encountering and ingesting macro or microplastics from fishing gear and food packaging are well documented. Additionally, many toxic chemicals, biocides and antibiotics originate from agriculture and aquaculture, many of which are highly biologically active, and concentrations often exceed thresholds.

Plant Based Treaty's food system boundaries

within the donut's social foundation

Food policy is around 30 years behind energy, and with so little time remaining, we need a paradigm shift and action plans at all levels: individual, institutional, business, city, country and global.

Our report presents the missing action plan that can reduce the 30-year shortfall by incorporating the Plant Based Treaty model into Kate Raworth's Doughnut Economics model which identifies social boundaries needed to meet basic human needs equitably. In our adaptation of Raworth's model, we focus on the food system and widening the lens to incorporate interspecies justice alongside intergenerational and intragenerational justice.

Plant Based Treaty has three core principles known as the 3Rs. Under these 3Rs, there are 40 detailed proposals for a plant-based transition which would reduce greenhouse gases, land use, ocean acidification, freshwater withdrawals and eutrophication and enable us to live safely and equitably within our planetary boundaries.

Figure 1: The Plant Based Treaty Donut, based on the work of Kate Raworth and the Planetary Boundaries frameworks.

1. No land use change

- Agricultural expansion has transformed habitats from complex ecosystems to simplified deserts, fuelled widespread deforestation and is one of the greatest pressures on biodiversity: of the 28,000 species evaluated to be threatened with extinction on the IUCN Red List, agriculture is listed as a threat for 24,000 of them.

- Transitioning to a plant-based food system could not only halt deforestation but would create an opportunity to rewild three quarters of agricultural land.

- The current global diet uses 4.13 billion ha of land and results in significant levels of wasteful land use. For example, 43 per cent of cropland is used to raise farmed animals rather than feed humans directly. If we combine all land required for farming animals for meat – including grazing pastures and land used to grow crops for animal feed – animal agriculture accounts for 83 per cent of global farming land. Yet despite taking up most of the world's agricultural land, animal farming only produces 18 per cent of the world's calories and just 37 per cent of total protein (Poore and Nemecek, 2018). In stark contrast, shifting to plant-based diets would require just 1 billion ha of land, a 75 per cent reduction. Eliminating cow and sheep flesh from our diets would almost halve land use to 2.21 billion ha. By further eliminating dairy, land-use would halve again to 1.1 billion ha, and excluding eggs and fish would reduce land by 0.01 billion ha.

2. Indigenous protection

- Although representing just 5 per cent of the world's population, Indigenous Peoples safeguard 80 per cent of the planet's biodiversity and tragically succumbed to 36 per cent of killings of land defenders. At least 1,390 killings of land defenders have taken place since the adoption of the Paris Agreement on 12 December 2015. In 2022, 10 killings were linked to agribusiness, more than any other sector.

- Worldwide, we need to shift towards plant-based diets through a Plant Based Treaty because the growing demand for meat and dairy globally is driving agricultural expansion into old growth forests and harming land defenders.

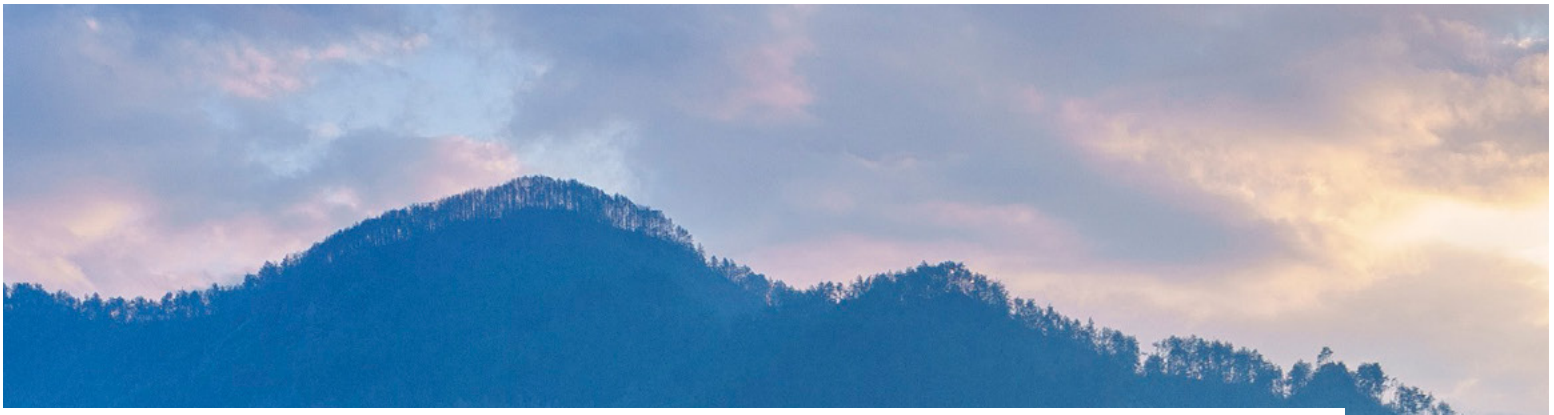
3. Ban live exports

- Transporting live animals is not only cruel and prolongs their suffering, but adds to the growing number of emissions associated with farming animals for food — a climate cost that is rarely factored in. For example, the total emissions of the Australian live export industry was approximately 1.8 million tonnes of CO_2 in 2009 alone, putting the industry among the top 40 emitters in Australia.

- There should be an immediate prohibition on live animal exports, ensuring stricter border control measures and tough penalties for illegal trade.

- Brazil and New Zealand have banned live exports and Luxembourg has banned exports to countries outside the EU. In 2023, the UK government announced a ban on the live exports of cows, sheep, goats, pigs, and horses for fattening or slaughter. Since the legislation was first announced in 2021, no animals have been exported for slaughter, however the legislation will ensure this is on a permanent basis.

Image: WeAnimals / Jo-Anne McArthur



4. Food security

- Many bread baskets are in areas that could be pushed out of the climate niche resulting in widespread food shortages in other parts of the world.
- By 2030, crop yield failures could be 4.5 times higher. By 2050, the likelihood shoots up to 25 times current rates and the world could be facing a rice or wheat failure every other year with the probability of soybean and maize failures even higher. Also by 2050, synchronized failure across all four crops becomes a possibility every 11 years.
- In 2022, global hunger affected between 691 and 783 million people, an increase of 122 million from 2019 pre-pandemic levels.
- Wheat, rice, maize, and soybeans account for almost 60 per cent of the calories grown by farmers. Just four countries harvest 76 per cent of the corn exported, five countries export 77 per cent of the world's rice, four supply 65 per cent of the wheat, and three countries grow 86 per cent of the world's soybeans, of which 75 per cent is used as feed for farmed animals.
- Animal agriculture, an extremely inefficient system to feed the global human population, jeopardises food security and the UN Sustainable Development Goal number two to end world hunger. For every 100 calories fed to animals as cereals, just 17-30 calories enter the human food chain as meat.
- We need a soil treaty to move away from monoculture-based farming which actively degrades soils, to restorative, regenerative, sustainable means of production that actively enhance the local ecosystem.
- Steps that can be taken to enhance, rather than deplete the soil using a diverse mix of crops (intercropping), crop rotation, some types of organic farming, 'no till' approaches, mulching, utilising permaculture and agro-ecological nature-based principles, and using perennial crops.
- Further temperature rises that risk food production must be prevented and we need to diversify crop production and prioritize crops for human consumption, rather than growing crops to feed farmed animals.

5. Education

- Public education is indispensable in catalyzing action among individuals, institutions, and political bodies to drive the necessary changes in food policy. Public education can lead to public pressure urging political leaders to act.

- Concurrently, it is essential for policymakers to spearhead public education as exemplified by New York City Mayor Eric Adams' "Eat a whole lot more plants" initiative. By rolling out public information campaigns on the benefits of plant-based diets, we can safeguard both public health and the planet's ecological thresholds.

- The Peoples' Climate Vote, the largest survey of public opinion on climate chaos ever conducted with 1.2 million respondents, reveals the majority of the public is (1) unaware of the relationship between food and climate change, and (2) unaware of the significant contribution of food emissions. Poore and Nemecek (2019) note, "A vegan diet is probably the single biggest way to reduce your impact on planet Earth, not just greenhouse gases, but global acidification, eutrophication, land use and water use". Despite this, The People's Climate Vote indicated that dietary change towards plant-based eating received the least support, ranking at the bottom of 18 proposed actions, with only 30 per cent of participants in favour.

- Mass media coverage of animal agriculture and its relation to the food system constitutes only 0.05 per cent of climate change-related conversations.

- Addressing climate change requires a deeper value system that recognizes our interconnectedness with the planet and the importance of the biosphere, which includes all living beings and their interrelations.

6. Health

- The largest use of antibiotics globally is for farmed animals. Roughly 73 per cent of medically important antibiotics sold globally in 2017 were for use in farmed animals.

- Antibiotic resistance in humans is promoted by the widespread use of non-therapeutic antibiotics in animals.

- Key solutions to reduce antimicrobial consumption in animal farming is to promote plant-based diets and charge a user fee, paid by veterinary drug users, on sales of antimicrobials for nonhuman use.

- In 2003, the World Health Organization and Food and Agriculture Organization of the United Nations recommended a daily intake of at least 400g of fruits and vegetables per day to prevent diet-related chronic diseases. Fruit and vegetable consumption decreases the risk of cardiovascular disease (CVD). It also showed a probable reduction in type 2 diabetes and cancer.

- The Plant-Based Health Professionals developed a guide that shows the proportions in which foods from different food groups are needed to achieve a balanced and healthy diet from ages over 1 year. "The Plant-Based Eatwell Guide" states people should: "Eat at least 5 portions of a variety of fruits and vegetables a day but aim for more, as eating up to 10 portions a day has additional benefits for health." They quantify a portion as 80g so that would translate into 400-800g of fruits and vegetables (double WHO recommendations).

- A recent systematic review of the UK's food-based dietary guidelines (FBDGs) known as the "Eatwell Guide" found it to be incompatible with our 'planetary boundaries'. If the UK population consumed the diet recommended by the Eatwell Guide, it would not stay within boundaries for greenhouse gas emissions, water use, land use and eutrophication. Rather, incorporating environmental sustainability into FBDGs, such as the Plant-Based Eatwell Guide, may be the first step towards the implementation of population-level policies that have been shown to support shifts away from animal-based foods.

- Switching to a plant-based food system would alleviate the global cascading crises of climate change, land-use change, human health, antibiotic resistance, and zoonotic disease.

7. Transparency and honest labelling

- Transparency and honest labelling offer a huge potential to shift both consumer food choices and manufacturing processes as businesses compete for market share.

- While some businesses, such as Oatly and Quorn, voluntarily display carbon labels on products, government-mandated labelling could further spread these initiatives and create an even playing field.

- Current food labelling can create confusion. For example, food carrying "locally made" labels will appeal to those trying to reduce food miles to reduce greenhouse gas emissions. However, *what* you eat matters far more than how far it's travelled. Because this fact is not widely understood, this type of labelling can be used to greenwash products.

- There isn't a global standard or legal requirement for carbon labelling; however, in 2022, Denmark set aside $1.3 million to develop carbon labelling proposals, becoming the first country to do so.

- Researchers from Durham University added warning labels to meat products to measure how they impacted purchasing choices. Meat that carried a poor health warning with an image of a heart attack reduced choice by 8.8 per cent; a climate change warning featuring an image of deforestation decreased selection by 7.4 per cent; and a pandemic warning featuring an exotic meat image led to a 10 per cent drop in selection.

- 83 per cent of the British population supports the introduction of easy-to-understand eco-labels across various product sectors and businesses to facilitate greener consumer choices.

8. Finance plant-based systems

- The 'hidden costs' of global food and land-use systems is around $12 trillion, compared to a market value of the global food system at $10 trillion.

- According to the World Bank, in 2023 a staggering $23 million per minute is being spent on subsidies worldwide in the animal agriculture and fossil fuel industry, two of the main drivers of the climate crisis.

- A 2023 One Earth study, which analysed major EU and US agricultural policies between 2014 and 2020, found that just £33m of public money was spent on plant-based alternatives (0.1 per cent) compared to £35bn spent on meat and dairy.

- The Plant Based Treaty calls for a major redirection of subsidies to end public funding for projects that promote increased consumption of meat and dairy, and to redirect funding to promote plant-based diets

- Between 2015 and 2020, global meat and dairy companies received over $478 billion in backing from more than 2,500 investment firms, banks, and pension funds headquartered around the globe.

- During the Finance in Common Summit in 2021, the public development banks committed in their "Joint Declaration of All Public Development Banks in the World" to shift their investment strategies and activities to align with, and support the objectives of the Paris Agreement. Despite this commitment, multilateral development banks continue to invest in the global expansion of factory farming.

- Multilateral Development Banks have labelled factory farming investments as "Paris-aligned." Such greenwashing underpins the lack of requirement in their methodology to demonstrate either comprehensive (Scope 1-3) greenhouse gas reporting or reduction targets in their Nationally Determined Contributions. This makes the notion of alignment with the Paris Accords "fundamentally nonsensical," according to Stop Financing Factory Farming coalition, of which Plant Based Treaty is member.

- We need stricter regulations on private financial instruments and multilateral development banks that properly address the safeguarding of the planetary boundaries.

- While it is true that the alternative protein market is growing, meat and dairy corporation executives are on record as saying they see alternative proteins as an addition to, not a subtraction from, their existing production models. "For us, this is about "and" - not "or". We remain firmly committed to our growing traditional meat business and expect to be a market leader in alternative protein," said Noel White, CEO of Tyson.

9. Reforestation and rewilding

- Animal agriculture (both feed production, grazing and farm units) occupies 83 per cent of the world's farmed land, of which three-quarters could be rewilded back to original ecosystems or reforested where appropriate for the wider local environment.
- Earth has lost one-third of its forest cover, with agriculture one of the primary drivers of deforestation and habitat loss.
- To restore habitats, we first need a dietary shift away from land and water intensive meat and dairy products. Without a food system transformation, we cannot reverse ecologically degraded areas and rewild others.
- Rewilding, reforestation and active ecosystem restoration offer significant opportunities for repairing and enhancing key ecosystem functions, such as sequestering carbon, temperature regulation, water management, and increased food security.
- Protecting at least half of our terrestrial realm, in each of our 782 ecoregions, is necessary to halt further extinction loss. Retaining intact regions would require restoration of 23.9 M km². Additionally, restoring 15 per cent of converted lands in priority areas could avoid 60 per cent of expected extinctions and help provide vital ecosystem functions.

10. Greening cities

- We need 20-25 per cent of every 1 km² of urban environments to be covered by greenery, since this is the distance pollinating and beneficial insects travel. The coverage and quality of greenery needed varies depending on factors like landscape type, climate, and topography. The amount of greenery required may even reach as high as 50 per cent for landscapes that are vulnerable to natural hazards, like steep slopes or easily erodible soils.
- Increasing tree level cover from the European average of 14.9 per cent to 30 per cent could lower city temperatures by 0.4°C and reduce heat-related deaths by as much as 39.5 per cent.
- Cities need to prioritize community gardens. For example, in the UK around 1 per cent of urban space is dedicated to allotments for food production, however, if all urban green spaces were used to grow food, the UK's output of fruit and vegetable production would increase by 800 per cent. Currently, there are more than 157,820 outstanding applications to local councils for allotments, with waiting lists of up to 15 years.
- Rooftop farming can help meet the growing food demand, enhance air quality, decrease carbon emissions, and reduce the cost of managing stormwater, benefiting both the environment and society.

11. Food justice

- Access to healthy nutritious food and a food system that doesn't harm and exploit others should be a basic human right. The Plant Based Treaty states: "Enhance food justice by providing access to healthy food for all, especially low-income communities of colour."

- Globally, poor diets are the main contributor to the global burden of disease, accounting for 20 per cent of premature disease-mediated mortality worldwide. Approximately 3 billion people cannot afford a healthy diet, and more than 3 billion people suffer one or more manifestations of poor nutrition.

- 60 per cent of all child labourers in the age group 5-17 years work in agriculture, including farming, fishing, aquaculture, forestry, and animal farming. This amounts to over 98 million children.

- To address food justice we need to implement food distribution and subsidy systems ensuring healthy food access, especially targeting marginalised communities. Community gardens, providing families with healthy food, redistributing food, and reducing food waste, should be prioritised by local and regional governments.

- Transitioning from intensive animal agriculture to more sustainable and plant-based food systems is an important part of addressing critical issues related to workers' rights and well-being. The production of plant-based food takes place in working environments that are generally safer, less stressful, and more conducive to overall well-being.

12. Land equity

- Land equity is related to equitable distribution of land and whether key ecosystems are considered part of the global commons. Currently, there is a high concentration of ownership in farms, distorting what food is produced, which is based more on profit than meeting human needs and environmental protection. 70 per cent of all farmland is operated by just 1 per cent of the world's farms.

- Land inequality has exacerbated the climate crisis and given rise to conflict with resources becoming increasingly scarce or unreliable. It also poses a grave risk to water shortages and food insecurity. Land should be more equally and equitably distributed and placed in community hands so it can be repurposed for reforestation, reclaiming Indigenous rights, green spaces, and edible gardens and allotments, as well as increasing biodiversity and food security.

- Pension funds are major holders of land, often preferring to invest in "flex crops" (commodities such as soy and corn that can be switched between different markets) thus promoting animal feed because it is easy to adjust what they produce based on the profitability of different commodities and the number of markets they can be sold to.

- Instead, if we are to look at food production from a health and planetary perspective we would emphasise the importance of plant-based whole foods like legumes, which not only hold great nutritional benefits, but act as soil improvers.

Chapter 3 | Why cities need a plant-based food strategy

Designing sustainable food systems through a Plant Based Treaty

- The Plant Based Treaty calls for cities to declare a climate emergency, calculate consumption-based greenhouse gas emissions and incorporate plant-based food strategies into Climate Action Plans and other priority areas.

- Cities must find ways to reduce their land use, water, and greenhouse gas emissions – cities already consume around 70 per cent of global emissions. Addressing dietary shifts in cities becomes key, providing a lever to mitigate environmental impacts and bolster sustainability within our global food system so that we can live within our planetary boundaries.

- The projected expansion of animal agriculture by 2050 has dire environmental consequences such as radical land-use change, exacerbated greenhouse gas emissions at odds with the Paris Agreement, increased water and air pollution, and intensified strain on finite freshwater resources. The consumption of animal products are also projected to rise: chickens and other birds (66 per cent), eggs (58.6 per cent), and cow and buffalo products (58.9 per cent).

Cities call for a Plant Based Treaty

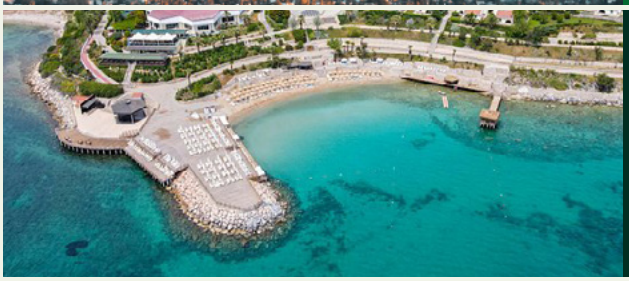
- From Edinburgh in Scotland, and Didim in Turkey to Los Angeles in the United States, a consortium of 23 cities has notably called for the negotiation of a global Plant Based Treaty as a companion to the Paris Agreement.

- Other initiatives, such as the C40 Good Food Declaration, are implementing strategic food policies aimed at expanding the accessibility and consumption of plant-based foods.

- Change often starts at the city level, where leaders can often act faster than at the national level, as cities tend to be more responsive to public pressure. Networks of cities working together nationally and internationally can influence national governments and drive change at the global level.

Edinburgh | Scotland

Los Angeles | USA



Didim | Turkey

Cities taking leadership

- Amsterdam has acknowledged that meat, dairy, and fish consumption have many environmentally harmful factors and the switch to plant proteins reduces the environmental burden of food production. The city council plans to accelerate a plant-based food and beverage transition by supporting public organizations with guidance regarding tenders, subsidies, and contracting in their purchasing policies.

- Edinburgh estimated city-wide consumption-based greenhouse gas emissions and found food and diet accounted for 23 per cent of their consumption-based footprint with around half of these emissions coming from meat consumption. In January 2023, the city council voted to endorse the Plant Based Treaty and committed to a food sustainability strategy which is due for publication in January 2024.

- New York City Health and Hospitals have made plant-based meals the default option for all inpatients in their network of 11 public hospitals. 60 per cent of eligible patients are sticking with the plant-based option. Meat Free Mondays and Plant Powered Fridays have been introduced in schools benefiting the lives of close to one million children in the NYC public school system.

- Haarlem, Bloemendaal and Utrecht in the Netherlands have banned meat adverts in public spaces due to their contribution to the climate crisis.

- Didim, Turkey, opened a fully plant-based kiosk on one of the town's busiest streets to increase accessibility to plant-based food. Workshops at seven cafes and two hotels in Didim, helped local businesses introduce vegan dishes on their menus, and the council allocated land to grow food.

Conclusion | Adopt the Plant Based Treaty to get us back into the safe operating space

> **"The way that we produce food in the world is the single largest reason that we have transgressed planetary boundaries. It is the single largest threat to the stability of the planet and our life support systems, from freshwater, pollinators, and soil health, to rainfall generation, and quality of air and water. Food production is putting our future at risk".** (Johan Rockström and Owen Gaffney, Breaking Boundaries, 2021, 131).

There has been a dramatic rise in global per capita meat consumption since the 1950s as part of the "great acceleration" discussed in Rockström and Gaffney's Breaking Boundaries. Between 1980 and 2023, meat production has grown by about 50 per cent in this short timeframe. The result of this increase has greatly impacted the planetary boundaries in the outer rim of Kate Raworths's doughnut economics framework, specifically climate change, land-use change, biodiversity, phosphorus and nitrogen, freshwater use, and ocean acidification, among others. It has also transgressed the social boundaries in the inner rim of our vegan donut economics framework, such

as R1, Relinquish: land conversion threatening forests, soils, waterways and land defenders, especially Indigenous Peoples; and growing live exports exacerbating animal exploitation; R2, Redirect: food insecurity, hunger and undernourishment; climate illiteracy and an awareness gap; public health crises, including zoonotic diseases, antibiotic resistance, heart disease, type 2 diabetes and some cancers; perverse subsidies and investments financing meat dairy and egg expansion; and R3, Restore: food injustice resulting in unsafe work and food deserts; land inequity and the concentration of ownership leading to conflicts and wars.

These worrying trends shows the pressing need to introduce policy measures and implement the Plant Based Treaty's 3R in areas such as: R1, Relinquish: no land use change, Indigenous protection and ending live exports; R2, Redirect: strengthening food security; funding for far-reaching public education campaigns; improved health; introducing food transparency and eco and carbon labelling; redirecting subsidies to veganic agriculture; introducing meat taxes, a ban on meat advertising; R3, Restore: reforestation and rewilding; creating greener cities with the incorporation of plant-based food strategies into existing Climate Action Plans, and interlinking programs that address biodiversity, food poverty, and community health; enhancing food justice; and addressing the challenges of equitable land distribution.

We need local, national, and international cooperation to reduce food impacts with plant-based diets. We propose bold and urgent national and city action plans for shifting towards plant-based food before COP30. Our *Safe and Just* report delivers a big idea with a bold action plan to transition to a plant-based food system with a globally and locally implemented treaty. The Plant Based Treaty sets forth an Earthshot trail for transitioning to a plant-based food system and rewilding to lead us to a green 'safe and just' Earth.

Eat plants, plant trees, negotiate a global and local Plant Based Treaty!

CHAPTER ONE

Overview: The big picture

1.1 The dire state of our climate

As we begin to leave stable conditions of the Holocene epoch, we find ourselves at a pivotal moment facing an unpredictable climatic future. The Holocene, which spanned over the past ~12,000 years, marked a period where human species witnessed the emergence of modern civilisations, all adapted to a specific climate niche. This climate niche not only facilitated the rise of civilizations but also played a foundational role in shaping our food systems, ensuring reliable food production attuned to the prevailing conditions. However, rapid anthropogenic changes are pushing us beyond this equilibrium. The shifting in our climate niche affects not just humans, but also other animals, ecosystems and the reliability and predictability of food systems that have evolved alongside it. Understanding the complex interactions of Earth Systems, particularly regarding the link between the climate niche and food production, is vital. Together, these systems shape our biosphere and determine our means of sustenance. In this section, we will delve into the departure from the Holocene, explore the potential trajectories for our future climate niche, and unravel the complexities of Earth's climatic systems and their profound impact on our global food systems.

1.1.1 Leaving the Holocene state

The Earth is estimated to be approximately 4.54 billion years old and throughout this extensive period, has experienced a series of complex changes, understood through the framework of the geological time scale. Recorded instances of permanent human settlements and communities allow us to trace the inception of human civilization to a notably recent period, about 11,700 years ago, a development closely tied to climatic stabilisation allowing the advent of agriculture which ensured a consistent supply of food. This pivotal climate shift denotes the onset of the 'Holocene' epoch, the current phase of the geological time scale that we are in. This phase of stable climate conditions which facilitated human advancement is illustrated in Figure 1 (Osmon et al., 2021). The graph illustrates the variations in Global Mean Surface Temperature Change (ΔGMST) over the past 24,000 years, highlighting its stabilisation and the onset of the interglacial period.

During the Holocene epoch, climatic conditions stabilised giving way to a period in which humanity flourished in unprecedented ways when compared to its previous history. This realisation is important because in the incredibly brief space of just 10 years, we face a very real risk of falling into unstable conditions due to human-induced pressures on the climate.

We've already reached 1.2°C of warming and are rapidly using up our 1.5°C carbon budget. This puts us at a significant risk of surpassing thresholds that thrust the Earth systems into instability, which historically prevented humanity from thriving, but this time it will be on the 'hot' side. Throughout the Holocene, it is noteworthy that the planet's global average temperature has fluctuated within a range of merely +0.5°C to -0.5°C. However, in recent research examining the Earth system's future pathways, Steffen et al. (2018) caution that activating a series of cascading 'tipping elements' could potentially propel the Earth climate systems and human society beyond the secure confines of the Holocene stability. Today, we describe this as climate breakdown, a term that encapsulates the rapid and unprecedented alteration of global climatic patterns due to human activities. It is no longer a distant possibility or a theoretical conjecture—it is a living reality.

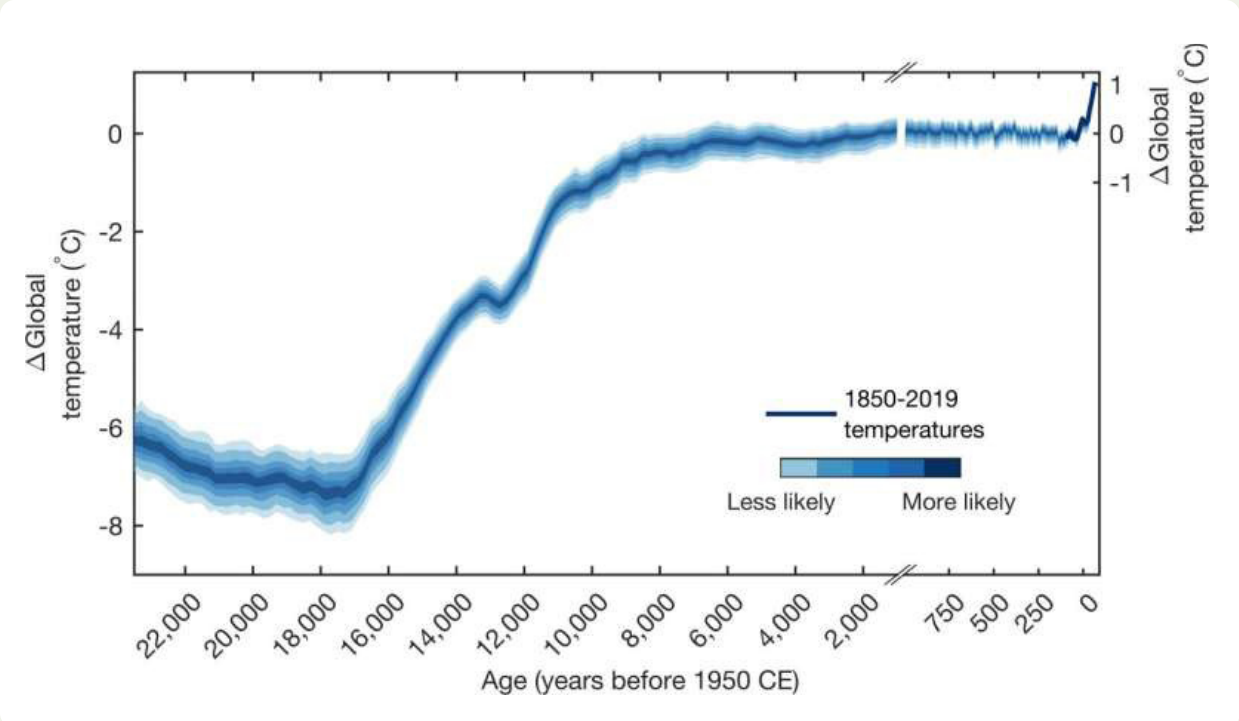


Figure 1: Global mean surface temperature change (ΔGMST) over the last 24,000 years, highlighting a clear stabilisation of the climate. Shown at top are corresponding spatial surface temperature anomalies (ΔSAT) for intervals discussed in the main text. The estimated last deglacial and interglacial onset timings are shown as dark and light histograms at bottom (Osmon et al. 2021).

1.1.2 Earth systems and the state of our climate

In a recent press conference, UN Secretary-General, António Guterres, voiced deep concerns about the intensifying climate emergency, stating that we've transitioned from global warming to a more perilous phase he described as "global boiling" (Niranjan, 2023). The delicate balance that has sustained life on our planet is reaching a critical threshold, teetering dangerously close to a point of no return. The combined effects of our rampant consumption, continuous emissions, and neglect of the environment have created a pressing need for intervention. Presently, our world is about 1.2°C hotter than it was in the late 1800s.

This year, we witnessed global air temperatures and global ocean surface temperatures set new all-time records in July 2023 followed by the second hottest month in August 2023 (Copernicus, 2023a). The World Meteorological Organisation (WMO), the Copernicus Climate Change Service (C3S), the National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA) reported that the average global surface air temperature for that month was the warmest ever documented, registering approximately 1.5°C above the baseline average from 1850-1900, the benchmark set by the Paris Agreement. This was soon succeeded by the warmest September ever recorded, with temperatures rising by about 1.75°C compared to the pre-industrial average temperature. It was also around 0.93°C above the 1991-2020 benchmark, a standard often referenced in climate-sensitive sectors such as agriculture (Copernicus, 2023b). The WMO indicates that 2023 is to become the warmest year we've seen. The speed and severity of climate change consequences seem to outpace original scientific projections. These rapid shifts have the potential to profoundly affect ecosystems, human societies, and the intrinsic balance of Earth's functions.

While the immediate effects of rising temperatures are substantial, the repercussions extend far beyond, leading to even more profound and serious consequences at a planetary level. The Stockholm Resilience Centre identifies several large biophysical systems that regulate the state of the climate on Earth, also referred to as Climate Tipping Elements (CTEs). As their name implies, these systems possess tipping points, which are defined as "critical thresholds where even minor disturbances can qualitatively transform the developmental trajectory of a system." This definition implies that triggering these tipping points can result in substantial and policy-relevant consequences, which are likely to include unprecedented sea-level rise due to collapsing ice sheets, the decline of biodiverse ecosystems like rich rainforests and warm-water corals, as well as the release of unprecedented amounts of Carbon Dioxide (CO_2) and Methane (CH_4) into the atmosphere due to thawing permafrost.

In a study conducted by Armstrong McKay et al. (2022), they identified 16 tipping elements that regulate Earth's climate. Each tipping element has multiple stable states (e.g. frozen or liquified ice sheets), and at a specific temperature threshold, they change from self-cooling to self-warming or from carbon sink to carbon emitter. Nine of them are considered global tipping elements and they play a critical role in shaping the climate and the overall functioning of our planet. These include Arctic summer sea ice, the Greenland ice sheet (GrIS), the West Antarctic ice sheet (WAIS), Atlantic Meridional Overturning Circulation (now AMOC, previously THC), the El Niño Southern Oscillation, the Indian Summer monsoon, the Sahara/Sahel and West African Monsoon, the Amazon Rainforest (AMAZ), and boreal forest. Additionally, they identified seven regional impact tipping elements that, while not as globally impactful, still significantly influence

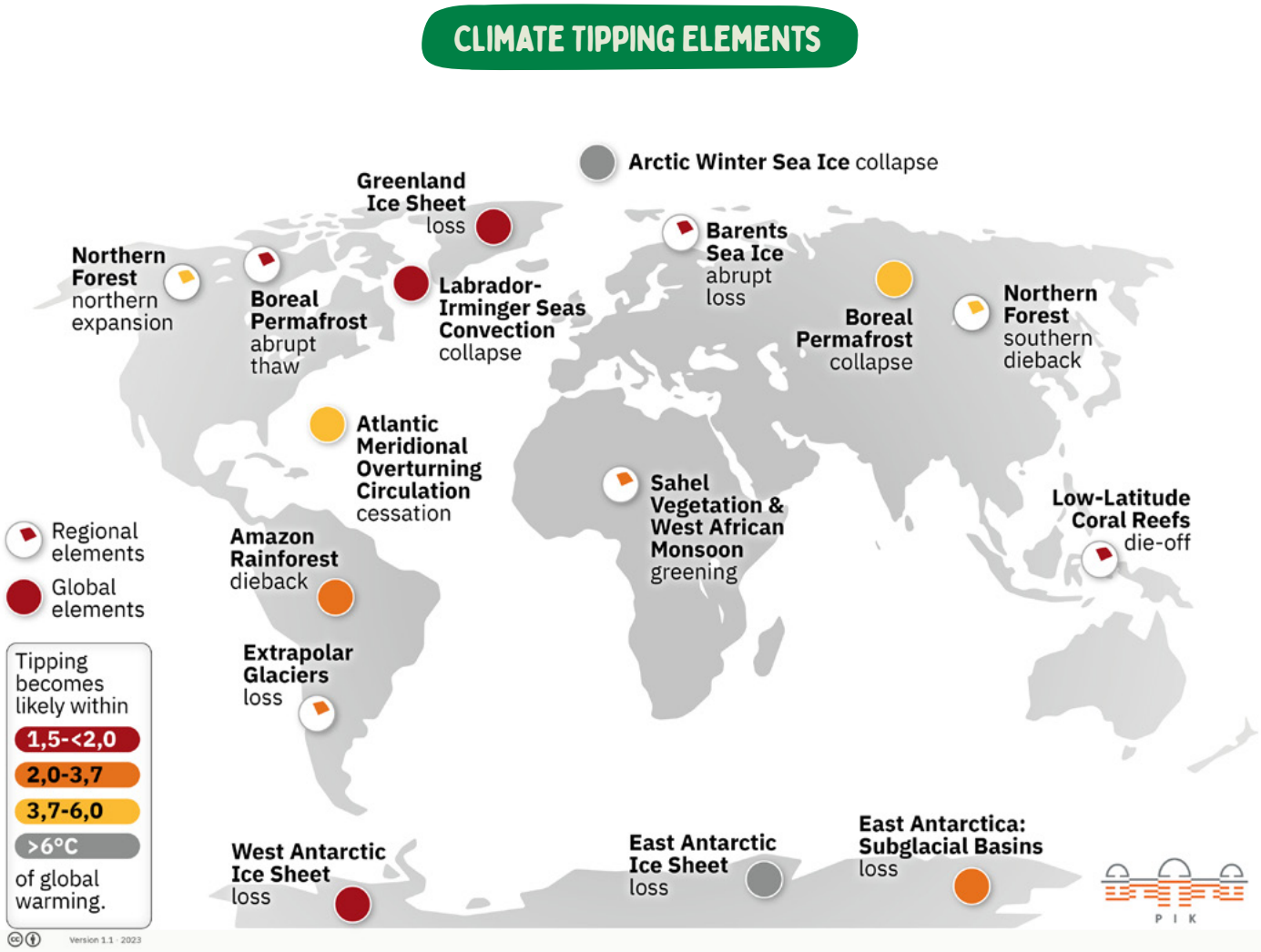


Figure 2: The geographical distribution of global and regional tipping elements, color-coded according to the best estimate for their temperature thresholds, beyond which the element would likely be 'tipped'. Figure designed at PIK (under cc-by licence), based on Armstrong McKay et al., Science (2022).

regional ecosystems and human well-being. When these climate tipping elements are surpassed, they shift from supporting human well-being to actively undermining it, and this has profound implications for the formulation of climate policies.

There is a substantial risk of surpassing tipping points, especially those related to major ice sheets (Feldmann et al., 2015, Waibel et al., 2018, Rignot et al. 2014, Joughin et al., 2014), at temperatures of 1.5°C of warming. Several other climate tipping elements have temperature thresholds in the same temperature range. The potential collapse of coral reefs would result in the loss of our planet's most biodiverse marine ecosystems, which, in turn, would have profound repercussions on the broader marine food chain and the cycling of nutrients and carbon in the oceans (Hughes et al., 2017). The IPCC has forecast a staggering 70-90 per cent loss of tropical and subtropical coral reefs at 1.5°C, with near-total loss occurring by the time temperatures reach 2°C (IPCC, 2022). Even the Amazon rainforest biome, which holds approximately 150 to 200 gigatons of carbon (GtC), has experienced the loss of approximately 17 per cent of its area due to deforestation since the 1970s. Deforestation rates have been on the rise since 2019, and future projections suggest a further decline in rainfall and an expected lengthening of the dry season. This combined loss and changing climate conditions could set in motion a self-reinforcing process of drying, potentially pushing this region into a degraded or savanna-like state. While its estimated temperature threshold is typically thought to fall within the range of 2 - 4°C, this estimation does not take into consideration the interplay between tipping elements and human pressures on these systems, which has the potential to lower this threshold.

We cannot currently dismiss the possibility that tipping points for the West Antarctic Ice Sheet (WAIS) and Greenland Ice Sheet (GrIS) have already been crossed. Additionally, several other climate tipping elements have minimum threshold values falling within the range of 1.1 to 1.5°C. This suggests that the Earth may have already moved beyond a safe climate state once global warming exceeds 1°C.

There is a significant likelihood of surpassing multiple tipping points if temperatures rise above 1.5°C. This scientific evidence underscores the significance of the 1.5°C warming threshold, which was established as a benchmark by the Paris Agreement. It highlights that this threshold represents a physical limit or boundary for stable Earth systems and not a political target to negotiate in political discussions. As Johan Rockström aptly puts it, ***"1.5°C is a physical limit, not a political target"***. Consequently, current policies that are leading to global warming in the range of 2 - 3°C are deemed unsafe, as they are likely to trigger multiple climate tipping elements.

A particular characteristic trait of a climate tipping element is that it involves self-perpetuating mechanisms, also known as feedback loops, that could give rise to a 'runaway' scenario. The latest and most comprehensive research on climate feedback mechanisms identifies a grand total of 41 biogeophysical feedback mechanisms (20 physical and 21 biological feedback mechanisms), some of which are linked to key tipping elements (Ripple et al., 2023). These include the effects of sea ice albedo, the stability of ice sheets, alterations in ocean circulation patterns, forest dieback, the thawing of permafrost, and the expansion of vegetation in the Sahara/Sahel region. **In a dire scenario, the interplay of feedback mechanisms could lead to the surpassing of tipping points within the climate tipping elements (Steffan et al., 2018, Wunderling et al., 2021), resulting in what is known as a 'climate cascade'.** In such cascades, the cumulative impact of reinforcing feedbacks becomes greater than the sum of their individual effects under current conditions, and can result in rapid and often unpredictable and possibly irreversible changes in the Earth's climate systems.

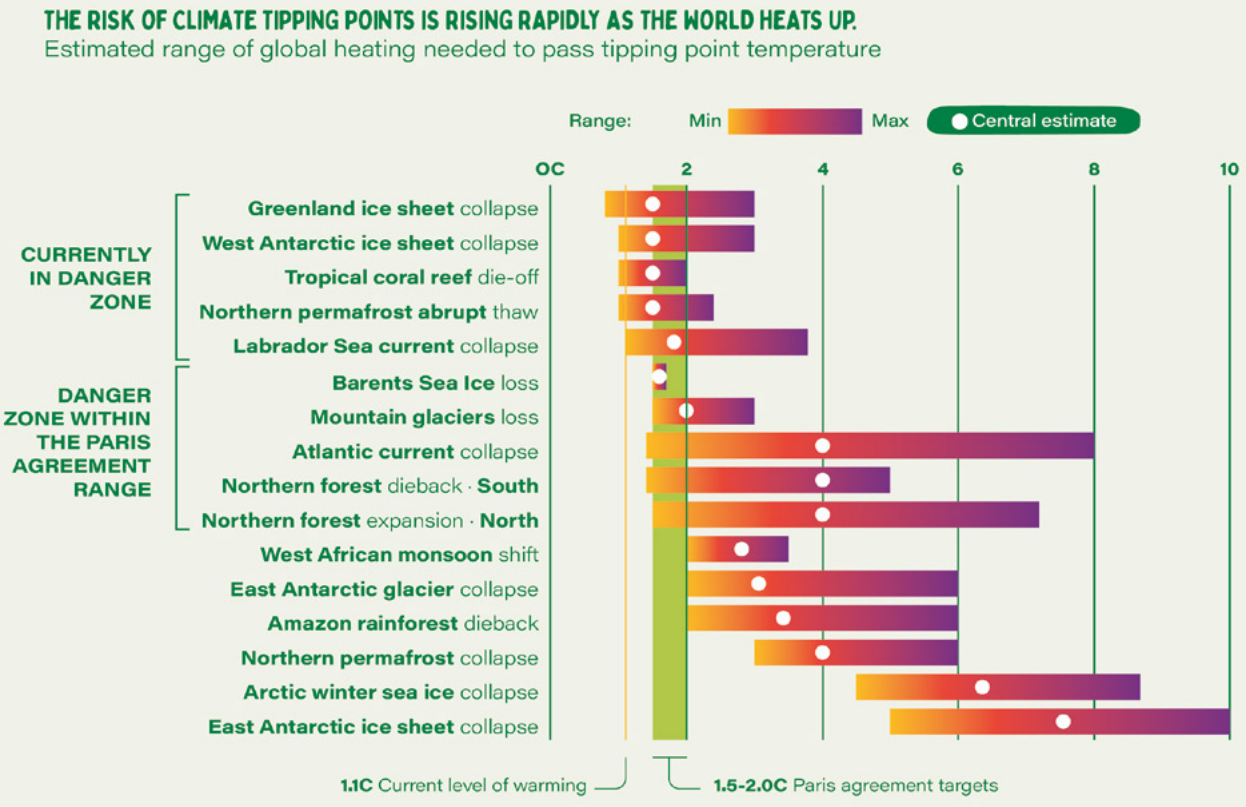


Figure 3: Global warming threshold estimates for global core and regional impact climate tipping elements. These estimates emphasise the five elements already at risk and an additional five in the danger zone within the range stipulated by the Paris Agreement. Figure designed at PIK (under cc-by licence), based on (Armstrong McKay et al. 2022).

Recent publications from the World Meteorological Organization (WMO, 2023) suggest 2023 is on track to be the warmest year yet, and combined with a strengthening El Niño event, current atmospheric GHG levels will boost global warming to record levels, making it very likely that we will temporarily breach the 1.5°C threshold for at least one year in the next five years.

Beyond that threshold, scientists predict that the impacts of climate change will rapidly escalate. There is even the risk that we permanently shift away from the Earth's current climate, which would have a catastrophic impact on people and ecosystems due to passing temperature thresholds of core climate tipping elements. **We stand at a pivotal moment in this decade, and the choices we make will reverberate for thousands of years.** Failure to prioritise mitigation strategies aimed at capping global warming at 1.5°C could result in climate changes that are permanent within the scope of human lifetimes. This would disrupt the current equilibrium of our natural systems, rendering them unable to sustain environments suitable for both non-human and human habitats.

1.1.3 The future of the climate niche

The impacts of climate change are not uniformly felt across the globe, and this trend is likely to continue. Different regions will witness varying rates of temperature rise, with terrestrial areas warming more quickly than the oceans, particularly in high latitude zones such as the Arctic and Antarctic.

For instance, the Greenland ice sheet is warming at a rate four times faster than the global average. While every part of the world is impacted by climate change, the consequences differ vastly. Some regions may grapple with prolonged droughts, others may face frequent and severe storms and floods, while some might endure both. The progression of global warming is nonlinear, implying that each incremental increase in temperature will inflict more harm than the last. A recent study by Lenton et al. (2023), shed light on the human impact of global warming, pinpointing the areas most affected by climate change and identifying the populations most at risk. Through their findings, the authors strongly advocate for immediate and aggressive policies to prevent warming above 1.5°C.

In this context, we present these impacts in terms of the number of humans who no longer reside within the 'climate niche.' This niche is defined as the historically stable distribution of relative human population density in relation to climatic conditions, such as the mean annual temperatures (MAT), and mean annual precipitation. In general, humans and their systems reside in areas with a MAT spread across 13°C and 25°C. These specific temperature ranges not only serve as the primary habitat for most crop cultivation but also play a pivotal role in climatic conditions for non-agricultural economic productivity across different countries (Xu et al., 2020). Outside of these temperature ranges, the environment becomes less favourable to human habitation and sustenance. Extreme heat, with a mean annual temperature (MAT) of 29°C or above, has been associated with various negative consequences.

These include reduced work efficiency, hindered cognitive and learning abilities, adverse pregnancy outcomes, decreased crop productivity, higher mortality rates, increased conflicts, and the spread of infectious diseases. Additionally, such high temperatures boost the growth of disease carriers, encourage the spread of crop "pests" and diseases, decrease the potential yield of crops, and limit access to irrigation and drinking water. A MAT of 29°C+ means prolonged exposure to temperatures that can be intolerable for humans and many mammals, especially for those living near the equator without adaptive resources. The repercussions of this scenario are extensive, leading to health problems, infrastructure, and property damages like melting roads, power failures, and water scarcity. This situation may also drive people to become climate migrants, relocating to more livable regions, causing widespread social, economic, and political instability (IPCC, 2022).

MORE THAN 600 MILLION PEOPLE HAVE ALREADY BEEN DISPLACED FROM THEIR CLIMATE NICHE

(Lenton et al. 2023)

Recent research indicates that climate change has already displaced approximately 9 per cent of the global population (> 600 million) from this temperature niche (Lenton et al., 2023). **If current end-of-century (2080-2100) policies persist and result in global warming of approximately 2.7°C, projections suggest that as much as one-third of the world's population (ranging from 22 per cent to 39 per cent) could find themselves living outside this temperature niche. For every reduction of 0.3°C in end-of-century warming, there is a corresponding 4.3 per cent decrease in exposure to extreme heat, affecting ~410 million people.**

It is also important to consider the possibility that climate policies may not be implemented, and the world could revert to fossil-fuel-driven development (as per the SSP5-8.5 scenario), resulting in an estimated global warming of approximately 4.4°C. Under this scenario, more than 55 per cent ± 7 per cent (5.3 ± 0.7 billion) people, when accounting for demographic changes, could be displaced from the human climate niche. Measuring the potential human toll and the possibility of climate change causing a global societal collapse or, even more direly, human extinction, remains a subject that has been dangerously neglected. Despite the lack of in-depth exploration in this area, there are substantial grounds to consider that climate change might indeed be capable of initiating a system-wide failure (Kemp et al., 2022). Therefore, it is imperative to shift from the anticipated 2.7°C global warming trajectory under current policies to achieve the 1.5 - 2.0°C target outlined in the Paris Agreement.

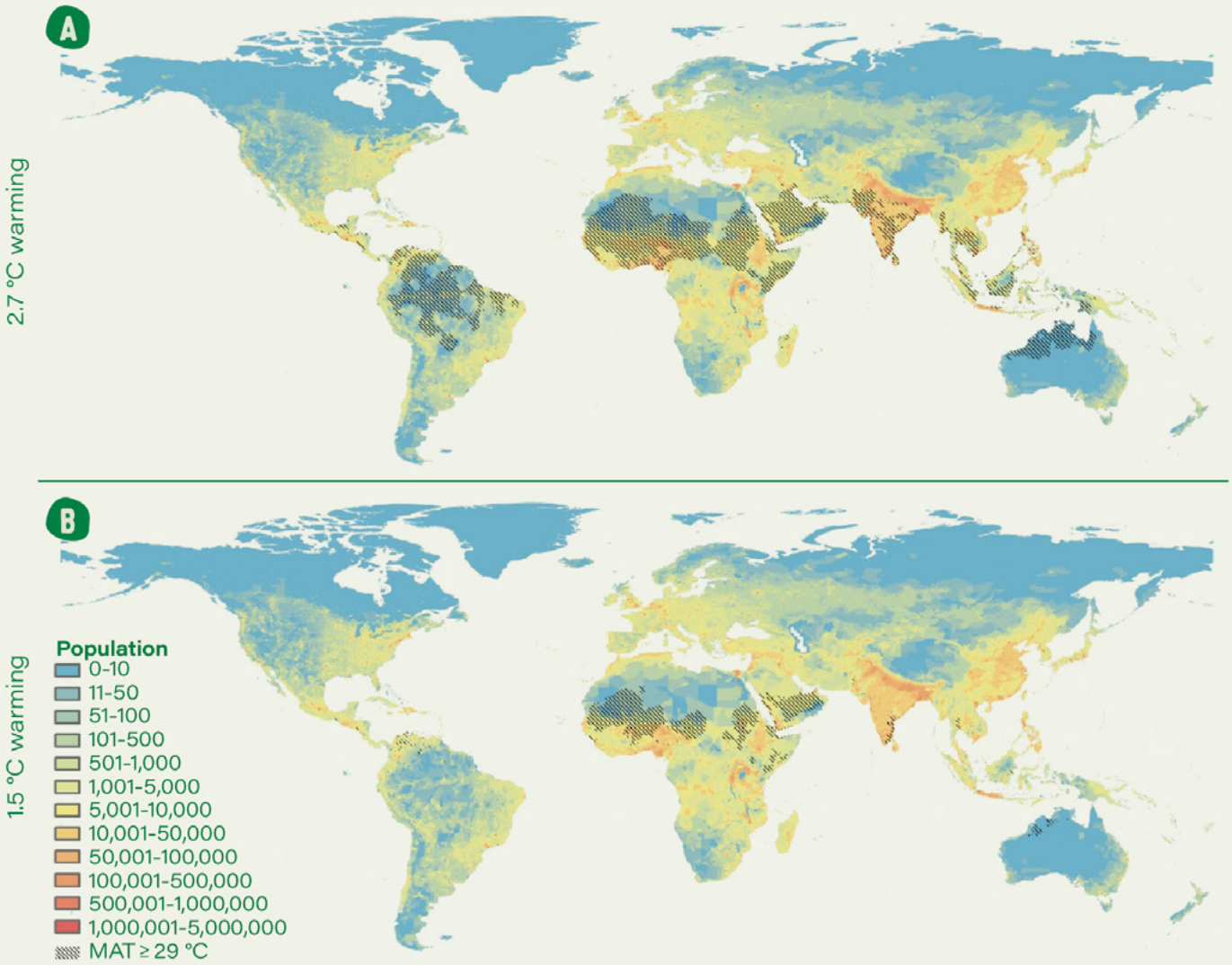


Figure 4: Regions exposed to unprecedented heat (MAT ≥29 °C) overlaid on population density (number in a ~100 km2 grid cell) for a world of 9.5 billion (SSP2, 2070) under 2.7 °C global warming (a) and 1.5 °C global warming (b) (Lenton et al. 2023). Figure adapted under Creative Commons License from http://creativecommons.org/licenses/by/4.0/

Considering that domesticated crops have an agriculture climate niche not too different to humans, an increase in the Mean Average Temperature (MAT) poses risks by making more regions climatically unsuitable for stable food production. The anticipated population growth already strains our global food systems to provide sufficient nutritious food. This challenge is exacerbated by the expanding regions exiting the climate niche suitable for agriculture. **Essentially, we face the dual challenge of feeding an increasing population while experiencing diminishing favourable conditions for food production.** Depending on the UN Fertility rate scenario referenced, population projections vary: 8.5 billion is anticipated between 2050-2070 under the low to medium fertility rate, 9.5 billion between 2070-2080 based on the medium fertility rate, and a rise to 12.6 billion by 2100, which exceeds the medium but stays beneath the high fertility estimates. These three scenarios are used within the five Shared Socio-economic Pathways (SSPs) to formulate climate projections. More worryingly, a recent publication from Ripple et al. (2023) highlights that in 2022, 735 million people faced chronic hunger, indicating an increase of 122 million since 2019. Addressing global hunger in our current climate remains a daunting challenge, often approached with solutions centred around increased production. Yet, the continuous rise in Mean Average Temperature pushes us further outside the agricultural climate niche, intensifying the problem. This is especially evident in already warm regions, as observed in countries like India, Nigeria, Indonesia, Philippines, Pakistan, Qatar, Aruba, and many more (Lenton et al., 2023).

1.2 Food and agriculture: sidelined and ignored

As the global community grapples with the ramifications of a rapidly depleting carbon budget and the urgent calls to action within this decisive decade, the elephant - or rather, the 'cow in the room' - remains largely ignored. The world's food and agriculture system, deeply embedded into our biosphere, stands as one of the most environmentally damaging industries. It's not just about reducing harm; our global food system must transition into being a carbon sink in the next two decades if we are to address the multifaceted challenges of our time. Alarmingly, not only are comprehensive solutions for this industry being sidelined but the very conversation around its environmental impact is rarely spoken about. This section aims to shed light on this oversight, emphasising the critical role of food and agriculture in charting a sustainable future.

1.2.1 The remaining budget

The global scientific community, in its efforts to understand and project the potential impacts of climate change, has developed standardised scenarios and pathways to model different future conditions. Among these, the Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs) are particularly important. The RCPs are used to describe various scenarios of greenhouse gas levels and radiative forcings that might arise in the future. Five distinct pathways with forcings of 1.9, 2.6, 4.5, 7.0 and 8.5 W/m2 are highlighted in the recent IPCC AR6 assessment. RCP1.9 envisions a world where we adhere to a 1.5°C temperature target. RCP2.6 is a stringent pathway where we temporarily overshoot 1.5°C of warming. RCP4.5 is the intermediate scenario that roughly aligns with current policies, and would likely lead to 2.7°C of warming at the end of the century. RCP7.0 is the baseline outcome if we continue with current emission levels. RCP8.5 is the high-emission scenario in which emissions continue to rise throughout the 21st century. These pathways delineate various climate change scenarios, each of which is deemed plausible based on the quantity of greenhouse gases emitted in the years ahead.

The SSPs, provide narratives on possible global trajectories, emphasising socioeconomic elements such as population growth, economic development, education, urbanisation, and technological advancements. Each SSP outlines a unique trajectory for the world and describes the challenges posed by climate mitigation and adaptation. SSP1, titled "Sustainability – Taking the Green Road," envisions a world geared towards sustainability and prioritises well-being. SSP2, known as "Middle of the Road," reflects a trajectory where present-day trends persist, presenting moderate challenges. SSP3, "Regional Rivalry – A Rocky Road," describes a world dominated by nationalism and regional conflicts, creating substantial adaptation and mitigation obstacles. SSP4, "Inequality – A Road Divided," portrays a world marked by stark disparities, where the privileged thrive while the majority remain stagnant, complicating adaptation efforts. Finally, SSP5, "Fossil-fueled Development – Taking the Highway," imagines a society driven by economic interests often sidelining environmental concerns, heavily dependent on fossil fuels, and facing major mitigation hurdles.

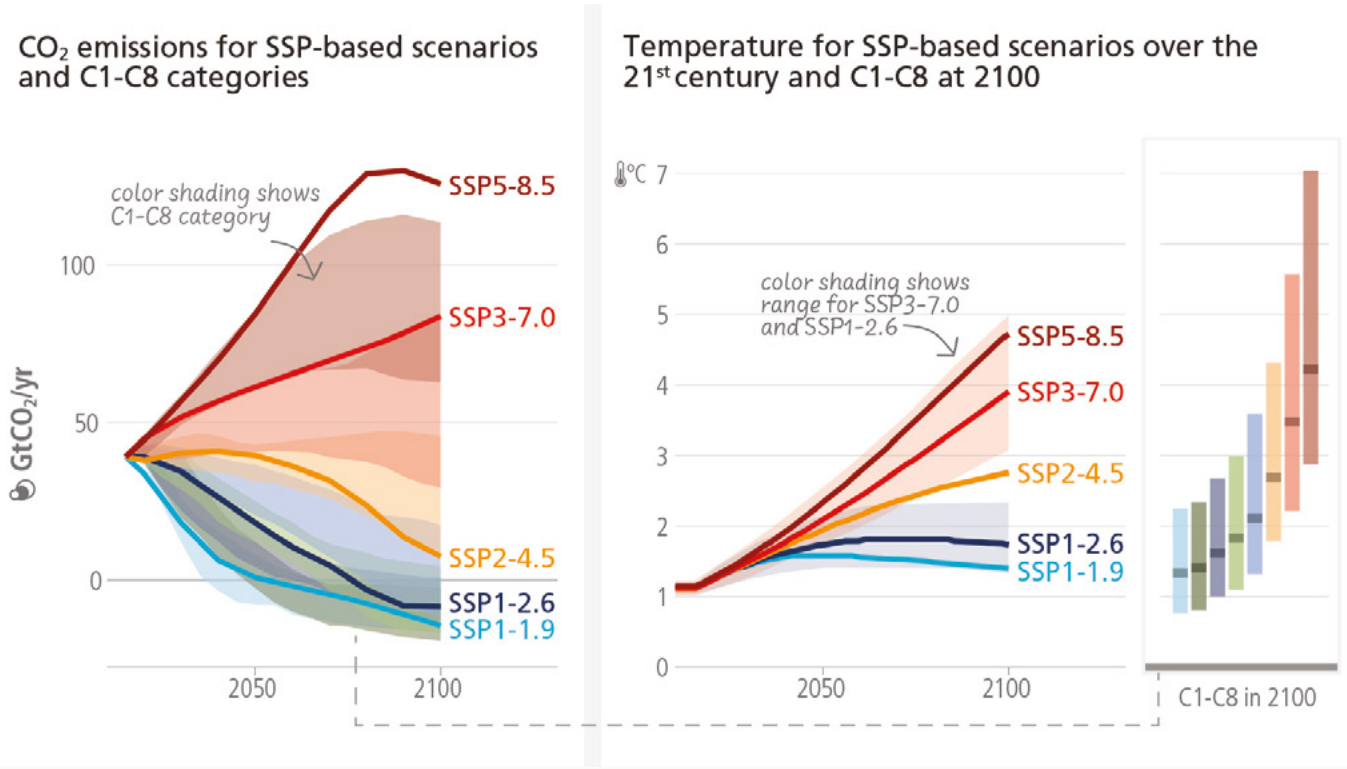


Figure 5: Scenarios and Associated Warming Levels. (Left) CO_2 emissions are depicted across SSP-based scenarios and C1-C8 categories. (Right) Projected temperatures for SSP-based scenarios throughout the 21st century, with C1-C8 values by 2100 (IPCC, 2022).

The primary differences among the SSPs stem from their assumptions regarding global population growth, educational access, urbanisation, economic expansion, resource availability, technological advancements, and shifts in lifestyles. Within a single shared socio-economic pathway, multiple emissions scenarios can exist, leading to a variety of radiative forcing levels. This variation arises because assumptions about climate policy, mitigation, and adaptation can lead to varying emissions, even if they originate from the same socio-economic context. For instance, both SSP1-1.9 and SSP1-2.6 belong to the SSP1 (Sustainability: Taking the Green Road) socio-economic scenario category but differ in emissions and consequently in radiative forcing values (1.9 vs 2.6 W/m2), due to the specific mitigation strategies implemented. In the most recent IPCC AR6 projections, five distinct scenarios are presented as potential pathways: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5.

With recent updates since the release of IPCC AR6, our radiative forcing stands at 2.91W/m2, suggesting we're on a path similar to SSP3-7.0 (Forster et al., 2023). On the other hand, when examining CO_2 emissions, with an average of 37$GtCO_2$ in 2022, our path appears to closely match the SSP2-4.5 scenario. The latter is predominantly used in climate projections, hinting that **we are on track for a 2.7°C temperature increase by the century's end.** While our present course seems to mirror SSP3-7.0 or SSP2-4.5, especially when overlaying current global emissions data onto the socioeconomic scenarios utilised in CMIP6, it's crucial to highlight that the 1.5oC threshold is attained more quickly under SSP2-4.5 than SSP3-7.0 (Gidden et al., 2019). This difference can be attributed to variations in demographic factors. It's clear that current policies and actions fall short of the 1.5°C target set by the Paris Agreement. With time running out, deep and rapid decarbonisation is our only viable option.

Compounding the issue, the SSP and RCP models utilised in the IPCC assessment reports to project Earth's possible futures are notably lacking in data for essential modelling elements. These include, but are not limited to, deep ocean temperature data, insights on aerosols and their influence on clouds, data on ice melt, and specifics about feedback mechanisms. As touched upon earlier, the complexity and importance of the 41 known reinforcing mechanisms tied to the 16 global climate tipping elements might escalate the state of the climate and the Earth systems with an increase of just 1.5°C. **These pivotal feedback mechanisms and tipping elements are currently excluded from the models, implying that our projections might be lacking in depth. This suggests that the current forecasts are likely on the conservative side, and the real situation might be even more dire.** It's clear that additional research is imperative to make projections that are both accurate and all-encompassing.

Considering the severe repercussions of breaching the 1.5°C limit, it's pertinent to evaluate the depth of the issue we are currently facing and determine the extent to which corrective actions can still be undertaken. To grasp the magnitude of the problem, we introduce the concept of a 'carbon budget', which signifies the remaining quantity of carbon dioxide that can be emitted into the troposphere while staying within a given temperature goal. This carbon budget is continuously decreasing as we 'spend' the limited remaining capacity left in the troposphere to remain aligned with one of the temperature objectives of the Paris Agreement. The current best estimates for the remaining carbon budget as of 2023 are presented in **Table 1**.

Table 1. Updated estimates of the remaining carbon budget for 1.5°C, 1.7°C, and 2°C global warming scenarios, for three levels of likelihood. The first row for each warming level provides the AR6 emulator update estimates. The second row for each warming level provides an estimated anthropogenic emissions for the period 2013-2022. Estimates are expressed relative to either the start of the year 2020 or 2023. The table is an adapted version of Table 7 in Forster et al (2023)

Remaining carbon budgets	Base year	Estimated remaining CO_2 budgets from the beginning of the base year ($GtCO_2$)		
Likelihood of limiting global warming to temperature limit		**33%**	**50%**	**67%**
1.5°C according to AR6 emulator update **The remaining budget with warming update**	**2020** **2023**	500 300	400 250	300 150
1.7°C according to AR6 emulator update **The remaining budget with warming update**	**2020** **2023**	950 800	750 600	600 500
2°C according to AR6 emulator update **The remaining budget with warming update**	**2020** **2023**	1650 1450	1300 1150	1100 950

According to a study by Clark et al (2020), in a business-as-usual scenario (which assumes the UN's Medium Fertility Projection of 9.7 billion people by 2050), the emissions from the global food system alone could preclude achieving 1.5°C and 2°C climate targets.

Since then, the carbon budgets have significantly shrunk and food emissions have increased. To have a 67 per cent chance of staying under 1.5°C, the estimated carbon budget of 150 Gt CO_2, is likely to be used up by 2026. For a 50 per cent chance, the estimated carbon budget of 250 Gt CO_2, is expected to be used up by 2029, based on an annual emission rate of 41 Gt CO_2 (Climate Change Tracker, 2023). The urgency of a food system transformation is now irrefutable (Webb et al., 2020), a conclusion also supported by the Global Panel on Agriculture and Food Systems for Nutrition (GPAFSN) in their 2020 publication: 'Foresight 2.0: Future Food Systems' (GPAFSN, 2020). To counteract historical emissions and stop global warming, we need to focus on rapid decarbonisation across our societies. **This not only means cutting emissions from fossil fuels but also recognising the critical role our global food system plays in land-use change, both as a future carbon sink and as a fundamental agent in regenerating and strengthening the biosphere's innate resilience through nature-based climate solutions (Clark et al., 2020, Ripple et al., 2023).**

The Indicators of Global Climate Change (IGCC) initiative states that **we're on a path where global temperatures are rising by +0.23°C every decade, predicting a 1.5°C average increase by 2034.**

Of all the scenarios presented, only SSP1-1.9 offers a route to prevent a 1.5°C temperature increase. Yet, the magnitude of transformation demanded within this pathway is unprecedented and perhaps overly optimistic. Notably, even SSP1 relies heavily on certain carbon capture technologies and storage that are not yet sufficiently advanced for large-scale implementation (Ripple et al., 2023). **Moreover, it optimistically presumes that our food system and land-use will evolve from a carbon source to a carbon sink in the next two decades despite current inaction in that direction.** More worryingly, all climate models used to simulate these scenarios still do not fully account for potential reinforcing impacts from feedback loops, climate tipping elements, and their interactions. This means that even in the most optimistic scenarios, given the uncertainty surrounding these tipping elements, there is a risk that we underestimate the impacts of climate change. Therefore, we need to adopt a more holistic and systemic approach to quickly decarbonise our societies within the limited timeframe.

1.2.2 A decisive decade

The carbon budget designated for the 1.5°C target is shrinking rapidly. We've exhausted nearly 3.0 per cent of it each month between 2020 to 2023 (Forster et al., 2023). This rate of consumption is concerning if we intend to adhere to the Paris Agreement. At this point, it's already likely that we've set in motion feedback mechanisms that have the potential to push Earth systems past their tipping point. As we approach the 1.5°C threshold, the probability of this occurrence shifts from likely to very likely. This places us at a critical juncture in human history, where the decisions made in this decade will shape the future for millennia to come. While the timeframe for action is narrowing, there are still pathways and preventive measures we can adopt to achieve the objectives outlined in the Paris Agreement. While CO_2 emissions play a pivotal role and often monopolise the global mitigation discourse, they aren't the sole concern. There are other significant factors and solutions to consider; as a global collective, we tend to be fixated solely on carbon emissions.

In their 2nd assessment report, the IPCC began reporting emissions in terms of their Global Warming Potential (GWP) to cater for the temperature impact of greenhouse gases over various time frames. GWP is a metric that describes how effectively a GHG traps heat in the atmosphere within a specified timeframe, usually 100 years, when compared to GWP of 1 from carbon dioxide (CO_2). This metric is instrumental in quantifying the impact of gases such as methane (CH_4) and nitrous oxide (N_2O), which possess considerably greater heat-trapping capacities than CO_2 but remain in the atmosphere for shorter durations. For example, methane has a GWP of approximately 27.2 - 29.8 (IPCC, 2022) over a 100-year period. However, when we consider CH_4, it is essential to acknowledge its average atmospheric lifespan, which is approximately 12.4 years. This implies that its influence on global warming is more significant when assessed over a shorter time frame. This perspective recognises the necessity for a more immediate outlook on the matter.

The aim here is to provide a more accurate portrayal of the near-term consequences of emissions. As a result, methane's 20-year GWP is approximately 80.8 - 82.5 (IPCC, 2022), highlighting the substantial warming effect compared to carbon dioxide. The IPCC AR6 presented data in Figure 6 on how global surface temperatures would shift over 10 and 100 years following a one-year burst of current emissions. It highlights the varied impacts over short (10-year) and long (100-year) periods due to the GWP of diverse climate forcers, especially CO_2 and short-lived climate forcers (SLCFs), and it identifies the distinct impacts of various sectors on present-day climate changes. Notably, sectors such as agriculture, fossil fuel production and distribution, and waste management have major warming effects due to the GWP of CH_4.

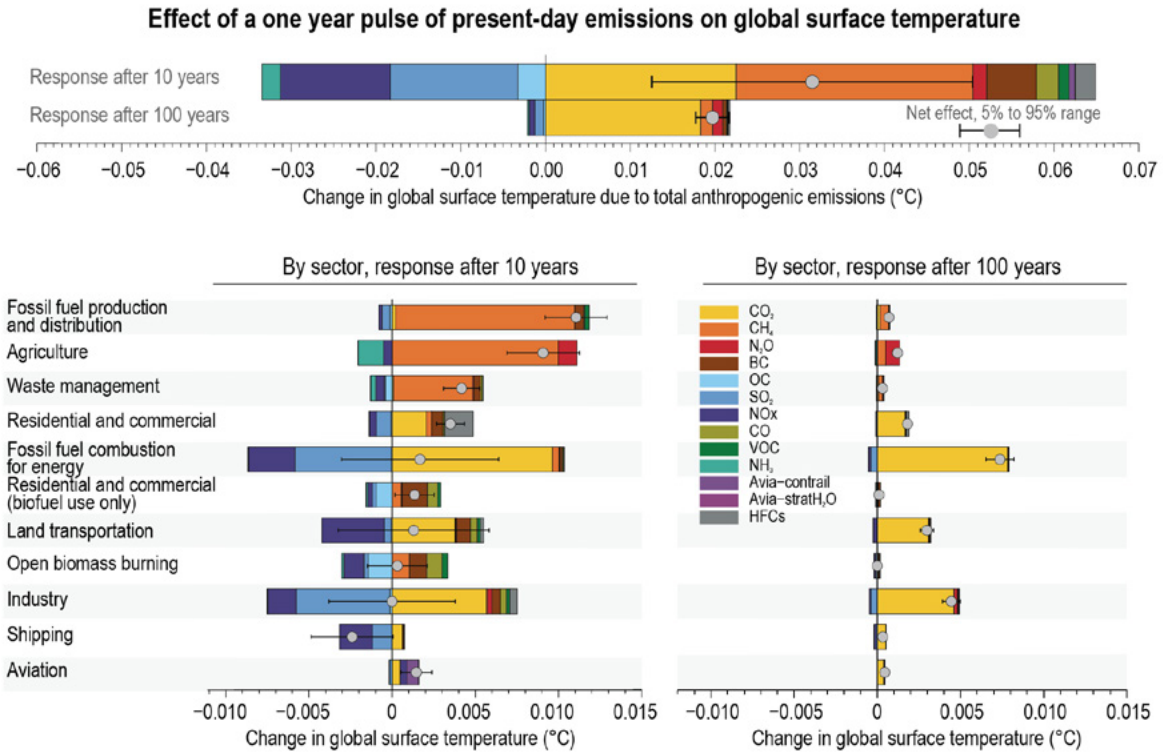


Figure 6: Temperature change after a one-year burst of current emissions, observed 10 and 100 years later, highlights the varying contributions from sectors like agriculture, fossil fuel production and distribution, and waste management. This analysis emphasises the impacts of short-lived climate forcers (SLCFs). The emissions data for 2014 are sourced from the CMIP6 (IPCC 2022)

The United Nations Framework Convention on Climate Change (UNFCCC) reports are typically based on the 100-year warming potential. This approach overlooks the mitigation potential of addressing methane as a top priority. Successive reports from the IPCC not only indicate that CH_4 concentrations have risen, but that its impacts on global warming have also surpassed that of CO_2 (EEA, 2022). **In fact, according to IPCC AR6, roughly 0.5°C, of the total 1.1°C (as of 2021) of global warming, can be attributed to CH_4 emissions.** This suggests tackling CH_4 emissions is the most effective mitigation strategy for limiting and slowing global warming in the short term. This holds significant importance considering the limited time frame remaining to avoid surpassing the 1.5°C threshold. A significant and swift reduction gives us additional time to transition our energy and industrial sectors away from carbon sources. In fact, an assessment carried out by the **Climate & Clean Air Coalition (CCAC) and the United Nations Environment Programme (UNEP), estimated that achieving a 45 per cent reduction in methane emissions by 2030, relative to 2020, could prevent a temperature increase of 0.3°C by the year 2045. They also conclude that tackling methane offers our biggest opportunity to limit global temperature rises (UNEP, 2021).**

ANIMALS RAISED FOR FOOD PRODUCTION REPRESENTED THE

LARGEST SINGLE CONTRIBUTOR TO ANTHROPOGENIC METHANE EMISSIONS

(Climate Change Tracker 2023)

In 2021, the most recent year for which records are available, animals raised for food production represented the largest single contributor to anthropogenic methane emissions, accounting for 36 per cent of the total CH_4 emissions (Climate Change Tracker, 2023).

The historical breakdown of annual anthropogenic CH_4 demonstrates that animal farming has consistently remained the predominant methane source for more than a century, and this trend continues to escalate due to the increasing demand of meat and dairy products. Animals raised for food production release methane as a byproduct of their digestive processes, primarily during rumination, with a smaller quantity being emitted from their manure. The emission levels vary based on the management of the manure, either in wet or dry conditions. Wet management results in greater methane emissions compared to dry management.

However, it's important to note that dry management leads to the emission of N_2O, a potent greenhouse gas with a significantly higher GWP than CH_4 - approximately 273 for both 100-year and 20-year timeframes. In 2021, crop production contributed to 10 per cent of methane emissions, with the primary source being rice cultivation. Furthermore, waste accounted for 21 per cent of methane emissions in 2021, mainly stemming from landfills where biodegradable materials decompose in the absence of oxygen. Of this 21 per cent, 39 per cent is attributed to food waste (Townsend et al., 2018), indicating that approximately 8.2 per cent of the total methane emissions are food waste which is connected to our food system. **Thus, our current global food system is responsible for more than 54 per cent of anthropogenic methane emissions.**

While the food sector contributes to 54 per cent of anthropogenic CH_4 emissions, it doesn't receive as much attention as the energy sector. A recent study by Madra Brava (2023) revealed that **media coverage of animal agriculture and our food system make up just 0.05 per cent of conversations related to climate change.** From the report's content so far, one might initially conclude that the situation is dire with no way out. However, as shown, there's a significant solution not yet widely discussed that can buy us time to decarbonise our societies.

By rapidly transitioning away from animal agriculture, we can transform our global food systems into a carbon sink and make land-use a vital tool for rejuvenating and strengthening the biosphere's natural resilience, but crucially, we can provide the time buffer needed for the decarbonization of our energy sector. This presents an unmatched chance to grant us more time, and it's a readily available solution waiting to be harnessed.

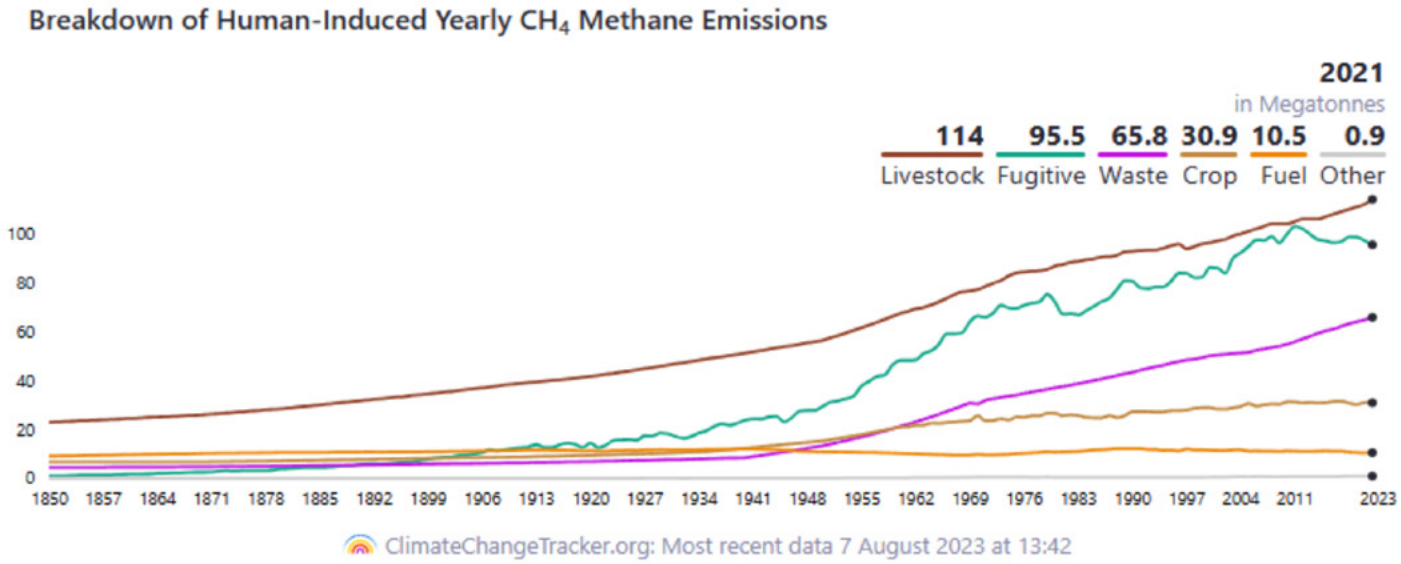


Figure 7: Historical breakdown of annual anthropogenic methane (CH_4) emissions by source over the past century, revealing a pronounced upward trend in emissions. (Climate Change Tracker 2023, Gütschow et al. 2021).

1.2.3 Rapid Decarbonisation

The need to transition our energy economy away from fossil fuels is clear, but it's just one piece of a bigger transformation. The current mitigation roadmap is one with insufficient emission cuts and an over-reliance on negative emission technologies in the near future, making it high risk. If we want to effectively mitigate climate change, we must do more. According to Rockström et al. (2017), we need to cut our emissions by half every decade and reach net zero by 2050, transition agriculture from being a major carbon source to a major carbon sink before the second half of this century, and sustain and restore terrestrial and ocean carbon sinks (Folke et al., 2021). While this roadmap still relies on negative emission technologies, it does underscore the importance of our food system and nature-based solutions in mitigating climate change.

Global sustainability goes beyond moving to a cleaner, more efficient economy. It means connecting these efforts to a deeper value system, something often overlooked in the broader climate discourse and on the global stage. It's about acknowledging our interconnectedness with the planet. From oceans to continents, the biosphere includes all living beings, their diversity and interrelations. There's a strong link between the biosphere and the Earth's overall system, and our progress as a society relies on this connection.

The current IPCC climate models assume a shift from source to sink in land-use and land-use changes (primarily the food system) in the next two decades. Yet, the AR6's brief reference of the global food system as "healthy diets," combined with the forecast of it becoming a carbon sink between 2040 and 2050, underscores an oversight and underestimation of its essential role in the biosphere. **The carbon storage in terrestrial ecosystems is immense,**

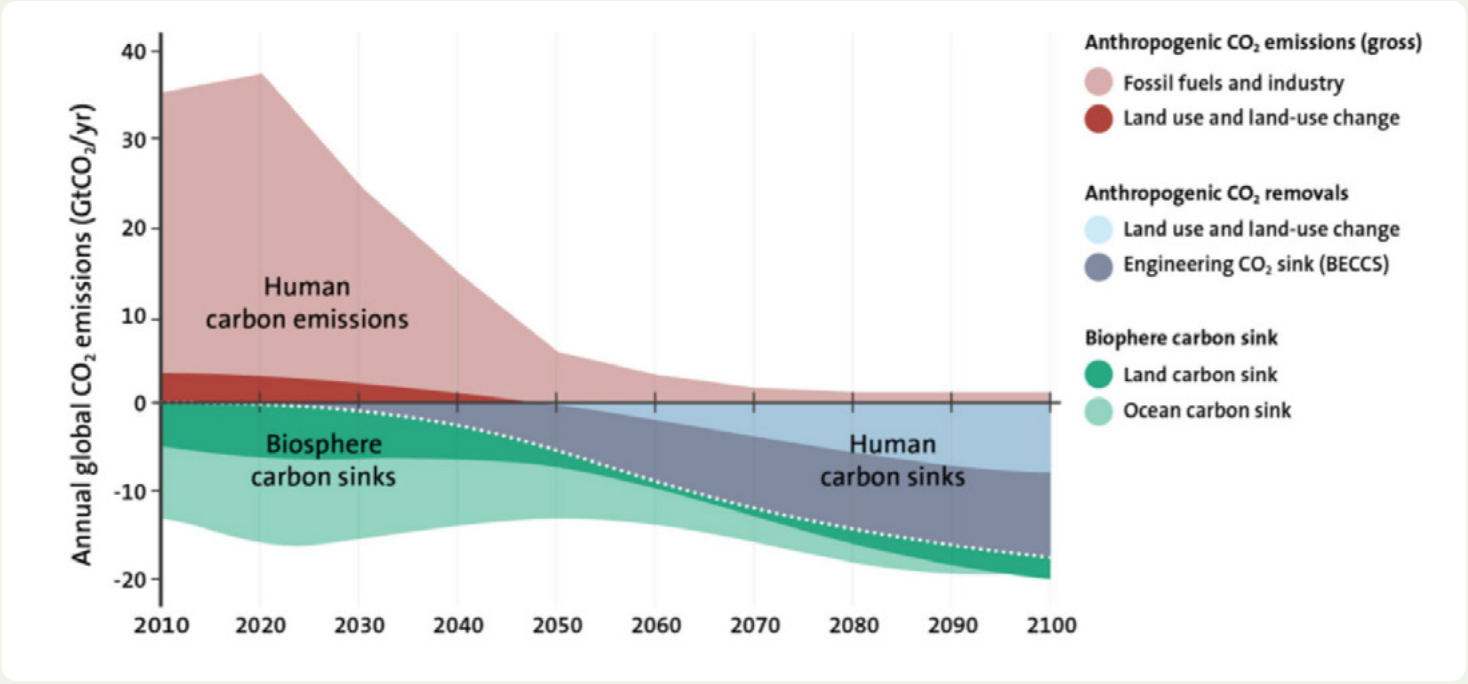


Figure 8: Three paths for rapid decarbonization; transitioning global agriculture from emitting to absorbing carbon, Utilising carbon capture methods such as BECCS, and preserving various carbon sinks. As emissions decline, natural carbon reserves, represented in green, will diminish (Rockström et al. 2017, Folke et al. 2021).

nearly 60 times more than the global GHG (CO_2 equivalents, 2017) emissions by humans annually, with a significant 70 per cent (1500–2400 Gt C) found in soil. Additionally, the ocean has an even greater carbon reservoir, storing around 38,000 Gt of carbon, meaning that marine and terrestrial ecosystems have historically acted as vital carbon dioxide sinks, playing a significant role in climate stabilisation.

At the present global average temperature, oceans take in around 25 per cent of yearly carbon emissions and capture over 90 per cent of the heat resulting from those emissions. On the other hand, terrestrial ecosystems like forests, wetlands, and grasslands capture carbon dioxide during their growth, collectively absorbing nearly 30 per cent of human-caused CO_2 emissions. In the 21st century, humanity and the planet are truly interwoven, evolving together and determining the foundations for civilizations. Our collective future within the biosphere hangs in the balance. This new reality has major implications for our wellbeing, especially with the challenges posed by climate change, biodiversity loss, and the complex interactions between them.

Mitigating the carbon emissions from deteriorated lands, equivalent to the levels in terrestrial ecosystems (~450Gt CO_2) by restoring these areas, is vital to keep global temperatures in check. Nature-based solutions, ranging from agricultural modifications to reforestation, could provide over 30 per cent of the necessary emission reductions by 2050 to keep global warming well below 2°C (Folke et al., 2021).

A holistic approach involving systems thinking, proactive stewardship, and the integration of environmental priorities into economic strategies are essential for combating the multifaceted challenge of climate change, with the global food system at its heart.

1.3 The urgency for a systemic food system approach

The climate crisis is commonly centred on carbon emissions, but this perspective tends to overlook broader environmental aspects such as biodiversity, freshwater, and pollution, underscoring the pressing need to widen the scope of this discussion. **The crisis is not just about the temperature anomalies or unpredictable climate patterns; it encompasses a plethora of issues, with our current food system as a major contributor.** This system is not just falling short of providing essential nutrition to a vast swath of the global population, but it's also contributing to environmental degradation, loss of biodiversity, and social inequalities. The manifestations of this crisis are diverse, affecting every aspect of our existence and the well-being of our planet. What is required now transcends mere reform; a comprehensive, systemic transformation of our food production and consumption is imperative. This section emphasises the critical need for a paradigm shift, highlighting how an integrated strategy in our approach to agriculture and food can serve as a pivotal solution to the multifaceted environmental emergency we face.

1.3.1 A planetary crisis: it is more than just climate change

In the midst of the climate crisis, our narrow focus on carbon emissions suggests that we might have a "carbon tunnel vision" (Figure 9). This tends to overshadow interconnected challenges within the biosphere, especially the rapid decline in biosphere resilience. The resilience of the biosphere influences feedback mechanisms that can either mitigate or amplify global warming through functions that regulate carbon sequestration. At the same time, our planet is experiencing a severe biodiversity crisis, arguably one of the most devastating consequences of anthropogenic forcings on Earth systems. Current data reveals that we are in the midst of the sixth mass extinction (Ceballos et al., 2017), with species disappearing at unprecedented rates. According to Richardon et al. (2023), the current rate of species extinction is believed to be hundreds to thousands

of times greater than the average over the last 10 million years, and it's accelerating. The unprecedented decline in species is fueled by various factors, including habitat destruction, pollution, exploitation, climate disturbances, and the introduction of invasive species. Over recent decades, these drivers have caused dramatic reductions in both population sizes and abundances.

Moreover, **human-induced homogenisation and oversimplification of land and marine ecosystems, typically found in the form of monoculture and pasture agricultural systems, weaken the biosphere's resilience.** This reduces the natural capacity of the environment to perform vital ecosystem functions such as carbon sequestration, water purification, oxygen production, erosion control, defence against pests and diseases, pollination, and the loss of ecosystem services like the harvesting of food and natural materials that we depend on.

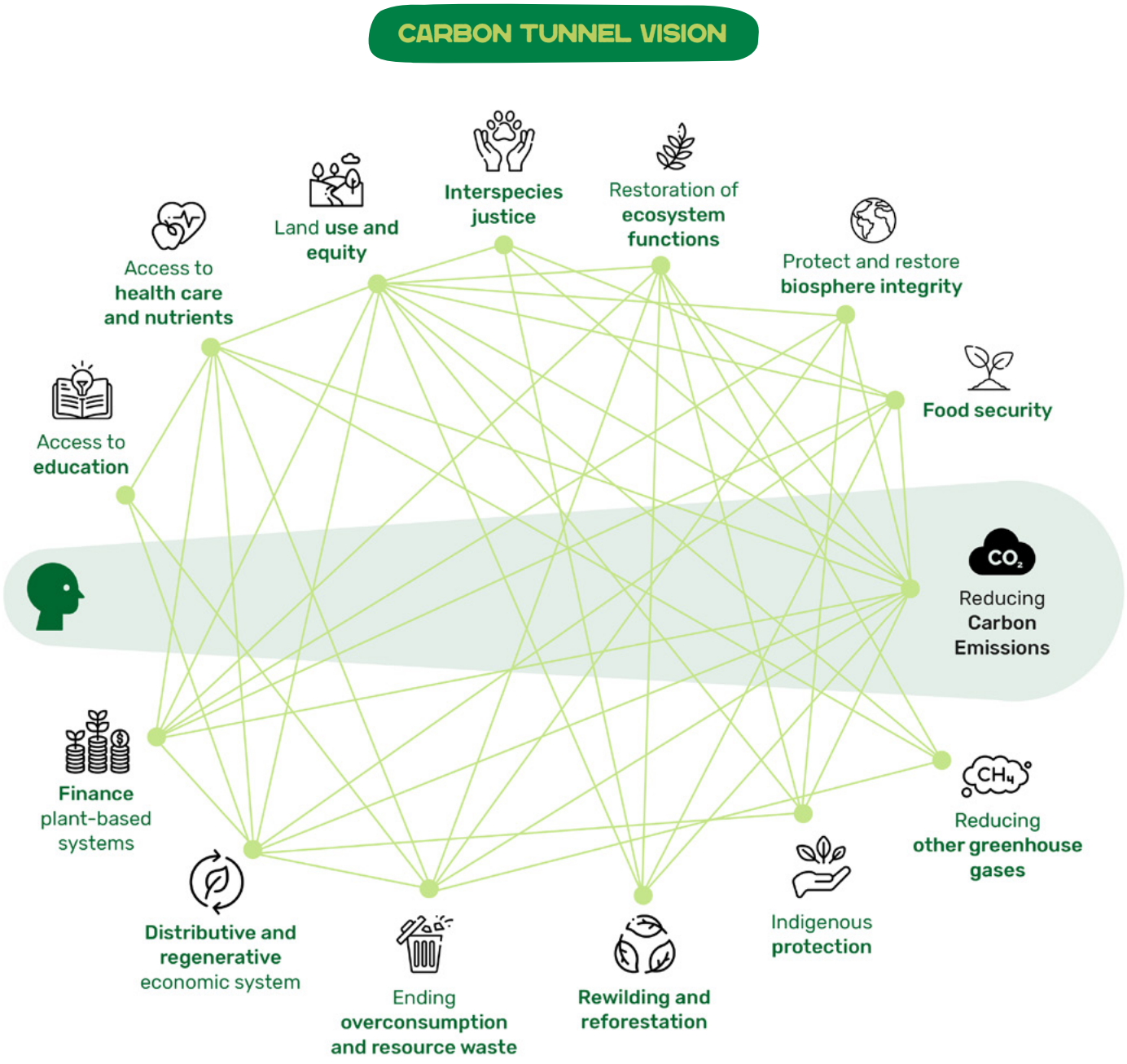


Figure 9: This illustration, based on "Carbon Tunnel Vision" by Jan Konietzko, portrays the narrow focus on carbon emissions while highlighting various interconnected environmental and societal challenges. The visual metaphor underscores the need to address a broad spectrum of solutions as part of a holistic approach to sustainability transition.

The world is also facing a pressing freshwater crisis. According to the United Nations SDG6 Report (2022) nearly two billion people lack access to safe water, and half experience intense water shortages annually. Unsurprisingly, as only 0.5 per cent of Earth's water is readily available freshwater, climate change jeopardises the supply. Over the last two decades, terrestrial water reserves have declined by 1 cm annually, threatening water security. With agriculture being responsible for 70 per cent of freshwater withdrawals, the food system is the primary threat to water security. Paradoxically, it's also the first victim when water sources dry up.

Climate change accelerates the evaporation of freshwater and the evapotranspiration from plants, leading to a decreased water table, increased air humidity, and elevated wet bulb temperatures. As a result of these shifts, atmospheric humidity is growing by 1-2 per cent every decade. Moreover, with each 1°C rise in temperature, the air can absorb an extra 7 per cent of water, which plays a role in the decreasing water table levels. This intensifies heat-related diseases and increases plant-stress. A declining water table increases land emissions, amplifies fire threats, and restricts the available freshwater for drinking and irrigation. These alterations influence local weather, heighten the severity of extreme weather events, and have ramifications for both ecological and human systems (IPCC, 2022). Addressing the freshwater crisis necessitates understanding its ties with climate change, biodiversity loss, and societal challenges like health, justice, culture, and even survival. We exist in a realm where crises are intertwined, not isolated.

The global food system, which greatly influences every aspect of the biosphere, is a primary driver of environmental degradation in the Anthropocene epoch. Central to this system is animal agriculture, which has a considerable ecological footprint. The clearing of forests for pastures destroys habitats, releases carbon, and removes crucial carbon sinks. Monocultures for animal feed create biodiversity deserts. Over-reliance on fertilisers results in nitrogen and phosphorus buildup in our soils, with runoff damaging nearby ecosystems.

1.3.2 A failing food production system

Our food system not only plays a pivotal role in biosphere degradation, with animal farming being a central issue, but it also grapples with meeting the dietary demands of our growing global population. As previously discussed, approximately 735 million people globally face hunger, which is an increase of 122 million since 2019. This upward trend is alarming, and has pushed humanity far off track from achieving zero hunger by 2030. It can be attributed to multiple factors, including climate extremes, economic downturns, and armed conflicts (Ripple et al., 2023). With the global population forecasted to reach 9.8 billion by 2050, based on a medium UN Fertility rate scenario, tackling hunger in today's changing climate is a monumental challenge. Additionally, the steady increase in average temperatures is pushing our agricultural zones out of their climate niche, exacerbating the issue. As the global population increases, **we face the dual challenge of having more people to feed while losing arable land**

suitable for stable food production due to changing climate conditions. It's a compounded dilemma.

Moreover, global food production is increasingly becoming over-simplified. As our agricultural practices gravitate towards homogenisation, we're witnessing a decline in species diversity, especially on a worldwide scale. Native species of plants and animals are vanishing across the globe. **Intensified land utilisation not only diminishes local biodiversity but also weakens the link between species diversity and the quality of diet, impacting ecosystem functions and services, particularly in lower-income countries.** In numerous regions, native crops have largely been supplanted by high-yielding varieties like wheat and rice, contributing to up to 90 per cent of the agricultural shift. While we have access to roughly 150 crop types at the national level, just 12 crop types make up 75 per cent of global consumption, with staples like rice, wheat, and maize at the forefront (Folke et al., 2021).

As this trend continues, the world's breadbaskets — vast regions or countries that produce a significant portion of the world's staple crops, ensuring global food security — face immediate threat in the face of climate, socio-economic and political shocks. These breadbasket nations, (e.g., Brazil, Argentina, and India, crucial for crops like soybean, maize, rice, and wheat) play a vital role in global food security. They significantly impact food prices and availability worldwide. **However, as these countries are increasingly displaced from their climate niches, the stability of global food production is at risk.** This situation is compounded by the oversimplification of our food systems, which now also confronts challenges like declining yields and losses due to climate-related events. Moreover, escalating geopolitical conflicts, such as those involving Russia and Ukraine – who jointly account for 29 per cent of the global wheat supply and are significant exporters of sunflower oil, rapeseed, corn, and fertiliser – are further unsettling the global food supply chain. These tensions create risks that extend beyond their regional borders, potentially leading to disruptions in food supply, especially in already vulnerable areas globally. As these shocks grow more frequent and severe, the imperative for robust international partnerships, open trade channels, and integrating biosphere resilience into our food system becomes even more crucial (World Bank, 2023).

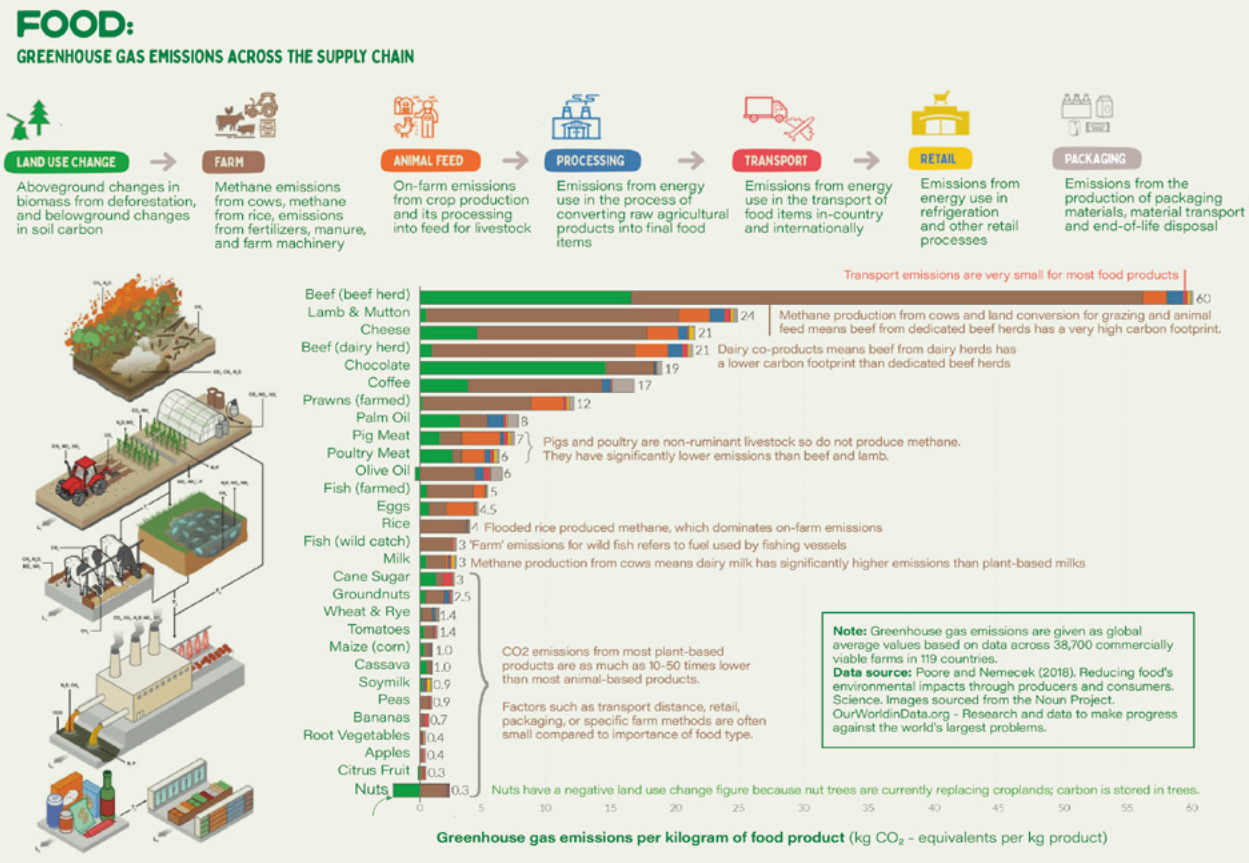
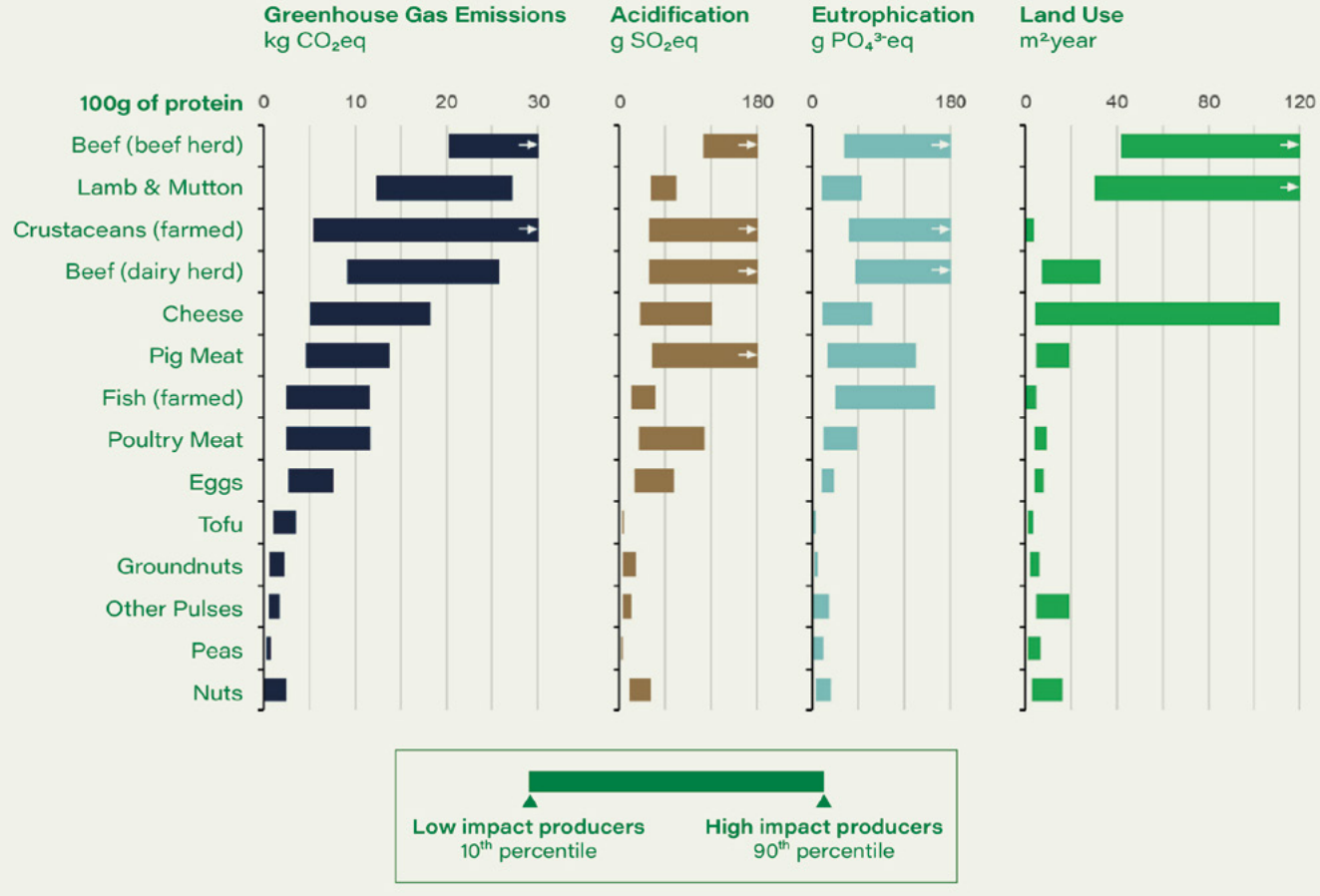


Figure 10: (Left) Illustration of the food supply chain, Poore and Nemecek (2018). (Right) Greenhouse gas emissions are given as global average values based on data across 38,700 commercially viable farms in 119 countries. Image based on data by Poore and Nemecek (2018) and Ritchie. H (2020). Adapted under Creative Commons License.

It's evident that our food system is vulnerable, intensified by the mounting pressures of climate change, diminishing biodiversity, water scarcity, imbalances in nitrogen and phosphorus, and the growing frequency and severity of extreme weather events – all problems that the food system itself notably exacerbates; a pivotal transformation is irrefutable.

Poore and Nemecek (2018) consolidated data on the multiple environmental impacts of ~38,000 farms producing 40 different agricultural goods around the world in a meta-analysis comparing various types of food production systems; including emissions across the supply chain. The findings revealed a distinct pattern: **all products derived from animals exhibit the highest emissions, while plant-based foods have notably lower emissions - See Figure 10**. This challenges common misconceptions, such as the emphasis on transportation and the 'eating local' narratives. The main contributors to emissions are changes in land-use, the selection of dietary items, and the necessity for animal feed in an animal-centric food system.

When we look beyond emissions and acknowledge that our global food system is deeply embedded in the biosphere, we see the significance of adopting a more holistic approach to assess its impact. In line with this perspective, Poore and Nemecek (2018) also evaluated acidification, eutrophication, and land-use for each type of food. These measurements are analysed per 100g of protein, a fundamental macronutrient in a healthy diet. **Figure 11** illustrates that when comparing various environmental impacts, **animal products contribute significantly to environmental degradation. In contrast, plant-based foods consistently appear at the lower end of the charts for each environmental parameter.**



Source: Poore & Nemecek (2018)

Figure 11: The estimated range of environmental impacts spanning the entire food supply chain, as evaluated through life cycle assessment (LCA) methodologies, for a curated set of 40 major food items. These food selections are categorised based on their primary protein sources, with the upper half mainly derived from animal products and the lower half primarily sourced from plant-based origins. This categorisation serves to underscore the disparities in environmental impact, enabling a comparison across various geophysical parameters. The plots in the figure unmistakably demonstrate that plant-based sources consistently exhibit lower impacts across multiple areas, including greenhouse gas emissions, acidification, eutrophication, and land-use (Poore and Nemecek, 2018). Permission given for use of this figure.

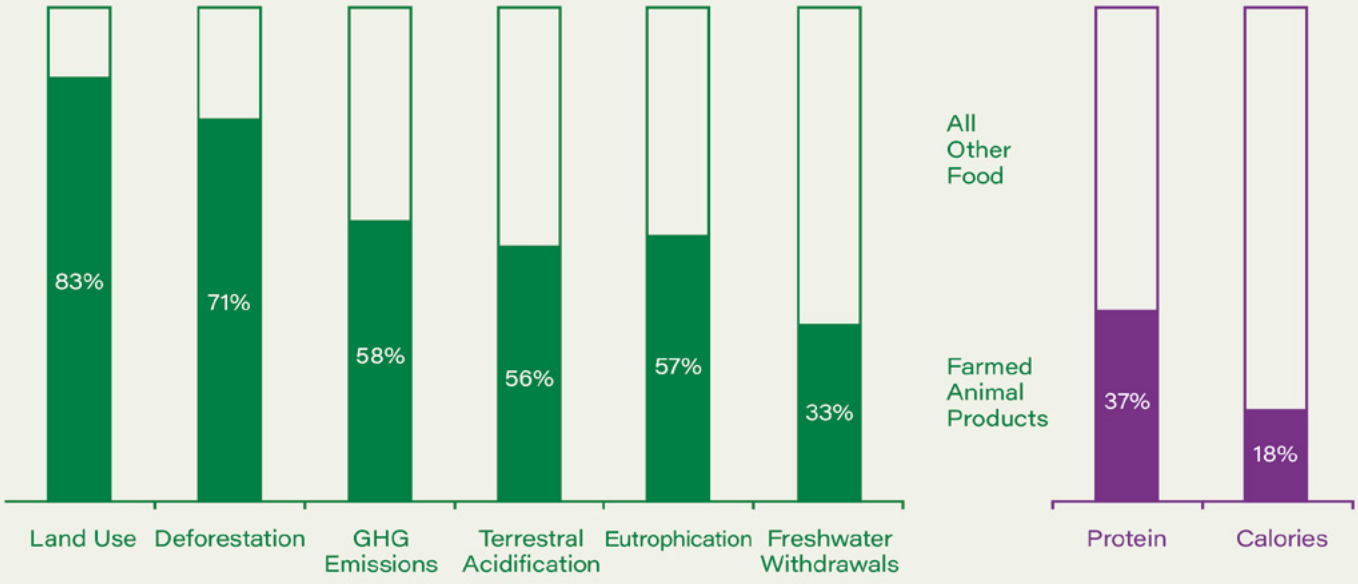
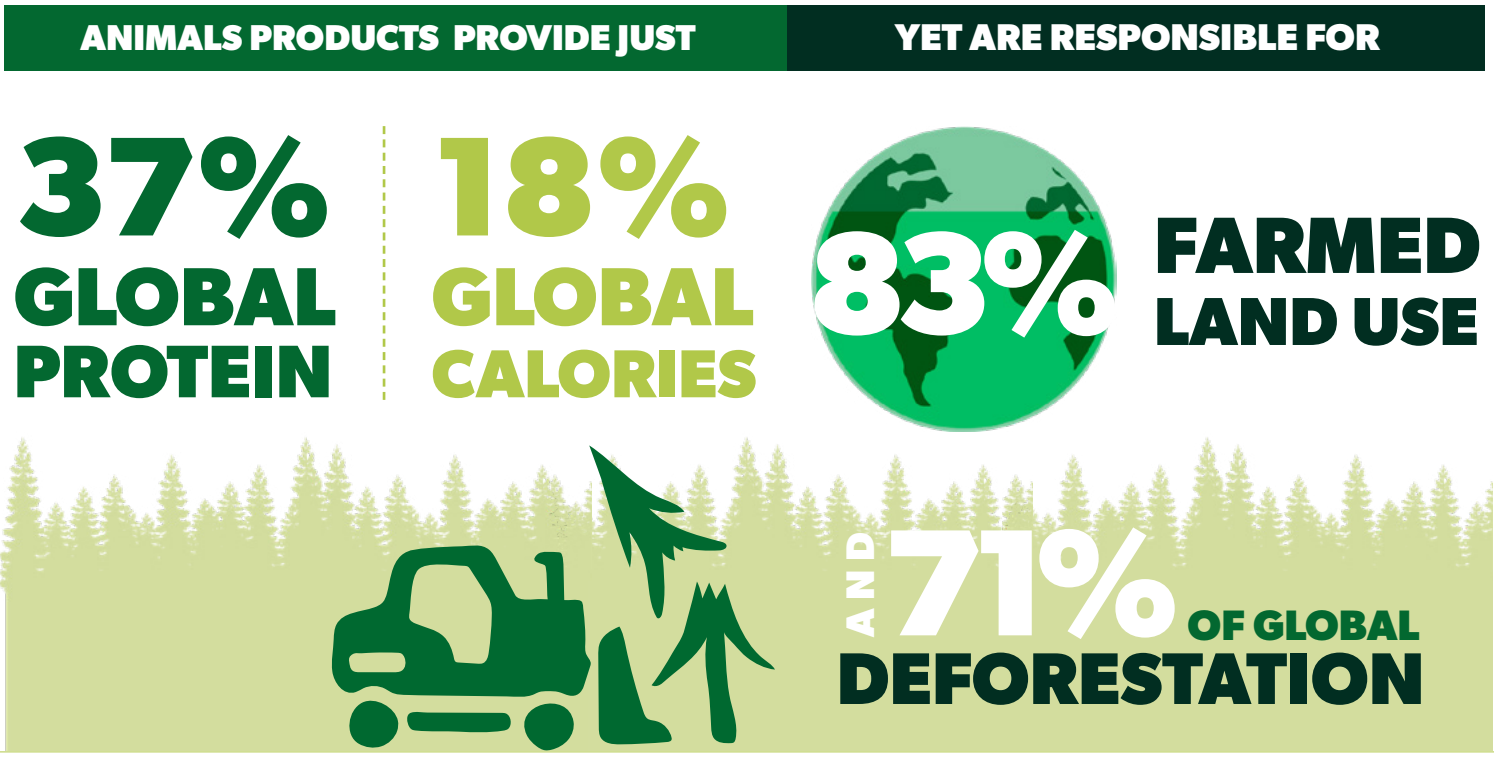


Figure 12: The estimated global variation in GHG emissions, land-use, terrestrial acidification, eutrophication, and scarcity-weighted freshwater withdrawals, within and between 40 major foods, comparing animal products vs plant-based food products (Poore and Nemecek, 2018). Permission given for use of this figure.

When assessing various environmental impacts, animal products consistently contribute heavily to environmental degradation, while plant-based foods are frequently positioned at the lower spectrum of these environmental charts. This comparison is further illustrated in **Figure 12**. In terms of the efficiency of our global food system, animal products provide only 37 per cent of global protein intake and a mere 18 per cent of calories. Yet, they are responsible for 83 per cent of agricultural land-use and 71 per cent of deforestation. The inefficiency of animal-based products, coupled with their substantial environmental impact across various areas, clearly indicates that an animal-centric global food system is not viable for meeting the needs of the 21st century. A consistent conclusion emerging from current research is the necessity for a global food system grounded on sourcing food directly from plants rather than via animals.



1.4 The Plant Based Treaty's vegan donut approach

The well-being of humanity is intricately entwined with the health of Earth's biosphere. So, the crucial question arises: How can we reshape and restore this fragile system? We need a food system that is both ecologically safe and socially just for all. This requires us to drastically rethink our food system and adopt a holistic approach that considers the connections between ecosystems and human systems and ultimately steers our global food system away from animal-based food sources. In the quest for a sustainable future, the Plant Based Treaty is a landmark international initiative to put food systems at the heart of combating the multifaceted planetary and humanitarian crises. To do so, in this report we use the Planetary Boundaries Framework, first introduced by Rockström et al. (2009), and the Doughnut Economics Framework, introduced by Kate Raworth (2012), that depict the ecologically safe and socially just space in which the humanity, including the food system, should operate. The most immediate steps must be to halt the widespread degradation of critical ecosystems caused by animal agriculture, promote a shift to more healthy, sustainable plant-based diets, actively reverse the damage done to Earth systems, and restore vital ecosystem functions and biodiversity. We advocate for a holistic systems thinking approach that ensures the well-being of citizens, farmers, and animals, as we navigate our global food system's safe and just transition.

1.4.1 A call for systems thinking

In the interconnected world of the 21st century, the imperatives of growth, profit, and expansion have dictated the trajectory of our global economy and our food system. **The foundations of this trajectory are built upon the principles of traditional capitalism, which, while driving innovation and progress in some areas, have simultaneously overlooked vital aspects of human well-being, environmental sustainability, and societal health.** The warning signs and calls for change are echoing louder than ever. The need for a new economic framework is evident in multiple facets of our current system. Firstly, there's the short-sightedness of our

economic ambitions. Modern businesses, often shackled by the expectations of stockholders, are obsessed with the next quarterly report, sacrificing the health of the planet and the well-being of future generations for immediate profits. Such a focus results in the unchecked degradation of our environment, evident through alarming rates of biodiversity loss, climate change, and the depletion of natural resources. The impacts vary greatly by wealth; in 2019, **the top 10 per cent of emitters were responsible for 48 per cent of global emissions, whereas the bottom 50 per cent were responsible for just 12 per cent (Ripple et al., 2023).**

The teachings of ecological economists like Daly (2007) remind us that a sustainable future lies in an economy that operates within ecological limits; a steady-state economy. Moreover, our mass industrialisation often commodifies nature, viewing it merely as a resource to exploit for profit. This commodification is evident in carbon markets and other similar mechanisms that, while designed to combat climate change, often end up providing a leeway for major polluters. Our worldwide food industry is currently driven by the demands of growth, profit, and expansion, signalling an urgent need for a fundamental change. At the heart of these issues is an overdependence on Gross Domestic Product (GDP) as the sole measure of economic prosperity. Similarly, in food systems, the focus on 'productivity' as the primary indicator fails to account for the numerous factors mentioned earlier. **Linking economic health exclusively to GDP fails to capture the full spectrum of societal well-being, environmental sustainability, and equitable wealth distribution** (Rajapakse, 2016, Nussbaum, 2000). Fortunately, there are frameworks that present both hope and a visionary approach for steering our economies and food systems in a way that fits the demands of the 21st century.

Doughnut economics offers a holistic approach to address the flaws of our current economic system. It prioritises staying within ecological limits and emphasises regenerative practices to protect the environment. At its core, it aims to create a balanced space where humanity thrives without compromising environmental and social boundaries.

This model challenges our traditional definition of economic success, advocating for policies that prioritise both human well-being and ecological preservation. It stresses the need for redistributive measures, including progressive taxation and robust social safety nets, to counteract growing inequalities. Businesses are encouraged to adopt a more sustainable and long-term perspective, considering not just profits, but their broader impact on society and the environment. **By fostering sustainable practices and moving away from a disposable consumerist culture, doughnut economics champions a circular economy model, which values reuse and minimal waste.**

Furthermore, it emphasises the importance of internalising previously external costs. Through regulations, taxation, and innovative pricing mechanisms, it seeks to ensure businesses account for their environmental and societal footprints. Doughnut economics also calls for a broader set of indicators, like the Human Development Index, to gauge societal progress, moving beyond just GDP. This ensures a more encompassing view of well-being, considering both social and environmental aspects.

The inner circle of the model represents a social foundation, grounded in the United Nations Sustainable Development Goals (SDGs), highlighting the imperative to cater to fundamental needs such as Health, Food, Water, Energy, Networks, Housing, Gender Equality, Social Equity, Political Voice, Peace and Justice, Income and Work, and Education. Any inadequacy in addressing these boundaries is viewed as a shortfall. Meanwhile, the outer circle sets the ecological ceiling, emphasising the planet's natural limits based on Johan Rockström's Planetary Boundary framework (Rockström et al., 2009), updated by Richardson et al. in

September 2023. This includes Climate Change, Land-system change, Biosphere Integrity, Freshwater Change, Biogeochemical Flows, Ocean Acidification, Stratospheric Ozone Depletion, Atmospheric Aerosol Loading, and Novel Entities. Exceeding these boundaries is termed as "overshooting", leading to adverse effects on the biosphere and Earth systems that maintain our Holocene equilibrium.

In a significant research paper by Rockström et al. (2023), the idea of "Safe and Just Earth System Boundaries (ESBs)" was introduced. This concept covers crucial Earth system boundaries like climate, functional integrity, natural ecosystem space, surface water, groundwater, nitrogen, phosphorus, and aerosols, spanning both global and regional levels. Additionally, it weaves in social elements, merging the doughnut economic model, UN Sustainable Development Goals, and the planetary boundary framework to propose a contemporary approach to stewardship. These boundaries are crucial as they signify the core systems of the Earth that are linked through cycles like carbon, water, and nutrients. These ESBs, derived from extensive research, expert perspectives, and milestones such as the Agenda 2030, outline both environmental and social thresholds. While operating within safe environmental limits, we should not overshoot social boundaries affecting both humans and the broader ecosystem. This introduces the notion of **a "safe and just corridor," where we coexist in harmony with nature, ensuring no one is left out.** For example, even if we stay within climate safety limits, its effects remain unequal, as seen with 9 per cent of the world's population living outside the climate niche. This model suggests that for issues like climate, where returning to just levels is challenging, adaptive measures are essential. As societal and food system transformations unfold, this perspective emphasises the importance of fairness and inclusion, safeguarding the welfare of all involved, from citizens to farmers and animals.

1.4.2 A shift to a Plant Based Treaty

We recognise the pivotal role of our global food system in guiding us back to the Earth system's safe and just boundaries—both within Earth's ecological ceiling and above the social foundation for all food system stakeholders, including citizens, Indigenous peoples, climate migrants, farmers and animals. The Plant Based Treaty draws on inspiration from Kate Raworth's Doughnut Economics, the Planetary Boundaries, the Safe and Just Earth System Boundaries, and holistic systems thinking, to offer a renewed and hopeful perspective on a global food system that prioritises universal well-being and environmental sustainability, guiding us towards responsible biosphere stewardship. The Plant Based Treaty embraces three justice criteria introduced in the safe and just Earth system boundaries, termed the '3Is'; interspecies justice and Earth system stability (I1), intergenerational justice (I2), and intragenerational justice (I3). While there's extensive research into interspecies and multispecies justice, there haven't been concrete attempts to put these concepts into practice. **The Plant Based Treaty's vegan donut approach introduces a value system that respects human and non-human entities, understanding that we coexist in a shared biosphere.** It serves as a practical embodiment of interspecies justice, structured around the three Rs: Relinquish, Redirect, and Restore - as described below.

RELINQUISH

No land use change, ecosystem degradation or deforestation for animal agriculture

REDIRECT

An active transition away from animal-based food systems to plant-based systems

RESTORE

Actively restoring key ecosystems, particularly restoring forests and rewilding landscapes

The Plant Based Treaty also outlines essential social boundaries, drawn from 40 detailed proposals. These boundaries are vital for food system transformation and include: the prevention of land-use change, Indigenous protection, a ban on Live Exports, financing plant-based systems, transparency, health, education, food security, land equity, food justice, greening cities, and restoration and rewilding. These boundaries are integral to the Treaty's three Rs framework: Relinquish, Redirect, and Restore, a concept that will be further expanded in the next chapter.

We are urging individuals, groups, businesses and cities to endorse this call to action and put pressure on national governments to negotiate an international Plant Based Treaty as a companion to the UNFCCC Paris Agreement.

The treaty would put food systems at the heart of the planetary crisis, aiming to halt the widespread degradation of critical ecosystems caused by animal agriculture, to promote a shift to more healthy, sustainable plant-based diets and to actively reverse damage done to Earth systems, and restore vital ecosystem functions and biodiversity. **Given the complexity of the planetary crisis, we understand it as a polycrisis, implying that no single solution can resolve the challenges we face.** To this end, we adopt a systems thinking perspective, acknowledging the complex but interconnected problems we face. The Plant Based Treaty Vegan Donut approach is our proposed strategy, emphasising its potential as a central framework for future global and local food systems discussions.

As we stand at the intersection of urgency and hope, we acknowledge our global food system's pivotal role — both as a future carbon sink and as a fundamental agent in regenerating and strengthening the biosphere's innate resilience. The approach of the Plant Based Treaty goes beyond a critique of the status quo; it is a testament to the effectiveness of collective action and systems thinking in driving regeneration and resilience. It also serves as a powerful reminder that together, we hold the power to redefine our relationship with the planet.

CHAPTER TWO

Plant Based Treaty's Vegan Donut Model

The global food and agriculture systems are deeply embedded in our biosphere but often escape scrutiny, despite their significant role in environmental degradation and the nutrition deficits faced by billions. The climate crisis tends to dominate discussions, overshadowing other planetary crises. The current food system contributes to the degradation of the environment and socio-economic inequalities. Our mission is twofold: to adopt holistic systems thinking, and to drive transformative changes in our global food systems. Embracing forward-thinking solutions like the Plant Based Treaty is essential, with a focus on a just transition that includes everyone.

Modern frameworks like Johan Rockström's planetary boundaries and Kate Raworth's Doughnut Economic model provide a systematic perspective on the planetary crisis. Our global food system plays a crucial role in shaping these boundaries. A transition to plant-based diets offers ecological and socio-economic benefits. In this chapter, we delve into planetary boundaries, exploring the food system's role in defining, potentially surpassing, and addressing these boundaries. In Plant Based Treaty's vegan donut model (Figure 1) we aim to address the food system through 12 social boundaries. Plant Based Treaty's 3R principles (Relinquish, Redirect and Restore) offers a pathway for a plant-based food transition and room for rewilding to reduce greenhouse gases, land-use, ocean acidification, freshwater withdrawals and eutrophication, and bring us back to a safe and just space for global food systems.

Figure 1: The vegan donut economics model of the Plant Based Treaty focuses on the food system and widens the lens to incorporate interspecies, intergenerational and intragenerational justice. Six of the nine planetary boundaries have been breached, as shown in the outer rim. The Plant Based Treaty aims to address the food system with 12 social boundaries in the inner rim. Plant Based Treaty's 3R principles (Relinquish, Redirect and Restore) offers a pathway for a plant-based food transition and room for rewilding to reduce greenhouse gases, land-use, ocean acidification, freshwater withdrawals and eutrophication, and bring us back to a safe and just space for global food systems. We have selected twelve of many detailed proposals to represent social boundaries that focus on the food system.

2.1 A food system within Earth's boundaries

Modern agriculture was able to develop due to the stable climate conditions and the rich biodiversity of the Holocene. But in the Anthropocene, our food system is the primary driver of a risky trajectory, pushing Earth toward a radically different climate state. It's increasingly evident that exceeding 1.5°C of warming puts us dangerously close to the thresholds of systems that regulate the Earth's climate. With the world already 1.2°C warmer than pre-industrial levels, and the fact that we are rapidly approaching the 1.5°C threshold, we are facing rapid vegetation die-back and biodiversity loss, increased and amplified extreme weather events, and major fresh water and food shortages. Without significant transformations across sectors and scales, we risk irreversible changes to the Earth system as we know it.

It is widely recognised that a profound transformation of our food system is needed to achieve global food security and nutrition while aligning with climate, biodiversity, and health targets. The choices people make regarding the foods they consume, how, and where they are produced, and the extent of waste and losses have profound effects on both human and planetary well-being. The global food system stands as the world's largest contributor to greenhouse gas emissions and is a leading driver of biodiversity loss, terrestrial ecosystem degradation, excessive freshwater use, and waterway pollution from nitrogen and phosphorus overuse. It exerts a significant influence on Earth's stability and the future of humanity (Rockström et al., 2020).

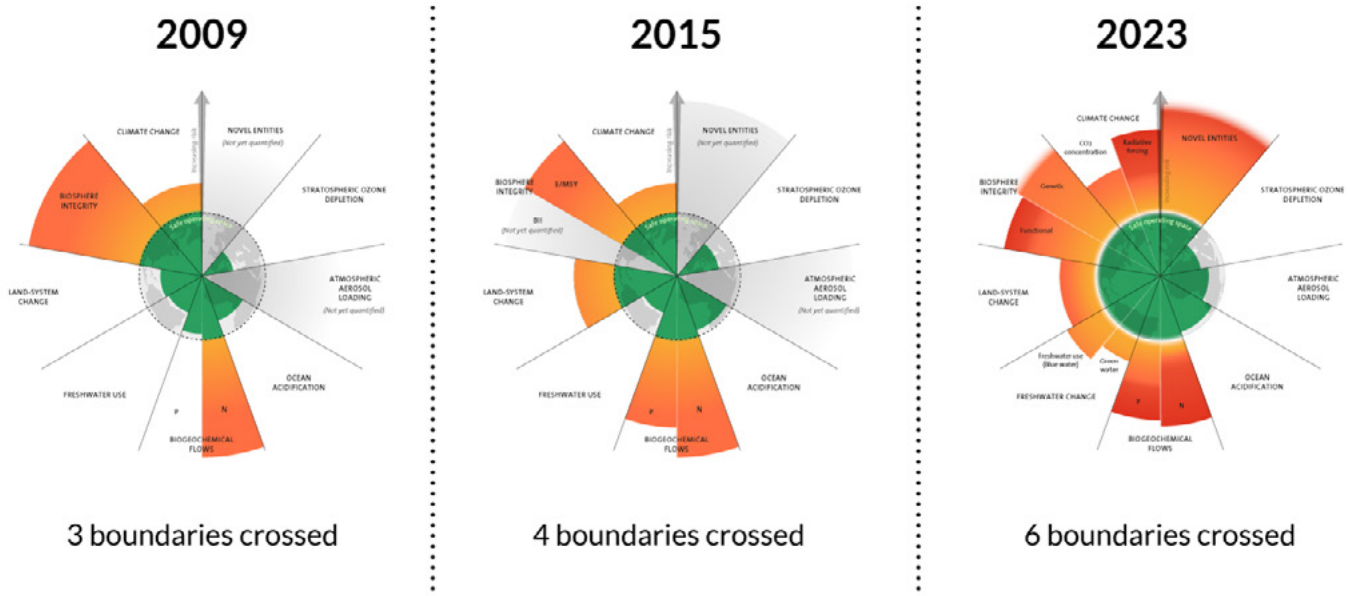
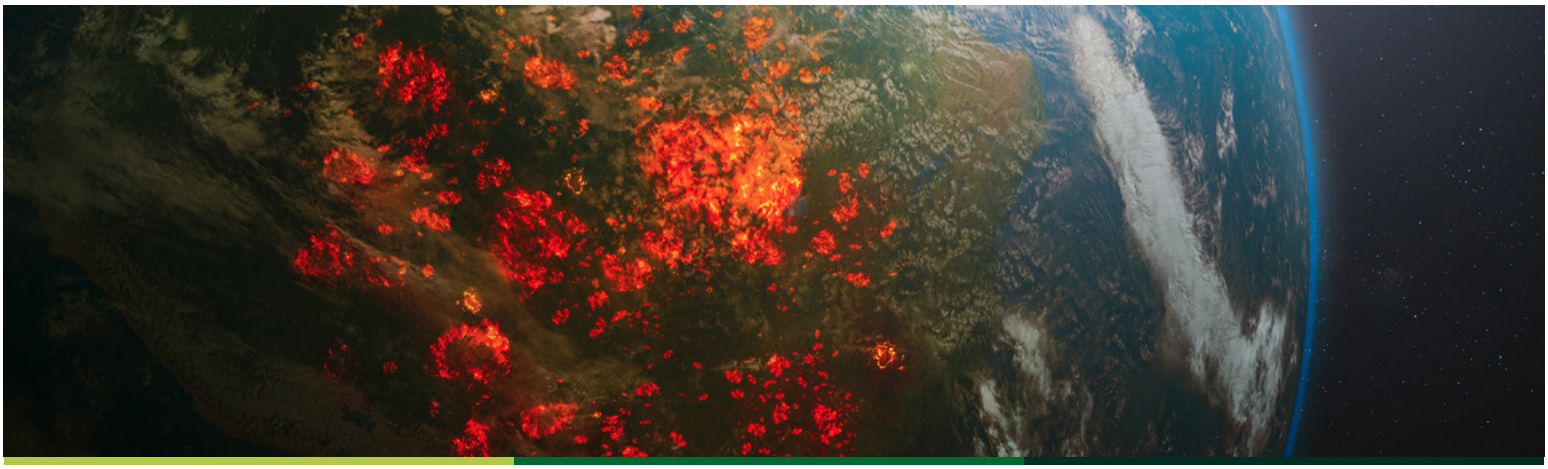


Figure 2: The evolution of the planetary boundaries framework. Licensed under CC BY-NC-ND 3.0. Credit: "Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009".

Paradoxically, although the food system is presently the primary source of environmental degradation and biodiversity loss, it is also among the most adversely affected by these deteriorations. The conversion of natural ecosystems into farmlands and pastures, alongside the repercussions of agricultural pollution, severely threatens vital ecosystem functions that underpin agriculture itself. A complete transformation is necessary, involving changes in production, landscape management, and the entire food system. This is because all food system activities, from agriculture, through processing, logistics and retail, to consumption, affect Planetary Boundaries, and thereby they offer multiple opportunities for mitigation (Campbell et al., 2017; Clark et al., 2020).

There is a critical need to scientifically define and move back to "the safe operating space" within planetary boundaries for the food system. The framework, introduced by Rockström et al. in 2009, has been revised several times since it was first released. Campbell et al. (2017) and Willett et al. (2019) defined the planetary boundary processes directly associated with agriculture, and both found that agriculture is destabilising the Earth systems at a planetary scale. Both studies used the updated framework from Steffen et al. (2015), which concluded that the boundaries of 'climate change', 'land-system change', 'biosphere integrity' and 'biogeochemical flows' were crossed. A recent assessment by Richardson et al. (2023) mapped all nine boundary processes and concluded that the boundaries of 'freshwater use' and 'novel entities' were also crossed, that 'ocean acidification' and 'atmospheric aerosol loading' are close to crossing, and that only 'stratospheric ozone depletion' is slowly recovering. The evolution of the planetary boundary framework is represented in Figure 2. In this sub-chapter, we will again assess the impact of the current food system on all nine planetary boundaries.

Paradoxically, although the food system is presently the primary source of environmental degradation and biodiversity loss it is also among the most adversely affected by these deteriorations.



2.1.1 Climate Change

Climate change is widely discussed in the international community because, on its own, it could drive the Earth's biosphere to a completely new state where ecosystems and human systems no longer thrive. In the midst of the climate crisis, our focus predominantly lies on limiting carbon emissions. But, according to Clark et al. (2020), even if fossil fuel emissions were eliminated today, the emissions from the global food system are enough to preclude the 1.5°C and 2°C targets. Hence, significant shifts in food production methods are necessary to align with the objectives of the Paris Agreement.

The most important drivers of anthropogenic climate change are the emission of greenhouse gases and aerosols, and surface albedo changes. Agricultural activities emit substantial quantities of crucial non-CO_2 greenhouse gases, and the expansion of agricultural lands through deforestation releases significant amounts of CO_2. The entire food chain, from fertiliser production to food distribution, also contributes to CO_2 emissions. In combination, agriculture ranks among the most significant human activities driving climate change. For agriculture, it is primarily land-clearing (slash-and-burn practices and biomass burning), animal farming (enteric fermentation and manure management), and crop production (fertilisers and emissions from land and paddies), that contribute to the global greenhouse effect (Poore and Nemecek, 2018). Earth system feedback mechanisms take up most of the accumulated heat, but it comes at a high cost; it has resulted in ocean warming, ice loss, sea level rise, increases in atmospheric water vapour, permafrost thawing, forest die-back, biodiversity loss, and an increased magnitude and frequency of extreme weather events. On top of it, the remaining climate forcing has accumulated to 1.2°C of warming in a single lifetime, which has profound implications for the entire food system.

The planetary boundary framework uses a dual approach to assess climate change, using atmospheric CO_2 concentration and radiative forcing as control variables. The two sub-boundaries are set at values of 350 ppm CO_2 and 1 W/m2 above pre-industrial levels, which are determined by: (i) the climate system's sensitivity to greenhouse gas forcing; (ii) the response of large polar ice sheets to global warming; and (iii) the observed behaviour of the climate system at the current CO_2 concentration of approximately 417 ppm and a net radiative forcing of +2.91 W/m2 (Richardson et al., 2023; Willett et al., 2009). Both climate change boundaries are far crossed, placing Earth well outside the safe operating space - see Table 1.

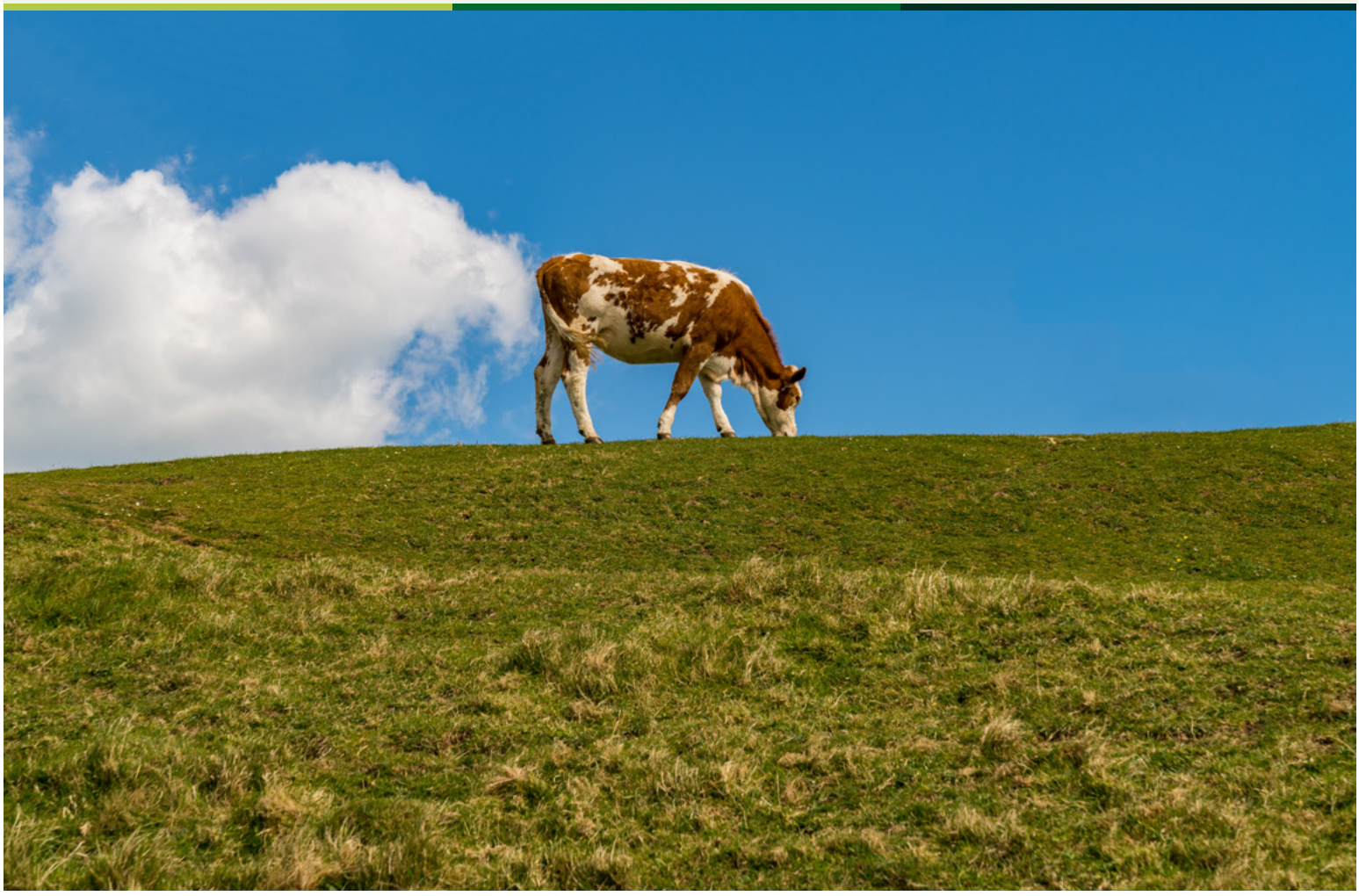
Table 1. The boundaries and current state of the two control variables for 'climate change'; Atmospheric CO_2 concentration expressed as parts per million (ppm CO_2) and radiative forcing expressed as Watt per square metre (W/m2) according to the September 2023 planetary boundaries update (Richardson et al., 2023).

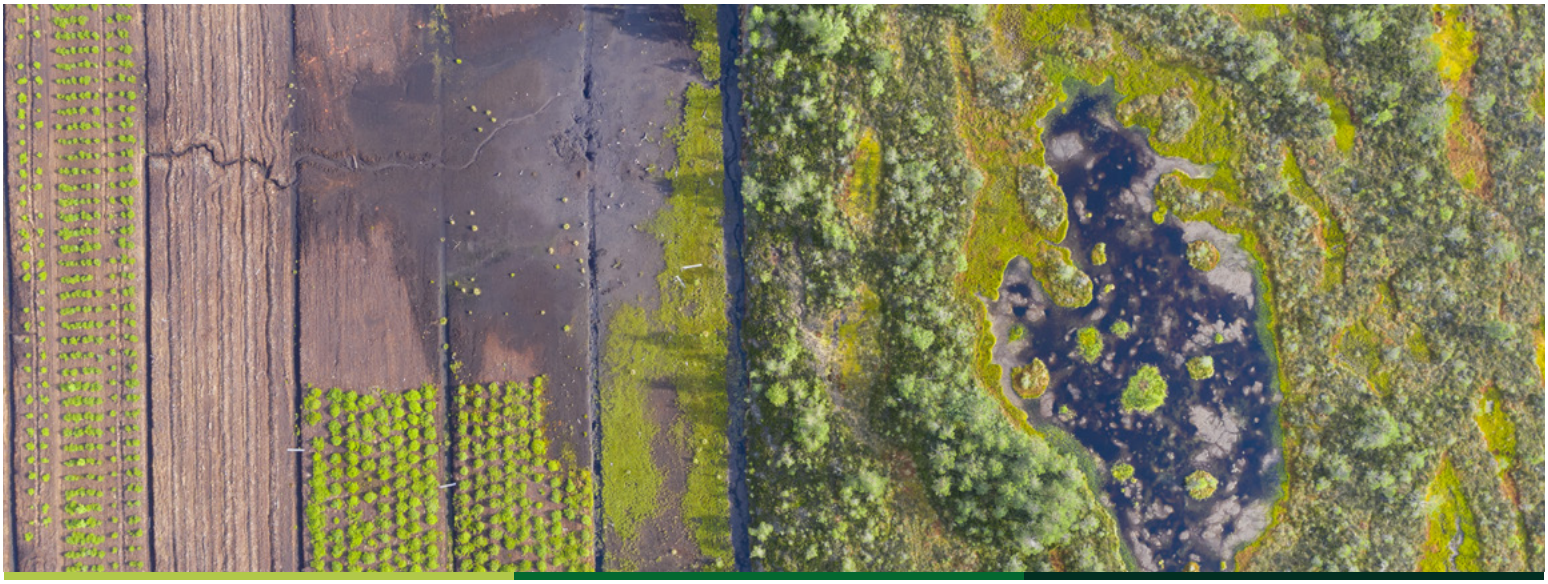
Remaining carbon budgets	CO_2 concentration [ppm CO_2]	Radiative Forcing [W/m2]
Holocene base value	280	0
Planetary Boundary	350	+1
High-Risk Boundary	450	+1.5
Current state	417	+2.91

The global food system is the single largest GHG-emitting sector in the world, responsible for more than a third of the global GHG emissions (CO_2eq; Crippa et al. 2021; Rockström et al., 2020). A shift in global diets and a transformation of agrifood systems is essential to mitigate global emissions and adapt to future warming. Food system assessments by Poore and Nemecek (2018) and Xu et al. (2021) estimated that animal agriculture is responsible for approximately 58 per cent of global food emissions (19.6 per cent of total) and that the share of plant-based foods is approximately 29 per cent (9.8 per cent of total). This means that the emissions from animal-based foods are twice those of plant-based foods, while only providing 18 per cent of calories and 37 per cent of protein compared to plant-based foods.

When we address the food system's climate impact, it is important to look at the carbon opportunity cost of agricultural land as well. According to Poore and Nemecek (2018), animal agriculture is the primary driver of deforestation, and it occupies approximately 83 per cent of all the land used for food production. Forests and natural ecosystems are crucial carbon sinks, absorbing vast amounts of carbon and playing an integral role in stabilising the Earth's climate. The land-clearing for agriculture has led and is still leading to accelerated global warming and rapid loss of biodiversity and ecosystem functions that are both vital for climate regulation. A global shift to plant-based food systems could potentially free up 75 per cent of agricultural land, which would both reduce food emissions and opportunity cost - no compromise needed. A recent study by Hayek et al. (2021) found that this shift could potentially lead to the sequestration of 332–547 Gt CO_2 by 2050. According to Ortiz-Bobea et al. (2021), climate change has reduced the extent of global agricultural productivity growth, so there is a danger that hunger will escalate in the absence of immediate climate action. Therefore, Ripple et al. (2023) **call for "a shift toward plant-based diets, particularly in wealthy countries" because this can both help mitigate climate change and improve global food and nutritional security.**

A shift in global diets and a transformation of agrifood systems is essential to mitigate global emissions and adapt to future warming.





2.1.2 Land-system change

The link between agriculture and land-system change is evident and consistent. According to Foley et al. (2005) and Poore and Nemecek (2018), agricultural ecosystems cover more than 40 per cent of the global land surface, making agricultural land the largest terrestrial biome on the planet. Animal agriculture, specifically, consumes 83 per cent of it (Poore and Nemecek, 2018). In the past 300 years, a staggering 55 per cent of all ice-free land has been converted into croplands, pastures and rangelands, leaving only 45 per cent for natural or semi-natural ecosystems (Ellis et al., 2010). As a result, agricultural production now stands as the world's most extensive land use. In tropical regions, the creation of new agricultural land has led to the loss of rainforests, savannas, and other ecosystems, with further expansion set to clear even more land (Campbell et al., 2017). Since the 1960s, the rise in global population and consumption has intensified land use, pushing land-system change further into the zone of increasing risk (Rockström et al., 2009, 2023). According to the Millennium Ecosystem Assessment in 2005, the conversion of forests and other ecosystems to agricultural land has occurred at an average rate of 0.8 per cent per year during that period. Recent assessments state that approximately 90 per cent of all deforestation is caused by the expansion of agriculture (Pendrill et al., 2022, Food and Agriculture Organisation of the United Nations, 2020).

The boundary land-system change primarily concerns the biogeophysical processes within land systems that directly influence climate - the exchange of energy, water, and momentum between the land surface and the atmosphere (Steffen et al., 2015). Rockström et al. (2009) suggested that no more than 15 per cent of the Earth's ice-free surface should be converted to cropland. At that time, 12 per cent was occupied by cropland, suggesting that agricultural cropland could still expand by 3 per cent before crossing the planetary boundary for land-system change. However, since major forest biomes significantly impact the relationship between land and climate more than other biomes, Steffen et al. (2015) changed the variable they used to measure land-system change. Instead of looking at the extent of cropland, they now focus on the amount of forest cover remaining compared to Holocene levels.

Of the forest biomes, tropical forests and boreal forests have strong feedbacks that impact regional and global climate systems. Therefore, a biome-level boundary was set to 85 per cent of forest cover remaining for both. Because temperate forests have a weaker climate coupling, 50 per cent cover remaining was proposed as the biome-level boundary. The weighted average (all forest biomes together) was set at 75 per cent, and the current value is estimated to be 60 per cent, but as seen in Table 2, regional transgression varies greatly. **Currently, seven out of eight major forest biome-boundaries have now been transgressed, with tropical forests in Asia and Africa showing the highest level of degradation** (Richardson et al., 2023). Recent analyses show that the Amazon rainforest is now close to, or past its tipping point, where it can no longer sustain itself and will slowly transition into a semi-arid savanna - this is the fate of all forest biomes when crossing the high-risk boundary. And when vegetation disappears, biodiversity declines, land emissions increase, and climate change is exacerbated.

Table 2. The boundaries and current state of the control variable for 'land-system change'; Remaining forest biomes expressed by the percentage of forest cover remaining compared to the potential area of forest in the Holocene according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Remaining forest biomes [% of original forest cover]			
Remaining carbon budgets	**Global average**	**Tropical**	**Temperate**	**Boreal**
Holocene base value	**100%**	**100%**	**100%**	**100%**
Planetary Boundary	**75%**	**85%**	**50%**	**85%**
High-Risk Boundary	**54%**	**60%**	**30%**	**60%**
Current state	**60%**	**83.9% Americas 54.3% Africa 37.5% Asia**	**51.2% Americas 34.2% Europe 37.9% Asia**	**56.6% Americas 70.3% Eurasia**

Halting the expansion of agriculture into intact ecosystems is necessary to halt the loss of biodiversity and to mitigate climate change.

Reversing the damage is needed to get the land-system boundaries back into the safe zone and to help stabilise the hydrological cycles. Currently, 15 per cent of converted lands need to be restored and reforested to get back into the safe space. This aligns with the Safe and Just Boundary for land-system change and is consistent with the recently adopted restoration goal of the Kunming Montreal Global Biodiversity Framework (GBF; Rockström et al., 2023). This goal aims to restore approximately 10-15 per cent of the Earth's land area by 2030, which is expressed as restoring 30 per cent of degraded lands. To do so could avoid 60 per cent of expected species extinction and help provide vital ecosystem functions, such as sequestering "30% of the total CO_2 increase in the atmosphere since the Industrial Revolution" (Strassburg et al., 2020, p. 724). Despite pledges to halt and reverse deforestation by 2030, humanity is not on track (UNEP, 2022). In fact, deforestation is still ongoing, and the ecosystems that remain are increasingly threatened by drought and potent climate feedback loops, including processes such as insect damage, dieback, and wildfire.

To keep up with the growing food demand while halting deforestation and restoring degraded lands, we must allocate cropland to the most productive regions while controlling processes that result in the loss of fertile land, like land degradation, diminished irrigation water, and competition with urban development. Managing demand-side factors is also essential, which includes dietary choices, individual food consumption, and reducing food waste throughout the entire production and supply chain. **Moving to a diet that excludes animal products has transformative potential, reducing food's land use by approximately 3.1 billion ha (a 75 per cent reduction), which is crucial if we want to mitigate the climate crisis, restore biosphere integrity, and provide healthy food for all** (Poore and Nemecek, 2018).

2.1.3 Biosphere Integrity

The integrity of the Earth's biosphere underpins our own ability to thrive on Earth. It is the functional integrity of ecosystems that regulate the state of the Earth system, and the wide range of genetic diversity within and between species that give ecosystems the resilience to persist under and adapt to change. Both functional integrity and genetic diversity have been in rapid decline since the late 19th century (Rockström et al., 2009, Richardson et al., 2023). According to IPBES (2019, p.12), the rate of loss since the 1970s "is unprecedented in human history", and it is primarily driven by land- and sea-use change (expansion of agriculture into ecosystems and exploitation of marine ecosystems), direct exploitation of organisms (primarily fishing), climate change, pollution and invasion of non-native species. Scientists fear that the current rapid loss in genetic diversity, decline in population abundance, and the degradation of ecosystems could disrupt services and functions we all depend on. The Earth's biosphere provides functions that are vital for the survival of all species living on Earth. Reports often refer to these functionalities as Nature's Contributions to People (NCP), while in fact, all species contribute and depend on the functionalities provided by ecosystems. Resilient and well-functioning ecosystems reduce the impacts of natural disasters and regulate the climate, nutrient flows, and air and freshwater quality. They provide and maintain habitats, pollination, and the dispersal of seeds. They protect and decontaminate soils and sediments, and regulate pathogens, biological processes, and population sizes. Nature underpins all dimensions of human and planetary health, but also contributes to non-material aspects of quality of life (Millennium Ecosystem Assessment 2005, Rockström et al., 2023).

Since the latest update of the Planetary Boundary Framework (Richardson et al., 2023), functional integrity is defined as the capacity of ecosystems to maintain and provide species interactions that secure ecosystem functions required to generate ecosystem services, such as food, fibres, medicine, and other natural materials and resources. Intact ecosystems have the capacity to provide these services, but this is generally not the case for fragmented-natural, semi-natural, and human-dominated landscapes. The extent to which human activities disrupt ecosystems is described through the change in Net Primary Production (NPP), often referred to as Human Appropriated Net Primary Production (HANPP). Net primary production is a fundamental concept that measures the net amount of carbon that is primarily captured by plants through photosynthesis and made available for consumption by other organisms in an ecosystem. The available natural NPP is greatly reduced by human appropriation through harvesting, alteration, and elimination.

The NPP loss in 2020, primarily driven by agriculture, grazing and forestry, totalled 16.8 Gt of C per year, meaning that HANPP was approximately 30 per cent of the mean Holocene NPP of 55.9 Gt of C per year. This is much more than the 10 per cent (Table 3) scientists say the biosphere can handle for functional integrity (Richardson et al., 2023). Since the 1960s, the world's population and consumption have grown rapidly, leading to more land use and increased environmental risks. We have always used HANPP for food, fibre and other resources, and we will continue doing so in the future. However, we'll need to generate more NPP beyond what was typical during the Holocene, excluding NPP used for carbon sinks. Theoretically, it's possible to feed a population of 10 billion people, and stay within the planetary boundaries, but it will require substantial changes to reduce environmental impacts from production, regulation of demand, a waste reduction and a transition to plant protein sources (Gerten et al., 2020).

Table 3. The boundaries and current state of the two control variables for 'biosphere integrity'; Loss of genetic diversity expressed as extinctions per million species per year (E/MSY), and the biosphere functional integrity expressed as human appropriation of net primary production (HANPP) according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Genetic diversity [E/MSY]	Functional integrity [HANPP]
Holocene base value	**1**	**NPP = 55.9 Gt of C per year**
Planetary Boundary	**<10**	**<10% HANPP**
High-Risk Boundary	**100**	**20% HANPP**
Current state	**>100**	**30% HANPP**

Since the 1700s we have been taking more resources than the Earth's biosphere can replenish. The growing pressure on ecosystems to supply us with food, water, land and energy is reducing the capacity to provide functions and services but is also resulting in biodiversity loss and increased species extinction. Currently, the rate at which species are going extinct worldwide is much higher than the rate at which new species are evolving, making species loss the main driver of changes in global biodiversity. According to fossil records, the average typical extinction rate for marine organisms or mammals was between 0.1 to 1 extinctions per million species per year (E/MSY) over Earth's history. However, human pressures have significantly increased this rate, resulting in a current global average extinction rate of ≥100 E/MSY. Moreover, the rate is expected to increase tenfold by the end of this century (Richardson et al., 2023 and IPBES, 2019).

Presently, out of the estimated 8 million species of plants and animals, a staggering 1 million species (75 per cent of which are insects) are facing the threat of extinction, and over 10 per cent of genetic diversity may have been lost over the past 150 years. Human activities have also led to the decline of 68 per cent of global wildlife populations in the past five decades. Biodiversity is one of the pillars supporting the biosphere, and by transgressing the boundaries for functional integrity and genetic diversity, we are now directly threatening our own survival. With current negative trends in biodiversity, we are not going to be able to feed the human population. Approximately 70 per cent of the world's crop species rely to some extent on insects for pollination. However, with the expansion of intensive monoculture agriculture and heavy reliance on chemicals such as insecticides, herbicides and pesticides, insect populations have drastically declined. **Essentially, the way we produce food is wiping out the very thing our food production relies on. And without insects, our biosphere won't function properly** (IPBES, 2019).

Campbell et al. (2017) suggest that since agriculture is the primary driver of land-system change, and both genetic diversity and functional integrity loss are driven by land-system change, it's agriculture that has shifted biosphere integrity and land-system change beyond their boundaries. The contribution of animal agriculture alone is enough to push humanity outside the safe operating space. To halt the loss of biodiversity and safeguard essential Earth system functions, it's essential to stop the expansion of agriculture into pristine natural areas. Presently, only 45 per cent of the world's land surface consists of intact ecosystems, but they are mainly found in desert, boreal, and tundra biomes.

It's imperative to keep at least half of the ecosystem area intact to conserve 80 per cent of species. Restoring an additional 10 per cent to 15 per cent is needed to avoid 60 per cent of species extinction. Restoration of natural elements around and between agricultural land is also needed to safeguard in-field and on-farm biodiversity and secure vital ecosystem functions that regulate the water cycle, maintain soil health, and provide pollination and population control. Targets to retain at least 10-20 per cent of natural area per km^2 have been proposed in agricultural policy, but many agricultural ecosystems fall below this threshold. In the absence of a proximate habitat (<500m) for pollinating and regulating species, ecosystem functions are not provided (DeClerck et al., 2023). Therefore, Rockström et al. (2023) added an additional biosphere Earth system boundary to secure ecosystem functions in human-dominated and modified lands, including cities. They set the safe and just boundary to 20-25 per cent of diverse semi-natural habitat per km^2. It's clear that we can only get back into the safe zone by restoring land quickly, starting to treat agricultural lands as agroecosystems, and working towards land management systems that work with nature instead of against it.

2.1.4 Freshwater change

Land conversion leading to ecosystem change significantly contributes to changes in water patterns. This, in turn, disrupts the structure of ecosystems, the balance of species, and the distribution of water — a harmful cycle leading to a decline in water resources and changes in the regional and global hydrological cycle (Rockström et al., 2023). Among human activities, it is primarily agriculture that consumes vast amounts of water and disrupts the water cycle through land-use changes. It is estimated that agriculture, particularly crop production for feed and food, is responsible for more than 70 per cent of global freshwater withdrawals. When including evapotranspiration from crops and water returned to rivers and groundwater, agriculture's share of water use is much higher - irrigated agriculture makes up 84 to 90 per cent of all human blue water consumption (Campbell et al., 2017, Boulay et al., 2018, Poore and Nemecek, 2018, Willett et al., 2019). Sterling et al. (2013) demonstrated that land-use change, from intact nature to cropland or land for grazing, decreased evapotranspiration by 5.6 per cent and increased water run-off by 6.8 per cent globally, significantly impacting water reserves and regional weather patterns. Several studies suggest that approximately 40 per cent of irrigation water extracted from surface water sources negatively impacts environmental flows. Additionally, around 20 per cent of irrigation water is currently depleting groundwater reservoirs, highlighting that 50-60 per cent of current global irrigation practices are unsustainable (DeClerck et al., 2023).

Initially, planetary boundary science quantified a maximum for freshwater withdrawals and consumptive water use to maintain Earth system resilience, but this evaluation accounted only for human consumption of blue water sourced from rivers, lakes, reservoirs, and groundwater reserves (Rockström et al., 2009, Steffen et al., 2015). This method overlooked the important role that green water, encompassing terrestrial precipitation, evaporation and soil moisture, plays in Earth system dynamics (Wang-Erlandsson et al., 2022). The latest update by Richardson et al. (2023) better acknowledges the many Earth system impacts that freshwater changes have and distinguishes between blue water and green water in assessing the planetary boundary for freshwater. Terrestrial and freshwater ecosystems have naturally adjusted to specific levels of freshwater, which vary within and between years. The global boundary condition is defined by the annual deviations in the water cycle that land areas experienced during the pre-industrial period, with boundaries set at 10.2 per cent for blue water and 11.1 per cent for green water. Currently (averaged over 1996–2005), approximately 18.2 per cent (blue) and 15.8 per cent (green) of the global land area experience deviations in local freshwater (Richardson et al., 2023), meaning that the freshwater boundary is transgressed substantially - see Table 4.

Table 4. The boundaries and current state of the two control variables for 'freshwater change'; Freshwater use as the percentage of human-induced disturbance of blue water flows compared to preindustrial levels and green water as the percentage of human-induced disturbance of green water flows compared to preindustrial levels according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Freshwater use [% disturbed]	Green water [% disturbed]
Holocene base value	**9.4%**	**9.8%**
Planetary Boundary	**10.2%**	**11.1%**
High-Risk Boundary	**50%**	**50%**
Current state	**18.2%**	**15.8%**

The conclusion is that the food system is the primary driver of the changes in the hydrological cycle and freshwater reserves, which is resulting in increased extremes in precipitation and river flow in the northern latitudes and increased drought frequency and severity in the tropics and subtropics. For blue water, a stark example is the destruction of the Aral Sea. Overuse of water for irrigation drastically reduced streamflow, depleting the lake, causing ecological damage, and altering the regional climate. Changes in green water contribute to lower productivity in natural and cultivated lands, as seen in forest dieback across the globe and food production shocks from both floods and droughts, particularly in South and East Asia, Australia, and North Africa. Although returning to a natural state may not be possible due to centuries of hydrological changes, reducing human disturbance through land use and management, water withdrawals, and reservoirs and dam operations is crucial. Agriculture is, and will continue to be, the largest consumer of freshwater. The water needed for food production varies based on the type of food and the production method. As the global population continues to grow in the coming decades and dietary preferences are projected to shift toward more meat, the demand for water will continue to rise. Specifically, the increase in animal agriculture amplifies water consumption due to the additional water needed to cultivate feed crops. A global transition to plant-based dietary patterns has the potential to reduce diet-related freshwater use by 21 per cent for blue water and 14 per cent for green water, making dietary change a key solution to get us back into the safe operating space (Gibbs et al., 2022, Campbell et al., 2017, Poore and Nemecek 2018).

2.1.5 Biogeochemical flows

The biogeochemical cycles are important as they regulate and recycle the nutrients (primarily water, carbon, nitrogen, and phosphorus) that build up all life forms on Earth. Since both the disruption of the carbon and water cycles are covered under other planetary boundaries, the boundary of the biogeochemical flow specifically focuses on the disruption of the nitrogen (N) and phosphorus (P) flows. Both elements are critical to plant growth, and their natural availability limits growth in most terrestrial and aquatic ecosystems (Richardson et al., 2023 and Willett et al., 2019). Agriculture, especially meat, dairy, and crop production, is the largest cause of global disruption of the N and P cycles, due to high demands and low use-efficiencies (Campbell et al., 2017). The rapid increase in human use of N (consuming 86 per cent of anthropogenic nitrogen) and P (consuming 96 per cent of all mined phosphorus) in the form of fertilisers has raised many concerns about their impacts on the environment. Major losses occur during food production, where more than half of the total extracted phosphorus, and more than two-thirds of anthropogenic nitrogen are lost to the environment through runoff, leaching, erosion and emissions (West et al., 2014). The excessive use of fertilisers is leading to soil and air pollution, biodiversity loss, terrestrial and aquatic pollution and eutrophication, and increases in reactive gases in the troposphere that lead to the depletion of ozone (Springmann et al., 2018, Poore and Nemecek, 2018). According to Campbell et al. (2017, p. 3), the environmental costs of N pollution in Europe alone have been estimated to "outweigh the entire direct economic benefits of N in agriculture combined".

The planetary boundary framework has defined three different boundaries for the N and P cycles compared to pre-agricultural inputs: (i) a global boundary for N fixation, set at 62 Tg N/y (million tonnes per year) to prevent eutrophication; (ii) a global boundary for the P flow from freshwater systems into oceans, set at 11 Tg P/y to avoid large-scale ocean anoxic events that have potentially caused past mass extinctions; (iii) a regional boundary of P application on land, set at 6.2 Tg P/y to prevent eutrophication of regional freshwater sources. With 190 Tg N/y, 22.6 Tg P/y and 17.5 Tg P/y (Richardson et al., 2023), respectively, current levels are far beyond the boundaries of biogeochemical flow, with global levels of N and regional levels of P far into the danger zone - see Table 5. Considering agriculture's 86 per cent share of total global anthropogenic N use and 96 per cent share of P use, the food system is the primary driver of the changes in the N and P cycles. According to Poore and Nemecek (2018), the food industry is responsible for approximately 32 per cent of global terrestrial acidification (terrestrial acidification potential in sulphur dioxide equivalents - SO2-eq) and 78 per cent of eutrophication (eutrophication potential in phosphate equivalents - PO_4^{3-}-eq), more than half of which is caused by the production of animal-based foods. Therefore, it's estimated that a global transition towards plant-based diets would reduce eutrophication and terrestrial acidification by 49 per cent and 50 per cent, respectively.

Table 5. The boundaries and current state of the control variable for 'biogeochemical flows'; Nitrogen expressed as anthropogenic nitrogen removed from the atmosphere in millions of tonnes per year (Tg N/y), global phosphorus expressed as anthropogenic phosphorus flowing into the oceans (Tg P/y), and regional phosphorus expressed as anthropogenic phosphorus applied through fertilisers on land (Tg P/y). Values according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Nitrogen	Phosphorus - global	Phosphorus - regional
Holocene base value	**0 Tg N/y**	**0 Tg P/y**	**0 Tg P/y**
Planetary Boundary	**62 Tg N/y**	**11 Tg P/y**	**6.2 Tg P/y**
High-Risk Boundary	**82 Tg N/y**	**100 Tg P/y**	**11.2 Tg P/y**
Current state	**190 Tg N/y**	**22.6 Tg P/y**	**17.5 Tg P/y**

The primary purpose of fertiliser may be to enhance food production, but most eventually ends up in the environment where it pollutes waterways and coastal zones, causing environmental degradation and biodiversity loss. Efforts to limit N and P pollution are crucial, and this can be achieved through the restoration of natural elements such as grassed waterways, riparian buffers, prairie strips, hedgerows, live fences, and wetlands around and between agricultural land. According to DeClerck et al. (2023), these elements are highly effective at capturing excess nutrients, regulating water and reducing soil erosion. Better tilling practices, crop rotations with nitrogen-fixing cover crops (beans, peas, lentils, which are all great protein alternatives), mixed cropping, and improved prediction of fertiliser requirements, timing and placement, along with strategies to recover and recycle losses, can all greatly reduce agriculture's impact on the environment. Minimising food waste throughout the entire production and supply chain is essential to reduce agriculture's need for fertilisation, and can, at the same time, lower emissions, land-use and water consumption. Closing yield gaps and nutrient loops are both key to getting us back into the safe operating space for biogeochemical flows (Willett et al., 2019 and Campbell et al., 2017).

2.1.6 Ocean acidification

Covering over 70 per cent of Earth's surface, the oceans absorb approximately 90 per cent of anthropogenic heat and 30 per cent of CO_2 emissions. Oceans actively buffer against global warming, and as a result, significant changes in perennial ice cover and ocean temperature and chemistry are observed. One of these changes is ocean acidification, and it is a direct consequence of the anthropogenic alteration of the carbon cycle. With higher carbon levels in the atmosphere, seawater absorbs more CO_2, and a series of chemical reactions occur, which have far-reaching consequences for the ocean and biodiversity. When CO_2 dissolves in water, carbonic acid is formed ($CO_2 + H_2O \rightarrow H_2CO_3$), a weak acid that dissociates into hydrogen ions (H^+) and bicarbonate ions ($H_2CO_3\ H^+ + HCO_3^-$). Hydrogen ions lower the pH of seawater, an effect that has resulted in a 34 per cent rise in seawater acidity since the 1800s (Campbell et al., 2017). In turn, the hydrogen ions bond with available carbonate ions (CO_3^{-2}) in ocean water to form bicarbonate ions ($H^+ + CO_3^{-2} \rightleftarrows HCO_3^-$), meaning that less carbonate ions are available to bond with calcium ions (Ca_2+) to form aragonite ($CO_3^{-2} + Ca^{2+} \rightleftarrows CaCO_3$), an important mineral for calcifying organisms that depend on it to build and maintain their shells, skeletons and other calcium carbonate structures. If the pH of seawater gets too low, calcium carbonate structures become more fragile over time and can even dissolve (Bednaršek et al., 2021).

Open ocean surface pH has declined by a range of 0.017–0.027 pH units per decade since the late 1980s, and without substantial reductions in CO_2 emissions, the acidity is projected to increase by approximately 150 per cent by 2100, marking the fastest chemical ocean change in millions of years (IPCC, 2019, Campbell et al., 2017, Kwiatkowski et al., 2020). With increasing ocean acidity and a decreasing aragonite saturation state (Ωarag), species composition and abundance are rapidly decreasing. Stark examples are the decrease in phytoplankton and the disappearance of coral reefs around the world, impacting the entire marine food web (Rockström et al., 2009). Over several generations, increasing ocean acidification could significantly impact the composition, growth rate, metabolism, and reproduction of marine life. Unfortunately, with the complexity of marine food webs, ongoing environmental degradation (e.g. fishing and pollution) and environmental problems like increased ocean warming and decreased salinity, it is difficult to predict how ecosystems will reorganise under increased seawater acidity. The planetary boundary for ocean acidification is set at 80 per cent of the average pre-industrial aragonite saturation state (2.75 Ωarag) to prevent high-latitude waters from becoming undersaturated and to maintain adequate conditions for coral systems. But with current levels of 2.8 Ωarag, the boundary is close to being breached (Richardson et al., 2023) - see Table 6.

Table 6. The boundaries and current state of the control variable for 'ocean acidification' are expressed by the average global surface ocean saturation state with respect to aragonite (Ωarag) according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Ocean acidity [Ωarag]
Holocene base value	**3.44 Ωarag**
Planetary Boundary	**>2.75 Ωarag**
High-Risk Boundary	**2.75 Ωarag**
Current state	**2.8 Ωarag**

The food sector is impacted by these changes, but contributes to it as well, as it is a major source of CO_2 emissions. The food production system releases CO_2 directly into the atmosphere and releases additional CO_2 through land-use change, forest clearing, wetland draining, soil tilling, and biomass burning. It also contributes indirectly through nitrogen inputs to coastal waters that stimulate algal growth, lowering oxygen levels when it starts to rot. The involved microbial respiration produces CO_2 emissions that add to regional seawater acidification. Following the method of Campbell et al. (2017) and according to emission data from FAOSTAT, agriculture's share in driving ocean acidification has been approximately 25 per cent over the past decades - this being the proportion of CO_2 emissions from agriculture, including land-use change (Campbell et al., 2017, FAOSTAT data Nov 2023).

With current atmospheric CO_2 concentrations, the planetary boundary for ocean acidification is bound to be crossed in the near future. A drastic reduction in GHG emissions is required to slow down future acidification rates, but it won't get us back into a safe operating space anytime soon. Mitigation efforts must be taken to prevent environmental degradation and to draw down CO_2 from the atmosphere:

(i) the protection and restoration of terrestrial and aquatic ecosystems to increase ecosystem resilience and carbon sequestration;

(ii) restoration of natural coastal elements and wetlands (e.g. seagrass, mangroves and peatlands) to prevent agricultural and industrial runoff to and increase the pH of coastal waters; and

(iii) a global transition of the food system from animal-based to plant-based sources to halt and reverse damage caused through unsustainable farming practices such as fishing and animal farming (Campbell et al., 2017).

25%

According to emission data from FAOSTAT, agriculture's share in driving ocean acidification has been approximately 25 per cent over the past decades

2.1.7 Stratospheric ozone depletion

The stratospheric ozone layer plays a crucial role in protecting life on Earth. It acts as a natural shield against the sun's harmful ultraviolet (UV) radiation, which can cause various adverse effects on living organisms, including (i) direct damage to DNA molecules with the possibility of causing mutations and cancer; (ii) cellular and tissue damage, disrupting cell function and causing degeneration; and (iii) damage to the photosynthetic apparatus, resulting in reduced plant growth and decreased productivity. Ozone (O_3) absorbs the vast majority of the incoming (UV-B) radiation, preventing it from reaching the Earth's surface. Therefore, the protection of the ozone layer is crucial for minimising the harmful impacts of UV-B radiation on living organisms.

Ozone molecules are continually regenerated in Earth's stratosphere in a process called the Chapman cycle (i.e. ozone-oxygen cycle), but the cycle is disrupted by reactive molecules (free radicals) - the most important being hydroxyl (OH), nitric oxide (NO) molecules, and bromine (Br) and chlorine (Cl) atoms - leading to a thinning of the ozone layer. Hydroxyl and nitric oxide are naturally present, but human activities have greatly increased the concentration of Cl and Br in the stratosphere, leading to rapid ozone depletion. This happens primarily through the emission of chlorine and bromine source gases (CFCs, HCFCs and other halons) but nitrous oxide (N_2O) also contributes to this effect. The accumulation of Ozone-Depleting Substances (ODSs) in the atmosphere has led to the formation of a hole in the Antarctic ozone layer, which is a "textbook example of a threshold in the Earth System being crossed", according to Rockström et al. (2009). The discovery of the ozone hole in 1985 led to the signing of the Montreal Protocol and the regulation and phase-out of ODSs, resulting in a slight recovery of the ozone hole since the beginning of this century. The planetary boundary for stratospheric ozone depletion is set at a global average ozone concentration of 276 DU (Dobson Units) - 5 per cent below the 1980 level of 290 DU. With the current (2020) level of 284.6 DU, the ozone level is back in the safe operating space - see Table 7. The boundary is currently only locally transgressed during the Austral spring over the Antarctic, but that will remain until the ozone hole is fully recovered (Richardson et al., 2023).

Table 7. The boundaries and current state of the control variable for 'stratospheric ozone depletion' is stratospheric ozone concentration expressed by Dobson units (DU) according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Stratospheric ozone concentration [Dobson units (DU)]
Holocene base value	**290 DU**
Planetary Boundary	**276 DU**
High-Risk Boundary	**261 DU**
Current state	**284.6 DU**

Even though the ozone hole is not an immediate threat anymore, recovery of the ozone layer highly depends on the chemical and climate effects of GHGs such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Increasing concentrations of CO_2 and CH_4 will increase ozone levels beyond the natural level last observed in the 1960s. Increasing N_2O emissions, on the other hand, will cause ozone depletion (World Meteorological Organisation 2022). Under low emission scenarios, the global average ozone level will not fully recover and will stay below the 1980 level. Agriculture's share in stratospheric ozone depletion is increasing, partly because of increased N_2O gases due to rising global food demand and a reduction in other ODSs. Unlike many ODSs, N_2O is not regulated and is now the single most important ODS emission (Rockström et al., 2009). In agriculture, N_2O emissions are mainly associated with the use of fertilisers, manure management and biomass burning, and its share of global N_2O emissions is approximately 80 per cent. Given the historical emissions of other ODSs, the current impact of the food sector is relatively low (approximately 5 per cent), but this is projected to increase as the atmospheric level of non-N_2O ODSs decreases (Campbell et al., 2017). Sustainable agricultural practices, such as optimised fertiliser use on cropland, are highly effective approaches to mitigate anthropogenic N_2O emissions. Limiting these emissions not only supports the recovery of the depleted ozone layer but is also beneficial to the climate system.

2.1.8 Atmospheric aerosol loading

Atmospheric aerosols are known to significantly affect air quality, health, and the climate. These aerosols can be natural, such as sea spray, mineral dust, pollen, and volcanic ash, or they can be anthropogenic, originating from human activities like chemical manufacturing, fossil fuel combustion, biomass burning, and the application of fertilisers and pesticides on land. Exposure to airborne particulate matter (PM) and other aerosols is associated with severe health problems, including asthma, bronchitis, lung cancer and cardiovascular disease, that lead to millions of premature deaths annually. Additionally, aerosols greatly influence the climate system through various physical, biogeochemical and biological processes that include scattering and absorption of solar radiation, changes in temperature and precipitation patterns, and changes to cloud formation and albedo (Rockström et al., 2009, Richardson et al., 2023).

According to Richardson et al. (2023), a planetary boundary for atmospheric aerosol loading was difficult to set due to the multitude of natural and anthropogenic sources of aerosols, the differences in their chemical composition and mixture, the seasonal changes and their atmospheric lifetimes, and the resulting spatial and temporal differences in their distribution and the impacts they have on the climate and ecosystems. Steffen et al. (2015), adopted the aerosol optical depth (AOD) control variable, which captures the total reduction of sunlight reaching the Earth's surface due to the absorption and scattering of aerosol particles throughout a vertical air column. A provisional regional boundary was set at an AOD of 0.25 because higher values in monsoon regions are likely to result in significantly less rainfall, which ultimately affects the integrity of the biosphere. Emissions from land-clearing (slash-and-burn practices) or fossil fuel combustion in densely populated areas, but also volcanic events and dust storms, can result in much higher AOD values. In fact, in certain regions, AOD values routinely transgress that boundary. As a reference, AOD values of approximately 1 indicate hazy conditions, and AOD values above 2 or 3 represent very high concentrations of aerosols in the atmosphere during severe pollution events.

The recent assessment by Richardson et al. (2023), redefined the boundary to the mean annual AOD difference between the Northern and Southern Hemispheres (interhemispheric difference) because AOD asymmetries can affect multiple monsoon systems. The high concentration of aerosol pollution and land use changes in the Northern Hemisphere are causing a temperature asymmetry that shifts tropical precipitation southward, reducing global land monsoon precipitation and water availability. A global boundary is set for an interhemispheric AOD difference of 0.1, and with the current estimated AOD of 0.076, atmospheric aerosol loading is still in the safe operating space - see Table 8. While this is still in the safe zone, the impacts of aerosol loading are already experienced today and are projected to exacerbate with future emissions.

Table 8. The boundaries and current state of the control variable for 'atmospheric aerosol loading' are expressed by the interhemispheric difference in aerosol optical depth (AOD) according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Interhemispheric difference in aerosol optical depth
Holocene base value	**0.03 AOD**
Planetary Boundary	**0.1 AOD**
High-Risk Boundary	**0.25 AOD**
Current state	**0.076 AOD**

Agriculture contributes to aerosol loading directly and indirectly through fossil fuel combustion, land clearing (slash-and-burn practices), biomass burning, and the application of fertilisers and chemicals (e.g. pesticides, herbicides, and insecticides) on land. **Agriculture, especially animal agriculture, is a major source of nitrate and sulphate aerosols, which are formed when fumes from nitrogen-rich fertilisers and animal manure (ammonia - NH_3) are mixed with combustion emissions, such as nitric oxide (NOx) and sulphur oxide (SOx).** Additionally, the burning of crop residues and other biomass is known to contribute significantly to atmospheric aerosol levels. From a human health perspective, fine particulate air pollution (PM_2.5) poses the greatest risk. In many areas, the emissions from agriculture dominate all other human sources of PM_2.5 (Bauer et al., 2016). Agriculture's impact on aerosol loading according to the method introduced by Richardson et al. (2023) is yet to be assessed, but agricultural activities do significantly contribute to aerosol loading. A previous assessment by Campbell et al. (2017) concluded that agricultural-related emissions are the dominant source of PM in some densely populated areas and that agricultural burning and fertiliser usage contribute approximately 3 per cent and 11 per cent of the global PM, respectively. Implementing bans on open burning of agricultural waste and slash-and-burn practices, and adopting more efficient fertiliser practices could effectively mitigate aerosol loading and would be beneficial for human health, ecosystems and the climate system.

2.1.9 Novel entities

Novel entities refer to substances or materials that are human-made and introduced into the environment, often with properties or compositions not previously encountered in the natural world. According to planetary boundary science, these can include synthetic chemicals and substances like microplastics, endocrine disruptors, organic pollutants, and other anthropogenically created materials. Additionally, novel entities encompass mobilised radioactive materials, such as nuclear waste and nuclear weapons, as well as human modifications of evolution, like genetically modified organisms (GMOs) and direct interventions in evolutionary processes (Richardson et al., 2023). The impact of novel entities on the Earth system is multifaceted. These substances can pose risks to biosphere integrity, human health, and overall ecological balance. For example, microplastics and other forever chemicals can accumulate in ecosystems and drinking water, affecting both aquatic and terrestrial life. Endocrine disruptors may interfere with hormonal systems in organisms, leading to reproductive and developmental issues. Genetically modified organisms introduce altered genetic material into ecosystems, raising concerns about unintended consequences for biodiversity. Evidence on the diverse risks of novel entities is growing, yet, there are still gaps in our understanding of their full impact on Earth system functioning, human health, and food security (Persson et al., 2022, Rockström et al., 2023).

It remains a scientific challenge to determine the extent to which the Earth's system can handle novel entities before an irreversible shift takes place. But with hundreds of thousands of synthetic chemicals now being produced and

released into the environment, without first considering the health of the environment and living organisms, scientists agree that this boundary is clearly transgressed. Novel entities have been introduced in the past that surprised humanity with unintended consequences, for instance, the impact of CFCs on the ozone layer, and the health and environmental harm related to insecticides like DDT and the release of PCBs (Persson et al., 2022 and Bierbaum et al., 2020). Thus, this boundary is set at 0 per cent untested synthetics, and that includes all entities that wouldn't be present in the absence of the anthroposphere - see Table 9. While current data availability is incomplete, and safety tests often don't consider "cocktail effects", Persson et al. (2022) highlight that among the chemicals currently listed under the EU Registration, Evaluation, Authorisation of Chemicals (REACH) regulation (which represents only a fraction of the overall chemical landscape), approximately 80 per cent of these substances have been in use for a minimum of 10 years without undergoing a safety and health assessment.

Table 9. The boundaries and current state of the control variable for 'novel entities' are expressed by the percentage of novel entities that can be allowed in the Earth's system according to the September 2023 planetary boundaries update (Katherine Richardson et al., 2023).

	Novel entities [%]
Holocene	**0%**
Planetary Boundary	**0%**
High-Risk Boundary	**N/A**
Current state	**Transgressed**

From discarded fishing gear to biocides, and from antibiotics to GMOs, there is no doubt that the global food system is responsible for the introduction of novel entities in the environment. Abandoned, lost or discarded fishing gear, such as nets, traps, pots, hooks, and lines, directly affects the integrity of the biosphere through ghost fishing and habitat destruction. The adverse impacts of land and marine animals encountering and ingesting microplastics from fishing gear and food packaging are well documented, and the impact of microplastics becomes increasingly clear. Additionally, many toxic chemicals, biocides and antibiotics originate from agriculture and aquaculture, many of which are highly biologically active, and concentrations often exceed thresholds (Stehle and Schulz, 2015). Whether or not engineered crops, seeds or microbes are needed to help transform agriculture, is still debated. Several case studies suggest that GMO crops reduce the need for pesticides while increasing yield and survival rates during stressful conditions like droughts, but many health and environmental safety concerns remain (Campbell et al., 2017). Modified microbes already play an important part in the food industry with precision fermented vitamins, enzymes and flavours, but they can also be used to produce specific proteins and fatty acids efficiently (Linder, 2019 and Matassa et al., 2016). Precision fermentation has the potential to drastically reduce the environmental impact of the global food system, but this highly depends on the used feedstock and production method. One thing is for sure, novel entities should not be used or introduced by the food system unless their potential impacts with respect to the environment and health have been thoroughly evaluated (Richardson et al., 2023).

2.2 Plant Based Treaty's food system boundaries within the donut's social foundation

In this section we will examine the inner circle of the Plant Based Treaty Donut Economics model. We have chosen twelve social boundaries that focus on the food system. In Johan Rockström and Owen Gaffney's (2021, 130) book, *Breaking Boundaries*, they say, "The final battle over whether we successfully deliver on the Paris Climate targets rests on whether we are able to transform the global food system". They stress the importance of addressing food system impacts and policy on our planetary boundaries:

"The way that we produce food in the world is the single largest reason that we have transgressed planetary boundaries. It is the single largest threat to the stability of the planet and our life support systems, from freshwater, pollinators, and soil health, to rainfall generation, and quality of air and water. Food production is putting our future at risk" (Rockström and Gaffney, 2021, 130).

According to Rockström and Gaffney (2021, 137), we need to cut greenhouse gas emissions 50 per cent by 2030. They advocate for a "zero goal" and say, "We must now ensure zero expansion of new agricultural land". In terms of intergenerational justice we need to cut emissions sooner and faster in rich nations and set a hard target of net zero by 2040. To achieve nature and biodiversity recovery as well as build resilience by 2050, governments must urgently end forest and wetland loss by 2030. If we did this, we would have an ordered exit rather than shock and a full recovery by 2050 (Rockström and Gaffney, 2021, 186).

Rockström and Gaffney (2021, 130) explain that food policy is around 30 years behind energy, and with so little time remaining we need a paradigm shift and action plans at all levels: individual, institutional, business, city, country, and global. This report makes the case for both individual diet change, policy change and system change.

This section will present the missing action plan that can reduce the 30 year shortfall by incorporating the Plant Based Treaty model into Kate Raworth's Doughnut Economics model. The model identifies social boundaries needed to equitably meet basic human needs such as water, food, health, education, income and work, peace and justice, political voice, social equity, gender equality, housing, networks, and energy (Raworth, 2017). The model draws on 12 of the 17 UN's Sustainable Development Goals (Global indicator framework for the Sustainable

Development Goals and targets of the 2030 Agenda for Sustainable Development). In our adaptation of Raworth's model, the focus is on the food system and widening the lens to incorporate interspecies justice alongside intergenerational and intragenerational justice (Rockström et al., 2023).

Plant Based Treaty has three core principles known as the 3Rs. These include 40 detailed proposals for a plant-based transition which would reduce greenhouse gases, land-use, ocean acidification, freshwater withdrawals and eutrophication, and enable us to live safely and equitably within our planetary boundaries. For example, the most extensive analysis to date on food system impacts by Dr. Joseph Poore and Dr. Thomas Nemecek, shows the imperative of dietary change: "Moving from current diets to a diet that excludes animal products has transformative potential, reducing food's land use by 3.1 … billion ha (a 76 per cent reduction), including a 19 per cent reduction in arable land; food's GHG emissions by 6.6 … billion metric tons of CO_2eq (a 49 per cent reduction); acidification by 50 per cent …; eutrophication by 49 per cent …; and scarcity-weighted freshwater withdrawals by 19 per cent … for a 2010 reference year" (Poore and Nemecek, 2018, 5). See Figures 3 and 4.

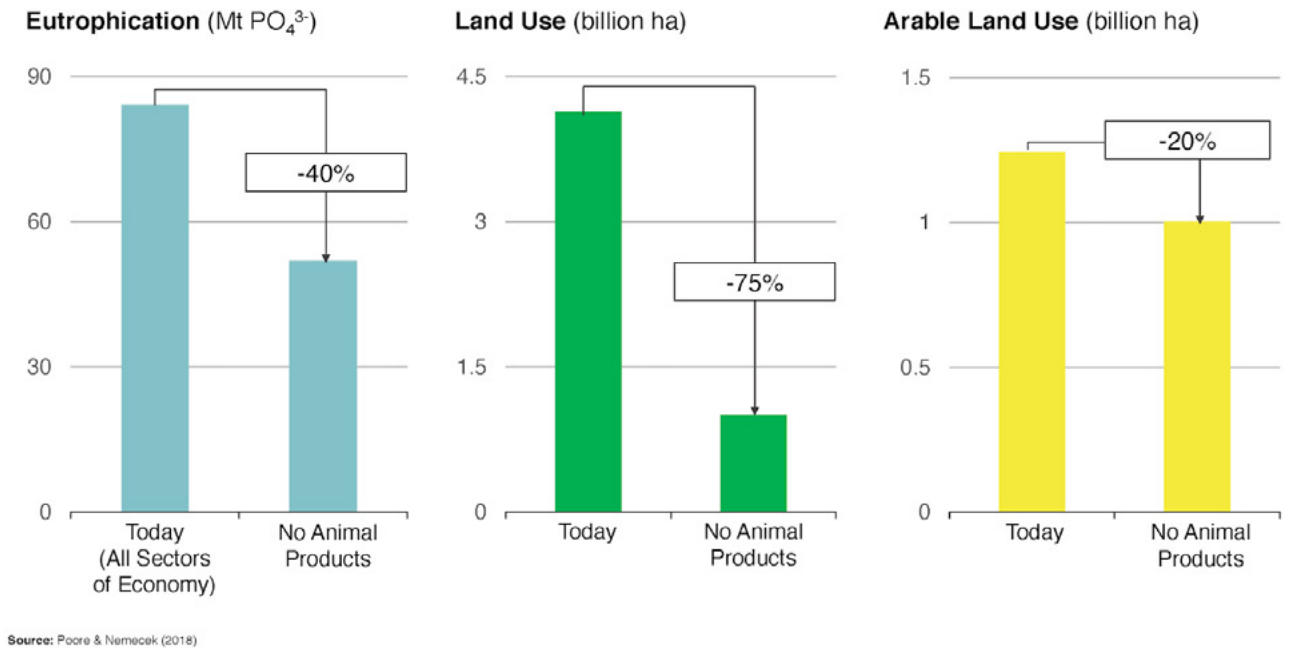


Figure 3: The imperative of dietary change is seen in its transformative potential for reducing food's impact on eutrophication, land-use and arable land-use.

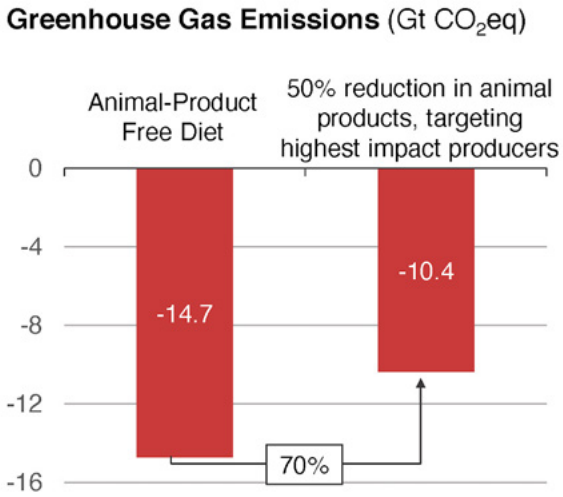


Figure 4: Joseph Poore and Thomas Nemecek (2019) show the imperative of dietary change on greenhouse gas emission reduction.

For R1, *Relinquish*, we will be looking at live exports, land-use change and Indigenous protection; in R2, *Redirect*, we will explore food security, education, health, honest labelling, transparency, and financing for plant-based systems; in R3, *Restore*, we examine reforesting and rewilding, greening cities, food justice and land equity. See Chapter 3 for more on city plans and for a list of best practices for institutions.

For each social boundary we explore indicators to assess safe boundaries, look at how we are falling short, detail the impact of the food system, and explain how to get back into a safe operating space.

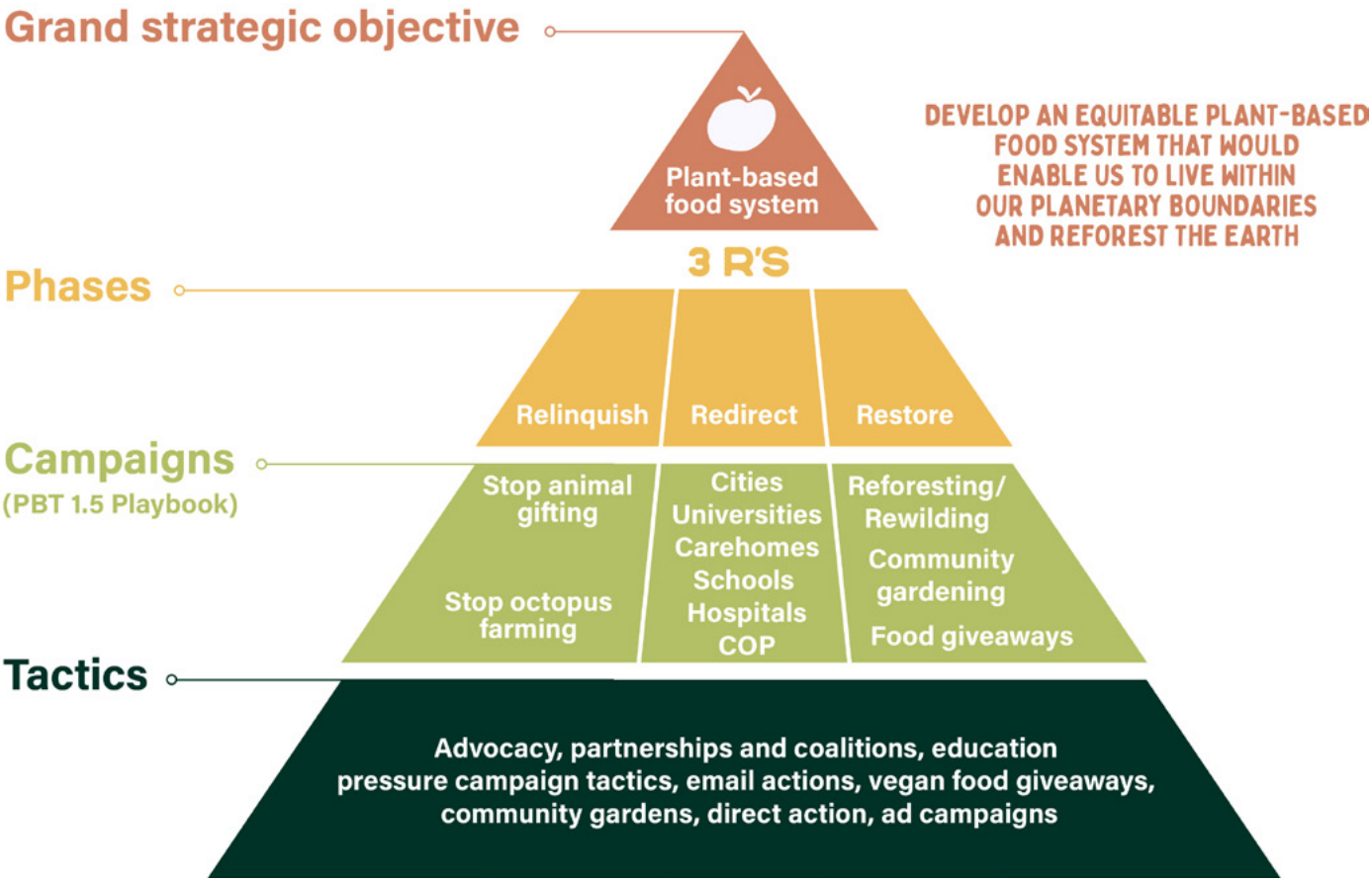


Figure 5: The Plant Based Treaty model: Our grand strategic objective is to develop an equitable plant-based food system that would enable us to live within our planetary boundaries. There are three main principles or phases: Relinquish, Redirect and Restore. Each phase contains a multitude of campaigns with 100s on nonviolent tactics to transform the food system.

2.2.1 No land use change

In Plant Based Treaty's R1, Relinquish, there are 10 proposals designed to "Stop the problem increasing," including, no clearing of forests or other ecosystems for animal grazing, animal rearing, or animal farming of any kind. Stabilising global climate, regulating regional water cycles and stopping the extinction of plants and animal species is dependent on protecting intact nature from land and ocean changes, particularly by halting ongoing conversion of land to agriculture, across all biomes (DeClerck, 2023). The Convention on Biological Diversity (CBD) Target 1, calls for "ensuring that all land and sea areas globally are under integrated biodiversity-inclusive spatial planning addressing land- and sea-use change, retaining existing intact and wilderness areas." A systems thinking approach is required in our policy making to address interrelated goals for biosphere integrity, freshwater use, and climate and ocean protection alongside health, food and nutritional security.

Indicators for safe boundaries and how we are falling short?

We need at least a global average of 75 per cent of forest cover as compared to what was in the Holocene. The current status is just 60 per cent as noted above in the planetary boundaries section of this chapter (Richardson K. et al., 2023).

The Declaration on Forests and Land Use launched at COP26 has been signed by over 140 countries, representing 90 per cent of the world's forests. It includes a commitment to halt and reverse deforestation by 2030: "Conserve forests and other terrestrial ecosystems and accelerate their restoration; Implement and, if necessary, redesign agricultural policies and programmes to incentivise sustainable agriculture, promote food security, and benefit the environment" (Glasgow Leaders' Declaration on Forests and Land Use). According to UNEP, current projections show that we are not on track. "Between 2021 and 2022, the global tree cover loss rate declined 9.7 per cent to 22.8 million hectares (ha) per year… However, humanity is not on track to end and reverse deforestation by 2030, despite pledges by more than 100 world leaders in 2021 at COP26." (UNEP, 2022). In Amazonas state, which covers 30 per cent of the Brazilian Amazon, an area of 10,781 km² was deforested in one year (August 2021 - July 2022). This deforestation was mainly due to agricultural expansion, particularly cattle ranching (Vilani et al., 2023, 148–151).

What is the impact of the food system on this social boundary?

As shown above in the planetary boundaries section of this chapter, agricultural expansion is the leading cause of land-use change globally. It has transformed habitats with complex ecosystems into simplified deserts, fuelled widespread deforestation and is one of the greatest pressures for biodiversity: of the 28,000 species evaluated to be threatened with extinction on the IUCN Red List, agriculture is listed as a threat for 24,000 of them (Ritchie, 2019).

According to Dr. Joseph Poore (2023), urban areas globally occupy around 2 per cent of the world's land. Arable land for crops significantly increases human land use to 24 per cent, and grown intensively, they exclude nature. Land for grazing animals occupies vast areas. Global agriculture is using a staggering 55 per cent of the world's land. As seen in Figure 6, the demand for dairy milk and cheese uses an area the size of Brazil, Paraguay, Uruguay, and Ecuador. Farmed cows and lambs for meat occupy an area the size of north and central America, a bit of South America plus vast areas of rangelands which involve less intensive forms of cow and sheep farming. Poore says, "There is a striking disparity between the land used for animal products and the land that is used for other food. Despite that being a lot of land we are still continuing to convert more land every year for food and agriculture." In George Monbiot's Regenesis (2022) he refers to this expansion as agricultural sprawl. He highlights how people are quick to rally against urban sprawl, despite it occupying a comparatively smaller proportion of land compared to grazing animals, bringing a high ecological opportunity cost due to the missing ecosystems that would otherwise exist.

How do we get back into a safe operating space?

Transitioning to a plant-based food system could not only halt deforestation but would create an opportunity to rewild three quarters of agricultural land (Poore and Nemecek, 2018).

A groundbreaking EU deal to ban the import of goods linked to deforestation has set a global benchmark and will hasten the passage of a similar law in the U.S., American lawmakers have said. The EU says this will in effect prohibit the import of commodities such as beef, soya, palm oil, coffee, cocoa, rubber, charcoal and paper, unless their origins can be traced, using geolocation data. The EU's environment commissioner, Virginijus Sinkevičius, described the agreement as "the most ambitious legislative attempt to tackle these issues worldwide ever". From 2025, a review clause in the law could allow it to be extended to "other wooded land" such as Brazil's Cerrado – the source of an estimated 65 per cent of the EU's soya-related deforestation – and to other commodities such as maize and biodiesel. From 2026, the law could cover other ecosystems with high biodiversity value or heavy carbon content (Neslen, 2023).

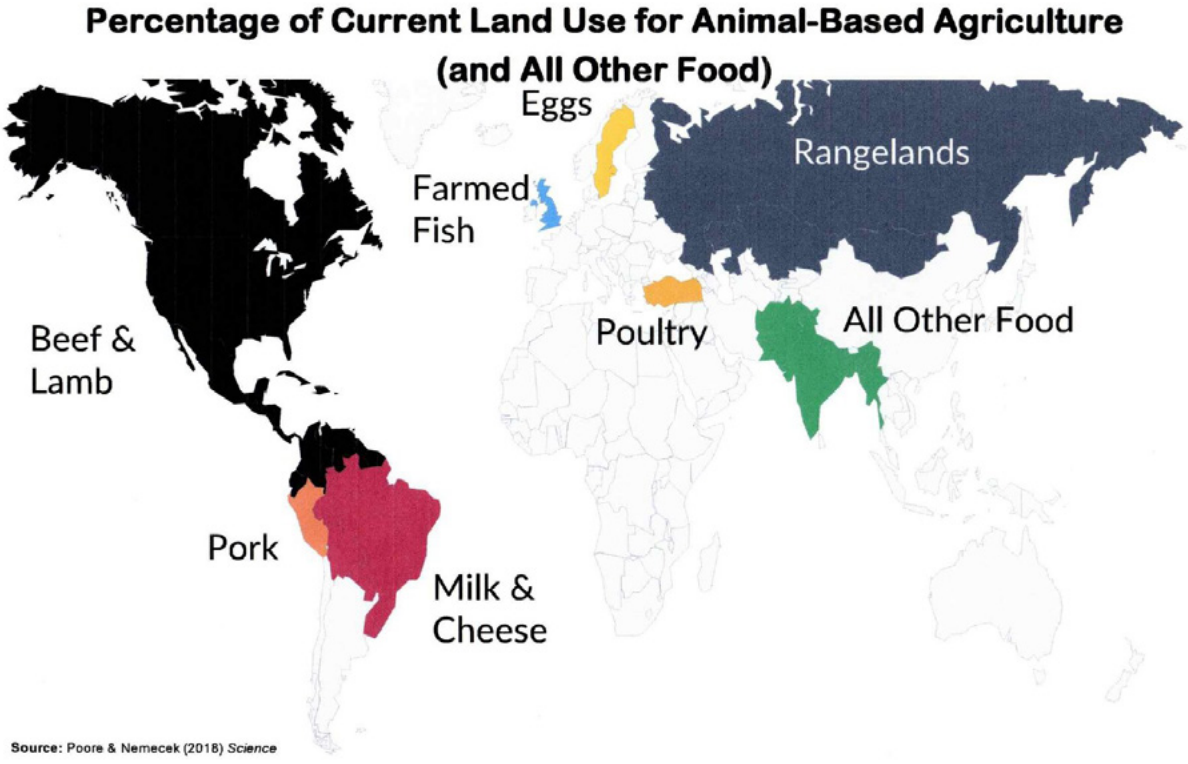


Figure 6: The use of land required globally for animal agriculture.

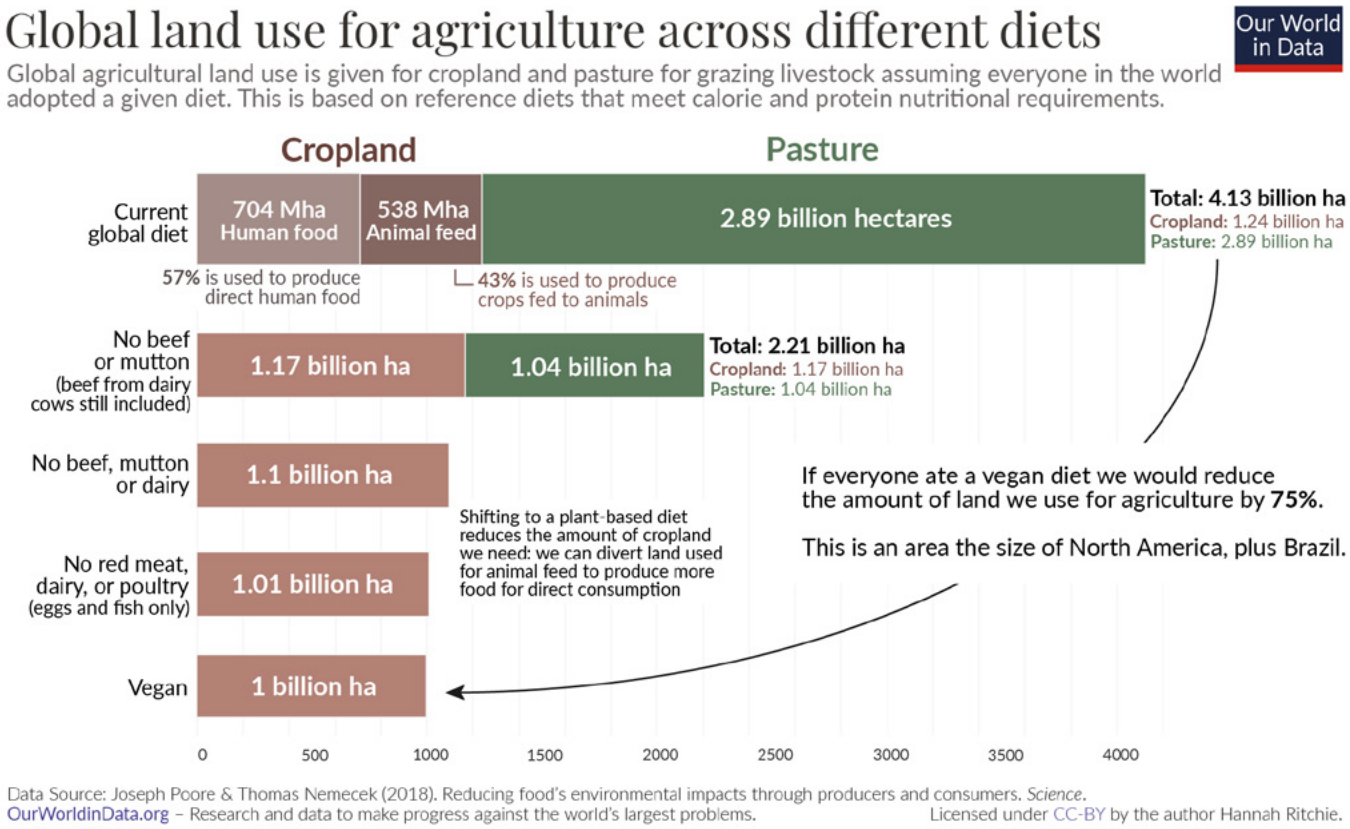


Figure 7: The current global diet uses 4.13 billion ha of land and results in a lot of wasteful land use. For example, 43 per cent of cropland is used to raise farmed animals rather than feed humans directly. If we combine all land required for farming animals for meat – including grazing pastures and land used to grow crops for animal feed – animal agriculture accounts for 83 per cent of global farming land. Yet despite taking up most of the world's agricultural land, animal farming only produces 18 per cent of the world's calories and just 37 per cent of total protein (Poore and Nemecek, 2018). In stark contrast, shifting to plant-based diets would require just 1 billion ha of land, a 75 per cent reduction. Eliminating cow and sheep flesh from our diets would almost halve land use to 2.21 billion ha. Further eliminating dairy would halve land-use again to 1.1 billion ha and excluding eggs and fish would reduce land by 0.01 billion ha.

2.2.2 Indigenous protection

There are 5,000 different Indigenous Peoples spread across more than 90 countries with a population of 476 million, speaking a combined 4,000 languages (Amnesty International, no date). Many Indigenous groups, including the Yanomami, Kayapo, and Ashaninka, in the Amazon, as well as the Nahua, Ngiwa, and Mixteco, in Mesoamerica, consider the forests home. Indigenous communities possess deep-rooted connections to their lands which are under severe threat from deforestation. Their holistic and symbiotic relationship with the environment allows a sustainable stewardship that's been fine-tuned over generations. This deep understanding and respect for the land has made many Indigenous practices inherently sustainable and adaptive.

Plant-based diets have been at the core of indigenous Mesoamerican civilizations for over 10,600 years. Since preceramic times, traditions of health and nutrition centred seeds, weeds, roots and mushrooms as major components of the diet, guarding alimentary, agronomic, and ecological complementarities within food systems, nature and societal relations. Indigenous Peoples are the guardians of this ancestral knowledge and traditions, which rely on the diversity of plant species from their various ecosystems.

Ecosystems, knowledge, and traditions that have sustained these alternative nurturing methods for nature and societies for thousands of years are now being systematically threatened. Since the very first introduction of animal farming through colonisation, and continuing with the neocolonial tendencies of 'Big Ag' promoting the consumption of Western meat-based diets, Indigenous Peoples have been resisting industrial agriculture and factory farming. These extractivist systems threaten the loss of plant biodiversity and the oral traditions surrounding ancestral diets.

Indigenous Peoples are often marginalised and face

discrimination in countries' legal systems, leaving them even more vulnerable to violence and abuse. Indigenous human rights defenders who speak out, face intimidation and violence, often supported by the state. Peaceful efforts by Indigenous Peoples to maintain their cultural identity or exercise control over their traditional lands, where biodiversity is protected, have led to accusations of treason or terrorism. "Communities, many of them indigenous, who have protected their land for generations, are left in the firing line of unaccountable companies, state security forces and contract killers. A lack of attention to the problem has fed endemic levels of impunity, with investigations into killings rare, and even fewer prosecutions" (Global Witness, Land Defenders).

Indicators for safe boundaries

Global Witness, in their Land Defenders project, tracks killings of land defenders and produces a yearly report since 2012. "Land and environmental defenders play a crucial role in protecting their land – and our climate – against destructive business practices. Yet more defenders than ever are being killed, while others are threatened, criminalised and attacked. Businesses, financiers and governments must protect defenders and bring those who harm them to justice."

How far are we falling short?

The Amazon plays a key role in a number of planetary boundaries, including climate, biosphere integrity and freshwater. The World Wildlife Fund says the Amazon is home to 10 per cent of known species on Earth. Indigenous territories cover around 30 per cent of the Amazon. Indigenous Peoples face threats to their safety and their Amazon home from deforestation, fires, and land grabbing. In 2022, at least 177 land defenders were killed trying to protect Earth, bringing the total number of deaths to 1,910 since Global Witness started recording killings in 2012 (See Figure 8).

DeClerck (2023) states, "Indigenous areas critically overlap with intact nature, with strong evidence that recognizing Indigenous Peoples' rights to land, benefit sharing, and institutions is essential to meeting local and global conservation goals (see also Garnett, 2019).

Although they represent just 5 per cent of the world's population, Indigenous Peoples safeguard 80 per cent of the planet's biodiversity and suffer 36 per cent of killings of land defenders (Amnesty International, Indigenous Peoples). At least 1,390 killings of land defenders have taken place since the adoption of the Paris Agreement on 12 December 2015. Global Witness (2023) says it can be difficult to identify the exact drivers of the killings of land defenders and connect them to specific sectors, however in 2022 they were able to link agribusiness to 10 killings, more than any other sector (see Figure 9). When reviewed within the context of the climate emergency, these figures are particularly heartbreaking. The protection of the Amazon rainforest is a matter of urgency to avoid the worst consequences of the planetary crisis.

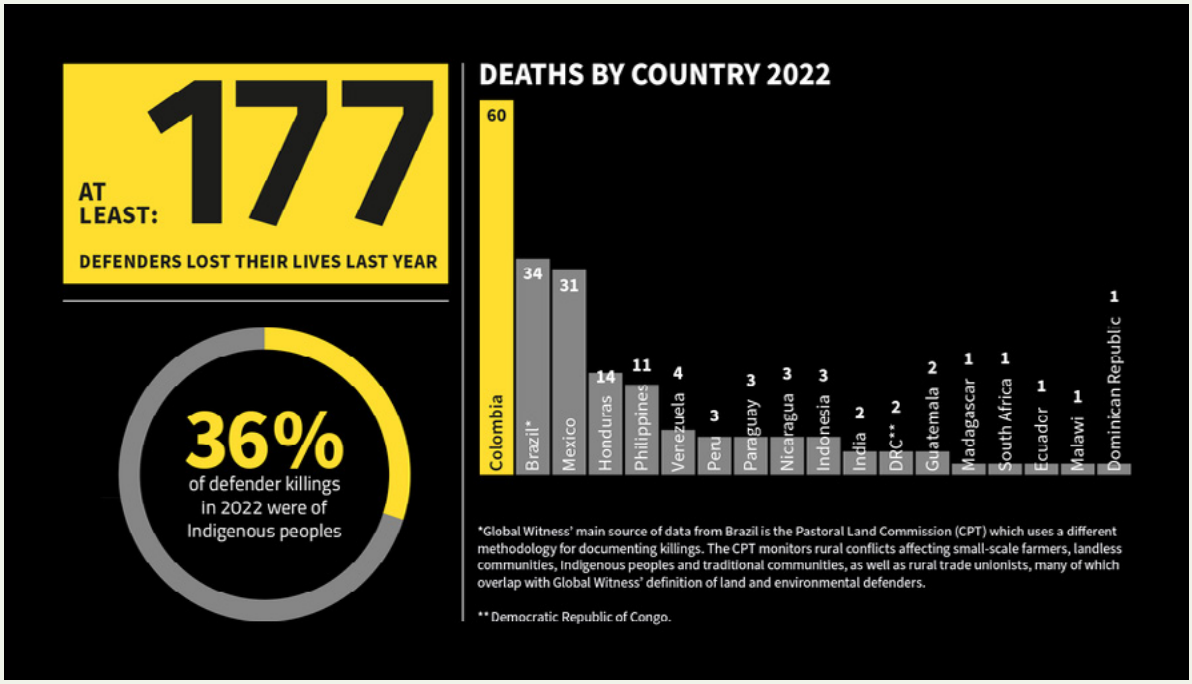


Figure 8: Standing firm: The Land and Environmental Defenders on the frontlines of the climate crisis

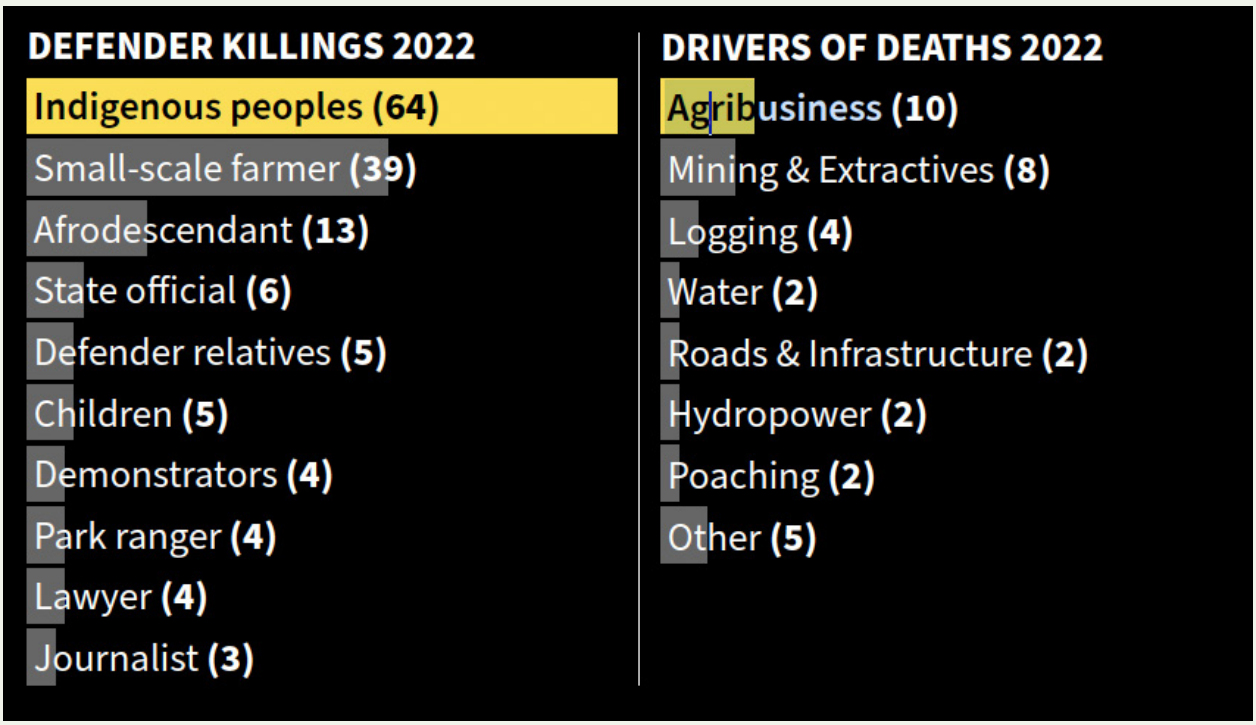


Figure 9: In 2022, Global Witness (2023) was able to link agribusiness to 10 killings of land defenders, more than any other sector

What is the impact of the food system on this social boundary?

In October 2023, a young Indigenous leader, Beka Saw Munduruku, travelled to Cargill's U.S. headquarters to appeal to the Cargill-MacMillan family to end their destruction of nature (Lakhani, 2023). Cargill is one of the largest agribusiness companies in the world and was branded the worst company in the world by the nonprofit Mighty Earth (2019). Their operations sprawl through the Brazilian Amazon and the Cerrado biome. Their operations have led to the deforestation of large areas of nature for the expansion of animal agriculture. Amazon Watch (2023), who arranged the trip for Beka Saw Munduruku, writes: "Cargill's reckless practices drive an ever-expanding wave of deforestation, pollution, and violence against local communities like the Munduruku."

In 2022, the Cargill-MacMillan family was the fourth richest family in America, with eight billionaires, more billionaires than any other family on Earth (Forbes, 2020). Cargill's owners refused to meet with Beka, so she gave her letter to security outside of Cargill's Minneapolis, Minnesota offices, demanding that the family stop the murder of land defenders and expansion of agricultural operations in her community's territories.

Beka's impassioned letter reads:

My name is Beka. I am 21 years old. I live on Sawré Muybu Indigenous territory in the Amazon forest in the state of Pará, Brazil. I have come to the United States to ask the Cargill-MacMillan family to stop the destruction of our land. My people are called the Munduruku, which means "the red ants." We are 13,000 strong, divided into 160 communities. Life is simple here. We plant, we harvest, we create. We learn by watching our elders. This is how we learn the riches of our culture: our stories, our forests, our animals. We defend our lands not just for our people but for all of humanity. Your company is harming our collective future. We have lived here in the heart of the Amazon for over 4,000 years. But now our world hangs by a thread. We have been fighting against Cargill for a long time. It has been devastating. Your executives tell us that Cargill is a good company, that they have pledged to end the destruction of nature. But this is not our experience. In every region where Cargill operates, you are destroying the environment and driving out or threatening the communities who live there. You must cease the destruction of our forests. You must stop expanding into our territory. You must stop selling commodities from lands stolen from Indigenous peoples. You must stop the murder of the defenders of these lands.

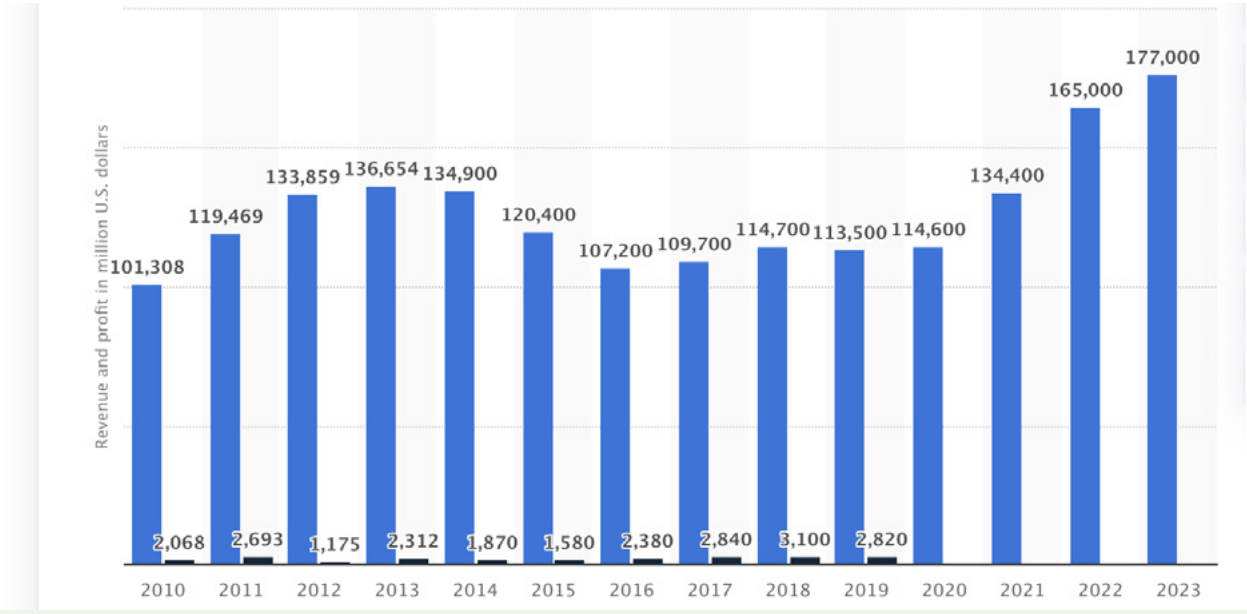


Figure 10: Cargill's revenue and profits (USD Millions)

The main driver of deforestation which causes harm to land defenders, is the expansion of soy production for animal feed. Mighty Earth (2022, 1) says, "Deforestation caused by soy production is at record levels in the vast but largely unprotected Cerrado savanna in Brazil and is devastating the climate-critical biomes such as the Santa Cruz and Chiquitania tropical forests in Bolivia. It is also destroying the livelihoods of local and Indigenous communities and threatens to wipe out more than 4,800 endemic species of plants and animals in the Cerrado alone."

An investigation from Mighty Earth (2022), found that two-thirds of meat products sold in Brazilian Carrefour stores came from JBS, a Brazilian firm who are the world's largest slaughterhouse company. 12 per cent of meat products were sourced from two slaughterhouses in Rondônia linked to deforestation on Indigenous land in the Amazon. The JBS facilities in Rondonia were also connected to illegal cattle farms on the Uru-Eu-Wau-Wau Indigenous territory in Rondônia state.

Despite the growing climate and biodiversity crisis and the severe impact of animal agriculture in making these problems worse (R1 of the Plant Based Treaty), Cargill, one of the world's leading animal feed, food producer and slaughterhouse companies, has reported record revenues for 2022 and 2023. Cargill's emissions reporting is also deceptive. For example, the company "declares its official annual emissions as 15 million tonnes. If it included the emissions arising from growing feed crops and their use by livestock then its climate impact, according to Global Justice Now's new findings, would be an estimated 145 million tonnes" (Levitt, 2015)

How do we get back into a safe operating space?

Land-use change, land grabbing and deforestation must be halted to protect Indigenous People and the lands must be returned to the Amazon under their guardianship. This will not only protect those communities but help protect the lungs of the Earth (World Wildlife Fund, Networks of support in the Amazon webpage). Enforcement of the Glasgow Leaders' Declaration on Forests and Land Use could also play a key role in land protection, by making the agreement legally binding and prohibiting the expansion of deforestation.

Plant Based Treaty's framework calls for the recognition and upholding of traditional land rights of Indigenous communities, ensuring their free prior and informed consent before any land-use change. It asks for collaboration with these communities to document and integrate their traditional knowledge into ecological management strategies and best practices. The IPCC highlights the importance of Indigenous communities and their traditional knowledge and ways of working with the land that has been sustainable for many generations, and provides ideal climate mitigation solutions (IPCC, 2022, 29-31). Worldwide, to stop the expansion of animal feed soy production and cattle ranching in the Amazon, we need to shift towards plant-based diets through a Plant Based Treaty, because the growing demand for meat and dairy globally is driving agricultural expansion and harming land defenders.

2.2.3 Ban live exports

The live export trade is a growing industry in the face of climate chaos and freshwater scarcity. There is a growing export trade of cows, sheep, and goats from Europe and North America into Asian and Middle Eastern countries directly linked to water shortages.

Live export refers to the practice of transporting live animals, such as cattle, sheep, chickens and horses, from one country to another for the purpose of sale, often for slaughter or breeding. This trade involves shipping animals over long distances, in unhygienic, cramped and stressful conditions. There are many groups worldwide such as Animals Australia, PETA, RSPCA, and Compassion in World Farming campaigning to ban live exports and public opinion polls routinely show support for a ban. For example, 78 per cent of Australians would support a phase of live exports out if farmers were supported through the transition (RSPCA, 2023). Another study found that women with a higher level of education were more likely to sign a petition to ban live exports (Fonseca and Sanchez-Sabate, 2022; Coleman, 2020, 10, 619). This section will describe the live export process from the perspective of the animals to highlight the deep connection between interspecies justice, the climate crisis, and water scarcity.

How far are we falling short?

Every day around five million animals sit in transit, in a secretive global trade of live farmed animals. To reduce greenhouse emissions, achieve interspecies justice, and ensure equitable distribution of finite resources such as water and land, the Plant Based Treaty calls for the continued expansion of live exports to be reversed and the trade brought to zero. The lengthy transport of animals inflicts substantial stress and suffering on them, leading to disease outbreaks, injuries, and even death during the journey (Bhatt et al., 2021). Currently, two billion animals a year, who begin life on factory farms, are transported via trucks, ships, and planes from the age of three weeks to new countries for breeding or slaughter (Osborne and van der Zee, 2020).

Animals start their long journey on a transport truck, often without food and water. On arrival at sea ports, they are moved into feeding lots/quarantine areas where they are held for up to a week. There can be anywhere between 7,000 to 30,000 animals held on each ship for medium capacity ships and as many as 120,000 sheep or 25,000 cows for the largest carriers. Sea journeys can take from two to 30 days depending on the distance to travel and speed of the ship. Summer months are the worst. For example, in Australia and the Middle East, where temperatures can reach up to 45°C inside the ships, animals are literally cooked from inside-out (Larsson and Levitt, 2020).

Inside the ship, animals urinate and defecate in the same spot together. Their bodies get covered with faeces which makes their body temperature rise, and many will develop a fever, diarrhea and vomiting. The unhygienic conditions increase the risk of disease outbreaks and pose serious risks to human health and biosecurity, and can result in substantial economic losses (Greger, 2007). Many animals become unwell and don't survive the trip and are thrown out to the sea. Injuries are commonplace due to the movement of the ship and tight quarters, resulting in

broken horns and legs. As well, some animals are blinded by another's horns or even due to the accumulation of ammonia inside the compartment. According to Australia's Department of Agriculture and Water Resources, over the years three million animals have died on live-export ships before reaching their destination, often from starvation or heat stress (Australia).

On arrival to their destination, cows that are too weak or injured to walk will be moved using a crane – sometimes only by hanging on one leg. During transit the majority of animals will have struggled to access food and water, because the supply is typically only on one side of the holding pen. This means the animals who do survive the journey are often sick, malnourished, dehydrated and wounded. On arrival to their destination, animals are taken into a quarantine holding area. The sick and injured animals who don't survive will be left there to die in pain typically without receiving any help or care.

Indicators for safe boundaries and impact of the food system

We are far from reaching zero live exports, on the contrary they are going up, with nearly two billion live pigs, chickens, cattle, sheep and goats shipped around the world in 2017 - see Figure 11, a figure that has almost doubled in a decade (FAO, Detailed Trade Metrix). Water scarcity and increasing demand for meat and dairy products are the key drivers of rising live exports, and have reshaped the global marketplace in the process (Michaelson and van der Zee, 2020).

Nations that can afford the political and financial costs are increasingly looking to avoid rearing animals from birth, which is a more water-intensive option. Figure 12 shows how exports to Egypt, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, and Saudi Arabia have risen dramatically over the past fifteen years, particularly from Europe. In just one year, Turkey went from importing $600m (£457m) worth of animals in 2016 to $1.2bn in 2017 (Michaelson and van der Zee, 2020).

The Guardian (Michaelson, 2020) reports, "the lack of water across the Middle East means that it is cheaper to import animals rather than raise them from birth. Dairy cows, a popular import from America and Germany, drink 30–50 gallons of water per day, with high-producing ones consuming even more. Cattle reared for meat consume slightly less water, but the overall amount is enough to encourage water-scarce countries to look for ways to shorten the amount of time they have to care for the animals, while reaping the benefits for their meat industries." In Egypt, due to the government premium on local beef, producers are saving water and expensive animal feed by importing 12-month old cows and raising them for their final six months before slaughter. A U.S. official noted: "Sudan is the largest single supplier of live animals – mostly cows – to Egypt… Egyptian beef farmers can then sell at market and say their product is Egyptian beef. But in terms of Sudanese water and feed – Egypt saves on those resources".

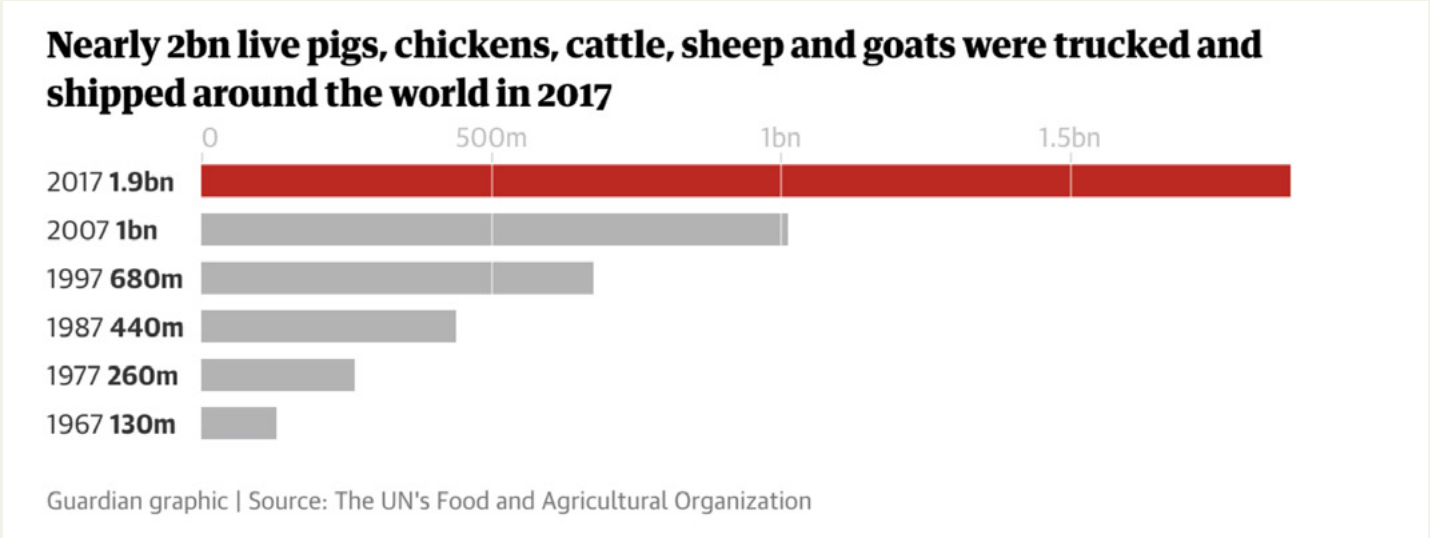


Figure 11: A bar chart demonstrating the total live exports of pigs, chickens, cows, sheep and goats between the years 1967 - 2017. Source: Guardian / UN FAO

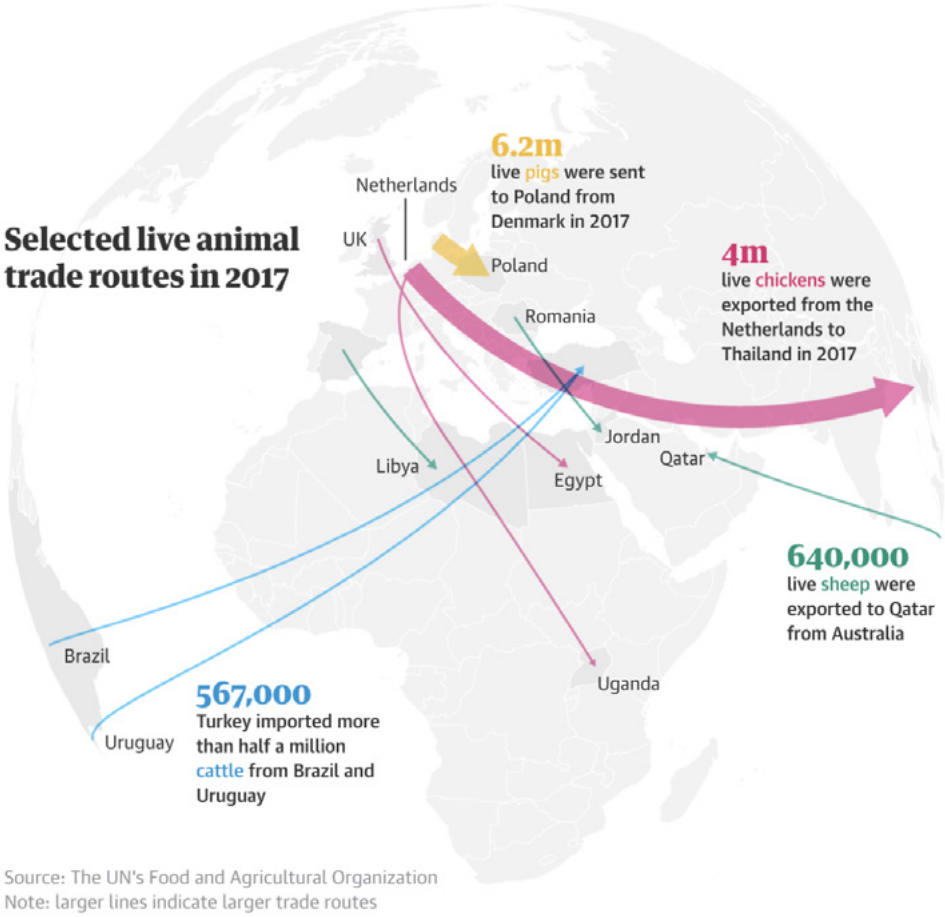


Figure 12: Global live transport trade routes, with thicker lines indicating larger quantities of animals exported along the route. Source: UN FAO

Air export

Animals are not only transported by land and sea. Canada is the largest supplier of horses to Japan, where they are slaughtered and served as a delicacy known as "bashishi", selling for over $75 USD per serving. These horses are flown almost weekly out of airports in Calgary, Edmonton and Winnipeg. Their destination is 9,000 kilometres away in Kumamoto Prefecture, in western Japan. The horses are brought to the airports from regions several hours away, are put in crates with 3-4 other horses, and loaded onto planes, so heavy that they have to stop to refuel in Anchorage, Alaska.

How do we get back into a safe operating space?

In line with R1 Relinquish of the Plant Based Treaty, there should be an immediate prohibition on live animal exports, ensuring stricter border control measures and tough penalties for illegal trade. Brazil and New Zealand have banned live exports and Luxembourg has banned exports to countries outside the EU (Compassion in world farming, 2023).

In 2023, the UK government announced a ban on the live exports of cattle, sheep, goats, pigs and horses for fattening or slaughter. Since the legislation was first announced in 2021, no animals have been exported for slaughter, however the legislation will ensure this is on a permanent basis (Hughes, 2023).


Photo: Canadian Horse Defence Coalition

2.2.4 Food security

As our planet heats up, plants and animals are pushed outside their climate niches. Conditions become too hot and dry for human societies and ecosystems to thrive, and these impacts are associated with lower food production. Every fraction of a degree of global warming will push more people to leave their lives and livelihoods behind due to food and water shortages and other crises, which is also linked to conflict (Xu et al., 2020, Kemp et al., 2022, and Lenton et al., 2023).

How far are we falling short?

Undernourishment is on the rise. In 2022, around 735 million people faced chronic hunger, a 122 million increase since 2019 (FAO et al., 2023). We are not on track to reach the United Nations goal of zero hunger by 2030 (FAO et al., 2023). The climate crisis has already reduced global agricultural productivity growth (Ortiz-Bobea et al., 2021, 306–312), and without addressing further greenhouse gas emissions will further escalate chronic hunger. Due to the increased risk of major multi-region crop failures, there is an urgent need to improve crop resilience and resistance to climate stressors, including heat and drought (Raza et al., 2019).

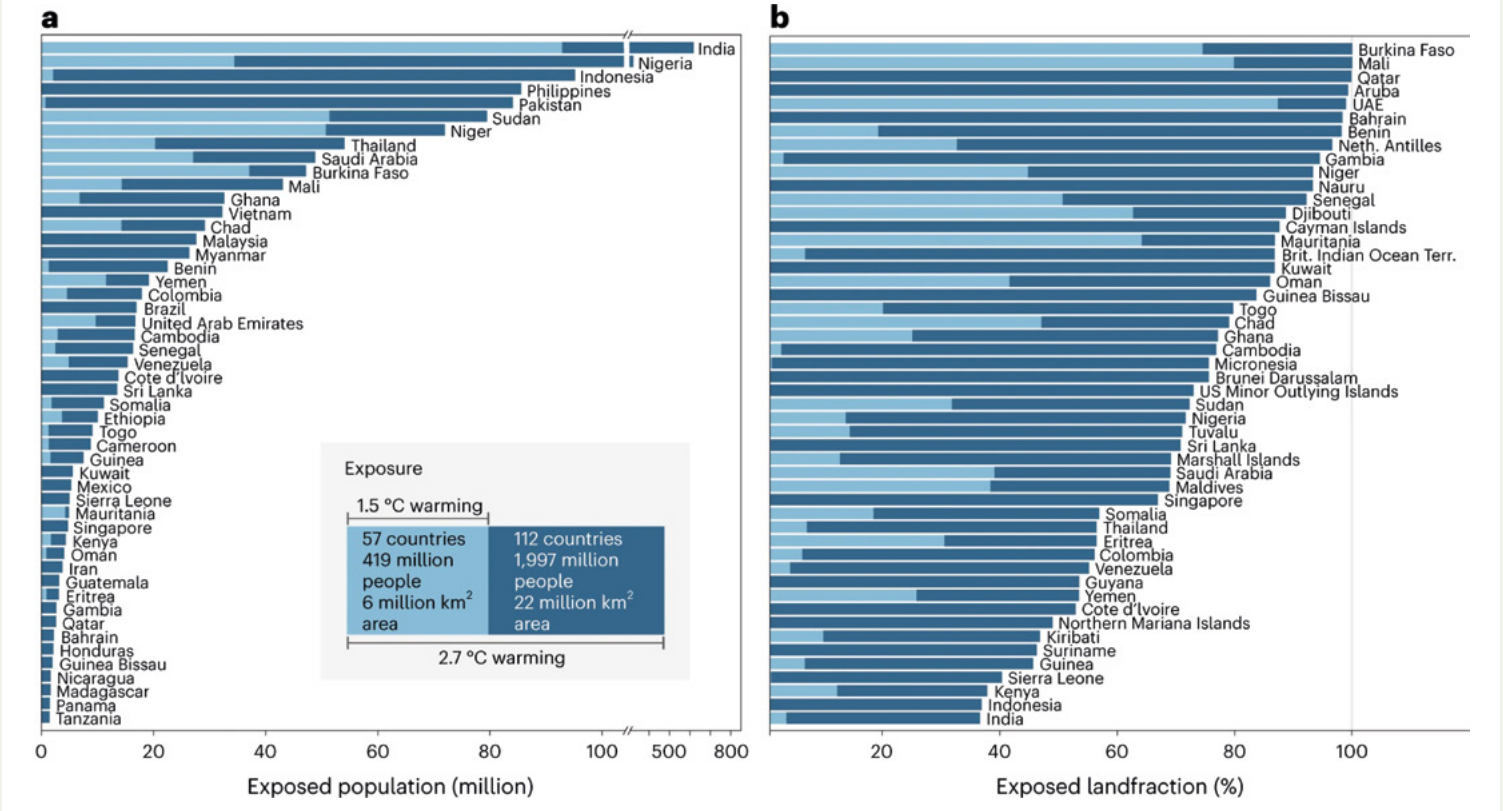


Figure 13: Lenton et al. (2023) provide an overview of the countries affected the most by unprecedented heat. Chart (a) shows the population heat exposure outside their climate niche for the top 50 countries ranked under 2.7 °C global warming (dark blue), with exposure at 1.5 °C global warming overlaid (pale blue). Note the break in the x axis for the top two countries, India and Nigeria, which would fall outside the chart. Chart (b) shows the fraction of land area exposed for the top 50 countries (ranked under 2.7 °C global warming with results for 1.5 °C global warming overlaid). At 1.5 °C warming, exposure will impact 57 countries, 429 million people, and 6 million km². At 2 °C warming, 112 countries, 1,997 million people, and 22 million km² area will be impacted (Ripple et al., 2023).

In Figure 13, Lenton et al. (2023) identify the human cost of global warming and map out which countries are most affected by unprecedented heat. The impacts of climate change on ecosystems, as well as human health, livelihoods, food security, water supply, and the economy will worsen with every fraction of a degree temperature rise (Xu et al., 2020). Under current policies, a third of the population would be left outside the climate niche at the end of the century, and in a worst-case scenario, this could even end up being half of the population. Of the growing populations, 3.5 billion people will experience Mean Average Temperatures or MAT ≥29.0 °C, "a situation found in the present climate only in 0.8 per cent of the global land surface, mostly concentrated in the Sahara, but in 2070 projected to cover 19 per cent of the global land." (Lenton et al., 2023; Ripple et al., 2023).

Farmers will experience crop failures due to human activities breaching several planetary boundaries such as climate change through drought, flooding and extreme weather events; biosphere integrity through disease, destructive insects and lack of pollinators; freshwater change through shortages and pollution; and biogeochemical flows through eutrophication in water.

Indicators for safe boundaries and impact of the food system

A diversity of food and ownership strengthens food resilience and security. Globally the food we produce has become less and less diverse. Many bread baskets are in areas that could be pushed out of their climate niche, resulting in food shortages in other parts of the world. Most of today's staple crops are grown in a handful of countries. Monbiot (2022, 32-33) notes: "Four plants—wheat, rice, maize, and soybeans—account for almost 60 per cent of the calories grown by farmers… Four countries (the U.S., Argentina, Brazil, and France) harvest 76 per cent of the corn exported to other nations. Five countries (Thailand, Vietnam, India, the U.S., and Pakistan) sell 77 per cent of the world's rice, and five (the U.S., France, Canada, Russia, and Australia) supply 65 per cent of the wheat. Only three nations, Brazil, the U.S., and Argentina, grow 86 per cent of the world's soybeans (which in turn supply three-quarters of its feed for farm animals)."

Woodwell Research Assistant, Monica Caparas who works on agricultural risk models, led a 2021 analysis of crop failures in global breadbaskets, projecting the likelihood of declining yields in the upcoming decades. Her results conjured a world where these centuries-old food producing regions may no longer be so reliable. By 2030, crop yield failures could be 4.5 times higher (Ruiz, 2022). By 2050, the likelihood shoots up to 25 times current rates and the world could be facing a rice or wheat failure every other year, with the probability of soybean and maize failures even higher. Also, by 2050, synchronised failure across all four crops will become a possibility every 11 years (Ruiz, 2022).

The food sector is highly concentrated in terms of the number of food producers resulting in a fragile food web. George Monbiot notes that 90 per cent of grain export is controlled by four companies — Cargill, Archer Daniels Midland, Bunge, and Louis Dreyfus. These companies are also consolidating vertically by buying into seed, fertiliser, processing, packing, distribution, and retail businesses. "Another four companies—ChemChina, Corteva, Bayer, and BASF— control 66 per cent of the world's agricultural chemicals market, while a similar cluster (with BASF replaced by LimaGrain) owns 53 per cent of the global seed market" (Monbiot, 2022, 35).

The international community was making steady progress on the UN Sustainable Development Goal, to reach zero hunger by 2030, until 2014 when the trend reverted. Between 2014 and 2019, world hunger grew from 60 million to 690 million. According to the UN's 2022 figures, "735 million people – or 9.2 per cent of the world's population – found themselves in a state of chronic hunger – a staggering rise compared to 2019." (UN Sustainable Goals, Goal 2). The cause was the spike in food prices. The privatisation of food provision, with some governments not storing as much food, also facilitated the crisis. George Monbiot (2022, 37) writes: "In Malawi, for example, the International Monetary Fund encouraged the government to reduce its stocks. When grain was needed, the Fund argued, it could be bought from private traders. But in 2001, when harvests failed and government silos were empty, food prices soared (as they do when supplies are short). By early 2002, as a result, people began to die of hunger."

Soil health is an indicator for food security. 52 per cent of the world's soils are degraded (Lewis 2019, Soil Association) and based on current trajectories, 90 per cent of the world's soil

will be degraded by 2050 if urgent and necessary action is not taken (FAO, Global Symposium on Soil Erosion). Plants and crops can't survive without healthy soils, yet they are vanishing at an alarming rate. The IPCC states we are losing soils at a rate 10 times faster than they're forming (Olsson and Barbosa 2019, IPCC chapter 4). Animal agriculture is the main driver of this loss (UN, 2022, Global Land Outlook 2); soil is degraded primarily due to poor farming approaches leading to erosion, compaction, fertility loss and eventually, crop failure.

Animal agriculture is an extremely inefficient system to feed the global human population and jeopardises food security and the UN Sustainable Development Goal number two, to end world hunger. Half of food in the form of crops is lost to feeding farmed animals (Monbiot, 2022, 40-41). For every 100 calories fed to animals as cereals, just 17-30 calories enter the human food chain as meat (Lundqvist et al., 2008).

The world's average meat consumption is 43 kg per year (see Figure 14), 82 kg in the UK (the weight of an average person), and 118 kg in the US (see Figure 15). "Whereas in the richest countries, meat consumption has stabilised and in some places declined a little, the rest of the world is catching up. In fifty years, the number of cattle on Earth has risen by around 15 per cent, while the number of pigs has doubled, and the number of chickens has increased fivefold. By 2050, according to the UN, world meat consumption is likely to be 120 per cent greater than it was in 2000. These animals must be fed. Already, roughly half the calories farmers grow are used for raising [farmed animals]"(Monbiot, 2022, 40-41).

While the world is seemingly oblivious to this, the predicted expansion of animal agriculture will create a higher demand for crops. Monbiot (2022, 40-41) notes that **while human population growth rates have fallen to 1.05 per cent, the population of farmed animals is growing by 2.4 per cent per year.** The biggest population crisis is the growth of the number of farmed animals, not human animals. "By 2050, to put it in brutal terms, the extra humans on the planet will weigh a little over 100 million tons, whereas, unless the current trend is disrupted, the extra farm[ed] animals will weigh 400 million tons."

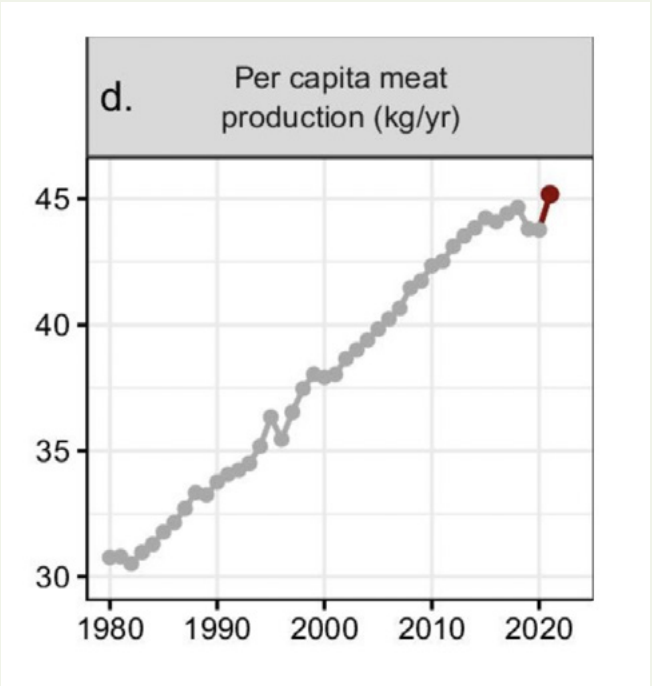


Figure 14: In line with the "great acceleration" discussed in Rockström and Gaffney's Breaking Boundaries book, Ripple et al. (2023) show the dramatic rise of per global capita meat production in a lifetime between 1980 and the early 2020s. Meat production has grown by about 50 per cent in this short time with devastating impacts on the world's forests, freshwater, biodiversity, eutrophication and ocean dead zones, soil degradation, climate and public health crises, including zoonotic diseases, antibiotic resistance, heart disease, type 2 diabetes and some cancers. Meat production per meat capita has increased again post covid. These worrying figures show the pressing need to introduce policy measures such as redirecting subsidies to veganic agriculture, introducing meat taxes, a ban on meat advertising, carbon labelling and funding for far-reaching public education campaigns.

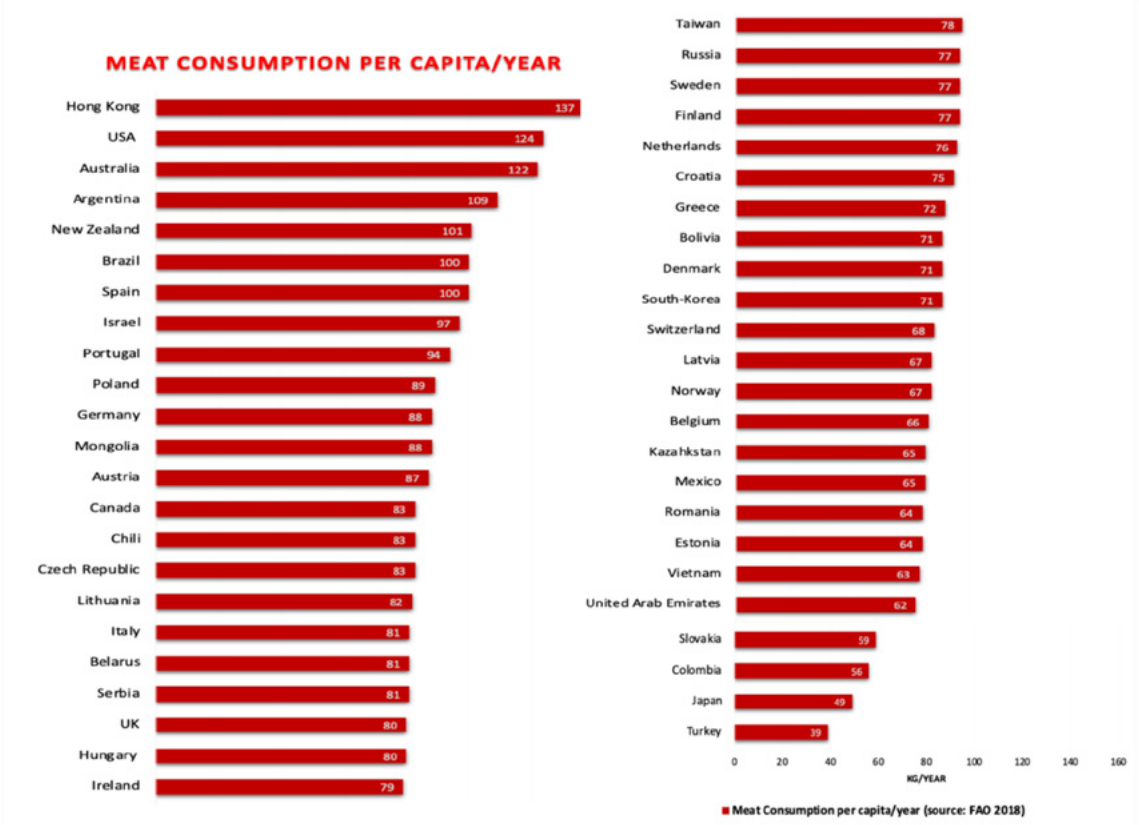


Figure 15: Breakdown of consumption per capita/year for countries, showing that high meat consumption is a huge problem in the West, such as in the USA, New Zealand, Spain, Germany, Italy, and Canada. The U.S. consumption of 124 kg per year is much larger than the Japan average of 49 kg. There are Eastern European countries with high consumption figures, such as Poland, Czech Republic, Lithuania, Belarus and Hungary. It also shows a number of countries in the global south, such as Argentina at 109 kg, and Brazil at 100 kg featuring in the top six meat-consuming countries. The number one spot goes to Hong Kong at 137 kg per year, with other Asian countries, including Mongolia and Taiwan with significant consumption rates. (FAO, 2018) Image source: https://www.tappcoalition.eu/

In *Regenesis*, George Monbiot (2022, 41) highlights the inefficiency of the food system, see Figure 16. He says, "Rich nations like the UK claim to produce a large part of the meat and eggs and dairy they eat, but they can do so only by importing feed. Much of this takes the form of soybeans from South America, and soybeans' expansion has been devastating to rainforests, wetlands, and savannas. **Because we eat so much meat, the UK's diet requires nearly 24 million hectares of land. But we farm only 17.5 million hectares here. In other words, our farmland footprint is 1.4 times the size of our agricultural area.** If every nation had the same ratio of consumption to production, feeding the world would require another planet the size of Mercury."

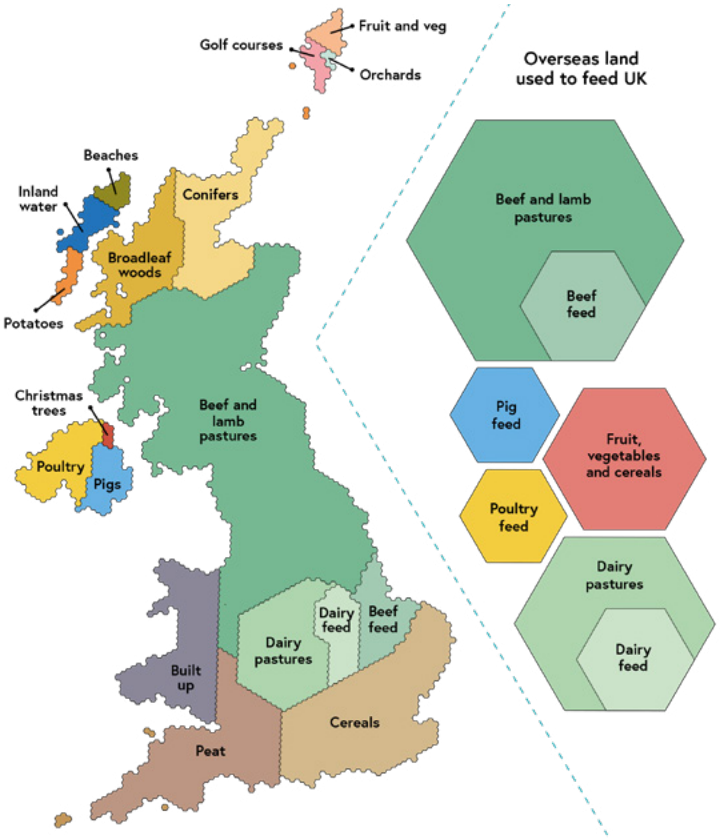


Figure 16: Source: 2021, The National Food Strategy, Independent Review, illustrating land use in the UK. The UK's diet requires nearly 24 million hectares of land, UK farmland occupies 17.5 million hectares. With a reduction in demand for resource-hungry food types such as meat and dairy, we can use land to sustainably produce more plant-based foods using less land. Modelling from Oxford University suggests that prescribing an apple a day to all adults in the UK aged 50 and over would prevent around 8,500 deaths from heart attacks and strokes every year, however there is only a small amount of land used in the UK for orchards, despite almost all varieties of apples, pears, plums and cherries able to grow in the British climate (Oxford University, 2013).

A 2020 analysis by Greenpeace found that in 2018/2019, 62 per cent of all cereal crops in Europe were used to feed animals and 12 per cent were used as biofuel, with only 23 per cent going to feed people. A striking 88 per cent of soy and 53 per cent of protein-rich pulses were also used for animal feed (Greenpeace, 2020). According to the World Wildlife Fund (2022), 40 per cent of the UK's most productive agricultural land is used to grow food for farmed animals instead of people and they have called for a rethink on an "inherently inefficient" approach to feeding farmed animals foods that humans can eat, which is fuelling the climate and nature crises.

How do we get back into a safe operating space?

In *Planet-proofing the global food system*, Johan Rockström et al. (2020) say, "building resilient food systems requires a systems-approach integrating carbon, nitrogen, phosphorus, water, soils, biodiversity and biome stability; and taking a truly interdisciplinary planetary health approach by addressing food cultures, nutritional security and geopolitical stability, as well as the role of governance, trade and equity."

"A shift toward plant-based diets, particularly in wealthy countries can improve both global food security and help mitigate climate change" (Cassidy et al., 2013).

Monbiot (2022) argues that we need to change the food system itself and suggests we focus on diversity rather than expansion. Standard diets heavy in meat, dairy and eggs are not resilient. In Kate Raworth's (2017) *Doughnut Economics*, she says, resilience "depends upon diversity and redundancy in the network, which means that there are ample alternative connections and options in times of shock or change. Too much efficiency makes a system vulnerable, while too much resilience makes it stagnant: vitality and robustness lie in a balance between the two." The same applies to the food system. For example, the lack of genetic diversity in our current food system makes it fragile. There are an estimated four hundred thousand edible plant species we could eat, but we only eat a couple of hundred plants and half of our plant sources of protein and calories come from rice, maize, and wheat.

In the face of temperature rises, particular attention must be paid to the potential risks of simultaneous harvest failures and the wasteful land use of growing crops for animal feed. To address this growing concern, firstly, the focus must be on adapting our crops to withstand heat, drought, and other climate challenges to prevent widespread crop losses in various parts of the world. Secondly, there is a greater urgency to diversify the food system and prioritise growing crops for humans rather than to feed farmed animal consumption. With the threat of global food shortages due to crop failures, a plant-based food system where crops are grown directly for human consumption would provide an abundance of crops. For example, **if the cereals that will be fed to animals in 2050 on a business-as-usual basis were used instead for direct human consumption, an extra 3.5 billion people could be fed annually** (UNEP, 2018; Nellemann et al., 2009). Greenpeace describes the current imbalance in production and consumption as driven by a focus on crops for profit, not food for people (Greenpeace, 2020). Thirdly, we need a soil treaty to move away from monoculture-based farming, which by its very nature actively degrades soils, and onto restorative, regenerative, sustainable means of production that actively enhance the local ecosystem. For example, soil can be enhanced such as using a diverse mix of crops (intercropping), crop rotation, some types of organic farming, 'no till' approaches, mulching, utilising permaculture and agro-ecological nature-based principles, and using perennial crops.

2.2.5 Education

In her foreword to *Breaking Boundaries*, vegan environmental activist, Greta Thunberg says, "People often ask me, is there one thing that they can do that will really make a difference, and if so–what is it? My answer is always: inform and educate yourself as much as you possibly can and then spread that awareness to others. Because once you understand the full meaning and real consequences of our situation, then you will know what to do" (Rockström and Gaffney, 2021, 11).

Raising public awareness about the impact of meat, dairy, and eggs on our planetary boundaries, as well as the benefits of transitioning to plant based foods, is crucial. Public education can be a catalyst for public pressure urging political leaders to act. Meanwhile, policymakers can also spearhead this movement. For instance, New York City Mayor Eric Adams rolled out the "Eat A Whole Lot More Plants" public information campaign, to highlight the benefits of plant-based diets on public healt

How far are we falling short?

A key indicator is public awareness of the climate emergency, the impact of the food system and the benefits of a plant-based diet. The "awareness gap" quantifies these discrepancies. The *Peoples' Climate Vote*, the largest survey of public opinion on the climate crisis ever conducted with 1.2 million respondents in 50 countries, reveals the majority of the public is (1) unaware of the relationship between food and climate change, and (2) unaware of the significant contribution of food emissions (UNDP, 2021).

Almost two-thirds (64 per cent) of participants understand that climate change is a global emergency and 59 per cent agreed that we should be doing everything that is necessary, urgently. All participants were asked about their preferred climate actions from a list of 18 potential strategies. The top three measures with the highest backing included conservation of forests and land (54 per cent), solar, wind, and renewable power (53 per cent), and climate-friendly farming techniques (52 per cent). Following a plant-based diet should have attracted widespread support because **a vegan diet is "probably the single biggest way to reduce your impact on planet Earth, not just greenhouse gases, but global acidification, eutrophication, land use and water use"** (Poore and Nemecek). However, in The *People's Climate Vote* dietary change towards plant-based eating ranked at the very bottom, with only 30 per cent of participants in favour. In some countries, there is a growing awareness among young people, led by Gen Z consumers (aged 16-24). For example, over half (54 per cent) of under 25s in the UK see the reduction of animal products as a good way to lessen their impact on the environment (Mintel, 2020).

The media is partially responsible for the "awareness gap". For example, only 70 of 1,000 climate articles (7 per cent) examined in a Faunalytics report (2023) mentioned animal agriculture's impact on the climate crisis. The authors report note that: "Across the 1,000 articles we examined, only a handful of stories reported in depth on the connection between consuming animal products and climate change. Most articles that mentioned animal agriculture failed to discuss the emissions and environmental degradation caused by the industry, let alone the importance of reducing meat consumption or switching to a plant-based diet to fight climate change. When diets were discussed, the effectiveness of plant-based diets was sometimes downplayed or, more often than not, presented almost as an afterthought rather than a legitimate strategy to mitigate climate change."

How do we get back into a safe operating space?

The potential of a plant-based food system in terms of greenhouse gas emissions is massive, saving 8 gigatonnes of carbon equivalent per year (IPCC, 2019). To increase awareness of this and other environmental benefits, we must increase public education. Redirect (R2) of the Plant Based Treaty calls for publicly funded education campaigns to raise awareness of the benefits of plant-based food for the environment, public health, and animal protection.

IPCC 2019: Human dietary choices and greenhouse gas emissions

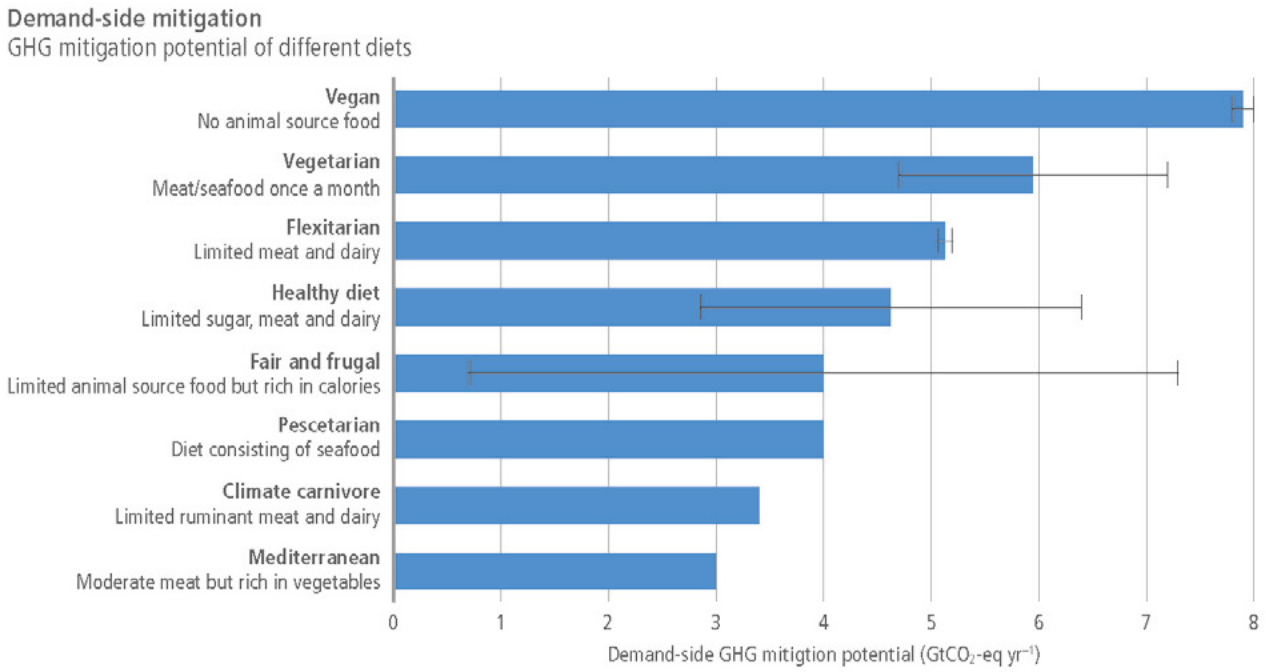


Figure 17: A vegan world (defined as no animal-based food) would save almost 8 gigatonnes of carbon equivalent per year in demand–side mitigation potential (IPCC, 2019)

Governments can launch multi-platform public advertising campaigns and leverage mass media, digital platforms, and community outreach.

For example, as seen in Figure 18, in 2022, as part of their Zero Carbon Manchester campaign, the city sponsored "Let's eat less meat & dairy" billboards. The official Manchester City Council website states, "Let's eat less meat and dairy. Meat and dairy have a very high carbon footprint, especially beef and lamb. Reduce your meat consumption and consider vegetarian or vegan options." In May 2023, New York City unveiled its flavorful "Eat A Whole Lot More Plants" initiative, aiming to put scrumptious sprouts and piquant produce on New Yorkers' menus, as seen in Figure 19. This campaign, broadcast through television, radio, subway ads, NYCLink, various digital platforms, and outdoor media, specifically targeted neighbourhoods grappling with health and socioeconomic inequities. By focusing on the incorporation of more plant-based foods, the campaign highlights how eating plant-based foods can improve health and can help manage and reduce the risk of type 2 diabetes.

Figure 18: In Manchester, UK, which is home to more than 500,000 residents, Let's eat less meat and dairy billboards were funded by Manchester City Council.

We need to consider the cultural differences regarding education, consciousness, and plant-based diets. In *Doughnut Economics*, Kate Raworth (2017, 99) calls for eco-literacy in every school to help develop holistic and ecological worldviews: "The need for such a shift in consciousness is particularly strong in WEIRD (WEIRD societies are Western Educated, Industrialised, Rich and Democratic) societies: in the U.S., for example, children growing up in urban centres today have a far more simplistic and anthropomorphic understanding of the living world than do children raised in rural Native American communities."

The Plant Based Treaty has Playbooks for best practices in early childhood education, schools, universities, and colleges which you can read more about in the next steps section of chapter 3. Lifelong habits often begin in childhood, making schools key to setting students up for a healthy and ethical lifestyle (Center on the Developing Child, 2010). Introducing plant-based nutrition modules within school curricula will benefit students and teachers alike. Teacher training should include topics such as planetary boundaries, new economic models such as doughnut economics, and the role of plant-based diets to foster critical thinking and student empowerment.

Figure 19: The New York City public education campaign "Eat A Whole Lot More Plants" ran on multiple digital and billboard platforms in 2023.

2.2.6 Health

Unhealthy diets are the world's leading cause of death and are a major cause of chronic disease (GBD, 2017; Diet Collaborators, 2019). Scientists say there is "high agreement and robust evidence" that **"healthy diets require dietary diversity, which requires greater crop diversity and agricultural biodiversity supporting production. Enhancing production of more diverse foods can be a win-win solution for both improved nutrition and biodiversity"** (DeClerck et al., 2023). Therefore, transforming the food system has the potential to be the single largest solution to both human and planetary health. It will require major policy changes and investment to implement food system changes such as from 'field to fork' (Rockström et al., 2020, 3-5).

Indicators for safe boundaries and impact of the food system

Dietary indicators

Diet-related diseases could be eradicated. Our food choices should protect us from disease rather than cause disease and death. The indicators would measure how food is impacting (1) chronic diseases such as cancer, diabetes, high blood pressure, and heart disease, and (2) death. According to the World Health Organization, around 71 per cent of all global deaths are caused by noncommunicable diseases (NCDs), and many of these diseases are strongly linked to unhealthy diets, lack of physical activity, and tobacco use (WHO, 2023).

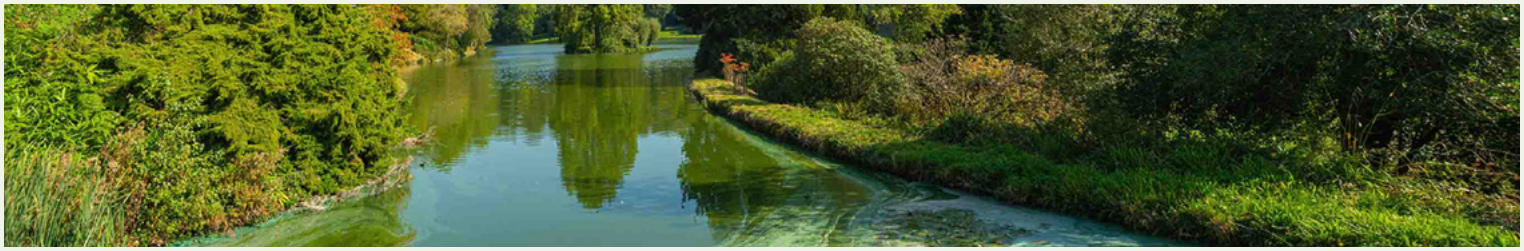
Health from planetary boundary perspective

The climate change planetary boundary transgression increases exposure to high wet bulb temperatures and unprecedented heat (connected to the climate niche discussed above). It is linked to heat-related diseases, such as heat stroke, heat exhaustion, heat wave mortality, decreased cognitive performance, adverse pregnancy outcomes, increased mortality, and spread of infectious diseases which also affects other mammals (Narayan, 2023). In addition, high temperatures impact the health and productivity of workers (Kemp, 2022).

Elevated nitrate and phosphate concentrations coming from excessive use of fertiliser, and from pollution from animal agriculture in particular, cause harm to people and marine life through the consequences of eutrophication on ecosystems and their services. Examples include toxic compounds released by algal blooms, fish die offs, and the health impacts of air pollution from ammonia-derived aerosols. Surface drinking water can also be contaminated with elevated levels of nitrate. The aerosols released during fires that clear land for human food, feed production, and cattle ranging are health hazards for nearby communities. Finally, mental health can be seen as a "service" provided by nature to people which is linked to the social boundary "greening cities", and connected to the planetary boundary "biosphere integrity" (see discussion below in the greening cities section).

Antibiotic resistance indicators

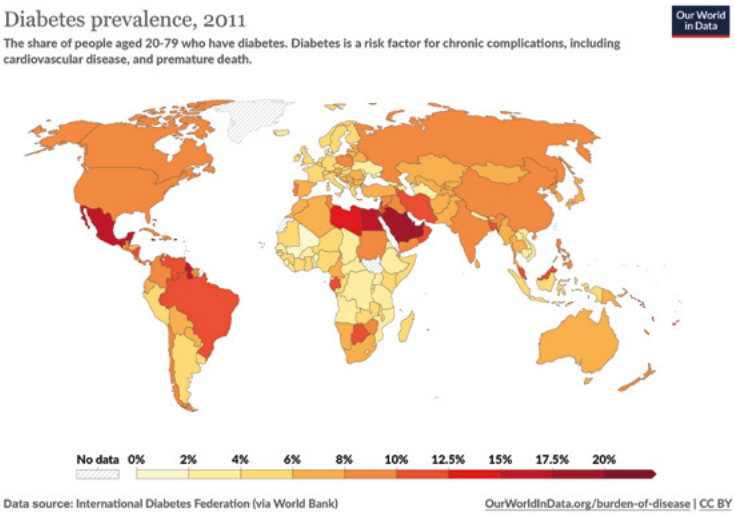
The indicators would include the quantity and strengths of antibiotics administered to farmed animals, how these are compromising resistance, and the health implications in terms of disease and death. The extensive use of antibiotics in farmed animals is causing bacteria to become resistant to antibiotics, allowing drug-resistant bacteria to proliferate and leading to higher numbers of deaths in humans and nonhuman animals.



How far are we falling short?

"Unhealthy and unsustainably produced food poses a global risk for people and the planet," states Willett et al. (2019) in the *Food in the Anthropocene* report. "Simultaneously, global food production is the single largest human pressure on Earth, threatening local ecosystems and the stability of the entire Earth system." The World Health Organization, on their website, estimates that worldwide "3 billion people cannot access safe, nutritious and sufficient food. In addition, the proliferation of highly processed food, supported by aggressive marketing, rapid unplanned urbanisation and changing lifestyles have contributed to more people eating unhealthy diets high in energy, free sugars, salt, saturated fats and trans fats."

Chronic disease and death are on the rise. In three decades, between 1990 and 2019, the total number of cancer deaths increased by 75 per cent, but in a world with a growing population, we would expect more people to die from cancer. However, during the same period, the cancer death rate, which is the number of deaths per 100,000 people, actually increased by 21 per cent (Roser and Ritchie, 2015). According to Global Burden of Disease, the death rates from cardiovascular disease between 1990 and 2019, on the other hand, are declining worldwide (Our World in Data, 2019).



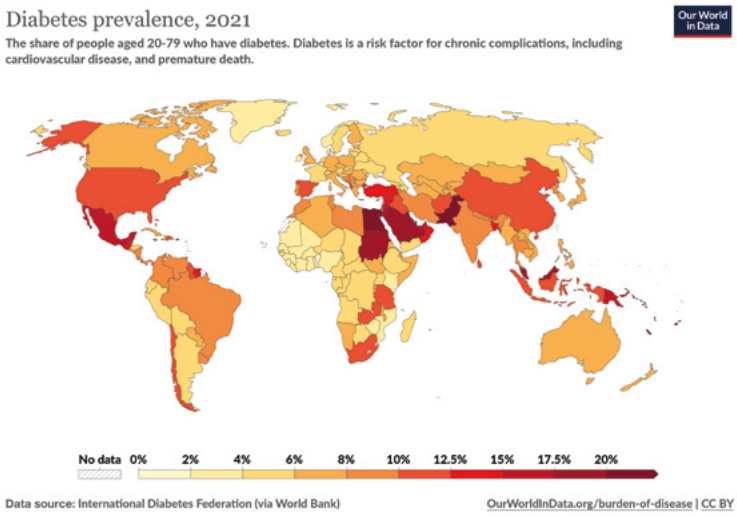


Figure 20: The rise of diabetes in one decade between 2011 and 2021 shows a dramatic increase in the U.S., China, Indonesia, Pakistan, Malaysia and Egypt and Sudan, and other parts of Africa (Our World in Data, 2021).

Research by the International Diabetes Foundation and World Bank shows the stark rise of diabetes in such a short time period of one decade, between 2011 and 2021 (see Figure 20). What needs further investigation is how this relates to the consumption of meat, dairy, and eggs. In India, dubbed the diabetic capital of the world, 101 million people are living with diabetes in 2023, compared with 70 million in 2019; 136 million people have prediabetes; and more than 315 million people have high blood pressure (Anjana et al., 2023; India Today, 2023).

Modelling by researchers at Oxford University has shown that eating meat no more than three times a week and replacing meat with plant-based foods would prevent 45,000 early deaths a year in the UK and save the NHS £1.2bn a year (Scarborough et al., 2012).

Planetary boundaries and health shortfalls

Measuring how we fall short for health from a planetary boundary perspective would involve analysis of where people experience heat-related diseases the most, and the number of people experiencing unprecedented heat (Medium Average Temperature ≥ 29°C). Heat waves result in mortality, increased risk of heat-related diseases and reduced working hours. For example, in densely populated India, deadly heat waves in 2010 killed more than 1,300 people in the city of Ahmedabad (See Figures in the *Food Security* section) (Omid Mazdiyasmi et al., 2017). To address the other indicators, further research is required on how many people are exposed to aerosols and how many people lack access to green spaces.

Antimicrobial resistance is a global health disaster that is already killing over 1,270,000 people a year (The Lancet, 2022).

The World Health Organization (2023) estimates there will be 5.2 million deaths in the western Pacific due to antibiotic resistance by 2030.

Evidently, antibiotic use in farmed animals needs to be brought to zero for us to live safely within planetary boundaries for the health of humans and the planet.

What is the impact of the food system on this social boundary?

Food system impacts on nutrition and health

The consumption of meat, dairy, and eggs is one of the leading causes of disease. Subsidised industrial animal agriculture is responsible for high levels of consumption of red and processed meat in the West and emerging economies, and contributes to heart disease, obesity, diabetes, and certain cancers (Friel et al., 2009; Aston et al., 2012; Anand et al., 2015). In *Regenesis*, George Monbiot (2022, 50-51) notes that with rising temperatures crops will be less nutritious because they will grow faster in higher temperatures with more carbon dioxide in the atmosphere, but will have less time to absorb nutrients such as iron, zinc, calcium, magnesium, protein and B vitamins.

Health-related effects of climate change include increased heat-related diseases, such as heat stroke, heat exhaustion and increased morbidity and mortality (Kemp et al., 2022).

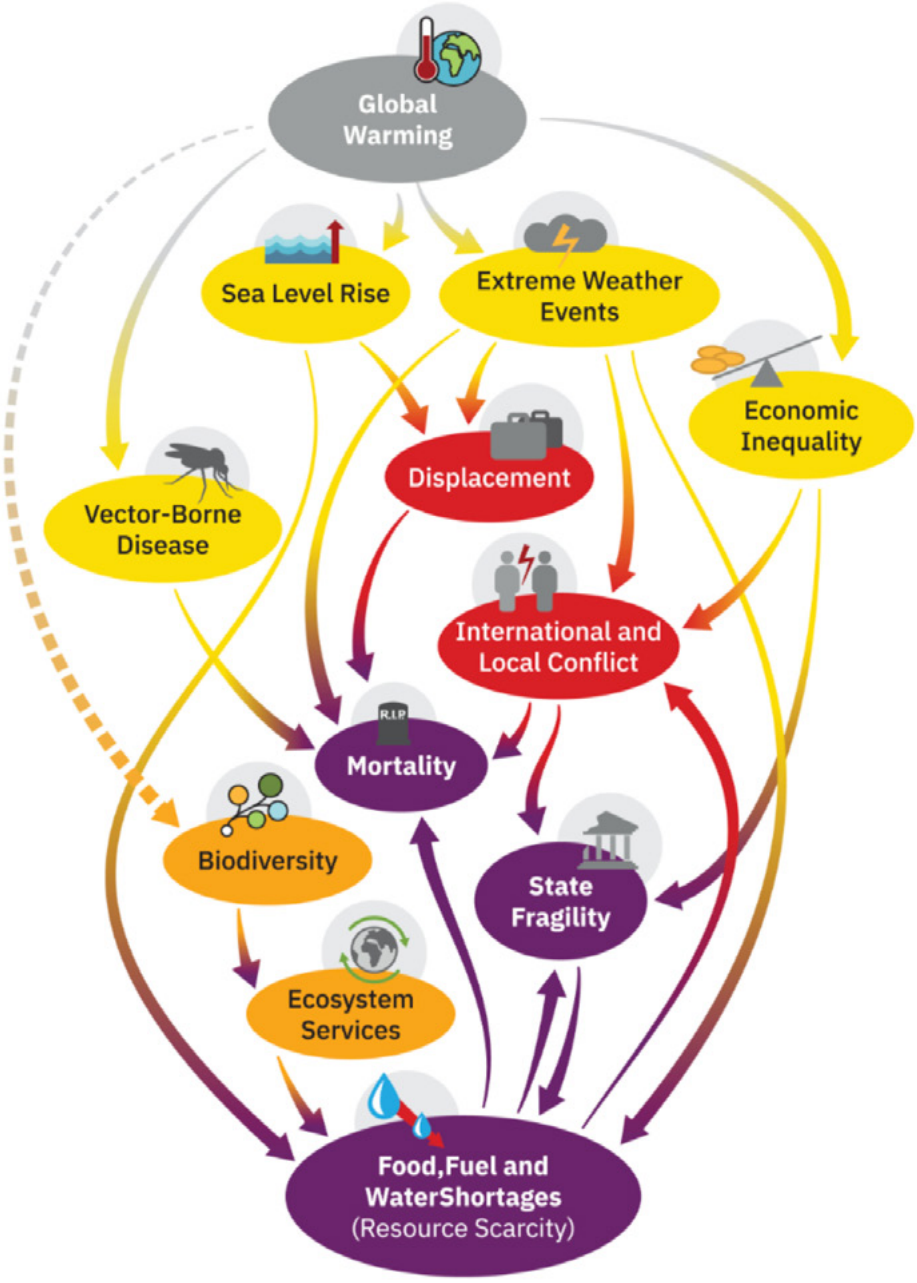


Figure 21: A simplified diagram highlighting how cascading global climate failure could unfold. Climate change will drastically impact ecosystem services, biodiversity, sea level rise, economic inequality, vector borne disease, and ultimately, international and local conflict, mortality state fragility and food and water shortages. Complete lines in the causal loop diagram represent amplifying feedback and a dotted line denotes dampening feedback (Kemp et al., 2022).

Food systems and antibiotic resistance

The largest use of antibiotics globally is for farmed animals. Roughly 73 per cent of medically important antibiotics sold globally in 2017 were administered to farmed animals to control bacterial infections in crowded warehouses, and to boost their growth (Tiseo et al., 2020). "There is growing evidence that antibiotic resistance in humans is promoted by the widespread use of non-therapeutic antibiotics in animals" (Martin et al., 2015).

When farmed animals receive antibiotics, it promotes the development of antibiotic-resistant bacteria. This can be spread to humans through fertiliser, water contaminated with bacteria on food crops, and contact with improperly handled or cooked meat products (see Figure 22).

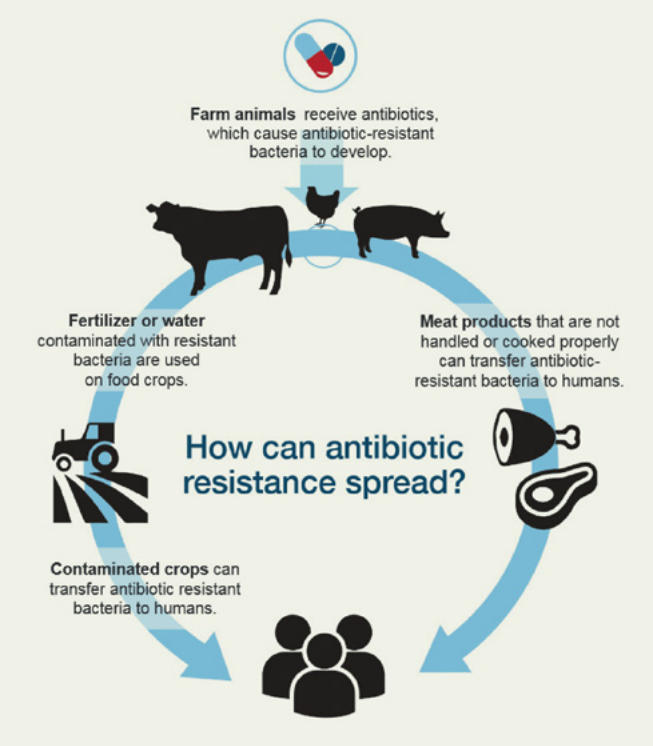


Figure 22: Image source (Government of Canada, Science Fact Sheet, Antimicrobial resistance)

Zoonotic Diseases and Pandemics

Three-quarters of emerging infectious diseases in humans originate from the farming of animals for food, clothing, and other purposes (CDC, Centers for Disease Control and Prevention, 2017). Major outbreaks like SARS, swine flu, and the 1918 Spanish flu, have their origins in animal agriculture facilities. The COVID-19 pandemic, in particular, has emphasised the urgency of evaluating strategies to prevent similar outbreaks in the future, a critical consideration for global public health (Galoustian, 2021). Zoonotic diseases, which are diseases that transfer from nonhuman animals to human animals, have been responsible for a significant number of epidemics and pandemics in recent years. As seen in figure 23, notable examples include HIV, avian flu, swine flu, SARS, Ebola, and most prominently, COVID-19 (Reperant and Osterhaus, 2017). These diseases, emerging from animal hosts, pose a grave threat to human health.

Several factors contribute to this connection such as agricultural intensification involving stressful high population density and close quarters, particularly in the case of pigs and birds (Bryony et al., 2013). This can weaken animals' immune systems, making them carriers of diseases, increasing the chances of transmission. Another factor is climate change, which favours pests and pathogens and increases the spread of infectious diseases, such as malaria (Hayek, 2022; Kemp et al., 2022). A third factor is environmental changes due to the destruction and fragmentation of natural habitats that lead to reduced biodiversity and fragile ecosystems (Hayek 2022; Kemp et al., 2022; Sentient Media, 2020). These insights underscore the pressing need to address the risk of infectious diseases associated with animal agriculture.

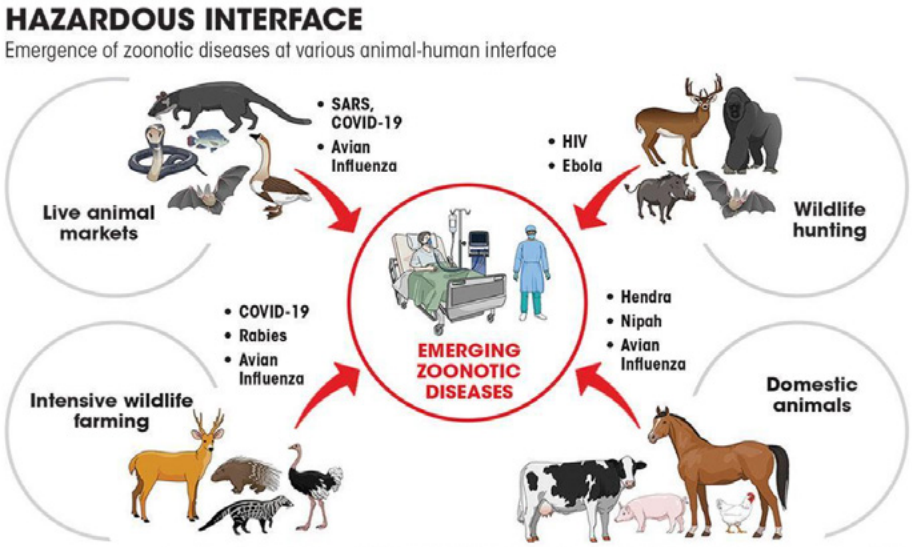


Figure 23: Emerging zoonotic diseases result from close contact with nonhuman animals including live animal markets, wildlife farming, wildlife hunting, and farmed animals.

How do we get back into a safe operating space?

Nutrition and the safe operating space

In Willett et al.'s article "*Food in the Anthropocene*", they say, "Dietary changes from current diets towards healthy diets are likely to result in significant health benefits that include averting approximately 7.4 to 10.8 million premature deaths per year, a reduction of between 18 per cent to 28 per cent" (Willett et al., 2019).

In Europe there have been a number of EPIC studies (European Prospective Investigation into Cancer and Nutrition) including one that looks at how fruit and vegetable intake can increase survival of older adults (Leenders et al., 2014). Lifestyle, diet, and vital status data was collected via questionnaires and population registries from more than 450,000 participants. Participants reporting consumption of more than 569 g/day of fruits and vegetables had lower risks of death from diseases of the circulatory, respiratory and digestive system when compared with participants consuming less than 249 g/day… A lower risk of death from increased vegetable consumption was more pronounced for raw vegetables when compared with cooked vegetable consumption. Raw vegetable consumption also decreased risk of death from neoplasms (abnormal growths both benign and malignant) and mental and behavioural disorders.

74,607 men and women, 60 years or older without any previous coronary heart disease, stroke or cancer, and complete information about dietary intakes and potentially confounding variables, enrolled in a study investigating the role of plant-based diets and mortality in older populations. **The results found an adherence to a plant-based diet was associated with a lower overall mortality of 14 per cent.** The Mediterranean Diet was also shown to be beneficial (Bamia et al., 2007).

Up to 63 per cent of deaths and 39 per cent of incident cancers could be prevented in a 20-year risk period by fully adopting the EAT–Lancet reference diet. "A reduction in mortality from adhering to the EAT–Lancet reference diet is supported by findings from the EAT–Lancet Commission report, where results from one analysis estimated that, by adopting their reference diet, about 11.1 million deaths per year could be avoided worldwide by 2030 and premature mortality reduced by 19 per cent. However, a replication study done in the U.S. did not support a reduction in mortality from adopting the EAT–Lancet diet, and the authors suggested the need for further independent validation" (Laine et al., 2021).

Studies show that substituting high quality plant foods such as legumes, nuts, or soy for red meat might reduce the risk of coronary heart disease (CHD)(Willett et al., 2020).

Plant-based diets have been linked to improved cardiovascular health, protection against some cancers and good gut health (Termannsen et al., 2022; Tai et al., 2024; Winston, 2009; Tamova et al., 2019). The American Dietetic Association confirms that well planned vegetarian diets, including vegan diets, are nutritionally adequate, and may provide health benefits in the prevention and treatment of certain diseases. These diets are suitable for all stages of life, including pregnancy, lactation, infancy, childhood, and adolescence, and for athletes (Winston et al., 2009).

In 2003, the World Health Organization and Food and Agriculture Organization of the United Nations recommended a daily intake of at least 400 g of fruits and vegetables per day to prevent diet-related chronic diseases. Higher intakes of fruit and vegetables are associated with a decreased risk of cardiovascular disease (CVD) as well as a probable reduction in type 2 diabetes and cancer (WHO, 2016). The strongest reductions in risk were observed at an intake of 800 g a day for fruits and vegetables, 225 g a day for whole grains, and 15–20 g a day for nuts, respectively. Most studies that have since been published have been consistent with these results (Aune, 2019).

Figure 24: "The Plant-Based Eatwell Guide".

The Plant-Based Health Professionals developed a guide that shows the proportions in which foods from different food groups are needed to achieve a balanced and healthy diet from ages 1 and above. "The Plant-Based Eatwell Guide" - in Figure 24, states people should: "Eat at least 5 portions of a variety of fruits and vegetables a day but aim for more, as eating up to 10 portions a day has additional benefits for health". They quantify a portion as 80 grams so that would translate into 400-800 g of fruits and vegetables, double what WHO suggests.

Countries such as the UK have dietary policies underpinned by food-based dietary guidelines (FBDGs), known in the UK as the "Eatwell Guide". A recent systematic review of the UK's FBDGs found that most are incompatible with our planetary boundaries. If the UK population consumed the diet recommended by the Eatwell Guide, it would not stay within boundaries for greenhouse gas emissions, water use, land-use and eutrophication. The report found that incorporating environmental sustainability into FBDGs, such as the the Plant-Based Eatwell Guide proposed by Plant-Based Health Professionals UK, may be the first step towards implementation of population-level policies that have been shown to support shifts away from animal-based foods (Scarborough et al., 2023).

Further work is required to compare the impact of the Lancet's Planetary Health diet and the Plant-Based Health Professionals Eatwell Guide, looking at the food impacts on our planetary boundaries, human health, and interspecies justice.

Achieving planetary health through food systems

Solutions to get back into the safe space require a shift to a plant-based food system and rewilding. **A shift to a plant-based food system would deliver significant reductions in greenhouse gas emissions, freshwater use, air pollution, and deforestation, which would limit extreme temperature rises and reduce deaths from unprecedented heat, and extreme weather events.** In the UK, a quarter of particle pollution in cities comes from farms. Farming is the main cause of the springtime smog that affects western Europe each year. Dr. Eloise Marais from UCL said: "Using two independent satellite instruments and a detailed model we found that ammonia

from farming, in particular dairy cattle, is underestimated in the official inventories that inform policies and assess compliance with international emissions targets." Agricultural ammonia emissions have not reduced for more than a decade. Solving our urban air pollution problems will therefore require innovation in the countryside as much as solutions in our cities (Macintyre et al., 2016).

WHO reports: "Evidence shows the health benefits of a diet high in whole grains, vegetables, fruit, legumes and nuts, and low in salt, free sugars and fats, particularly saturated and trans fats. A healthy diet starts early in life with adequate breastfeeding. The benefits of a healthy diet are reflected in higher educational outcomes, productivity, and lifelong health. A healthy diet is also more environmentally sustainable, as it is associated with lower greenhouse gas emissions, lower use of freshwater and land mass. However, healthy diets can be inaccessible, particularly in low- and middle-income countries, and also in places and situations with high rates of food insecurity" (WHO, Healthy Diet).

Food system transformation: Impacts on antibiotic resistance and zoonotic disease

A plant-based food system will reduce global antibiotic use by almost three quarters, and would greatly reduce instances of antibiotic resistance and emergence of superbugs (Morse et al., 2012). Recently, the World Health Organization called antimicrobial resistance "an increasingly serious threat to global public health that requires action across all government sectors and society (Martin et al., 2015). In one study published in *Science*, Thomas P. Van Boeckel et al., proposed a way to reduce "antimicrobial consumption in animal production may be to promote low-animal-protein diets: China has recently revised downward its nutritional guidelines for meat intake to 40 to 70 g/day (10), which is approximately half the current consumption level in the country. If followed, this measure could have an indirect but substantial impact on the global consumption of veterinary antimicrobials" (Van Boeckel et al., 2017). Another suggestion to cut antimicrobials is "to charge a user fee, paid by veterinary drug users, on sales of antimicrobials for nonhuman use" (Hollis et al., 2013).

A plant-based food system along with rewilding would eliminate close contact with farmed animals and reduce our close contact with wild animals thus lessening the likelihood of transmission of zoonotic diseases.

2.2.7 Transparency and honest labelling

Honesty and transparency in food labelling offers a huge potential to shift both consumer food choices and the manufacturing processes as business competes for market share. While some businesses have voluntarily adopted carbon labelling, government mandating of labelling could spread these initiatives further to create an even playing field and raise public awareness of the environmental cost of food.

Indicators for safe boundaries

One of the indicators could be the number of countries that have adopted (1) carbon labelling and (2) environmental labelling laws. These labels should include a transparency index which would shine a light on the social, animal and environmental risks in previously hidden places where violations are likely to occur. Without transparency throughout the supply chain, watch dogs cannot do checks on honest labelling. For example, The Fashion Revolution publishes the Fashion Transparency Index (Fashion Transparency Index, 2023) that ranks fashion brands and retailers based on their public disclosure of human rights and environmental practices across their operations and supply.

Another indicator could be the percentage of companies that conform with Plant Based Treaty's 3R principles. For example, a report card, similar to ones used for deforestation or human rights violations in different sectors, could report on a country's progress on each Plant Based Treaty proposal.

How far are we falling short?

To tackle the environmental impacts of food, they first need to be measured. At least 40 countries require facilities or companies to measure and report their greenhouse gas emissions periodically. These reports create a data pool that leaders can use to inform environmental policy decisions and track their progress (UL Solutions, 2020), however these reports are not very accessible to the public and the data does not make its way onto individual product labels where they can influence purchasing choice. A 2020 YouGov poll commissioned by Carbon Trust found that the majority of consumers in the UK, US, France, Italy and Spain supported carbon labels on food items (Carbon Trust, 2020). **As yet, there is not a global standard or legal requirement for carbon labelling, although a number of countries are making moves in that direction.** In 2022, Denmark set aside $1.3 million to develop carbon labelling proposals, becoming the first country to do so. (Kommenda, N. et al., 2022).

The Hilton chain is the first UK hotel chain to add carbon labels to its menus at scale (Hunter, 2023). Menus in almost 30 hotels across the UK will show the carbon footprint per serving alongside nutritional information such as the calorie count. Hilton says that the introduction has been successful so far, with lower carbon items becoming more popular since the launch. Christoffer Connée, co-founder of Klimato, a green-tech startup which produced the ratings: 'Early findings suggest the introduction of the system has led to a shift in guest behaviour, with low and medium footprint dishes proving particularly popular.'

In 2023, food delivery platform Just Eat added carbon labels in a trial aimed at encouraging more environmentally friendly choices. Just Eat trialled carbon labels on products from five Brighton restaurants for 12 weeks with ratings ranging from A, for very low emissions, to E, for very high emissions.

Quorn was the first major food brand in the UK to introduce carbon labelling on its products, using carbon footprint data certified by the Carbon Trust. The greenhouse gas impact of mycoprotein – the fungi-based protein used in Quorn products – is 90 per cent lower than beef. The UK's largest retailer Tesco, for example, dropped its plan to label all its products with their carbon footprint, after promising "a revolution in green consumption", blaming the work involved and other supermarkets for failing to follow its lead (Smithers, 2020).

Also in the UK, Restaurant chain Wagamama, which in 2021 announced that their entire menu would be transitioning to 50 per cent plant-based, has a carbon strategy which focuses on reducing carbon output first before offsetting, stating 'measuring our total carbon emissions allows us to set goals and identify where we can make reductions. our ambition is to be net zero by 2040.'

Swedish oat drink manufacturer, Oatly first introduced carbon labelling in the UK in 2019 - as illustrated in Figure 25, and in North America January 2023. They are now lobbying the UK government to make publishing carbon footprints mandatory on food and drinks for all businesses to improve transparency to make it easier for consumers to make informed choices and to raise consumer awareness about food system impacts. A shift to a plant-based diet is a key prerequisite to decarbonising the UK economy." (Oatly, UK) Oatly has submitted a petition to the Petitions Committee of Germany demanding that all food sold in the German food retail trade be labelled with the greenhouse gases (CO_2e) emitted by their production (Vegconomist, 2019).

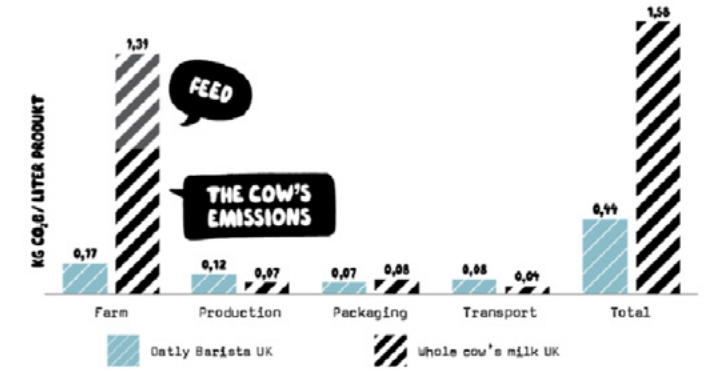


Figure 25: Swedish oat drink manufacturer, Oatly, carbon labelling in the UK.

What is the impact of the food system on this social boundary?

Current food labelling can often be misleading. For example, food carrying "locally made" labels will be appealing to those trying to reduce food miles to reduce greenhouse gas emissions. However, as Dr. Joseph Poore points out in his research, what you eat matters far more than how far it's travelled. That is not to say that locally produced plant-based foods are not optimal; however this fact is not widely understood and some labelling can be used by meat and dairy companies to greenwash their products.

Companies such as Cargill have lobbied against country of origin labelling in Washington DC, U.S., to hide links to deforestation. For example, it would hide meat products imported from the Amazon on deforested lands.

How do we get back into a safe operating space?

Plant Based Treaty's second demand, R2: Redirect calls for: "Honest labelling of food products including carbon labelling." Governments should legislate for comprehensive food labelling and reporting for businesses and institutions, reflecting impacts such as carbon footprints, water use and health warnings such as cancer warning labels on all processed meats which have been declared carcinogenic by the World Health Organization. **Proper food labelling not only educates consumers on the environmental implications of their choices but also directly impacts public health.** Informing consumers about potential health risks associated with certain products allows them to make informed dietary choices, potentially reducing the burden on healthcare systems.

Researchers from Durham University added warning labels to meat products to measure how it impacted purchasing choices. Meat that carried a poor health warning with an image of a heart attack reduced choice by 8.8 per cent; a climate change warning featuring an image of deforestation decreased selection by 7.4 per cent; and a pandemic warning featuring an exotic meat image led to a 10 per cent drop in selection (Hughes et al., 2023).

Businesses could voluntarily introduce company and industry wide carbon and environmental labelling. The UK's Behavioural Insights Team recommends introducing ecolabels on products, and on firms (The behavioural insights team, 2023). They recommend creating "a simple system of ecolabels across key product sectors (food, clothing, pensions) and businesses (supermarkets, banks, airlines, retail chains) to help engaged consumers choose green. By extension, this incentivises businesses to become more sustainable, helping everyone buy greener products and services." Schools, hospitals, universities, care homes, prisons and other institutions could also introduce environmental labelling.

The UK's Behavioural Insights Team (2023), found that **an overwhelming 83 per cent of the British populace supports the introduction of easy-to-understand eco-labels across various product sectors and businesses to facilitate greener consumer choices.** Such credible ecolabeling can also act as a deterrent against "greenwashing". Even though labelling might have a marginal influence on immediate consumer behaviour, a slight shift in demand can jeopardise market share for non-compliant businesses, incentivising better environmental performance.

Honest labelling is directed to consumer goods manufacturers and food producers. We also need full transparency from every link in the supply chain regarding emissions, deforestation, human rights abuses, funding, and resource extraction. Due diligence from corporations requires that they investigate, audit and report on the impact on the biosphere and social boundaries and then label accordingly.

2.2.8 Finance plant-based systems

Food choices are shaped by multiple external forces including price (Darmon and Drewnowski, 2015), particularly at a time when many countries are experiencing record breaking inflation. **Today, food from animal farming is exceptionally subsidised, artificially lowering the price of animal-based foods and hampering a shift towards plant-based diets. Therefore there is a pressing need to redirect harmful subsidies and taxes to favour lower impact plant-based foods to make them more affordable and accessible to the public en masse.**

In the 2020 Nature Food article by Rockström et al., "Planet-proofing the Global Food System", they say, "A recent assessment puts the 'hidden costs' of global food and land-use systems at $12 trillion, compared to a market value of the global food system at $10 trillion. If current trends continue, these hidden costs could rise to more than $13 trillion a year by 2030… Not only is the planet subsidising the global food system at a level that probably exceeds its global market value, the food system is also receiving massive direct subsidies from governments around the world" (Rockström et al., 2020).

Indicators for safe boundaries

A global carbon and methane tax could address pricing and ensure it reflects the environmental cost of food. The IMF suggests implementing a methane tax at source, which could be practical in countries where governments already manage business taxes and/or support programs. This proposal, particularly aimed at large producers within the sector, recommends a methane fee of $70 per ton among major economies (Parry, I. W. H. et al., 2022; O'Toole, 2022). The Plant Based Treaty has signed an open letter organised by Future Food Price, calling on 50 Presidents and their Ministers of Finance, Climate, Agriculture to introduce carbon pricing for food starting with meat and dairy (Carbon Pricing Food Coalition, 2021). The revenues would be used to compensate low-income groups by reducing taxes for low-carbon foods (plant-based) and by compensating farmers for measures that cut GHGs. A global agreement to adopt carbon pricing would help finance the transition towards plant-based food systems.

How far are we falling short?

A 2023 One Earth study, which analysed major EU and U.S. agricultural policies between 2014 and 2020, found that just $41m of public money was spent on plant-based alternatives (0.1 per cent) compared to $43bn spent on meat and dairy (Vallone and Lambin, 2023 and Carrington, 2023). EU cattle farmers earned at least 50 per cent of their income from direct subsidies. Animal farmers in the EU received 1,200 times more public funding and in the U.S. 800 times more than plant-based meat or cultivated meat groups.

Up to a staggering $23 million per minute is spent on subsidies worldwide in the animal agriculture and fossil fuel industry, two of the main drivers of the climate crisis. The 2023 World Bank report, Detox Development, says trillions of dollars per year of subsidies for fossil fuels, farming and fishing are causing "environmental havoc", severely harming the planet and "driving the degradation of the world's foundational natural assets – clean air, land, and oceans." According to the report, fishing subsidies of $118 billion a year are a key factor in the exploitation of marine life, which has sent the oceans into "a collective state of crisis." In addition, farm subsidies were responsible for the destruction of 2.2 million hectares (5.4 million acres) of forest a year. Another report from the FAO, UNDP, and UNEP, stated a staggering 87 per cent of global food subsidies are harmful to the environment and human health (FAO, UNDP and UNEP, 2021).

Private financial aid

In *Money to Burn*, Global Witness (2019) notes that between 2015 and 2020, global meat and dairy companies received over $478 billion in backing from more than 2,500 investment firms, banks, and pension funds headquartered around the world - see Figure 26. According to a different study by Feedback Global (2020), findings indicate that in April 2020, 3,000 investors collectively invested $228 billion in the 35 largest meat and dairy corporations worldwide. Notably, BlackRock, Capital Group, and Vanguard emerged as the principal shareholders of these companies. These investments help the animal agriculture industry to continue to expand on a massive scale. (See Figure 27)

Many financial institutions and investors that have pledged to address deforestation and confront the climate crisis find themselves deeply entangled in providing financial support to the global animal agriculture industry (GRAIN & ITAP, 2018). For instance, HSBC is implicated in funding Brazilian beef associated with deforestation and forest fires, despite the bank's ethical investment policies expressly prohibiting such activities (Forest & Finance). Another case brought to light by the nonprofit Forest 500 (2020), which ranks companies and financial institutions based on their deforestation practices, involves Rabobank. The bank, which 'focuses explicitly on sustainability in livestock (sic) farming', loaned $5.7 billion to meat and dairy companies with a combined emissions footprint of 727 million tonnes of CO_2 equivalent a year (Forest 500 (2020). Notably, 14 members of the influential Net-Zero Asset Owners Alliance, committed to achieving net-zero portfolios by 2050, collectively hold $5 billion in bonds and shares of industrial meat and dairy companies that pose challenges in terms of decarbonisation (Feedback Global, 2020). In a ShareAction (2020) review, encompassing 75 of the largest asset managers, only a third explicitly acknowledged agriculture as a viable and sustainable investment opportunity.

Feedback Global (2020) reports that Investment firms allocated $45.5 billion in companies with medium risk profiles (Fonterra, Tyson, Marfrig, Hormel, BRF, Charoen Pokphand, and JBS) and an additional $11.4 billion has been invested in higher-risk enterprises (WH Group, Minerva, NH Foods, New Hope, Wens Foodstuff Group, and Industrias Bachoco). Notably, Mondrian Investment Partners serves as an illustrative example, holding a 5 per cent stake in the high-risk pork giant WH Group, (a subsidiary of Smithfield).

Multilateral Development Banks

At the first Finance in Common Summit, held in Paris in November 2020, public development banks committed in their "Joint Declaration of All Public Development Banks in the World" to shift their investment strategies and activities to align with and support the objectives of the Paris Agreement (Finance in Common 2020). Despite this commitment, multilateral development banks (MDBs) continue to invest in the global expansion of factory farming across Africa, Asia, Eastern Europe, and Central and Latin America. According to research by World Animal Protection (2021), leading MDBs including the European Bank for Reconstruction and Development, European Investment Bank (EIB), IDB Invest (a member of Inter-American Development Bank), and the International Finance Corporation (IFC, World Bank Group) invested $4.6 billion in the sector between 2010 and 2021. The European Bank for Reconstruction and Development and International Finance Corporation emerged as the primary investors in private sector industrial operations, contributing a substantial $2.6 billion. This financial support aimed to facilitate the expansion of global operations for major players in the meat and dairy industry, including notable entities like Smithfield and Danone (Wasley 2020).

Prominent MDBs have introduced methodologies aligned with the Paris Agreement. However, these frameworks are not strong enough and still permit factory farming investments to be labelled as "Paris-aligned," signifying compatibility with the 1.5°C target. **Public policy needs to be more stringent on labelling financial instruments to prevent greenwashing. Notably, Paris-aligned operations are currently not mandated to demonstrate comprehensive greenhouse gas reporting, covering Scope 1-3 emissions, or establish specific reduction targets.** This lack of requirement for both comprehensive reporting and reduction targets "makes the notion of alignment with Nationally Determined Contributions or low-greenhouse gas development pathways fundamentally nonsensical," according to Stop Financing Factory Farming (2023) coalition, of which Plant Based Treaty is a member of.

Only about 40 per cent of countries have incorporated animal farming-specific greenhouse gas reduction measures into their Nationally Determined Contributions (NDC) (Consultative Group on International Agricultural Research, 2022). According to the Joint MDB Assessment, "If [an] activity or sector is not included in the relevant strategy [NDC], then in most cases it can be concluded that the activity is not inconsistent with the strategy..." This is an incautious assumption considering how few countries include animal agriculture in their NDCs. The European Bank for Reconstruction and Development has acknowledged this shortcoming of the MDB approach in their methodology: "The aggregate commitments in current NDCs are insufficient to secure an emissions trajectory consistent with the global temperature goals [of the Paris Agreement]...Only in rare cases will alignment with an NDC be sufficient to give assurances as to alignment with the Paris Agreement goals" (European Bank for Reconstruction and Development, 2022). An examination of the UN Framework Convention on Climate Change's Long-Term Strategies portal has brought to light that a significant number of countries, where MDBs are currently directing investments to expand factory farming, have not submitted low greenhouse gas long-term development strategies (UNFCCC, 2023). If such strategies do not exist, it is not possible for MDBs to assess the environmental impacts of investments in factory farming. Although the European Bank for Reconstruction and Development's Assessment and the World Bank's note on applying Paris alignment methods acknowledge these climate vulnerabilities, MDBs continue to fund industrial animal agriculture operations.

The problem of economic growth in a destructive industry:

The expansion of meat and dairy companies often results in economies of scale, lowering the cost per unit of production such as per chicken, beefsteak, or litre of milk. This, in turn, leads to reduced prices for consumers. However, these seemingly advantageous lower prices mask the broader consequences and environmental costs associated with this production model. The substantial market power wielded by these large agribusinesses not only jeopardises public interests but also undermines human rights and has profound impacts on the environment, small-scale farmers, workers, nutrition and animals. When our food is controlled by such a small number of big animal agriculture companies, competition is reduced, leaving them with fewer choices, less independence, squeezing their margins and ultimately driving smaller producers out of business (Howard 2017; Kelloway 2019; Shand 2019).

The growth paradigm is deeply ingrained in the nature of publicly listed big animal agriculture companies, where the pursuit of economies of scale and market expansion serves as a crucial strategy to deliver attractive dividends to shareholders. For example, dairy giant Arla increased production by 14 per cent between 2015 and 2020 (Arla, Good Growth 2020). Marfrig, in the same vein, reported a 2.6 per cent growth in North American sales volume and a 4 per cent expansion in its South American operation in 2019 (Marfrig, 2020). Similarly, JBS Brazil experienced significant growth in 2019, with a 13 per cent increase in volume for domestic sales and a notable 16 per cent rise in exports (JBS, 2019). Research conducted by IATP and GRAIN (2018) reveals ambitious growth plans for New Zealand's dairy giant Fonterra, aiming for a staggering 40 per cent increase in production between 2015 and 2025. Tyson has forecasted an annual growth rate of 3-4 per cent from beef and poultry sales (Marfrig, 2020).

Dutch meat giant VION anticipates a 1-2 per cent decline in meat and dairy consumption in Europe over the next decade, due to the rise of alternative proteins. However, the company also foresees an expansion in its international meat business (Burgers, 2020). **Despite the projected growth of the alternative protein market, executives from various meat and dairy corporations are on record stating that they view alternative proteins as complementary rather than substitutionary to their existing production models.** This perspective seems to be supported by data, as the market for alternative proteins is estimated at around $76.4 billion, while the global meat market is significantly larger, standing at approximately $1.3 trillion in 2023. This suggests that, at present, alternative proteins are seen as an additional market segment rather than a direct replacement for traditional meat and dairy products (Feedback Global, 2020).

"For us, this is about "and" - not "or". We remain firmly committed to our growing traditional meat business and expect to be a market leader in alternative protein,"

Noel White, CEO of Tyson (Feedback Global, 2020).

How do we get back into a safe operating space?

The UK Health Alliance on Climate Change recommends that sustainable diets should be supported by taxation of high-carbon foods (Scarborough et al. 2023). We must develop tax policies for meat products and direct the revenue towards ecological restoration of land that has been destroyed by animal agriculture. In "How to Cut Methane Emissions" (Parry et al., 2022), the IMF recommends a global Methane Tax at source on animal agriculture. Incorporating a meat and methane tax is an economic instrument that can help internalise the external environmental and socio economic costs of animal agriculture. These external costs include not only greenhouse gas emissions but also water pollution, soil degradation, and biodiversity loss. This is a very complex issue because first, the external costs not only include deforestation, antibiotic resistance, and social costs (such as occupational hazards for workers and health effects on communities living near livestock operations, which can be challenging to internalise through taxation alone), but also, and more importantly, the animals side, such as suffering, welfare, sentience and loss of life. Internalising these costs would mean reflecting all of those in the market price, which is impossible. Moreover, the effectiveness of such taxes in internalising external costs can vary depending on their design and implementation. A comprehensive approach might involve a combination of taxes, subsidies, and regulatory measures.

When industries do not bear these costs, they fall upon society at large, resulting in what economists term 'negative externalities'. **By taxing meat and methane, governments can effectively reduce meat consumption and encourage the food industry to adopt more sustainable practices. This approach can also generate revenue for ecological restoration efforts, subsidize plant-based alternatives benefiting low-income consumers, and support public health initiatives.** Additionally, as consumers become more aware of the real costs of meat consumption through price signals, they can make more informed decisions that align with both personal health and planetary wellbeing.

A recent article by Springman analysed options for agricultural subsidy reform and found that redirecting farming subsidies was in alignment with climate goals, can be economically feasible and play a role in transitioning to a healthy and sustainable food system (Springmann and Freund, 2022). The 2022 UNEP Gap Report also supports subsidy reform for a food system transition (United Nations Environment Programme, 2022). Currently, the majority of subsidies go to animal farming even though it produces a low volume of calories and causes great harm. We need to redirect subsidies to plant-based food production, support farmers in a plant-based transition and ensure financing is available to rewild agricultural land.

We must prioritise the affordability and accessibility of a whole foods, plant-based diet, especially in low-income communities. Today, many communities face the challenge of food deserts, where nutritious options like fresh fruits and vegetables are scarce or expensive (National Library of Medicine, 2009). By specifically allocating subsidies to the production and distribution of these foods, governments can ensure that more people have affordable access to a healthier diet. Studies and programs like the USDA's Healthy Incentives Pilot have shown that subsidising or lowering the price of produce can increase consumption for low-income households and save hundreds of thousands of lives (USDA, 2014). This action not only supports public health by potentially reducing diet-related illnesses but also uplifts small-scale farmers who focus on plant-based production.

Greenpeace is calling for EU and state governments to set targets for meat and dairy reduction and say governments should "end public subsidies for industrial animal farming, including feed production, and use public funds to encourage farmers to transition away from industrial meat, dairy and egg production" (Greenpeace Report, Marketing Meat, 2021). They add, "meat and dairy consumption should be reduced by at least 70 per cent by 2030 and 80 per cent by 2050 compared to current levels." Greenpeace and Plant Based Treaty are both calling for a major redirection of subsidies to end public funding for projects that promote increased consumption of meat and dairy, and redirect funding to promote plant-based diets. Plant Based Treaty also advocates for stricter regulations on private financial institutions and multilateral development banks that properly address the safeguarding of the planetary boundaries.

Fig. 1: Overview of agricultural support measures in 2017, including major spenders and the distribution by final use per commodity.

From: Options for reforming agricultural subsidies from health, climate, and economic perspectives

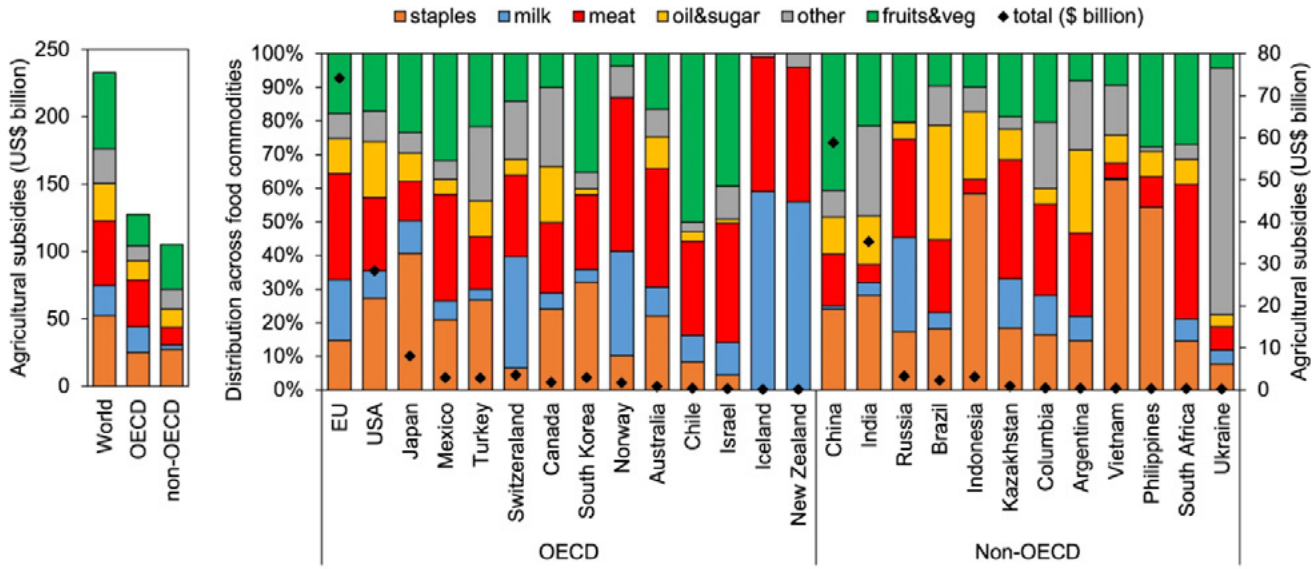


Figure 28: Overview of agricultural support measures in 2017 for Organization for Economic Cooperation and Development (OECD) and non-OECD countries, including major spenders and the distribution by final use per commodity such as staples, milk, meat, oil and sugar, fruits and vegetables and others. Total subsidy payments in billions of USD for major spenders, grouped by OECD and non-OECD countries, are shown on the right axis. The percentage distribution of about a quarter trillion in agricultural subsidies appears on the left axis (Springmann and Freund, 2022).

2.2.9 Reforestation and rewilding

If protected, intact forests offer an incredible opportunity to directly reduce atmospheric carbon emissions whilst simultaneously providing other critical ecological functions. Trees are essential for the cycling of nutrients, water and air quality, temperature regulation, soil protection, and many other functions that are essential for all life on Earth (Crowther et al., 2015).

Forests are suffering the adverse impact of the climate and ecological emergency. Forests act as critical carbon sinks, sequestering CO_2 and storing it as carbon in roots, soil and plant matter. However, forests are at increasing risk of becoming carbon sources – a catastrophic tipping point that has the potential to add significant and disastrous additional warming to the atmosphere (Zuidema et al., 2022; Albert et al., 2023).

Progress on Plant Based Treaty's Relinquish (R1) and Redirect (R2) principles, will create opportunities to shift the focus to nature-based solutions implemented through Plant Based Treaty's Restore (R3) principle. This will allow the repair of key degraded ecosystems such as mangroves, peat bogs, forests, and some types of grassland, which are essential for carbon sequestration cycles.

Indicators for safe boundaries

When looking at the Planetary Boundaries framework, scientists point out that we must retain 85 per cent of tropical and boreal forests and 50 per cent of temperate forests to stay within a safe operating space (Steffen et al., 2015). According to the Planetary Boundaries Framework, the current rate of deforestation and biodiversity loss has already breached the 'Land-Use Change' boundary, leaving us outside of the safe and just operating space (Steffen et al., 2015). From a policy perspective, indicators would include access to subsidies for rewilding, and grants for farmers to switch from animal agriculture to diversified plant production.

How far are we falling short?

Between 1970 and 2018, the diversity of forest specialist species declined by an average of 79 per cent (Living Planet Index, 2023). When considering critical ecosystems and their overall intactness, it is important to note that 75 per cent of the global land surface has been significantly altered, 66 per cent of the ocean is experiencing increasing cumulative negative impacts, and over 85 per cent of wetland area has been lost (IPBES, 2019). According to DeClerck et al. (2023), in 552 ecoregions globally (69 per cent of the total), "less than 10 per cent of the area remains intact and may be too far gone for meaningful restoration of intactness, or may conflict with food and nutrition security. In these locations, integrating biodiversity into production will be a more viable option."

What is the impact of the food system on this social boundary?

Earth has lost one-third of its forest cover. Figure 29 shows the impact of agriculture on deforestation and land-use change. According to Poore and Nemecek (2018), agriculture is one of the primary drivers of deforestation and habitat loss. Animal agriculture including feed production, grazing, and farm units occupies 83 per cent of the world's farmed land, of which three quarters could be rewilded back to original ecosystems or reforested if we switch to a plant-based food system.

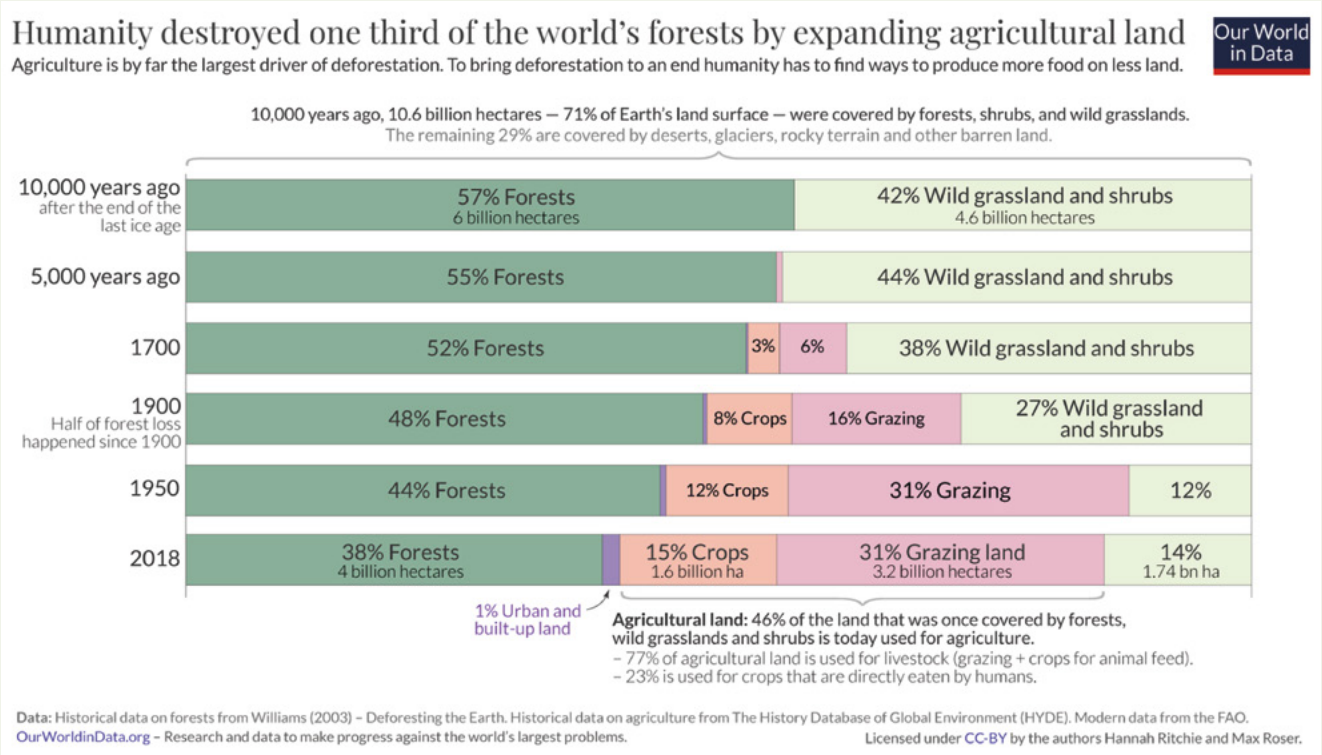


Figure 29: Ritchie (2021) notes Earth has lost one-third of its forest cover, and only 4 billion hectares of forest remains. Farmed land is heavily simplified with little ecological value. 10,000 years ago, 71 per cent of Earth's surface was covered by forests, shrubs, and wild grasslands. There is a direct correlation between agricultural expansion and forest loss, and now only 38 per cent of Earth is covered in forest and 14 per cent wild grassland and shrubs. 46 per cent of the land that was once covered by forests, wild grasslands and shrubs is today used for agriculture, the vast majority of which is for animal farming and animal feed production.

How do we get back into a safe operating space?

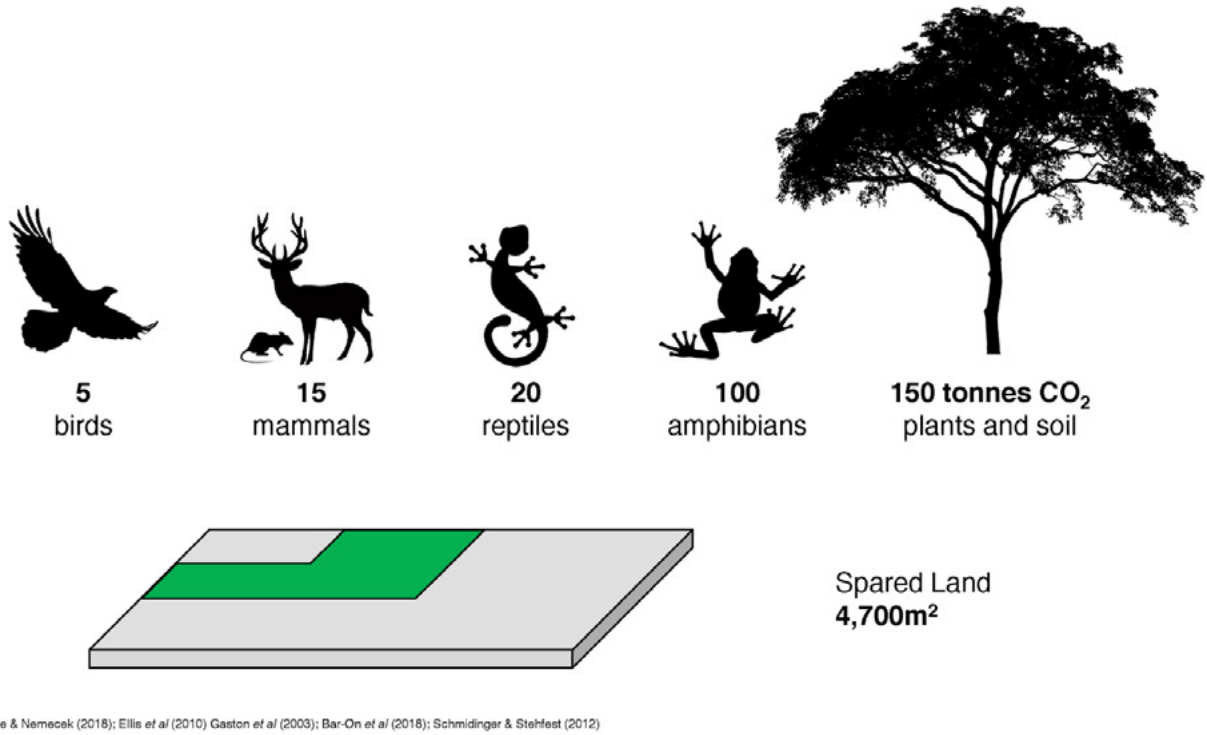
Plant Based Treaty's R3: Restore principle calls for subsidies to be made available for rewilding and restoration schemes as well as to support farmers shifting from animal agriculture to diversified plant production.

In DeClerck et al. (2023) they argue that "Many parts of the world are currently in intactness deficit, considering a 50 per cent intactness target. Estimates of how much restoration is needed range between 19 and 24 million km², with the lower value targeting high conservation value areas, and the higher value targeting half-intact ecoregions, across all ecoregions. Protecting at least half of our terrestrial realm, in each of our 782 ecoregions, is necessary to halt extinction loss. Retaining intact regions in ice-free areas (>67 M km²) and achieving half intactness for all ecoregions would require restoration of 23.9 M km²." Additionally they say that "restoring 15 per cent of converted lands in priority areas could avoid 60 per cent of expected extinctions and help provide vital ecosystem

functions, such as sequestering 30 per cent of the total CO_2 increase in the atmosphere since the Industrial Revolution". This aligns with the safe and just boundary for land-system change and is consistent with the recently adopted restoration goal of the Kunming Montreal Global Biodiversity Framework (GBF; Rockström et al., 2023). This goal aims to restore approximately 10-15 per cent of the Earth's land area by 2030, which is expressed as restoring 30 per cent of degraded lands.

Agriculture's use of land and space prevents reforestation or other ecosystems that capture carbon. In order to restore habitats, we first need a dietary shift away from meat and dairy products, which are land and resource intensive. Without a food system transformation, we cannot reverse ecologically degraded areas and rewild others - see Figure 30. Rewilding offers a huge carbon sink potential which would help lowering CO_2 emissions.

We need healthy and thriving ecosystems to draw down our emissions and increase wildlife populations and abundance. By far, the quickest, cheapest and benign way of doing that is restoring ecosystems to make sure the trees and the wetlands return. It's not just nice to have - although it is nice to have - this is our life support system.



Sources: Poore & Nemecek (2018); Ellis *et al* (2010) Gaston *et al* (2003); Bar-On *et al* (2018); Schmidinger & Stehfest (2012)

Figure 30: Benefit of one person switching to a plant-based diet. In 1 year 4700m² land would be spared which could be rewilded, and absorb 150 tonnes of CO_2 in the plants and soils ,as well as provide homes for five birds, 15 mammals, 20 reptiles and 100 amphibians.

2.2.10 Greening cities

Cities face growing challenges such as sea level rise threatening millions, more intense storms, deadly heatwaves and droughts, threatened infrastructure, ensuring safe housing, and access to nutritious, affordable and culturally appropriate food. City leaders will have to be prepared to accommodate large numbers of climate migrants, as well as nonhuman animals, fleeing flooding, droughts, wildfires, and deforestation (Bayulken et al., 2021). Cities need to play a leading role in mitigation strategies as well as adapting to withstand the forthcoming crises. Cities have the potential for scalable action as centres of economic, cultural, and social activities. Communities can thrive through legislation, public education, policy incentives, and public participation on localised food production and rewilding.

Indicators for safe boundaries

According to the Safe and Just Earth System Boundaries Framework from Rockström et al. (2023), we need 20-25 per cent of every 1 km2 of urban environments to be covered by greenery. This is the distance pollinating and beneficial insects travel. The coverage and quality of greenery needed varies depending on factors like landscape type, climate, and topography. The amount of greenery required may even reach as high as 50 per cent for landscapes that are vulnerable to natural hazards, like steep slopes or easily erodible soils.

The European Commission's proposal for a Nature Restoration Law recommends a minimum of 10 per cent tree canopy cover for European cities, while other studies have recommended that urban neighbourhoods should aim for 30 per cent tree coverage to improve microclimate, air quality and health (Konijnendijk, 2021). Too few trees and too little green cover in cities impacts temperature, mental health, physical health, and air quality. For example, mental health is seen as a "service" provided by nature to people. Cities should increase high-quality green spaces in urban environments to promote health and welfare.

According to a study by Turunen et al. (2023), of 16,000 randomly selected residents of Helsinki, Espoo and Vantaa in Finland, visits to parks, community gardens and other urban green spaces may lower city dwellers' use of drugs for anxiety, insomnia, depression, high blood pressure, and asthma. Compared with less than one weekly visit, visiting green spaces three to four times weekly was associated with 33 per cent lower odds of using mental health drugs, 36 per cent lower odds of using blood pressure drugs, and 26 per cent lower odds of using asthma drugs. In an article on the importance of greenspace for mental health, Barton and Rogerson (2017) argue that "simple exposure to natural environments is psychologically restorative and has beneficial influences on individuals' emotions and ability to reflect on life problems." A study by Kingsley and EcoHealth Ontario (2019) found that when people have access to local, neighbourhood green spaces, birth outcomes and social cohesion are improved, and mortality from all causes, the level of obesity, the number of people with cardiovascular diseases, the symptoms of mental illness, and the self-reported feelings of stress are reduced.

How far are we falling short?

40 per cent of the world's human-dominated land surface does not have sufficient functional integrity, and what remains is losing its ability to recover. In 'Safe and Just Earth System Boundaries', Rockström et al. (2023), state "The shortfall for functional integrity in agricultural and urban ecosystems reduces the ability to handle natural disasters and pollution and increases the reliance on harmful chemicals such as pesticides and biocides. This impact is more significant in areas with vulnerable communities."

Several environmental risk factors contribute to non-communicable diseases in cities. Air pollution is the largest of these, accounting for 6.7 million deaths globally, of which about 5.7 million are due to stroke, ischaemic heart disease, chronic obstructive pulmonary disease, and lung cancer (WHO, 2023 on non-communicable diseases).

As discussed before in 'biosphere integrity', nature provides essential functions and services such as water management, air quality, and shade (IPBES 2019 and Rockström et al., 2023). According to the United Nations' World Urbanization Prospects 2018, the number of people living in urban areas around the world is projected to increase from 55 per cent in 2018 to 68 per cent by 2050 based on the UN's medium fertility scenario (9.8 billion people in 2050). Feeding the world's population is a major challenge. With the majority of the world's food being eaten in cities, the 2019 Veolia Institute's review on urban agriculture concludes that it is imperative to shift to plant-based food systems and to produce more food within cities.

What is the impact of the food system on this social boundary?

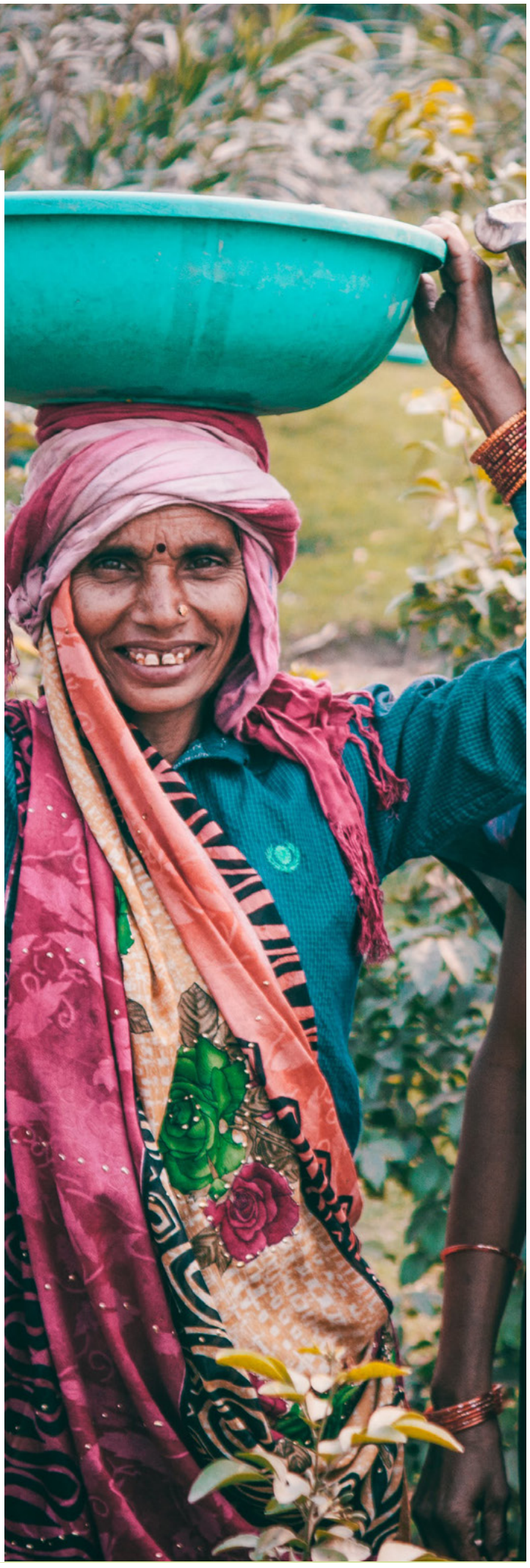
The most significant environmental impact of food is what we eat rather than how far it's travelled, as discussed earlier. However, growing low impact, locally produced fruits and vegetables in cities would be optimal. Currently, cities lack sufficient numbers of community and rooftop gardens. For example, according to a study by Walsh et al. (2022), in the UK around 1 per cent of urban space is dedicated to allotments for food production. However, if all urban green spaces were used to grow food, the UK's output of fruit and vegetable production would increase by 800 per cent. Currently, there are more than 157,820 outstanding applications to local councils for allotments, with waiting lists of up to 15 years (Gayle, 2023). These figures demonstrate the desire among people to tackle the worsening climate, nature, health and cost of living crises.

How do we get back into a safe operating space?

We need regenerative cities to build a restorative relationship with nature and bring back healthy local ecosystems, and create inclusive well-being, health and happiness for everyone. In a study of 93 European cities, researchers found that increasing tree level cover from the European average of 14.9 per cent to 30 per cent could lower city temperatures by 0.4°C, which could reduce heat-related deaths by as much as 39.5 per cent (Lungman et al., 2023). The UN's 2023 Adaptation Gap Report points out that mitigation is cheaper than adaptation. Mitigation measures include coastal defences, urban flood prevention, and green corridors. Since 2016, Medellín, in Colombia, has established 30 'Green Corridors', connecting and enhancing green spaces across the city. This project boosts urban biodiversity, decreases the city's heat island effect, cleans the air, and stores a lot of carbon dioxide. The Green Corridors project shows how nature-based initiatives like widespread tree planting can greatly benefit the environment and the well-being of the city's residents (C40 Cities Climate Leadership Group, Nordic Sustainability, 2019).

Rooftop farming offers an innovative solution to meet growing food demand while contributing to a more sustainable and livable city. It has been demonstrated that rooftop farming can enhance air quality, decrease carbon emissions, and reduce the cost of managing stormwater, benefiting both the environment and society. A 2017 study about rooftop farming in the city of Dhaka, one of the most populated cities in the world, shows rooftop farming can help meet the growing food demand, lower temperatures, and contribute to a healthier environment overall (Safayet et al., 2017).

Urban tree planting and urban forests have also been proposed as climate mitigation strategies. Other examples of green infrastructure include green roofs, green facades (green walls), urban agriculture systems, disconnecting downspouts and installing rain barrels, bioswales (vegetated ditches which allow for the collection and filtration of stormwater), permeable pavements, and tree-based intercropping systems (growing trees together with crops). These strategies require cohesive urban forest, climate, and nature retention policies along with major investments in retrofitting existing structures or establishing new cityscapes (Feigin et al., 2023).



2.2.11 Food justice

Access to healthy nutritious food and a food system that doesn't harm and exploit others should be a basic human right. The Plant Based Treaty states: "*Enhance food justice by providing access to healthy food for all, especially low-income communities of colour.*"

Indicators for safe boundaries

Indicators include access to healthy whole foods at stores within a short distance from people's home and access to seeds, allotments, and community gardens. To achieve food justice, everyone must have adequate access to nourishment without barriers (Feller, 2020).

How far are we falling short?

Everyone deserves a dignifying job, yet in animal farming in particular, there are many human rights issues at all stages. For example, phosphate, which is added to fertiliser, is mined in marginalised countries under poor working conditions, exposing the communities to mining waste, destroyed land, and human rights abuses. The mining of phosphate is connected to the breaching of the biogeochemical planetary boundary.

Slaughterhouse workers are more likely to feel depression and anxiety, post-traumatic stress disorder (PTSD), have violence-supportive attitudes, and commit sexual crimes (Slade and Alleyne, 2023). The conditions they are exposed to include traumatic situations, long working hours, inadequate safety protocols, limited access to proper healthcare, and a heightened risk of exposure to zoonotic diseases such as avian influenza, swine flu, and COVID-19 (Bhaskara et al., 2020). Communities with slaughterhouses can become unsafe due to increased crime rates among slaughterhouse employees, including rape and sexual assault (Fitzgerald et al., 2009).

People who live near animal factory farms, slaughterhouses, polluted waterways, and non-organic monoculture fields, which are disproportionately located in poorer communities, face environmental justice issues. For example, BIPOC communities, who live adjacent to large pig farms in North Carolina, U.S., experience adverse health issues when farms spray animal waste on fields (Cappiello, 2021). The U.S. Centre for Disease Control reports that waste from Concentrated Animal Feeding Operations (CAFOs) "contains a variety of contaminants, such as nitrogen and phosphorus; pathogens such as E. coli; growth hormones; antibiotics; chemicals used as additives to the manure or to clean equipment; animal blood; silage leachate from corn feed; or copper sulphate used in footbaths for cow" (Mercy for Animals Report, 2022).

It has also been found that people living near animal farms face higher levels of illness including asthma, eye irritation, nausea, headaches and psychological distress from the strong smell, loud noise, scenes of animal suffering, and greater exposure to infectious zoonotic diseases. A study in the Netherlands linked residents living near animal farms to higher levels of respiratory mortality (Simões et al., 2022; Borlée et al., 2017). In India, where there are 3,600 legal and 32,000 illegal slaughterhouses, waste disposal is a health hazard, especially for illegal slaughterhouses. "The results show that land degradation, water and air pollution was higher in close vicinity of the slaughterhouse and as one goes farther away it decreases" (Singh et al., 2014).

In food deserts, low income communities have easy access to fast food chains but very limited access to healthy, whole plant-based foods. In the UK, ten million people live in food deserts. These areas often have high densities of fast-food outlets, which contribute to rising diet-related conditions such as obesity and diabetes (Corfe, 2018). In the United States, official U.S. government data shows that more than 18.8 million people, or 6.1 per cent of the population live more than 1 mile away in an urban area, or more than 10 miles away in a rural area, from a supermarket (USDA Economic Research Service).

Globally, poor diets are the main contributor to the global burden of disease, accounting for 20 per cent of premature disease-mediated mortality worldwide. Approximately 3 billion people cannot afford a healthy diet, and more than 3 billion people suffer one or more manifestations of poor nutrition. Poor nutrition can lead to reduced earning potential and increased costs for healthcare, locking individuals and families into inter-generational cycles of poverty, and perpetuating inequality and disadvantage (Webb et al., 2020).

What is the impact of the food system on this social boundary?

"In the United States, animal agriculture produces between 335 million and 2 billion tons of animal waste per year; China exceeds 2 billion. In contrast, the U.S. human population produces just 7 million tons of waste" (Mercy for Animals Report, 2022).

According to a report by the International Labour Organization, around 24,000 fishers engaged in fish farming and processing are killed every year, putting fishing among the most dangerous of all professions (ILO 1999). In Guinea, west Africa, it is estimated that one in every 200 fishers dies in a canoe accident. The fatality rate for the fishing industry in Denmark between 1989 to 1996 was 25-30 times higher than for those employed on land. In the U.S., prisoners are often exploited for animal agriculture (Williams, 2023).

Worldwide. 60 per cent of all child labourers in the age group 5-17 years work in agriculture, including farming, fishing, aquaculture, forestry, and animal farming. This amounts to over 98 million children. The majority (67.5 per cent) of child labourers are unpaid family members (ILO, Child labour in agriculture). Child labour is a problem across the agricultural sector, from slaughterhouses where minors work as cleaners with dangerous chemicals and equipment to child labourers working in aquaculture (Yang, 2023; ILO, Fishing and aquaculture). Children's attendance at school can be impacted by having to care for animals in pastoral communities, for example, by having to lead farmed animals long distances to water sources in remote areas (ILO, Livestock production). Animal Save India's investigation of Heifer International and Cargill's "Hatching Hope" campaign in Odisha, India, found testimonials of children reporting skipping school to look after chickens (Government of Odisha, Pattanaik and Padhi, 2019).

How do we get back into a safe operating space?

Transitioning from intensive animal agriculture to more sustainable and plant-based food systems is an important part of addressing critical issues related to workers' rights and well-being. The production of plant-based food takes place in working environments that are generally safer, less stressful, and more conducive to overall well-being. A plant-based food system raises the possibility of a healthy and compassionate work environment, reducing the risks of physical and mental health issues among workers, and upholding the dignity and the rights of workers.

To address food justice we need to implement food distribution and subsidy systems ensuring healthy food access, especially targeting marginalised communities. Community gardens, providing families with healthy food, redistributing food, and reducing food waste, should be prioritised by local and regional governments.

In New York City, Mayor Eric Adams is attempting to combat food deserts by incentivising local neighbourhood food stores to offer healthy fresh produce like fruit and vegetables. NYC's FRESH program offers financial incentives designed to bring fresh foods closer to communities that often have limited access to fresh grocery food. Improving access to fresh foods in underserved communities is a crucial step in moving towards healthier, more equitable, and more sustainable food systems.

Globally, smallholders produce one-third of the world's food while being some of the poorest people in the world (Ritchie and Roser, 2022). According to IPBES (2019, 28) "Small landholdings (less than 2 hectares) contribute approximately 30 per cent of global crop production and 30 per cent of the global food caloric supply, using around a quarter of agricultural land and usually maintaining rich agrobiodiversity." (IPBES, 2019). They are too often left out because each smallholder only produces a small share of the world's food, but as a whole, their productivity and production could increase and become more sustainable. Smallholders need access to markets, literacy programs, education in their own language, and resources. Women, who have less access to productivity resources, need improved access to increase output.

A focus on urban farming through the expansion of allotment schemes, community gardens, seed distribution hubs, and training can help increase food security in cities where 68 per cent of the population is projected to live by 2050, and where 80 per cent of food grown will be eaten (UN DESA, 2018; The Veolia Institute, 2019). Community gardens can also be set up at schools or college campuses to give students hands-on experience of growing fruits and vegetables, empowering them with the knowledge of nurturing seeds and plants to become delicious and nutritious food. Food researchers at Ohio State University and Cornell University in New York found that children are five times more likely to eat salad when they have grown it themselves (Davis et al., 2021).

2.2.12 Land equity

Land inequality has exacerbated the climate crisis and given rise to conflict. It also poses a grave risk to water shortages and food insecurity. In Chad, where communities have been grappling with drought and desertification for decades, conflicts have arisen where animal farming has infringed on land used for plant-based crop farmers. Land-use rights and access to water in Chad have become the leading cause of these community clashes, particularly during dry season, where water sources and pastures become scarce.

Indicators for safe boundaries

One important indicator is how equitably land is distributed and whether key ecosystems are considered part of the global commons. Currently, there is a high concentration of ownership in farms and farmland, resulting in food production being based more on profit than meeting human needs and environmental protection.

How far are we falling short?

According to the International Land Coalition (2020), 70 per cent of all farmland is operated by just 1 per cent of the world's farms. George Monbiot (2022, 45) explains:

"Global farm seizures in the twenty-first century, driven to a large extent by ultra-rich people and institutions adding land to their portfolios, often involving corruption and coercion, have pushed millions of cultivators off their land. Since 2000, 9 per cent of Africa's land—often the best land, often in countries where many people go hungry—has been bought or seized. Today, over 70 per cent of the world's farmland is owned or controlled by just 1 per cent of its "farmers." I put farmers in scare quotes because some of the biggest owners have no experience or even direct connection with growing crops or raising animals. They include investment banks, pension funds, hedge funds, and private-equity vehicles."

What is the impact of the food system on this social boundary?

George Monbiot notes that pension funds are major holders of land, often preferring to invest in soy and promote animal feed, because it is easy to adjust what they produce based on the profitability of different commodities and the number of markets they can be sold to. "Small farmers, on average, grow a wider range of crops, using a wider variety of techniques, than big ones. The land grabbers who replace them tend to focus on what traders call "flex crops": commodities that can be switched between different markets. For example, soybeans and corn can be used to produce food, animal feed, or biofuel. The system becomes more generalised, more homogeneous, less buffered. The biggest problem the global food system faces appears to be the global food system" (Monbiot, 2022, 46).

Figure 31: The Catholic charity Caritas is trying to transform the system by helping refugees switch to plant-based farming. "*I breed animals. I have never grown any crops at home in the Central African Republic. Caritas is helping us to grow vegetables. I wanted to be re-trained too. With seeds, equipment and the training I got, I have become an agricultural producer,*" said Dairou Abdoulaye.

How do we get back into a safe operating space?

Instead, if we were to look at food production from a health and planetary perspective, we would emphasise the importance of legumes, which are not only healthy for us, they are healthy for the planet (Polak, 2015). Adding legumes to crop rotations can meet our protein needs and also regenerate healthy soils. "Some nitrogen is replaced by planting clover, beans, and other members of the legume family, which have formed a remarkable relationship with bacteria species that turn atmospheric nitrogen into the nitrate minerals that plants and animals need. These plants form nodules on their roots in which the bacteria live and grow, exchanging the nitrates they produce for sugars the plants create. But legumes like clover and beans cannot compensate for losses on this scale" (Monbiot, 2022, 113). Legumes give us the opportunity to limit agriculture's impact on the planet and eat our way to healthier soils through healthy plant proteins.

Plant Based Treaty also supports legislation that shifts land ownership into community hands so it can be repurposed for reforestation, reclaiming Indigenous rights, green spaces, and edible gardens and allotments. Planetary stewardship is not a new idea; Indigenous people have always talked about environmental stewardship and it is embedded into Maori culture. In 2017 New Zealand/Aotearoa granted the Whanganui river the same rights, power, and duties as a legal person. This law grants nature personhood and in practice means the river can sue you. The former national park, Te Urewera and Mount Taranaki, also have legal status. The Ngati Wai and Ngati Whatua communities have a saying which means "the ecosystem defines my quality of life" (Rockström and Gaffney 2021, 112). This challenges the dominant world view that our quality of life is defined by increased consumption, and that growth, waste, and pollution are inevitable. Similarly, in 2021, Juan Evo Morales Ayma's Bolivian government, widely regarded as the country's first president to come from its Indigenous population, passed the 'Law of the Rights of Mother Earth', granting nature the same rights as humans. Ecuador has a similar law.

Planetary stewardship requires us to live within planetary boundaries and expand the global commons. For the past century, the global commons have been recognized in a narrow legal sense to manage four zones beyond national jurisdiction: Antarctica, High Seas, Outer Space and the atmosphere. Nakicenovic et al. (2016) argue that we need to extend this list to cover ecologically essential ecosystems that maintain the Earth's balance, such as the Amazon. They propose a new definition of global commons in which all parts of Earth's system that protect Earth's ability to remain in Holocene stability should be viewed as global commons.

There is a mountain to climb for planetary stewardship to go mainstream. For example, in the UK, the right to roam exists in only 8 per cent of the countryside and 3 per cent of rivers (Hayes, 2020). Resetting world views and achieving equitable land distribution is not easy, but as a starting point, communities need access to lands to be able to appreciate and cherish them, so they want to protect them.

2.3 Conclusion - Adopt the Plant Based Treaty to get us back into the safe operating space

"The way that we produce food in the world is the single largest reason that we have transgressed planetary boundaries. It is the single largest threat to the stability of the planet and our life support systems, from freshwater, pollinators, and soil health, to rainfall generation, and quality of air and water. Food production is putting our future at risk" (Rockström and Gaffney 2021, 131).

There is a worrying trend regarding the dramatic rise in global per capita meat consumption since the 1950s as part of the "great acceleration" discussed in Rockström and Gaffney's Breaking Boundaries. Between the early 1980s and early 2020s, meat production has grown from around 30 kg per year to about 45 kg per year or 50 per cent in this short timeframe. The result of this increase has greatly impacted the planetary boundaries depicted in the outer rim of Kate Raworths's doughnut economics framework, specifically climate change, land-use change, biodiversity, phosphorus and nitrogen, freshwater use, and ocean acidification, among others. We decided to adapt the inner rim of the donut to illustrate how the food system contributes to the transgression of social boundaries. We incorporated recommendations from Plant Based Treaty's 3Rs and dozens of detailed proposals by zeroing in on 12 specific policy areas.

The Plant Based Treaty sets forth an Earthshot trail for transitioning to a plant-based food system and rewilding the Earth to lead us to a green, 'safe and just' space. We need a global agreement and local implementations of the 3Rs: R1, relinquish the expansion of animal agriculture; R2, redirect major economic resources and large-scale public education towards plant-based food systems; and R3, restore and rewild to reverse damage to critical ecosystems and their functions and services.

R1 RELINQUISH

Land conversion is threatening forests, soils, waterways and land defenders, especially Indigenous Peoples; and growing live exports exacerbating animal exploitation.

Agricultural expansion is the leading cause of land-use change globally. We have already converted half of Earth's surface, and we must take decisive action to keep the other half intact. Degraded lands must be restored as future carbon sinks and as a fundamental agent in strengthening the biosphere's resilience. If we transition to a vegan world, there would be a significant opportunity to rewild the Earth and allow us to feed the world with just 1 billion hectares of land and rewild three quarters of agricultural land (Poore and Nemecek, 2018). Globally, urban areas occupy around 2 per cent of the world's land while a staggering 55 per cent is used for agriculture, and we are still continuing to convert more land every year for food and agriculture. Compared to the problem of urban sprawl, there are glaring gaps in awareness on the wasteful land-use from animal agriculture, particularly animal grazing and feed crops.

Currently we are not on track to reverse deforestation by 2030, as pledged by more than 140 countries through the COP26 Declaration on Forests and Land Use. This is driven by the expansion of animal agriculture which disproportionately occupies 83 per cent of agricultural land, yet produces only 18 per cent of global calories and 37 per cent of protein. A groundbreaking EU deal designed to ban the import of goods linked to deforestation such as beef, soya, palm oil, coffee, cocoa, rubber, charcoal, and paper, unless their origins can be traced using geolocation data, takes effect in 2024. This legislation is a welcome first step, but should go much further and protect other fragile ecosystems, such as Brazil's Cerrado savannah and peatlands in south-east Asia, which are both rich stores of carbon, plant, and animal life.

Indigenous Peoples are on the frontlines acting as land defenders, and face disproportionate killings connected to the agribusiness sector. In the Amazon, the main driver of deforestation is the expansion of soy production for farmed animal feed. Multinational companies like Cargill and JBS as commodity traders are profiteering in a big way from global exports. It is our collective responsibility to give power back to Indigenous People and protect the global commons.

The growing live export trade highlights a profound intersection between the climate crisis, water scarcity, and interspecies justice, with the expansion of live animal exports from the global North to Asian and Middle Eastern countries directly linked to the climate crisis and water shortages. The Plant Based Treaty calls for an immediate ban on live exports.

R2 REDIRECT

We need to redirect policies and allocate resources to strengthen food accessibility and security; public education campaign to address climate illiteracy and major awareness gaps; address public health crises, including zoonotic diseases, antibiotic resistance, heart disease, type 2 diabetes and some cancers; introduce food transparency and eco and carbon labelling; reverse perverse subsidies and investments financing in meat dairy and egg expansion along with the introduction of meat taxes and subsidies for veganic agriculture, and a ban on meat advertising.

We have left the Holocene and are being pushed out of the climate niche, resulting in widespread food shortages in other parts of the world. By 2030, crop yield failures could be 4.5 times higher. By 2050, the likelihood shoots up to 25 times current rates and the world could be facing a rice or wheat failure every other year with the probability of soybean and maize failures even higher. Also by 2050, synchronized failure across all four crops becomes a possibility every 11 years. In 2022, global hunger affected between 691 and 783 million people, an increase of 122 million from 2019 pre-pandemic levels. Animal agriculture, an extremely inefficient system to feed the global human population, jeopardises food security and the UN Sustainable Development Goal number two to end world hunger. For every 100 calories fed to animals as cereals, just 17-30 calories enter the human food chain as meat.

It is urgently required that we address the major gap in climate literacy, public opinion polls, mass media coverage, and policy discussions at COP, in legislative chambers when it comes to food system impacts. We need to update our worldview where the ecosystem defines our quality of life: "A paradigm towards planetary stewardship, as an integral part of human development, is today a very necessary next evolutionary step in our world" (Rockström and Gaffney, 2021, 111). The majority of the public, media, and policy makers are largely unaware that adopting a vegan diet is the single biggest action a person can take to reduce their impact on Earth. It is only when people become aware of the full facts about the impacts of our current food system, and the far reaching benefits of plant-based diets, that we will see a paradigm shift. We need advertising campaigns beyond the scale we witnessed during the COVID-19 pandemic – where we saw adverts and education at every turn whether it was on the highway, in the supermarket, or on our TV screens – to match the level of the threats to planetary boundaries and the social foundation's SDGs.

With respect to health, plant-based diets, particularly those with high intakes of fruits, vegetables, legumes, grains, nuts and seeds, have been shown to decrease the risk of cardiovascular disease, type 2 diabetes, some cancers, and more. The consumption of meat, dairy, and eggs is one of the leading causes of disease. Three-quarters of emerging infectious diseases in humans originate from the farming of animals for food. Switching to a plant-based food system would alleviate the global cascading crises of climate change, land-use change, human health, antibiotic resistance, and zoonotic disease.

Honesty and transparency in food labelling offers a huge potential to shift both consumer food choices and the manufacturing processes as businesses compete for market share. While some businesses have voluntarily adopted carbon labelling, government mandating of labelling could spread these initiatives further to create an even playing field and raise public awareness of the environmental cost of food.

Last but not least, another hefty priority is to introduce powerful economic tools, in particular, a meat or methane tax. In addition, governments need to redirect subsidies from projects that promote increased consumption of meat and dairy, to instead promote plant-based diets. Stricter regulations are needed on private financial instruments and multilateral development banks to properly address the safeguarding of the planetary boundaries.

R3 RESTORE

Progress on R1 and R2 will give rise to increased action and progress in R3, Restore in the areas of: reforestation and rewilding; creating greener cities with the incorporation of plant-based food strategies into existing Climate Action Plans; enhancing food justice and address unsafe work and food deserts; and addressing the challenges of equitable land distribution.

An astounding 46 per cent of the land that was once covered by forests, wild grasslands, and shrubs has been destroyed by agriculture, the vast majority for animal farming and animal feed production. We need healthy and thriving ecosystems to draw down our greenhouse gas emissions and increase wildlife populations. By far, the most efficient and cost effective way to do this is by restoring ecosystems. Rewilding is not just a nice to have, it's our life support system, and if we want to pull the planet back from the brink of collapse, we need to halt expansion of animal agriculture and reverse agricultural sprawl.

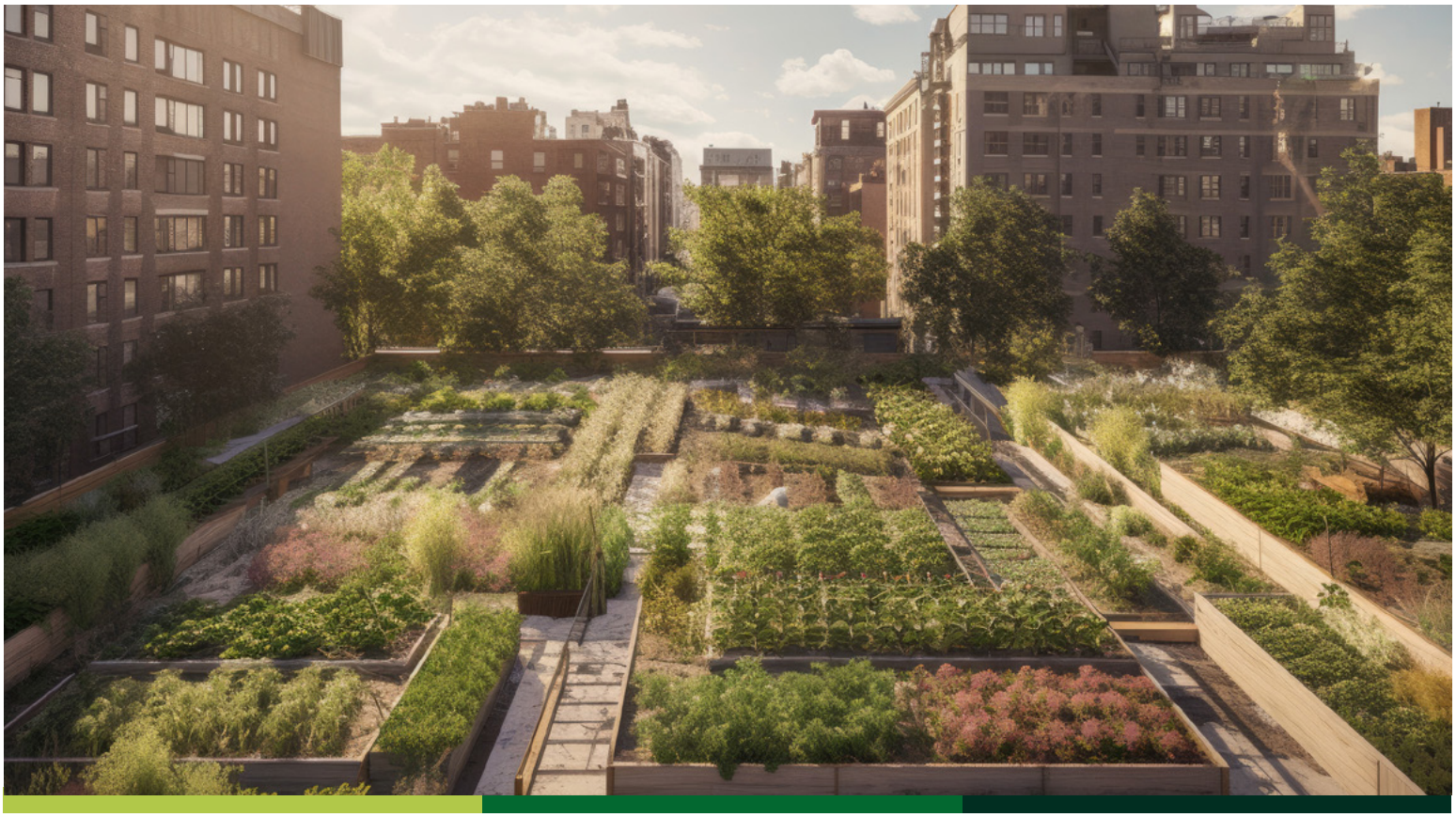
Siloed visions of agricultural systems being separate from the natural world and somehow exonerated from environmental responsibilities are no longer compatible with global commitments or city actions on food and nutrition, climate, biodiversity, environmental and livelihood security, and interspecies justice. Policymakers at local and global levels must recognize that all parts of the food system need to work together as a whole to promote food justice, delivering diets that are high quality and sustainable.

Plant Based Treaty's vision is to repurpose the land freed up from animal grazing and animal feed production for rewilding, reforestation (if appropriate), returning land to Indigenous Peoples, nature reserves, hiking zones, community growing, allotments (if appropriate), and agroecological food growing (where possible). When land previously used for animal agriculture is transitioned, it presents a golden opportunity to address multiple ecological and societal challenges simultaneously.

The next chapter looks at the key role cities can play in local food transportation and advocacy. More than 20 cities, including Los Angeles, Amsterdam and Edinburgh have called for world leaders to negotiate a Plant Based Treaty and are taking action at the city level to help us shift towards sustainable plant-based diets.

EAT PLANTS, PLANT TREES

NEGOTIATE A GLOBAL AND LOCAL PLANT BASED TREATY!



CHAPTER THREE

Cities calling for a Plant Based Treaty

3.1 Introduction

We need local, national, and international cooperation to reduce food impacts with plant-based diets. The Plant Based Treaty calls for cities and countries to declare a climate emergency, calculate consumption-based greenhouse gas emissions and incorporate plant-based food strategies into Climate Action Plans.

One of the most important things cities can do as global climate champions is integrate plant-based food strategies into their existing Climate Action Plans, and interlinked programs that address biodiversity, food poverty, and community health. These strategies can also be incorporated into other priority areas. For example, Lambeth Borough Council in the UK, who endorsed the Plant Based Treaty in October 2023, has included a plant-based food strategy as part of their Food Poverty and Insecurity Action Plan, recognising that a "shift toward plant-based diets can contribute to improving the health and wellbeing of [their] residents." In the Lambeth Biodiversity Action Plan, the council will work with community groups to promote the establishment of new and appropriate community gardens to protect and enhance biodiversity by supporting the "availability of diverse plant-based food options for [their] residents while also safeguarding vital habitats for wildlife."

Cities are key actors in addressing food system impacts and the appropriate policy responses. Change often begins at the city level before percolating to the global level because councillors are apt to demonstrate climate leadership, act within the scope of their jurisdiction and collaborate with sister cities. They experience first-hand the severe impacts of the climate and planetary crises and tend to be more responsive to citizen pressure.

3.2 Designing sustainable food systems through a Plant Based Treaty

Cityscapes and sustainability through a plant-based transition

According to the United Nations, 55 per cent of the global population currently lives in urban areas and this is expected to rise to 68 per cent by 2050 (UN DESA, 2018). Urbanisation differs worldwide; for example, across the Americas, over 80 per cent of the population live in urban areas compared to inhabitants of African cities, which comprise just over 40 per cent of the population (Chatham House, 2022). As urbanisation and population growth simultaneously advance, 2.5 billion individuals could be added to urban environments by 2050 (UN DESA, 2018). Therefore, a shift towards healthy plant-based diets in urban environments offers potential within the global food system to pivot consumer demand and reduce environmental impacts.

To accommodate future populations, major cities will continue to expand, and small and medium-sized cities will also experience rapid growth (Chatham House, 2022). Cities will grapple with climate adaptation manifested in challenges like extreme weather events, flooding and heat waves, and issues related to poor air quality and water shortages. To accommodate more people, cities must find ways to reduce their land-use, water, and greenhouse gas emissions – cities already consume around 70 per cent of global emissions (IPCC, 2022). Addressing dietary shifts in cities becomes key, providing a lever to mitigate environmental impacts and bolster sustainability within our global food system so that we can live within our planetary boundaries.

Anticipating future patterns in global diets

The trajectory of global animal product consumption sheds light on an alarming paradox: despite a notable uptake in plant-based diets in some regions, aggregate global consumption of animal-derived products is predicted to surge significantly by 2050. The projected rise in the consumption of chickens and other birds is 66 per cent, eggs, 58.6 per cent, and cow and buffalo products, 58.9

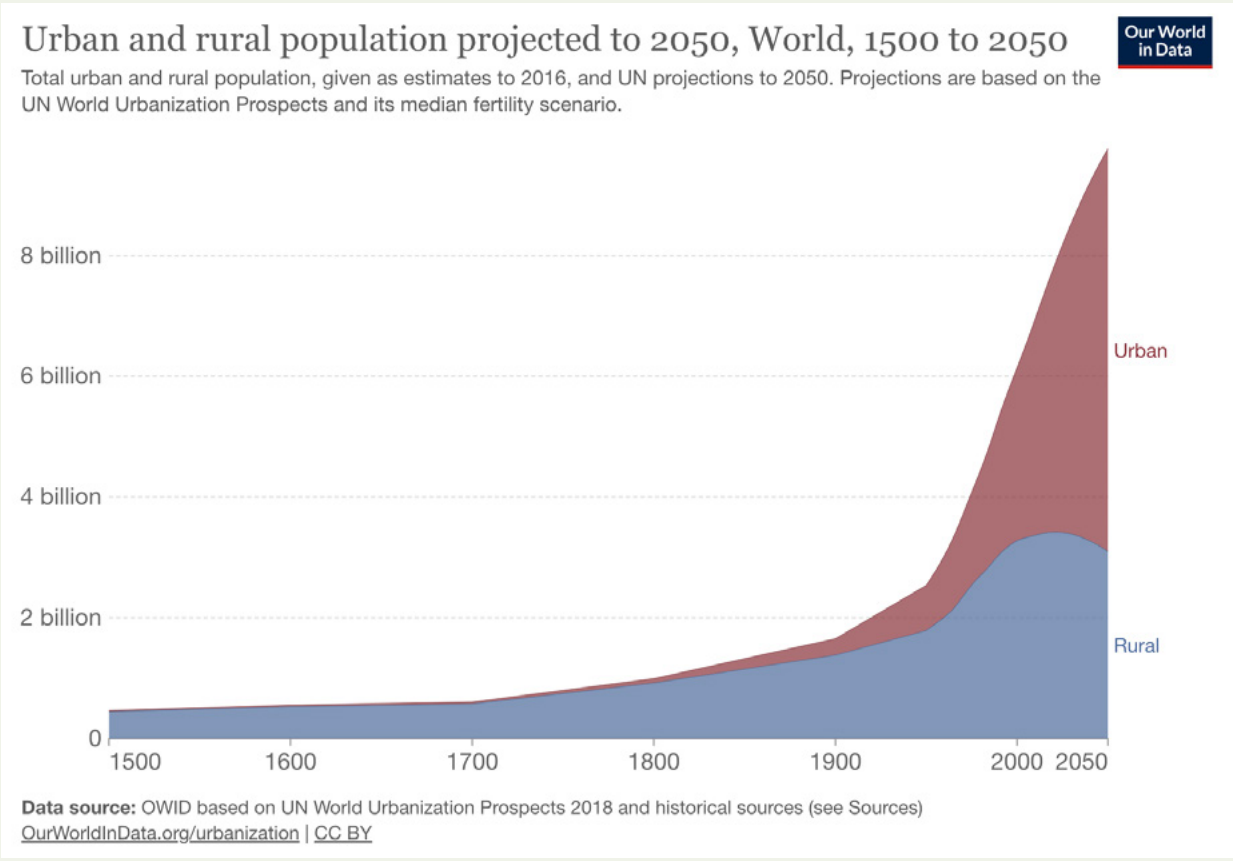


Figure 1: World population in urban and rural communities since 1500 and projected growth by 2050

per cent. As it stands, agriculture occupies 50 per cent of Earth's habitable terrain, with a staggering 83 per cent dedicated to animal production - a sector which contributes a mere 18 per cent towards global calorie supply (Poore and Nemecek, 2018). The projected expansion of animal agriculture demands dire environmental consequences, such as radical land-use change, exacerbated greenhouse gas emissions at odds with the Paris Agreement, increased water and air pollution, and intensified strain on finite freshwater resources.

In contrast, if the world were to embrace plant-based diets now, we could restore and rewild 75 per cent of global farmland and still feed a growing population (Poore and Nemecek, 2018). A 2023 detailed analysis of 55,000 UK diets found that plant-based diets resulted in 75 per cent less climate-heating emissions and water pollution than diets containing more than 100g of meat per day. Plant-based diets also cut the destruction of wildlife by 66 per cent and water use by 54 per cent (Scarborough, Clark, and Cobiac, et al., 2023).

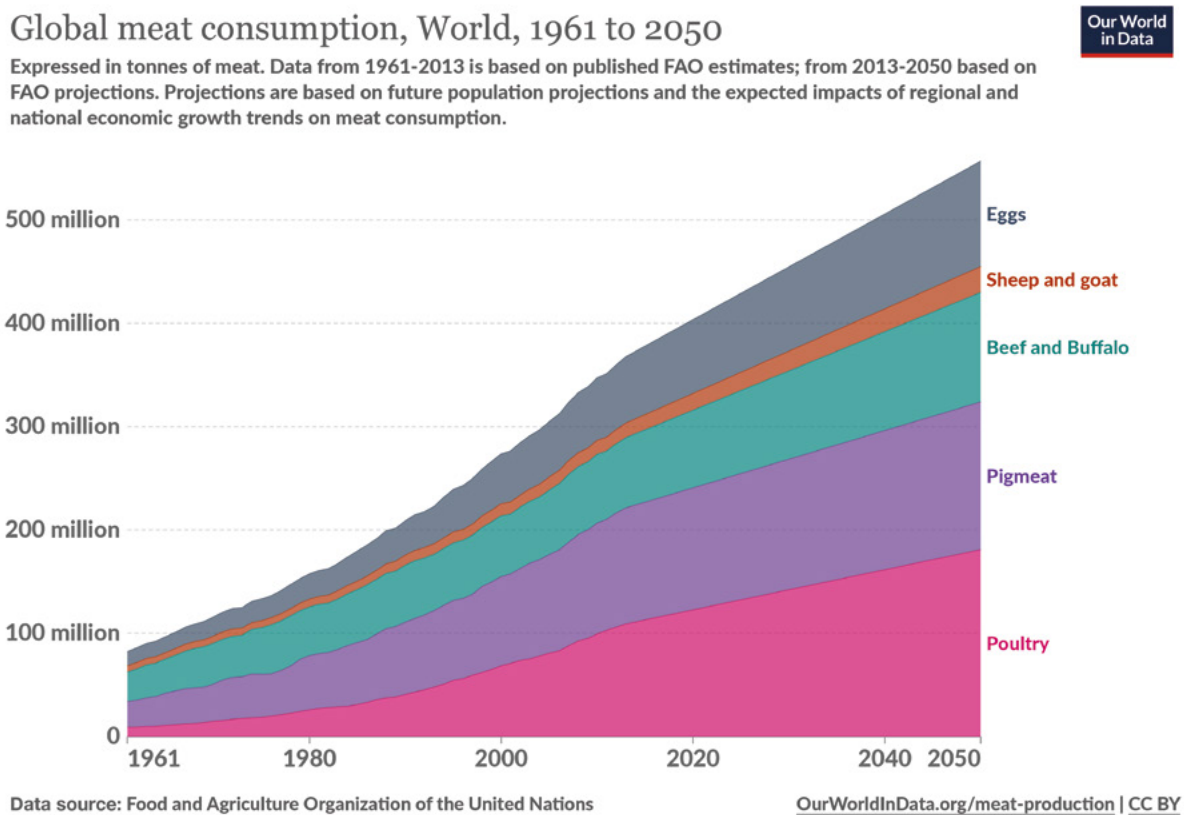


Figure 2: Global meat consumption since 1961 and projected consumption by 2050. Data extending from 1961-2013 is based on the UN Food and Agriculture (FAO) Statistics database: http://www.fao.org/faostat/en/

PLANT-BASED DIETS RESULT IN

75%
LESS CLIMATE HEATING EMISSIONS

75%
LESS WATER POLLUTION

AND CUT WILDLIFE DESTRUCTION BY
54%

3.3 Cities call for a Plant Based Treaty

"Any council that has declared a climate emergency must be matching this with action and endorsing the Plant Based Treaty is key when emissions linked to food outweigh those from many other sectors."
- Councillor Alex Catt, Norwich City Council

The current unsustainable food system, paired with alarming consumption trends, urgently beckons a collective, global response. From Edinburgh in Scotland, Amsterdam in the Netherlands and Didim in Turkey to Los Angeles in the United States, a consortium of 26 cities has notably called for the negotiation of a global Plant Based Treaty as a companion to the Paris Agreement. Towns and cities endorsing the Plant Based Treaty and other initiatives, such as the C40 Good Food Declaration, are implementing strategic food policies to expand the accessibility and consumption of plant-based foods.

"We are aware of the seriousness of the climate crisis and we believe that the Plant Based Treaty campaign will make a positive contribution towards solutions to this crisis."
- Mayor Ahmet Deniz Atabay, Didim, Turkey

The power of cities

While the municipal powers vary from city to city and country to country, many have decision-making authority over land-use, urban planning and food procurement. It is not unusual for the biggest food purchasers in a city to be the municipal government, who may be responsible for food purchasing within institutions such as schools, hospitals, care facilities, prisons, and for public events.

Even where cities don't have direct control over food procurement, they can still influence, persuade, educate, and collaborate with key institutions. They can also partner and engage with Business Improvement Districts, business leaders and civil society to encourage a shift to sustainable plant-based food policies.

Change often starts at the city level as the leaders are more responsive to public pressure and can act faster than those at a national level. Networks of cities working together nationally and internationally can influence national governments and drive change at the global level. Research shows that networks of cities are replacing nation-states as the main drivers of climate policy (Sánchez et al., 2020 and Surowiec et al., 2021).

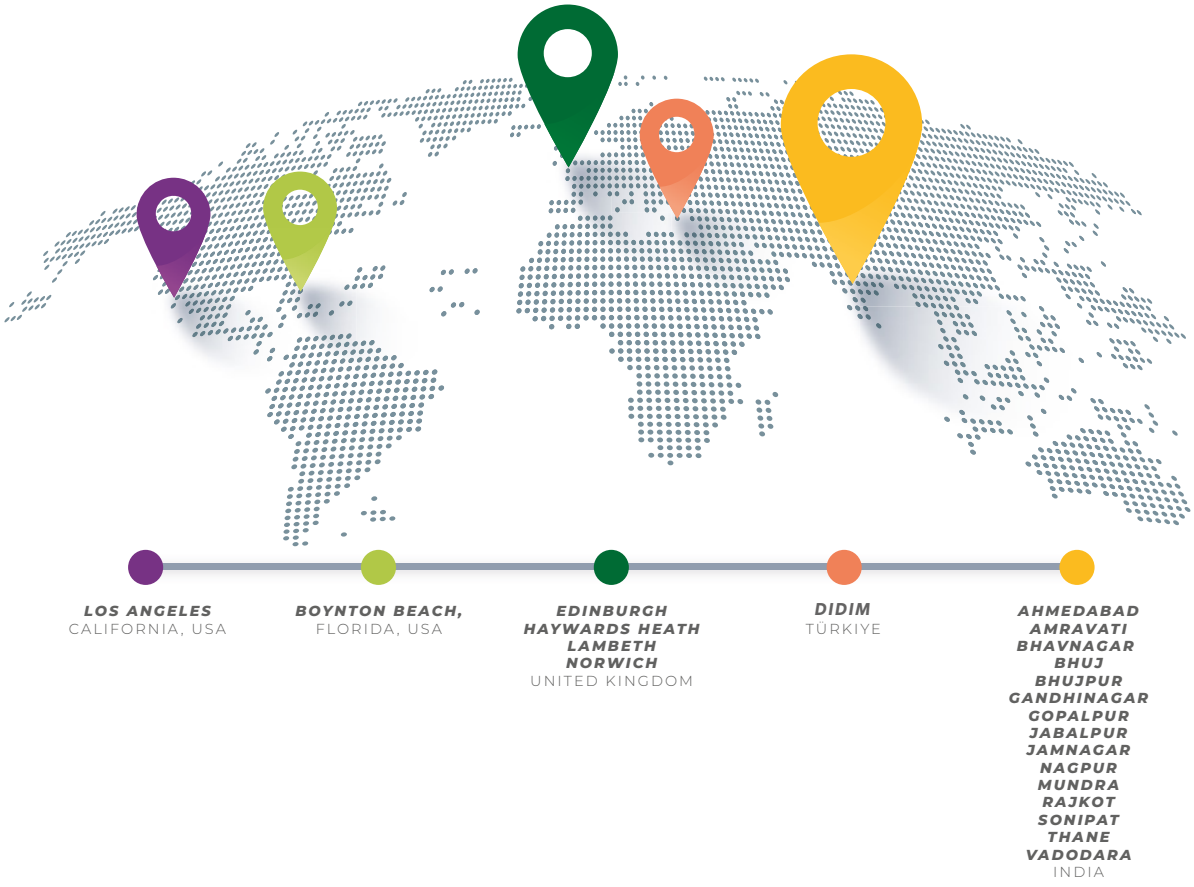


Figure 3: Plant Based Treaty city endorsements

3.4 Cities taking leadership

Amsterdam, Netherlands

In April 2020, during the first wave of COVID-19, the city government of Amsterdam announced it would recover from the pandemic and avoid future ones by adopting doughnut economics. Amsterdam aims to bring its 872,000 residents inside the doughnut to ensure everyone has access to a good quality of life, safely within our planetary boundaries. The city has introduced huge infrastructure projects, employment schemes and policies, and 400 residents and organisations have set up a network called the Amsterdam Doughnut Coalition to run their programs at a grassroots level.

Amsterdam city council has also committed to increasing access to healthier, more sustainable food by serving vegetarian food by default at all its events and has set a target for its residents to be 50 per cent plant-based by 2030, rising to 60 per cent by 2040 (Baker, 2021). This will involve making plant-based foods more available in grocery stores, restricting permits for fast-food restaurants and community education to promote plant-based food. A report by the Good Food Institute (GFI) and NielsenIQ found that the Dutch have the highest consumption of plant-based foods per capita in Europe (GFI, Europe).

In 2024, Amsterdam endorsed the Plant Based Treaty, calling for a global treaty and to send a strong signal about plant-based action at the city level, adhering to their principles for a climate-neutral and circular food system in line with the Paris Agreement.

Through their new and innovative protein strategy, Amsterdam aims to revolutionise the city's food system by establishing alternative pathways for food production, waste management, processing, and consumption. This initiative challenges traditional market supply models, focusing on sustainable and efficient methods to meet the city's nutritional needs. In concrete terms, they are forming at least six area-oriented food hubs in which food production and consumption, processing, distribution, logistics, culinary encounter, and gathering are combined.

Currently, only 15 per cent of adults in Amsterdam consume the recommended daily amount of fruit and vegetables. The city council plans to accelerate a plant-based food and beverage transition within the municipality by supporting public organisations with guidance regarding tenders, subsidies and contracting in their purchasing policies.

The city has committed to utilising green space and urban agricultural areas for edible greenery and local food production, highlighting the clear link between food hubs and the need for healthy soils as a precondition. Currently, 10 per cent of Amsterdam residents are involved in urban agriculture either as a visitor, volunteer, initiator or consumer. The ambition is to double this to 20 per cent by 2026 by increasing the impact of existing initiatives in the area.

Amsterdam has acknowledged that meat, dairy, and fish consumption have many environmentally harmful factors, and the switch to plant proteins reduces the environmental burden of food production, including water needed, greenhouse gas emissions, land-use and ocean depletion. The plan acknowledges the benefits of consuming plant-based proteins and their positive influence on health, such as a lower risk of cardiovascular disease, colon cancer, and the burden of chronic conditions.

Edinburgh, Scotland

"To sign the treaty is to show that we take our climate commitments seriously, and recognise the science behind the climate emergency – that is, to know that food systems are key drivers of emissions, and that plant-based foods must figure as part of the solution to tackling climate change."

- Ben Parker, Co-Convenor of the Green group of Councillors in the City of Edinburgh Council

Following emails from residents in Edinburgh asking their councillors to support the Plant Based Treaty initiative, in March 2022, the unitary authority unanimously voted to conduct an impact assessment of the council endorsing the Plant Based Treaty. The impact assessment explored the Plant Based Treaty's detailed demands and identified areas where the council had jurisdiction to act and where they could influence, such as school meals, public events, and council buildings. It also estimated city-wide consumption-based greenhouse gas emissions and found food and diet accounted for 23 per cent of Edinburgh's consumption-based footprint, with around half of these emissions coming from meat consumption. Following the presentation of the impact assessment to the Policy and Sustainability Committee in January 2023, the city council voted to endorse the Plant Based Treaty and committed to a food sustainability strategy in line with the Plant Based Treaty, which is due for publication in January 2024.

Prior to launching the food sustainability strategy, Edinburgh has continued to work with the Plant Based Treaty to launch initiatives in the city. In the summer of 2023, members of the Plant Based Treaty team joined the council at a community outreach event in underprivileged areas of the city aimed at educating the public on measures to increase their wellness. At the event, Plant Based Treaty handed out free fruit and smoothie samples, had an outreach table, and had numerous positive conversations with community residents about the health and climate benefits of plant-based diets.

The Plant Based Treaty was also invited to give a presentation at the central library in the city, where the implementation of the treaty was discussed, and feedback and questions from residents were debated in a positive and educational way.

Figure 4: Slide from Dr Joseph Poore's 2023 webinar, Reducing the Environmental Impact from Food, illustrating a 1.7 million tonnes of CO_2eq saving, equal to removing 532,000 cars from the road if residents in Edinburgh became vegan.

Figure 5: Slide from Dr Joseph Poore's 2023 webinar, Reducing the Environmental Impact from Food, identifying 232,000 hectares of land that could be rewilded if residents in Edinburgh became vegan.

Figure 6: Edinburgh's council leader Cammy Day participated in the 2023 Eurocities Food Cities campaign and encouraged all European cities to follow Edinburgh's lead and sign the Plant Based Treaty.

New York City, USA

"Plant Based Treaty encourages individuals, businesses, and organisations to adopt veganism or plant-based philosophies to actualise a brighter future, in conjunction with other demands, such as ending subsidies for the meat and dairy industries... It is movements such as this that have the potential to alter our food system, and in the process, transform our communal mindset."

- NYC Mayor Eric Adams, New York City

Since taking office in January 2022, Mayor Eric Adams has reshaped New York City, establishing it as a trailblazer in plant-based food strategy to address the climate crisis and enhance public health simultaneously (Krajnc and O'Toole, 2023). His personal journey of reversing advanced Type 2 diabetes by switching from a fast-food regimen to a whole-food, plant-based diet has been a compelling narrative, underscoring his advocacy for plant-based diets even prior to his mayoral tenure.

In April 2023, New York City committed to a 33 per cent reduction in food-based emissions by 2030 to combat climate change. The announcement came in response to the city's first integrated greenhouse gas inventory, which found food to be the third largest source of overall emissions, behind transportation and buildings. New York City has measured citywide emissions since 2005; however, this was the first time household consumption emissions were included. The inventory found that 20 per cent of New York City's greenhouse gas emissions came from household food consumption, which could be significantly reduced by eating plant-based foods (Greene).

Public education

May 2023 saw New York City's 'Eat a Whole Lot More Plants' campaign launch, educating the public through radio, outdoor billboards, and digital media. Focusing on neighbourhoods grappling with health and socio-economic inequity, the campaign has helped normalise the consumption of healthy plant-based foods and provide resources to help residents incorporate whole foods into their diets. The initiative goes a step further, encouraging residents to engage with the city for nutritional queries directly, ensuring full support with their transition towards a plant-based diet.

"WHEN WE CHANGE OUR DINNERS, WE CHANGE OUR DESTINIES, AND IN DOING SO, WE SAVE LIVES."

- NYC Mayor Eric Adams

Figure 7: May 2023 saw New York City's 'Eat a Whole Lot More Plants' campaign launch, utilising radio, outdoor billboards, and digital media.

Plant Powered Fridays

NYC's Department of Education launched Meatless Mondays across schools in 2019, and in February 2022, Mayor Eric Adams added Plant-Powered Fridays, requiring that the main entrée served in all public schools each Friday be vegan, benefiting the lives of close to one million children in the NYC public school system.

Normalising plant-based food through city events

Plant-based foods are exclusively served at NYC's cultural events hosted by the Mayor's Office, including heritage events such as LGBTQ Pride, Juneteenth Celebration, Greek Heritage, Puerto Rican Heritage, Jewish Heritage, and Asian-Pacific American Heritage. This not only helps reduce the city's consumption-based greenhouse gas emissions but also helps normalise plant-based eating and reinforces healthy habits.

Default plant-based in hospitals, 60 per cent stick with the plant-based option

New York City Health and Hospitals has partnered with The Better Food Foundation and Greener by Default to make plant-based meals the default option for all inpatients in their network of 11 public hospitals. Greener by Default provides behavioural strategies to "nudge" patients towards making sustainable, healthy food choices without restricting their choices. All eligible patients are now offered two vegan Chef's Special meals by default and can opt out of both if they prefer a non-vegan entrée. The hospitals report that 60 per cent of eligible patients are sticking with the plant-based option, which is delivering significant greenhouse gas emissions savings, as well as ensuring patients are eating healthier food. The city expects to serve 850,000 plant-based meals to hospital patients in 2023.

Lifestyle medicine expansion to six of NYC's public hospitals

In February 2022, the lifestyle medicine program at hospitals was extended from one hospital to six public health care sites across New York City — the most comprehensive expansion of lifestyle medicine programming in the U.S, in an effort to make New Yorkers healthier.

200,000 of the city's doctors, nurses, and dietitians are now eligible for the world's largest lifestyle medicine training program, which uses evidence-based, therapeutic lifestyle interventions. The preventative medical training applies the six pillars of lifestyle medicine: a healthy plant-based diet, physical activity, stress reduction, sleep health, avoidance of risky substances, and positive social connections.

"I am pleased to commend the Plant Based Treaty for its efforts to forge a healthful, equitable and sustainable New York City."

– NYC Mayor Eric Adams

Figure 8: In September 2022, La Vie became the first plant-based meat brand to advertise in Haarlem.

Haarlem, Netherlands

In 2024, Haarlem, which is about 10 miles from Amsterdam, will enact a ban on meat adverts in public spaces after meat was added to a list of products that contribute to the climate crisis. The ban also includes holiday flights, fossil fuels, and cars that run on fossil fuels, and will apply to buses, shelters and screens in public spaces. This led to two additional municipalities, Bloemendaal and Utrecht, to follow suit. North Holland was also the first province to vote for an advertising ban on meat, fish, and fossil products (Vegconomist, 2023).

Didim, Turkey

Didim made history by becoming the first municipality in the MENA region to support the Plant Based Treaty in 2022. The council is dedicated to transforming Didim into a vegan-friendly city. Following the endorsement, businesses have been encouraged to endorse the Plant Based Treaty and introduce plant-based options in cafes and restaurants, and use cruelty-free cleaning products.

Plant Based Treaty ran a series of training workshops at seven cafes and two hotels in Didim, helping them introduce vegan dishes on their menus. Furthermore, Didim council opened Vegan Buffet, a 100 per cent plant-based kiosk on one of the town's busiest streets, on the beachfront promenade. They hired a skilled vegan chef to prepare meals, and the product selection was curated with input from the Plant Based Treaty team. The Vegan Buffet has experienced remarkable success, drawing significant attention to the benefits of plant-based foods and expanding accessibility to them. The Mayor personally participated in a free plant-based food giveaway event at the kiosk to raise awareness about the importance of shifting towards plant-based diets. Additional business workshops within the town are scheduled under the guidance of a vegan chef.

Didim dedicated open lands to cultivate plants and fulfil the community's needs. Additionally, they prioritised veganic farming in their town plans. Land has been allocated to cultivate peppers, eggplants, tomatoes, and herbs. The Plant Based Treaty is working with the municipal staff to encourage veganic growing. The town is composting kitchen waste to reduce methane emissions and reduce landfill waste.

Salford, Greater Manchester, UK

In the summer of 2022, the Plant Based Treaty communications team met with the principal climate change officer of Salford City Council. This led to a series of meetings with various representatives from the council, including a presentation to the full climate action board. While the city has not yet endorsed the Treaty, in the meantime, plant-based champions within the city have introduced various plant-based initiatives. In late 2022, the city agreed to distribute Plant Based Treaty vegan starter kits at community hubs throughout the city. This includes community centres, libraries, and doctors' surgeries.

The city has also worked with ProVeg International with regard to school menus. In April 2023, they introduced one meat-free day every three weeks, In November, this increased to fortnightly and will increase to weekly from April 2024. A meat-free hot meal option is also available every day on all menus and available to all children.

Figure 9: The official Salford City Council X (Twitter account), actively promotes plant-based diets for both health benefits and climate action.

C40 Cities

Cities are joining forces to respond to the climate emergency. 16 cities have signed the C40 Good Food Declaration committing to achieve a 'Planetary Health Diet' for all by 2030, with nutritious, sustainable food that reflects the culture, geography, and demography of residents' (C40 Cities).

For C40 cities to reach their target, such as lowering per capita meat consumption from 58kg to 16kg by 2030 (C40 Report, 2019), **they must develop, adopt and diffuse best practices to increase plant-based food consumption throughout cities.**

C40 CITIES
CLIMATE LEADERSHIP GROUP

Cities signing the declaration have agreed to the following measures by 2030:

- Aligning food procurement to the Planetary Health Diet, ideally organically sourced
- Supporting an overall increase of healthy plant-based food consumption by shifting away from unsustainable, unhealthy diets.
- Reducing food loss and waste by 50 per cent from a 2015 baseline.
- Within two years of endorsing this accelerator, working with residents, businesses, public institutions and other organisations to develop a joint strategy for implementing these measures and achieving these goals inclusively and equitably, and incorporating this strategy into Climate Action Plans.
- Developing and sharing an action plan, including baseline figures, and environmental, health, social, and economic co-benefits where available, which they will regularly report.

Figure 10: C40 good food cities: Barcelona, Copenhagen, Guadalajara, Lima, London, Los Angeles, Milan, Montréal, New York City, Oslo, Paris, Quezon City, Seoul, Stockholm, Tokyo, Toronto

3.5 Country plans

In October 2023, Denmark became the first country to publish a national action plan for plant-based foods to outline how the country can shift towards plant-based diets. The action plan was released by the Ministry of Food, Agriculture and Fisheries of Denmark, and details how the government wants to strengthen and promote the Danish plant-based sector and to inspire the rest of the world (GFI Europe, 2023). It will also support and enable more action at the city level.

Actions in the plan include training chefs in public and private kitchens on how to prepare plant-based meals, as well as a greater focus on plant-based dishes in schools and strengthening plant-based skills throughout the education system. The plan also includes initiatives to increase exports of Danish-made plant-based foods through embassies and increase research and development funding.

Also in October 2023, South Korea's Ministry of Agriculture, Food and Rural Affairs unveiled its own plant-based action plan to further develop the country's plant-based industry. The plan includes setting up a dedicated research centre for alternative proteins and laying out steps to use more locally produced ingredients in the production of plant-based alternatives to meat and dairy.

Elsewhere, Taiwan's 2023 Climate Bill includes the promotion of plant-based diets at all levels of government and requires the government to support civil society events promoting low-carbon diets (Ettinger, 2023). The Swiss government's 2023 Climate Strategy for Agriculture and Food also acknowledges the impact of animal farming and outlines the benefits of eating more plant-based food due to the benefits for health and the environment (Hamlett, 2023).

In November 2023, Plant Based Treaty endorser, Dr. Zoe Mayer, Member of the German Bundestag and Green member of the Committee on Food and Agriculture, announced a groundbreaking €38 million in Germany's 2024 budget to promote plant-based proteins and the plant-based transformation of agriculture. The protein crop strategy will promote proteins primarily for human nutrition rather than animal feed. A competence centre, 'Proteins of the Future', will be created along with a transition support program to help farmers exit from animal agriculture and switch to plant-based production.

3.6 Next steps

You can make a change, whether you're an advocate, city Mayor, school, business, organisation, or international negotiator. Please find below a list of resources and actions you can take now to bring the Plant Based Treaty and vegan donut economics to your community and the negotiating table.

"The way that we produce food in the world is the single largest reason that we have transgressed planetary boundaries. It is the single largest threat to the stability of the planet and our life support systems, from freshwater, pollinators, and soil health, to rainfall generation, and quality of air and water. Food production is putting our future at risk." (Rockström and Gaffney, 2021, 130).

Food policy is around 30 years behind energy, and with so little time remaining we need a paradigm shift and action plans at all levels: individual, institutional, business, city, country, and global. This report makes the case for both individual diet change and policy and system change.

Vegan donut economics - a donut that's actually good for you!

The *Safe and Just* report shines a light on the urgency of addressing the transgression of planetary boundaries beyond the critical climate crisis, and raising the alarm bell on interrelated tipping points. We are on track for a breakdown of Earth's systems and societies unless bold action is taken on food systems. The devastating and even apocalyptic impact of animal agriculture on Earth's planetary boundaries, from land-use changes, ocean dead zones, incessant heat waves and melting ice caps, to scorching forest fires, requires comprehensive solutions for shifting to plant-based diets, addressing food justice, and rewilding the Earth. By embracing the vegan donut economics framework, we utilise an ethical, scientific and socio-economic systems approach to connect the scientific mandate to act with the Plant Based Treaty's forward-thinking principles, policies, and detailed proposals, focusing on a just transition that includes everyone.

Please share this crucial report with your elected officials, community and environmental groups, academics, businesses, and schools. Stay tuned for a series of webinars about our Safe and Just report and how to design and implement vegan donut economics in your community and beyond.

City Action page

→ For the public: you can take action now! Go to our website city action page where you can email your councillor and ask them to endorse the Plant Based Treaty and take measures to implement menu changes and rewilding projects. Visit www.plantbasedtreaty.org/city-action

→ For Councillors and Mayors: email hello@plantbasedtreaty.org to request template motions and country climate science factsheets to help draft motions specific to your region.

→ For groups and businesses: reach out to your networks to amplify Plant Based Treaty and vegan donut

Plant Based Treaty Playbooks for best practices

Plant Based Treaty has developed a series of Playbooks for policy advocates and policymakers featuring best practices in plant-based food policy and action at the city level, including schools, universities, and senior care homes. These can be found by visiting www.plantbasedtreaty.org/playbooks

Welcoming Calls

We hold Plant Based Treaty welcoming calls every Friday at 10 am EST and 2 pm EST where you can meet the team and find out how to take action where you live. Register on our website: www.plantbasedtreaty.org/start

Plant Based Treaty Webinars

Visit our YouTube Channel for all the latest webinars and trainings, including:

- Reducing the Environmental Impact from Food: A Webinar with Joseph Poore
- Tips for individuals, groups and business endorsements
- How to deliver a Plant Based Treaty public statement at your Council meeting webinar
- Try Veganuary University Pledge Campaign: A Webinar by Plant Based Treaty
- How to develop a community garden

Resources

Check out the Plant Based Treaty vegan starter kits which you can distribute at events and through community hubs like libraries and community centres. You can ask your local city council to help distribute them in the community!

The website's Reading Hub contains position papers, key reports and recommended books.

Check out Plant Based Treaty's Campaign Hub for downloadable posters, stickers, and banners, as well as campaign toolkits for individuals, groups, businesses, and cities. We have helpful tips like "20 ways to make an impact and build momentum" and more!

References

Albert, J.S., et al. (2023). Human impacts outpace natural processes in the Amazon. *Science*, 379 (6630), 39 p.eabo5003. https://www.doi.org/10.1126/science.abo5003

Amazon Watch (2023). Taking on Cargill Alongside the Munduruku People. Available at: https://amazonwatch.org/news/2023/1017-taking-on-cargill-alongside-the-munduruku-people (Accessed Nov 2023)

Amnesty International. Indigenous People's, Available at: https://www.amnesty.org/en/what-we-do/indigenous-peoples/ (Accessed Nov 2023)

Anand, S.,S. et al. (2015). Food Consumption and its Impact on Cardiovascular Disease: Importance of Solutions Focused on the Globalized Food System. *Journal of the American College of Cardiology*, Volume 66, no 14. 1590-1614, doi: 10.1016/j.jacc.2015.07.050

Animals Australia, *"Live export ships exposed"*, Available at: https://animalsaustralia.org/take-action/campaigns-and-investigations/live-export-ships-exposed/ (Accessed Nov 2023)

Anjana, R. M., et al. (2023). Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study, DOI: https: //doi.org/10.1016/S2213-8587(23)00119-5, Volume 11, issue 7, Jul 7, The Lancet. https://www.thelancet.com/journals/landia/article/PIIS2213-8587(23)00119-5/fulltext

Arla. Good Growth (2020). Arla.com Available at: https://www.arla.com/ company/strategy/strategy-2020/for-our-farmer-owners/ (Accessed Nov 2023)

Armstrong McKay. D. I., et al. (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*. 377. https://doi.org/10.1126/science.abn7950

Aston, L. M., et al. (2012). Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: a modelling study. Volume 2, Issue 5, http://bmjopen.bmj.com/content/2/5/e001072.full.pdf+html

Aune D. (2019) Plant Foods, Antioxidant Biomarkers, and the Risk of Cardiovascular Disease, Cancer, and Mortality: A Review of the Evidence. *Adv Nutr.* 2019 Nov 1; volume 10, no 4 :S404-S421. doi: 10.1093/advances/nmz042.

Baker, E. (2021). "Amsterdam Residents Urged to go 50% Plant-Based by 2030", *Plant Based News*. Available at: https://plantbasednews.org/lifestyle/health/amsterdam-plant-based/ (Accessed Nov 2023)

Bamia, C., et al. (2007). Dietary patterns and survival of older Europeans: the EPIC Elderly Study (European Prospective Investigation into Cancer and Nutrition). *Public Health Nutr*. 2007 Jun;10(6):590-8. doi: 10.1017/S1368980007382487.

Barton, J. & Rogerson, M. (2017). The importance of greenspace for mental health. *BJPsych International*. 14(4), 79-81. https://www.doi.org/10.1192/S2056474000002051

Bauer, S.E., et al. (2016). Significant atmospheric aerosol pollution caused by world food cultivation. *Geophysical Research Letters*. 43, no. 10, 5394-5400, https://www.doi.org/10.1002/2016GL068354

Bayulken, B., et al. (2021). How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review. *Journal of Cleaner Production*. Volume 288. https://doi.org/10.1016/j.jclepro.2020.125569

Bednaršek, N., et al. (2021). Extensive dissolution of live pteropods in the Southern Ocean. *Nature geoscience*. 5, 881-885. https://doi.org/10.1038/ngeo1635

Behavioural insights team (2023). Report: How to build a net zero society. Available at: https://www.bi.team/publications/how-to-build-a-net-zero-society/ (Accessed Nov 2023)

Benton. T., et al. (2021). Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature. Energy, Environment and Resources Programme. *Chatham House*. ISBN: 978 1 78413 433 4. Available at: https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss

Bhaskara, L. et al. (2020). The Causal Relationship between Eating Animals and Viral Epidemics. Microbial Physiology, 30 (1-6): 2–8. https://doi.org/10.1159/000511192

Bhatt, N., et al. (2021). A Detailed Review of Transportation Stress in Livestock and its Management Techniques. *International Journal of Livestock Research*, 11(1), 30-41.

Bierbaum, R., et al. (2020). Novel entities and technologies: Environmental benefits and risks. *Environmental science & policy*. 105, 134-143. https://doi.org/10.1016/j.envsci.2019.11.002

Borlée, F. et al. (2017). Air Pollution from Livestock Farms Is Associated with Airway Obstruction in Neighboring Residents, *American Journal of respiratory and critical care medicine*, Vol 196, issue 9, //doi.org/10.1164/rccm.201701-00210C

Boulay, AM., et al. (2018). The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining. *The International Journal of Life Cycle Assessment*. 23, 368–378. https://doi.org/10.1007/s11367-017-1333-8

Bryony A., et al. (2013). Zoonosis emergence linked to agricultural intensification and environmental change, *Proc Natl Acad Sci USA*, May 21, Vol 110 (21), doi: 10.1073/pnas.1208059110,110(21): 8399–8404.

C40 Cities, Achieving a planetary health diet for all. Available at: https://www.c40.org/accelerators/good-food-cities/ (Accessed Nov 2023)

C40 Cities Climate Leadership Group (2019), Nordic Sustainability, 2019, "Cities100: Medellín's interconnected green corridors", Case study and Best Practice Example, Oct 2019. Available at: https://www.c40knowledgehub.org/s/article/Cities100-Medellin-s-interconnected-green-corridors?language=en_US#:~:text=The%20Green%20Corridors%20project%20demonstrates,'%20lives%20and%20well%2Dbeing (Accessed in Nov 2023)

C40 Report (2019) In Focus: Addressing food-related consumption-based emissions in C40 cities, Available at: https://www.c40knowledgehub.org/s/article/In-Focus-Addressing-food-related-consumption-based-emissions-in-C40-Cities?language=en_US (Accessed in Nov 2023)

Campbell, B. M., et al. (2017). Agriculture production as a major driver of the Earth system exceeding planetary boundaries. *Ecology and Society*. 22(4):8. https://doi.org/10.5751/ES-09595-220408

Cappiello, J. (2021). "The Meat Industry Hurts BIPOC Communities. Here´s How.", World Animal Protection, Nov 2, Available at: https://www.worldanimalprotection.us/blogs/meat-industry-hurts-bipoc-communities-heres-how (Accessed Nov 2023)

Carbon Pricing Food Coalition (2021). *Open letter*. Available at: https://futurefoodprice.org/ (Accessed Nov 2023)

Carbon Trust (2020). Product carbon footprint labelling: consumer research 2020.

Carrington, D. (2023). "'Gigantic' power of meat industry blocking green alternatives, study finds", The Guardian, Aug 18. Available at: https://www.theguardian.com/environment/2023/aug/18/gigantic-power-of-meat-industry-blocking-green-alternatives-study-finds (Accessed Oct 2023)

Cassidy, E.S., West P.C., Gerber J.S., Foley, J.A.. (2013). Redefining agricultural yields: From tonnes to people nourished per hectare. *Environmental Research Letters* 8.

CDC, Centers for Disease Control and Prevention (2017). Zoonotic Diseases, July 14. Available at: https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html (Accessed Nov 2023)

Ceballos. G., et al. (2017). Biological annihilation via the ongoing sixth mass extinction signalled by vertebrate population losses and declines. 114, 6089-6096. https://doi.org/10.1073/pnas.170494911

Center on the Developing Child, Harvard University (2010). *The Foundations of Lifelong Health Are Built in Early Childhood*, Available at: www.developingchild.harvard.edu (Accessed Nov 2023)

Clark, M. A., et al. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science*. 370, 705-708. https://doi.org/10.1126/science.aba7357

Climate change tracker. *Sources of Human-Induced Methane Emissions*. Available at: https://climatechangetracker.org/methane/breakdown-human-induced-yearly-methane-ch4-emissions#data-source (Accessed Nov 2023)

Compassion in world farming (2023). Citizens worldwide unite to stop transport cruelty, June 14. Available at: https://www.ciwf.org/news/2023/06/citizens-worldwide-unite-to-stop-transport-cruelty (Accessed Nov 2023)

Consultative Group on International Agricultural Research (CGIAR) (2022). *Info note: Livestock management ambition in the new and updated nationally determined contributions: 2020-2022*. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/115885/CCAFS%20Info%20Note%20Livestock%202021%20NDCs.pdf (Accessed Nov 2023)

Copernicus (2023a). *The warmest month in Earth's recent history*. Available at: https://climate.copernicus.eu/july-2023-warmest-month-earths-recent-history (Accessed July 2023)

Copernicus (2023b). Surface air temperature for August 2023. Available at: https://climate.copernicus.eu/surface-air-temperature-august-2023 (Accessed September 2023)

Copernicus (2023c). Surface air temperature for September 2023. Available at: https://climate.copernicus.eu/surface-air-temperature-september-2023 (Accessed October 2023)

Corfe, S. (2018). What are the barriers to eating healthy in the UK? *Social Market Foundation*. Available at: https://www.smf.co.uk/wp-content/uploads/2018/10/What-are-the-barriers-to-eating-healthy-in-the-UK.pdf (Accessed Nov 2023)

Crippa, M., et al. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*. 2, 198–209. https://doi.org/10.1038/s43016-021-00225-9

Crowther et al. (2015). Mapping tree density at a global scale. *Nature* doi:10.1038/nature14967

Daly, H. E. (2008). *Ecological economics and sustainable development*, selected Essays of Herman Daly. Edward Elgar Publishing.

Damania, R., et al. (2023). Detox Development: Repurposing Environmentally Harmful Subsidies.

Washington, DC. *World Bank.* Retrieved from: https://openknowledge.worldbank.org/server/api/core/bitstreams/61d04aca-1b95-4c06-8199-3c4a423cb7fe/content

Damien Gayle. (2023). "Waiting list for allotments in England almost doubles in 12 years". Guardian, October 22, 2023. Retrieved from: https://www.theguardian.com/environment/2023/oct/11/waiting-list-for-allotments-in-england-almost-doubles-in-12-years

Darmon, N. Drewnowski, A. (2015). Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis, *Nutrition Reviews*, Volume 73, Issue 10, Pages 643–660, https://doi.org/10.1093/nutrit/nuv027

Davis, J. N. et al. (2021). School-based gardening, cooking and nutrition intervention increased vegetable intake but did not reduce BMI: Texas sprouts - a cluster randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity*; 18 (1) 10.1186/s12966-021-01087-x

DeClerk, F. A. J. et al. (2023). A Whole Earth Approach to Nature-Positive Food: Biodiversity and Agriculture, Springer Link, *Science and Innovations for Food Systems Transformation* pp 469–496, DOI: https://doi.org/10.1007/978-3-031-15703-5_25, Retrieved from: https://link.springer.com/chapter/10.1007/978-3-031-15703-5_25

EEA European Environment Agency (2023). *Methane Emissions in the EU: the key to immediate action on climate change*. Retrieved from: https://www.eea.europa.eu/publications/methane-emissions-in-the-eu (Accessed Sept 2023)

Ellen Macarthur Foundation. *Circular economy introduction*. Retrieved from: https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview (Accessed November 2023)

Ellis, E. C., et al. (2010). Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography.* 19(5), 589-606. http://dx.doi.org/10.1111/j.1466-8238.2010.00540.x

Ettinger, J. (2023). "It's the Law: Taiwan´s New Climate Bill Mandates Government Backing of Plant-Based Diets". *Green queen*, Jan 23. Retrieved at: https://www.greenqueen.com.hk/its-the-law-taiwans-new-climate-bill-mandates-government-backing-of-plant-based-diets/ (Accessed November 2023)

European Bank for Reconstruction and Development (EBRD, 2022). Methodology to determine the Paris Agreement alignment of EBRD investments. https://www.ebrd.com/paris-agree- ment-methodology.pdf.

FAO. *Detailed Trade Metrix*, Retrieved from: https://www.fao.org/faostat/en/#data/T (Accessed Nov 2023)

FAO, IFAD, UNICEF, WFP, WHO (2023). The State of Food Security and Nutrition in the World. 316 p, ISBN: 978-92-5-137226-5, series number 2023.

Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development, the United Nations Children's Fund, the World Food Program, the World Health Organization. Retrieved from: https://www.fao.org/documents/card/en?details=cc3017en (Accessed Nov 2023)

FAO, UNDP and UNEP (2021). A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems. *In brief*. Rome. Retrieved from: https://do.org/10.4060/cb6683en (Accessed Nov 2023)

FAO. *Global Symposium on Soil Erosion*, Retrieved from: https://www.fao.org/about/meetings/soil-erosion-symposium/key-messages/en/ (Accessed Nov 2023)

Farm Animal Investment Risk and Return (FAIRR) (2022). *Nationally Determined Contributions Still Lack Ambition on Agriculture*. Retrieved from: https://www.fairr.org/article/nationally-determined-contributions-lack-ambition-on-agriculture/#:~:text=7%20G20%20countries%20updated%20their,of%20these%20updates%20mention%20livestock (Accessed Nov 2023)

Fashion Transparency Index (2023). How transparent are 250 of the world's largest fashion brands? *Fashion Revolution*, Available at: https://www.fashionrevolution.org/fashion-transparency-index-2023/ (Accessed Nov 2023)

Faunalytics and Sentient Media (2023). *Animal Agriculture In Climate Media Coverage*. https://osf.io/q4evn (Accessed Nov 2023)

Feedback Global (2020). *Butchering the planet: The big-name financiers bankrolling livestock corporations and climate change*. Retrieved from: https://feedbackglobal.org/wp-content/uploads/2020/07/FeedbackReport-ButcheringPlanet-Jul20-HighRes.pdf (Accessed Nov 2023)

Feigin, S. V. et al. (2023). Proposed solutions to anthropogenic climate change: A systematic literature review and a new way forward, *Science Direct*, Volume 9, issue 10, Heliyon, DOI: https://doi.org/10.1016/j.heliyon.2023.e20544, Retrieved from: https://www.sciencedirect.com/science/article/pii/S2405844023077526 (Accessed Nov 2023)

Feldmann. J., et al. (2015). Collapse of the West Antarcticlce Sheet after local destabilisation of the Amundsen Basin. *PNAS*. 112, 14191–14196. https://doi.org/10.1073/pnas.1512482112

Feller, M (2020). "Healthy Food Is a Right for Black People, Not a Privilege", *Healthline*, Oct 13 2020, Retrieved from: https://www.healthline.com/nutrition/what-is-food-justice (Accessed Nov 2023)

Foley, J. A., et al. (2005). Global Consequences of Land Use. *Science*. 309, 570-574. https://doi.org/10.1126/science.1111772

Folke. C., et al. (2021). Our future in the Anthropocene biosphere. *Ambio*. 50, 834-869. https://doi.org/10.1007/s13280-021-01544-8

Forest 500 (2020). Global brands ignoring deforestation caused by commodities they use. Available at: https://forest500.org/analysis/insights/global-brands-ignoring-deforestation-caused-commodities-they-use#:~:text=It%20ranks%20the%20strength%20and,in%20the%20companies%20they%20finance. (Accessed Nov 2023)

Forest & Finance. Finance's Role in Deforestation. Available at: https://forestsandfinance.org/ (Accessed Sept 2023)

Fonseca, R.P, Sanchez-Sabate, R. (2022). Consumers' Attitudes towards Animal Suffering: A Systematic Review on Awareness, Willingness and Dietary Change, 19 (23), 16372; https://doi.org/10.3390/ijerph192316372

Food and Agriculture Organisation of the United Nations (2020). FAO Remote Sensing Survey reveals. Retrieved from: https://www.fao.org/3/cb7449en/cb7449en.pdf (Accessed Nov 2023)

Forbes, (2020). *Cargill-MacMillan Family*. Available at: https://www.forbes.com/profile/cargill-macmillan-1/?sh=2069b65d23b6 (Accessed Nov 2023)

Forster, P. M., et al. (2023). Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence. *Earth System Science Data*. 15, 2295–2327. https://doi.org/10.5194/essd-15-2295-2023

FAOSTAT (Nov 2023). Emission indicators. Retrieved from: https://www.fao.org/faostat/en/#data/EM (Accessed Nov 2023)

Finance in Common (2020). *Joint Declaration of All Public Development Banks in the World*. Paris. Available at: https://financeincommon.org/sites/default/files/2020-11/FiCS%20-%20Joint%20declaration%20of%20all%20Public%20Development%20Banks.pdf (Accessed Nov 2023)

Finance in Common (2022). Public Development Banks joining forces to transform the financial system towards climate and sustainability. Available at: https://financeincommon.org/ (Accessed Nov 2023)

Fitzgerald, A. J. et al. (2009). Slaughterhouses and Increased Crime Rates, Sage Publications, Retrieved from: https://animalstudies.msu.edu/Slaughterhouses_and_Increased_Crime_Rates.pdf (Accessed Nov 2023)

Friel S., et al. (2009). Health and Climate Change 4: Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. *Lancet*, 12;374(9706): 2016-25, https://pubmed.ncbi.nlm.nih.gov/19942280/

Galoustian, G. (2021). Future Pandemic? Consider Altering Animal Agriculture Practices, Jun 2, Accessed Nov 2023, Retrieved from: https://www.fau.edu/newsdesk/articles/pandemic-animal-agriculture.php (Accessed Nov 2023)

Garnett, S. (2019). A spatial overview of the global importance of Indigenous lands for conservation, *Nature Sustainability* 1 (7) https://www.researchgate.net/publication/326424629_A_spatial_overview_of_the_global_importance_of_Indigenous_lands_for_conservation

GBD 2017 Diet Collaborators (2019). Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 11; 393(10184): 1958-1972.

Gerten, D., et al. (2020). Feeding ten billion people is possible within four terrestrial planetary boundaries. *Nature Sustainability*. 3, 200–208. https://doi.org/10.1038/s41893-019-0465-1

GFI, Europe. *Market insights on European plant-based sales 2020-2022*. Available at: https://gfieurope.org/market-insights-on-european-plant-based-sales-2020-2022/?noredirect=en_GB (Accessed Nov 2023)

GFI Europe (2023). Denmark publishes world´s first national action plan for plant-based foods. Available at: https://gfieurope.org/blog/denmark-publishes-worlds-first-national-action-plan-for-plant-based-foods (Accessed Nov 2023)

Gibbs, J., Cappuccio, FP. (2022). Plant-Based Dietary Patterns for Human and Planetary Health. *Nutrients*. 14(8):1614. https://doi.org/10.3390/nu14081614

Glasgow Leaders' Declaration on Forests and Land Use. Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20230418175226/https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/ (Accessed Nov 2023)

Gerbens-Leenes. P.W., et al. (2013). The water footprint of poultry, pork and beef: A comparative study in different countries and production systems, *Water Resources and Industry*, 1–2, 25-36, ISSN 2212-3717.

Gidden, M. J., et al. (2019). Global emissions pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century. *Geoscientific Model Development*. 12. 1443–1475. https://doi.org/10.5194/gmd-12-1443-2019

Global Witness, *Land and environmental defenders*, Available at: https://www.globalwitness.org/en/campaigns/environmental-activists/ (Accessed Nov 2023)

Global Witness (2023). *Standing Firm, The land and environmental defenders on the frontline of the climate crisis*, Available at: https://www.globalwitness.org/en/campaigns/environmental-activists/standing-firm/?gclid=CjwKCAjw15eqBhBZEiwAbDomErRjXWqZ2MmmYzZ0asilGNHJiJb0Dk8rtho48YM25FwUPEEIVK0vYhoCVwUQAvD_BwE (Accessed Nov 2023)

Global Witness (2019). *Money to Burn*, Available at: https://www.globalwitness.org/en/campaigns/forests/money-to-burn-how-iconic-banks-and-investors-fund-the-destruction-of-the-worlds-largest-rainforests/ (Accessed Nov 2023)

Government of Canada, *Science Fact Sheet, Antimicrobial resistance*, Available at: https://inspection.canada.ca/science-and-research/our-research-and-publications/science-fact-sheet-antimicrobial-resistance/eng/1509647559865/1509647560617 (Accessed Nov 2023)

Government of Odisha, *Child Labour in Odisha*, Available at: https://labdirodisha.gov.in/?q=node/58 (Accessed Nov 2023)

GPAFSN (2020). *Future Food Systems: For people, our planet, and prosperity*. Retrieved from: https://foresight.glopan.org/ (Accessed Nov 2023)

GRAIN & ITAP (2018). Emissions impossible: How big meat and dairy are heating up the planet. Available at: https://grain.org/article/entries/5976-emissions-impossible-how-big-meat-and-dairy-are-heating-up-the-planet#:~:text=New%20research%20from%20GRAIN%20and,warming%20to%201.5%20degrees%20Celsius. (Accessed Nov 2023)

Greger, M. (2007). The Long Haul: Risks Associated With Livestock Transport. Biosecurity and Bioterrorism: *Biodefense Strategy, Practice, and Science* 5(4): 301-312, https://www.wellbeingintlstudiesrepository.org/cgi/viewcontent.cgi?article=1001&context=acwp_faaf

Greene, L. (2023). *New York City commits to 33 percent Reduction in Food Based Emission by 2030 to combat Climate Change*, Foodtank, available at: https://foodtank.com/news/2023/04/new-york-city-commits-to-reduction-in-food-based-emissions-to-combat-climate-change/ (Accessed Nov 2023)

Greenpeace (2020). *False sense of security*, Available at: https://www.greenpeace.org/static/planet4-eu-unit-stateless/2020/10/85cc908b-false-sense-of-security_final_en.pdf (Accessed Nov 2023)

Greenpeace (2021). *Marketing Meat. How EU Promotional Funds Favour Meat and Dairy.* Available at: https://www.greenpeace.org/static/planet4-eu-unit-stateless/2021/04/20210408-Greenpeace-report-Marketing-Meat.pdf (Accessed Nov 2023)

Gütschow, J. et al (2021). The PRIMAP-hist national historical emissions time series (1750-2021) v2.4.2 (2.4.2). https://doi.org/10.5281/zenodo.7727475

Hamlett, C. (2023) *"Swiss Government Encourages Reduced Meat Consumption In climate Strategy"*, Plant Based News, Sep 14 https://plantbasednews.org/news/environment/swiss-government-climate-strategy-meat/

Hayek, M. N. (2022) The infectious disease trap of animal agriculture, *Science Advances*, Vol 8, Issue 44, DOI: 10.1126/sciadv.add668.

Hayek. M., et al. (2021). Underestimates of methane from intensively raised animals could undermine goals of sustainable development. *Environ. Res. Lett.* 16. https://doi.org/10.1088/1748-9326/ac02ef

Hayek, M. N., et al. (2021). The carbon opportunity cost of animal-sourced food production on land. *Nature Sustainability*. 4, 21–24. https://doi.org/10.1038/s41893-020-00603-4

Hayes, N. (2020). The Book of Trespass. Bloomsbury, 2020.

Hollis, A., et al. (2013) Preserving Antibiotics, Rationally, *N Engl J Med* 2013; 369:2474-2476, DOI: 10.1056/NEJMp1311479

Howard, P. H. (2017). Corporate Concentration in Global Meat Processing: The Role of Feed and Finance Subsidies. in *Global Meat: Social and Environmental Consequences of the Expanding Meat Industry* (eds. Winders, B. & Ransom, E.) 31–53 (MIT Press, 2017)

Hughes. T. P., et al. (2017). Coral reefs in the Anthropocene. Nature. 546, 82–90. https://doi.org/10.1038/nature22901

Hughes, J., et al. (2023) *Climate labels similar to cigarette packet warnings could cut meat consumption – new research*, Durham University, Nov 1, 2023, Available at: https://www.durham.ac.uk/research/current/thought-leadership/2023/11/climate-labels-similar-to-cigarette-packet-warnings-could-cut-meat-consumption--new-research/ (Accessed Nov 2023)

Hughes, D. (2023) *Export of livestock for slaughter or fattening to be banned under new law*, The Independent, Nov 7. (Accessed Nov 2023), https://www.independent.co.uk/climate-change/news/export-joanna-lumley-government-london-uk-government-b2443063.html

Hunter, W. (2023) "Hilton adds carbon ratings to its menus to encourage customers to choose more environmentally friendly meals", Daily Mail, UK, Oct 9, Available at: https://www.dailymail.co.uk/sciencetech/article-12609641/Hilton-adds-carbon-ratings-menus-environment.html (Accessed Nov 2023)

India Today (2023) "Over 100 million people have diabetes in India, Goa has the highest number: ICMR", Jun 9. Accessed Nov 2023, Retrieved from: https://www.indiatoday.in/health/story/over-100-million-people-have-diabetes-in-india-goa-has-the-highest-number-icmr-2390784-2023-06-09

International Land Coalition. (2020). Uneven ground: Land inequality at the heart of unequal societies. ILC, retrieved from: https://www.landcoalition.org/en/uneven-ground/report-and-papers/

ILO (1999) Press release: "Fishing among the most dangerous of all professions, says ILO" Dec 13, (Accessed Nov 2023) Retrieved from: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_071324/lang--en/index.htm

ILO, Child labour in agriculture, Available at: https://www.ilo.org/ipec/areas/Agriculture/lang--en/index.htm#:~:text=Worldwide%2060%20percent%20of%20all,labourers%20are%20unpaid%20family%20members. (Accessed Nov 2023)

ILO, Fishing and aquaculture, Available at: https://www.ilo.org/ipec/areas/Agriculture/WCMS_172419 (Accessed Nov 2023)

ILO, Livestock production, Available at: https://www.ilo.org/ipec/areas/Agriculture/WCMS_172431/lang--en/index.htm (Accessed Nov 2023)

IPBES. (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn, Germany: IPBES Secretariat. https://doi.org/10.5281/zenodo.3553579

IPCC (2019) Special Report on Climate Change and Land Use, https://www.ipcc.ch/srccl/

IPCC. (2019). Summary for Policymakers. In IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. https://doi.org/10.1017/9781009157964.001

IPCC (2022). Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

IPCC (2022). Climate Change 2022; Mitigation of Climate Change, https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Full_Report.pdf

Intergovernmental Panel on Climate Change (IPCC) (2022). Summary for Policymakers. In Climate Change and Land: IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Cambridge: Cambridge University Press. https://www.cambridge.org/core/books/climate-change-and-land/summary-for-policymakers/BACDCBE9CB0F9F0729BE006926569FDB

Joughin. B. E., et al. (2014). Marine Ice Sheet Collapses Potentially Under Way for the Thwaites Glacier Basin, West Antarctica. Science. 344, 735–738. http://dx.doi.org/10.1002/2014GL060140

Kelloway, C. & Miller, S. (2019) Food and Power: Addressing Monopolization in America's Food System.

Kemp, L. (2022). Climate Endgame: Exploring catastrophic climate change scenarios, PNAS, Vol. 119, No. 34, https://doi.org/10.1073/pnas.2108146119

Kimberly, K. (2019) *This foreign meat company got U.S. tax money. Now it wants to conquer America*. The Washington Post.

Kingsley, M. & EcoHealth Ontario (2019). Commentary Climate change, health and green space co-benefits. *Health Promotion and Chronic Disease Prevention in Canada.* 39(4): 131–135. https://www.doi.org/10.24095/hpcdp.39.4.04

Kommenda, N., et al. (2022) *Would Carbon Food Labels Change The Way You Shop*. Financial Times. https://ig.ft.com/carbon-food-labelling/

Konijnendijk, C.C. (2022). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule. *Journal of Forestry Research*, 1–10. https://doi.org/10.1007/s11676-022-01523-z

Kornhuber, K., et al. (2023). Risks of synchronized low yields are underestimated in climate and crop model projections, *Nature Communications*. 14: 3528. https://doi.org/10.1038/s41467-023-38906-7, https://www.nature.com/articles/s41467-023-38906-7,

Krajnc, A. and O'Toole, J. (2023). 8 ways NYC Mayor Eric Adams is creating a plant-based city. https://plantbasedtreaty.org/eric-adams-plant-based-city/

Kwiatkowski, L., et al. (2020). Twenty-first century ocean warming, acidification, deoxygenation, and upper-ocean nutrient and primary production decline from CMIP6 model projections. *Biogeosciences*. 17, 3439–3470 https://doi.org/10.5194/bg-17-3439-2020

Laine, J. E. et al (2021) Co-benefits from sustainable dietary shifts for population and environmental health: an assessment from a large European cohort study, Vol 5, ISSUE 11, E786-E796, Oct 21, *The Lancet*, DOI:https://doi.org/10.1016/S2542-5196(21)00250-3

Lakhani, N. (2023) "'Our world hangs by a thread': Indigenous activist asks US agri giant to stop destroying Amazon rainforest", *The Guardian*, Oct 12. Available at: https://www.theguardian.com/environment/2023/oct/12/amazon-rainforest-cargill-indigenous-activist-destruction (Accessed Nov 2023)

Lancet (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Volume 399. Issue 19325, P629-655, DOI: https//doi.org/10.1016/S0140-6736(21)02724-0 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02724-0/fulltext#seccestitle190

Larsson N., Levitt T. (2020). *'"Floating feedlots': animals spending weeks at sea on ships not fit for purpose"*, The Guardian, Jan 26. Accessed Nov 2023, Retrieved from: https://www.theguardian.com/environment/2020/jan/26/floating-feedlots-animals-spending-weeks-at-sea-on-ships-not-fit-for-purpose (Accessed Nov 2023)

Latham. J., (2021). *Chapter 5: The myth of a food crisis In Rethinking Food and Agriculture: New ways forward* (1st ed.). Elsevier.

Leenders, M., et al. (2014) Dietary patterns and survival of older Europeans: Fruit and vegetable intake and cause of specific mortality in the EPIC study 2014, *Public Health Nutr*. 10(6):590-8. doi: 10.1017/S1368980007382487.

Lenton, T.M., et al. (2023). Quantifying the human cost of global warming, *Nature Sustainability*, 6, 1237–1247. https://www.nature.com/articles/s41893-023-01132-6

Levitt, T. (2015) *"Three food companies with a climate footprint bigger than the Netherlands"*, The Guardian, Dec 7, Retrieved from: https://www.theguardian.com/sustainable-business/2015/dec/07/food-climate-footprint-cargill-tyson-yara-netherlands (Accessed Nov 2023)

Lewis, J. (2019). *This IS a crisis*, Soil Association, Feb 13. Accessed Nov 2023, Retrieved from: https://www.soilassociation.org/blogs/2019/february/13/soil-degradation-mass-insect-decline-and-ultra-processed-food/ (Accessed Nov 2023)

Linder, T. (2019). Making the case for edible microorganisms as an integral part of a more sustainable and resilient food production system.

Feed security. 11, 265-278. https://doi.org/10.1007/s12571-019-00912-3
Living Planet Index (2023), Forest Specialists Index. Accessed 22/11/23. Available at: https://livingplanetindex.org/fsi

Lundqvist, J., de Fraiture, C. Molden, D., (2008) *Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain*. SIWI Policy Brief. http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf (Accessed Nov 2023)

Lungman, T., et al. (2023). Cooling cities through urban green infrastructure: a health impact assessment of European cities. *The lancet*. 401, 577-589. https://doi.org/10.1016/S0140-6736(22)02585-5

Macintyre, H. L., et al, (2016) Mortality and emergency hospitalizations associated with atmospheric particulate matter episodes across the UK in spring 2014, *Environment International*, Volume 97, Pages 108-116.

Marfrig (2020). Marfrig reports record-high results for 4Q19. (2020).

Martin, M.J., et al. (2015) Antibiotics Overuse in Animal Agriculture: A Call to Action for Health Care Providers, American Journal of Public Health. 105(12): 2409-10. https://ajph.aphapublications.org/doi/full/10.2105/AJPH.2015.302870

Matassa, S., et al. (2016). Microbial protein: future sustainable food supply route with low environmental footprint. *Microbial Biotechnology*. 9(5), 568–575. https://doi.org/10.1111/1751-7915.12369

McBride, C. (2021) *"Should we be paying farmers to go away?"* Briefings for Britain, May 23, Available at: https://www.briefingsforbritain.co.uk/should-we-be-paying-farmers-to-go-away/ (Accessed Nov 2023)

Mercy for Animals Report (2022) Public Health Impacts of Animal Agriculture, Accessed Nov 2023, Retrieved from: https://file-cdn.mercyforanimals.org/mercy4animals.wpengine.com/sites/450/2022/04/Public-Health-Report.pdf

Michaelson, R., van der Zee, B. (2020). "How the Middle East's water shortage drives demand for live animal imports", The Guardian, January 23. Retrieved from: https://www.theguardian.com/environment/2020/jan/23/how-the-middle-easts-water-shortage-drives-demand-for-live-animal-imports

Mighty Earth (2019) Cargill: The Worst Company in the World. Available at: https://stories.mightyearth.org/cargill-worst-company-in-the-world/ (Accessed Nov 2023)

Mighty Earth Report (2022), Carrefour's Smokescreen. Available at: https://www.mightyearth.org/wp-content/uploads/202210_Meat_Carrefour_Report_EN.pdf (Accessed Nov 2023)

Mighty Earth Report (2023) Cargill Still The Worst Company in the World, Available at: https://www.mightyearth.org/wp-content/uploads/Cargill_report_final_12SEPT.pdf (Accessed Nov 2023)

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. Retrieved from: https://wedocs.unep.org/handle/20.500.11822/8701 (Accessed Nov 2023)

Monbiot, G. (2022). *Regenesis: Feeding the World without Devouring the Planet*, Great Britain, Allan Lane

Madre Brava. (2023). Media Analysis of industrial meat and climate change. Retrieved from: https://madrebrava.org/media/pages/insight/people-don-t-see-industrial-meat-as-a-key-cause-of-global-warming-poll/e502b3de61-1678981785/meat-and-climate-media-coverage-analysis_madre-brava_16-march.pdf (Accessed Nov 2023)

Mazdiyasmi, O., et al. (2017) Increasing probability of mortality during Indian heat waves, *Science Advances*.
Vol 3, Issue 6, DOI: 10.1126/sciadv.170006

Mekonnen.M.M, Hoekstra. A.Y (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, 15, 401-415. https://doi.org/10.1007/s10021-011-9517-8

Mintel (2020) "Plant-power: UK sales of meat-free foods shoots up 40% between 2014-19, Jan 17". Retrieved from: https://www.mintel.com/press-centre/food-and-drink/plant-based-push-uk-sales-of-meat-free-foods-shoot-up-40-between-2014-19 (Accessed Nov 2023)

Morse, S.S., et al. (2012) Prediction and prevention of the next pandemic zoonosis. Lancet. 2012; 380 (9857):1956-1965. https://doi.org/10.1016/S0140-6736(12)61684-5

Munang, R., et al. (2013). The role of ecosystem services in climate change adaptation and disaster risk reduction. *Current Opinion in Environmental Sustainability*. 5(1), 47-52. http://doi.org/10.1016/j.cosust.2013.02.002

Myers, N. *4.3 Perverse Subsidies*, Available at: https://www.cbd.int/financial/fiscalenviron/g-subsidyperverse-iucn.pdf (Accessed Nov 2023)

Nakicenovic, N., et al. (2016). *Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet*. IIASA Working Paper. http://pure.iiasa.ac.at/14003/

Narayan, E. (2023) How climate change will affect your pet – and how to help them cope, UNDRR, Prevention Web, Aug 6. Retrieved from: https://www.preventionweb.net/news/how-climate-change-will-affect-your-pet-and-how-help-them-cope (Accessed Nov 2023)

National Library of Medicine (2009) The Public Health Effects of Food Deserts - NCBI Bookshelf, 2009. Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK208018/ (Accessed Nov 2023)

Nellemann, C., et al. (2009) The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. *United Nations Environment Programme*, GRID-Arendal

Neslen, A. (2023) *"EU ban on deforestation-linked goods sets benchmark, say US lawmakers"*, Jan 5,
The Guardian. Retrieved from: https://www.theguardian.com/environment/2023/jan/05/eu-ban-on-deforestation-linked-goods-sets-benchmark-say-us-lawmakers (Accessed Nov 2023)

Niranjan. A. Era of global boiling has arrived. The Guardian. Retrieved from: https://www.theguardian.com/science/2023/jul/27/scientists-july-world-hottest-month-record-climate-temperatures (Accessed Nov 2023)

Nussbaum, M. C. (2000). *Women and human development: The capabilities approach* (Vol. 3). Cambridge university press. Retrieved from: http://www.cambridge.org/9780521660860

Oatly UK, *Response: CMA consultation on misleading green claims response from Oatly UK*, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1131444/Oatly_UK_response.pdf (Accessed Nov 2023)

Oliver, T. H., et al. (2015). Biodiversity and resilience of ecosystem functions. Trends in ecology & evolution. 30(11), 673-684. https://doi.org/10.1016/j.tree.2015.08.009

Olsson, L., Barbosa, H. et al. (2019) IPCC, Chapter 4: Land Degradation, Retrieved from: https://www.ipcc.ch/site/assets/uploads/2019/08/2e.-Chapter-4_FINAL.pdf (Accessed Nov 2023)

Ortiz-Bobea, A., et al. (2021). Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change*, Apr 01, 11: 306–312. https://www.nature.com/articles/s41558-021-01000-1, https://doi.org/10.1038/s41558-021-01000-1

Osborne H., van der Zee B. (2020). *"Live export: animals at risk in giant global industry,"* The Guardian, Jan 20. Retrieved from: https://www.theguardian.com/environment/2020/jan/20/live-export-animals-at-risk-as-giant-global-industry-goes-unchecked (Accessed Nov 2023)

Osman. M.B., et al. (2021). Globally resolved surface temperatures since the Last Glacial Maximum. *Nature*. 599, 239–244. https://doi.org/10.1038/s41586-021-03984-4

Ostrom, E. (2008). Tragedy of the commons. *The new Palgrave dictionary of economics.* 2.1-4. http://dx.doi.org/10.1057/978-1-349-95121-5_2047-1

O'Toole, J. (2022). IMF recommends animal agriculture methane tax https://plantbasedtreaty.org/imf-recommends-methane-tax-on-animal-agriculture/ (Accessed Nov 2023)

Our World in Data (2021) *Diabetes prevalence*, Available at: https://ourworldindata.org/grapher/diabetes-prevalence (Accessed Nov 2023)

Our World in Data (2019) *Death rate from cardiovascular disease*, 1990 to 2019, Available at: https://ourworldindata.org/grapher/cardiovascular-disease-death-rates?tab=char (Accessed Nov 2023)

Oxford University (2013) *"An apple a day keeps the heart doctor away"*, Available at: https://www.ox.ac.uk/news/2013-12-18-apple-day-keeps-heart-doctor-away, (Accessed Nov 2023)

Parry, I. W. H et al. (2022) How to Cut Methane Emissions. IMF Staff Climate Note 2022/008, *International Monetary Fund*, Washington, DC. Oct 31, Retrieved from: https://www.imf.org/en/Publications/staff-climate-notes/Issues/2022/10/28/How-to-Cut-Methane-Emissions-525188 (Accessed Nov 2023)

Pattanaik, I. P., Padhi, S. K. (2019) Magnitude and Nature of Child Labour in Odisha, *International Journal of Research in Social Sciences* Vol. 9 Issue 9

Pendrill, F., et al. (2022). Disentangling the numbers behind agriculture-driven tropical deforestation. *Science*. 377. https://doi.org/10.1126/science.abm9267

Persson, L., et al. (2022). Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environmental Science & Technology*. 56(3), 1510– 1521. https://doi.org/10.1021/acs.est.1c04158

Polak, R., et al. (2015). Legumes: Health Benefits and Culinary Approaches to Increase Intake. *Clin Diabetes*, 33(4), 198-205. https://doi.org/10.2337%2Fdiaclin.33.4.198

US Department of Agriculture (n.d.) *Policy.* Available at: https://www.ers.usda.gov/topics/animal-products/dairy/policy/ (Accessed Nov 2023)

Poore, J. (2023). *Reducing the environmental impacts of food: The critical role of plant-based diets.* Plant Based Treaty. https://www.youtube.com/watch?v=tXwt6vQ0Gi8 (Accessed Nov 2023)

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*. 360, 987-992. https://doi.org/10.1126/science.aaw9908

Rajapakse. N. (2016). Amartya Sen's capability, approach and education, enhancing social justice. *Educational action research*, 13, 103-110.

Raworth, K. (2012). *A safe and just space for humanity*. Oxfam International.

Raworth, K. (2017). *Doughnut economics : seven ways to think like a 21st-century economist*. London: Random House.

Raza, A., et al. (2019). *Impact of climate change on crops adaptation and strategies to tackle its outcome: A review*. 2019 Jan 30;8(2):34. doi: 10.3390/plants8020034. PubMed, Retrieved from: https://pubmed.ncbi.nlm.nih.gov/30704089/

Reperant, L. A., et al. (2017) AIDS, Avian Flu, SARS, MERS, Ebola, Zika… What Next?. *Vaccin*, 35.35: 4470–4474. https://pubmed.ncbi.nlm.nih.gov/28633891

Research and Markets (2021) *Meat Products Global Market Opportunities And Strategies To 2031: COVID-19 Impact And Recovery*, Available at: https://www.researchandmarkets.com/reports/5240276/meat-products-global-market-report-2021-covid-19 (Accessed Nov 2023)

Rice, M., et al. (2020) The impact of a negative media event on public attitudes towards animal welfare in the red meat industry. *Animals*. 10, 619. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7222821/

Richardson, K., et al. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*. 9. https://doi.org/10.1126/sciadv.adh2458

Rignot. J. E., et al. (2014). Widespread, rapid grounding line retreat of PineIsland, Thwaites, Smith, and Kohler glaciers, West Antarctica,from 1992 to 2011. *Geophys. Res. Lett.* 41, 3502–3509. Retrieved from: http://dx.doi.org/10.1002/2014GL060140

Ripple, W. J., et al. (2023). The 2023 state of the climate report: Entering uncharted territory. *BioScience*. https://doi.org/10.1093/biosci/biad080

Ripple. J. W., et al. (2023). Many risky feedback loops amplify the need for climate action. *OneEarth*. Vol 6, Issue 2, Pages 86-91. Retrieved from: https://docs.google.com/document/d/1c1nZhfIvYd0jfL-U6lkuA7s9p2Kuis_69czganUUR4I/edit, https://doi.org/10.1016/j.oneear.2023.01.004 (Accessed Nov 2023)

Ritchie, H. (2019). *Half of the world's habitable land is used for agriculture*, Published online at OurWorldInData.org., Retrieved from: https://ourworldindata.org/global-land-for-agriculture (Accessed Nov 2023)

Ritchie, H. (2020). *You want to reduce the carbon footprint of your food? Focus on what you eat, not whether your food is local.* Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/food-choice-vs-eating-local (Accessed Nov 2023)

Ritchie (2021) *The world has lost one-third of its forest, but an end of deforestation is possible*, Published online at Our World in Data. Accessed 22/11/23. Available at: https://ourworldindata.org/world-lost-one-third-forests (Accessed Nov 2023)

Ritchie, H., & Roser, M. (2022). *Farm Size and Productivity*. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/farm-size (Accessed Nov 2023)

Roser, M., Ritchie, H. (2015) *Cancer*. Published online at OurWorldInData.org, Retrieved from: https://ourworldindata.org/cancer (Accessed Nov 2023)

Rockström, J., et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, 14(2), 32. Retrieved from https://www.ecologyandsociety.org/vol14/iss2/art32/ (Accessed Nov 2023)

Rockström, J., & Gaffney, O. (2021). *Breaking Boundaries: The Science of our Planet*. Great Britain: Dorling Kindersley Limited DK

Rockström, J., et al. (2023). Safe and just Earth system boundaries. *Nature*. 619, 102–111. https://doi.org/10.1038/s41586-023-06083-8

Rockström, J., et al. (2020). Planet-proofing the global food system. *Nature Food*, 1, 3–5. https://doi.org/10.1038/s43016-019-0010-4

RSPCA (2023) Overwhelming community support for a legislated end date to live sheep export, Sep 4, Retrieved from. https://qld.rspca.org.au/media-centre/news/2023/overwhelming-community-support-legislated-end-date-live-sheep-export (Accessed Nov 2023)

Ruiz, S. (2022). Agriculture and food security threatened by warmer, dryer world. Woodwell Climate Research Center, Feb 14. Retrieved from: https://www.woodwellclimate.org/climate-change-food-security-crop-failures/ (Accessed Nov 2023)

Safayet, M. et al (2017) Present practice and future prospect of rooftop farming in Dhaka city: A step towards urban sustainability, Vol 6, issue 2, Pages 56-65, *Journal of Urban Management*, Science Direct, https://doi.org/10.1016/j.jum.2017.12.001

Sánchez, J.L.M.et al. (2020) Climate change begins at home: City Diplomacy in the Age of the Anthropocene. Springer Link

Scarborough. P., et al. (2023). Vegans, vegetarians, fish-eaters and meat-eaters in the UK show discrepant environmental impacts. Nat Food 4, 565–574. Retrieved from: https://doi.org/10.1038/s43016-023-00795-w (Accessed Nov 2023)

Scarborough, P., et al. (2012) Modelling the health impact of environmentally sustainable dietary scenarios in the UK. *Eur J Clin Nutr*. 66(6):710-5. https://pubmed.ncbi.nlm.nih.gov/22491494/

Sentient Media (2020), *"Factory Farms Are the Perfect Breeding Ground for Zoonotic Diseases"*, Dec 2. Retrieved at: https://sentientmedia.org/zoonotic-diseases/ (Accessed Nov 2023)

Shand, H. & Wetter, K. J. (2019) Plate tectonics: Mapping Corporate Power in Big Food.

ShareAction (2020). *Point of No Returns Part III – Climate Change*.

Simões, M. et al. (2022) Residential proximity to livestock animals and mortality from respiratory diseases in The Netherlands: A prospective census-based cohort study, *Environment International*, Vol 161, https://doi.org/10.1016/j.envint.2022.107140

Singh, A. L. et al. (2014) Environmental and Health Impacts from Slaughter Houses Located on the City Outskirts: A Case Study, *Journal of Environmental Protection*, Vol 5, no 6, 10 pages, DOI:10.4236/jep.2014.56058

Slade, J., Alleyne, E. (2023) The Psychological Impact of Slaughterhouse Employment: A Systematic Literature Review, *Trauma, Violence and Abuse*, 2023, Vol. 24(2) 429–440

Smithers, R. (2020) *"Quorn to be first major brand to introduce carbon labelling"*, The Guardian, Jan 9, Available at: https://www.theguardian.com/environment/2020/jan/09/quorn-to-be-first-major-brand-to-introduce-carbon-labelling (Accessed Nov 2023)

Springmann, M., et al. (2018). Options for keeping the food system within environmental limits. *Nature*. 562, 519–525. https://doi.org/10.1038/s41586-018-0594-0

Springmann, M., Freund, F. (2022) Options for reforming agricultural subsidies from health, climate, and economic perspectives. *Nat Commun* 13, 82 (2022). https://doi.org/10.1038/s41467-021-27645-2

Steffen. W., et al. (2018). Trajectories of the Earth System in the Anthropocene. *PNAS*. 115, 8252-8259. https://doi.org/10.1073/pnas.1810141115

Steffen, W., et al. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*. 347, 1259855. https://doi.org/10.1126/science.1259855

Steffen, W. et al. (2015). "Planetary boundaries: Guiding human development on a changing planet". *Science*. 347 (6223): 1259855, DOI: 10.1126/science.125985

Stehle, S. and Schulz, R. (2015). Agricultural Insecticides Threaten Surface Waters at the Global Scale. *Proceedings of the National Academy of Sciences*. 112, 5750-5755. https://doi.org/10.1073/pnas.1500232112

Sterling, S., et al. (2013). The impact of global land-cover change on the terrestrial water cycle. *Nature Climate Change*. 3(4), 385-390. https://doi.org/10.1038/nclimate1690

Strassburg, B.B.N., et al. (2020). Global priority areas for ecosystem restoration. *Nature*. 586, 724–729. https://doi.org/10.1038/s41586-020-2784-9

Surowiec, P, Manor, I. (eds.) (2021) Public Diplomacy and the Politics of Uncertainty. Palgrave Macmillan Series in Global Public Diplomacy. Cham, Switzerland: Palgrave Macmillan. Retrieved from: https://link.springer.com/book/10.1007/978-3-030-54552-9, (Accessed Nov 2023)

Tai, L., et al. (2014) Beyond Meatless, the Health Effects of Vegan Diets: Findings from the Adventist Cohorts, 6(6), 2131-2147, https://doi.org/10.3390/nu6062131

Termannsen, A. D., et al. (2022) Effects of vegan diets on cardiometabolic health: A systematic review and meta-analysis of randomized controlled trials, Volume 23, Issue 9, Retrieved from: https://doi.org/10.1111/obr.13462;

Theurl, M.C., et al. (2020). Food systems in a zero-deforestation world: Dietary change is more important than intensification for climate targets in 2050. *Elsevier*, Volume 735. https://www.doi.org/10.1016/j.scitotenv.2020.139353

Tiseo, K., et al. (2020) Global Trends in Antimicrobial Use in Food Animals from 2017 to 2030, 9(12): 918. doi: 10.3390/antibiotics9120918, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7766021/pdf/antibiotics-09-00918.pdf, retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7766021/ (Accessed Nov 2023)

Tolstoy, L. (2003) *Esarhaddon, King of Assyria, in Walk in the Light and Twenty-Three Tales*. Maryknoll, New York, Orbis Books.

Tomova, A., et al. (2019) The Effects of Vegetarian and Vegan Diets on Gut Microbiota, Vol 6, Retrieved from: https://doi.org/10.3389/fnut.2019.00047 (Accessed Nov 2023)

Townsend, T., et a.l (2018). Determination of As-Discarded Methane Potential in Residential and Commercial Municipal Solid Waste. *Waste Management*. 76, 82-89. https://doi.org/10.1016/j.wasman.2018.03.017

Turunen, A.W., et al. (2023). Cross-sectional associations of different types of nature exposure with psychotropic, antihypertensive and asthma medication. *Occupational and Environmental Medicine*. 80:111-118. https://doi.org/10.1136/oemed-2022-108491

Twine, R. (2021). Emissions from Animal Agriculture—16.5% Is the New Minimum Figure. *Sustainability*. 13, 6276. https://doi.org/10.3390/su13116276

UL Solutions (2020) *Mandatory Emission reporting Around the Globe*, Aug 25, Available at: https://www.ul.com/news/mandatory-emissions-reporting-around-globe. (Accessed Nov 2023)

UN Decade. (n.d.). *Preventing, halting and reversing loss of nature*. Retrieved from: https://www.decadeonrestoration.org/ (Accessed Nov 2023)

UN Sustainable Development Goals, *Goal 2: Zero Hunger*, Retrieved from: https://www.un.org/sustainabledevelopment/hunger/ (Accessed Nov 2023)

UN (2022). *Global Land Outlook 2*, Retrieved from. https://www.unccd.int/resources/global-land-outlook/glo2 (Accessed Nov 2023)

UN DESA (2018) *2018 Revision of World Urbanization Prospects, produced by the Population Division of the UN Department of Economic and Social Affairs*. Available at: https://www.un.org/en/desa/2018-revision-world-urbanization-prospects (Accessed Nov 2023)

UNDP (2021) The People's Climate Vote. Retrieved from: https://www.undp.org/publications/peoples-climate-vote (Accessed Nov 2023)

UNEP. (2023). Adaptation Gap Report 2023. Accessed Nov 2023. Retrieved from: https://www.unep.org/resources/adaptation-gap-report-2023 (Accessed Nov 2023)

United Nations Environment Programme (2022). *Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies*. Nairobi. Oct 27. Available at: Retrieved from: https://www.unep.org/emissions-gap-report-2022 (Accessed Nov 2023)

United Nations Environment Programme (2022). *Making good on the Glasgow Climate Pact: a call to action to achieve one gigaton of emissions reductions from forests by 2025.* Nairobi. Retrieved from: https://www.unep.org/resources/report/making-good-glasgow-climate-pact-call-action-achieve-one-gigaton-emissions (Accessed Nov 2023)

UNEP (2022). *Making Good on the Glasgow Climate Pact: A Call to Action to Achieve One Gigaton of Emissions Reductions from Forests by 2025.* UNEP. Nov 7. Retrieved from. https://www.unep.org/resources/report/making-good-glasgow-climate-pact-call-action-achieve-one-gigaton-emissions (Accessed Nov 2023)

UNEP et al. (2021). *Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions.* Available at: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions (Accessed Nov 2023)

UNEP (2018), *The environmental food crisis – The environment's role in averting future food crises*. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal,

UNFCCC. (2023). *Long-term strategies portal*. Available at: https://unfccc.int/process/the-paris-agreement/long-term-strategies. (Accessed Nov 2023)

United Nations (2023). *Ensure Availability and Sustainable Management of Water and Sanitation for All, SDG6*. Retrieved from: https://unstats.un.org/sdgs/report/2022/Goal-06/?_gl=1*128dkoa*_ga*NTk5MjUwMjI0LjE2ODIxNzIzNTM.*_ga_TK9BQL5X7Z*MTY5ODQxNjQxNS41LjAuMTY5ODQxNjQxNS4wLjAuMA (Accessed Nov 2023)

USDA. *Evaluation of the Healthy Incentives Pilot (HIP) Final Report.* 2014. Available at: https://fns-prod.azureedge.us/sites/default/files/ops/HIP-Final-Summary.pdf (Accessed Nov 2023)

USDA Economic Research Service, *Food Access Research Atlas*, Available at: https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/ (Accessed Nov 2023)

Vallone, S., Lambin, E.F. (2023) Public policies and vested interests preserve the animal farming status quo at the expense of animal product analogs, Vol 6, issue 9, P1213-1226, *One Earth*, DOI: https://doi.org/10.1016/j.oneear.2023.07.013, Retrieved from: https://www.cell.com/one-earth/fulltext/S2590-3322(23)00347-0. (Accessed Nov 2023)

Van Boeckel, T. P., et al, (2017) Reducing antimicrobial use in food animals, *Science*, Vol 357, Issue 6358 pp. 1350-1352, DOI: 10.1126/science.aao1495

Vegconomist (2019) *"Petition by Oatly: CO2 Labelling of Food to Become Law"*, Oct 16, Available at: https://vegconomist.com/society/petition-by-oatly-co2-labelling-of-food-to-become-law/ (Accessed Nov 2023)

Vegconomist (2023) *"Dutch Municipalities to Ban Meat and Dairy Ads in Public Spaces"*, Nov 6, Retrieved at: https://perma.cc/L9GE-ZCLQ (Accessed Nov 2023)

Veolia Institute (2019). *The Veolia Institute Review, Urban agriculture: another way to feed cities*. Issue 20. Retrieved from: https://www.institut.veolia.org/en/nos-publications/la-revue-de-linstitut-facts-reports/urban-agriculture-another-way-feed-cities (Accessed Nov 2023)

Vilani, R.M., et al. (2023). The first acts of Brazil's new president: Lula's new Amazon institutionality. *Environmental Conservation* 50: 148–151.

Waibel. M. S., et al. (2018). Rate of Mass Loss Across the Instability Threshold for Thwaites Glacier Determines Rate of Mass Loss for Entire Basin. *Geophys. Res. Lett.* 45, 809–816. http://dx.doi.org/10.1002/2017GL076470

Walsh, L.E., et al. (2022). Potential of urban green spaces for supporting horticultural production: a national scale analysis. *Environmental Research Letters*, 17 014052. https://www.doi.org/10.1088/1748-9326/ac4730

Wang-Erlandsson, L., et al. (2022). A planetary boundary for green water. *Nature reviews earth & environment*. 3, 380–392. https://doi.org/10.1038/s43017-022-00287-8

Webb, P., et al. (2020). The urgency of food system transformation is now irrefutable. *Nat Food*. 1, 584–585. https://doi.org/10.1038/s43016-020-00161-0

West, P.C., et al. (2014). Leverage points for improving global food security and the environment. *Science*. 345(6194):325-8. https://www.doi.org/10.1126/science.1246067

Williams, M (2023) *"Factory Farms Are Sourcing Their Cheap Labor From Prisons"*, Sentient Media, March 6, Retrieved from: https://sentientmedia.org/prison-labor-meat/ (Accessed Nov 2023)

Willett, W., et al. (2019). Food in the Anthropocene: The EAT- Lancet Commission on healthy diets from sustainable food systems, *The Lancet*, Vol: 393, Issue 10170, P447-492, DOI: http//doi.org/10.1016/S0140-6736(18)31788-4.

Willett, W. C., et al. (2020) Red meat intake and risk of coronary heart disease among US men: prospective cohort study. *BMJ* 2020; 371, https://doi.org/10.1136/bmj.m4141

Winston, C. (2009) Health effects of vegan diets, Volume 89, Issue 5, Pages 1627S-1633S, https://doi.org/10.3945/ajcn.2009.26736N

Winston, C., et al. (2009). Position of the American Dietetic Association: vegetarian diets, *J Am Diet Assoc*. 109 (7):1266-82. Vol 109, issue 7, P1266-1282, doi: 10.1016/j.jada.2009.05.027.

World Bank (2020). *Agriculture and Food*. Retrieved from: https://www.worldbank.org/en/topic/agriculture/overview (Accessed Nov 2023)

World Bank., et al. (2019). *Creating a sustainable food future*. Retrieved from: https://files.wri.org/d8/s3fs-public/wrr-food-full-report.pdf (Accessed Nov 2023)

WHO, *"Healthy Diet"* Available at: https://www.who.int/health-topics/healthy-diet#tab=tab_1 (Accessed Nov 2023)

WHO (2016) *Increasing fruit and vegetable consumption to reduce the risk of noncommunicable diseases*. Retrieved from https://www.who.int/tools/elena/commentary/fruit-vegetables-ncds#:~:text=Current%20evidence%20suggests%20that%20higher,risk%20factors%20for%20cardiovascular%20disease. (Accessed Nov 2023)

WHO (2023) *Antimicrobial resistance expected to cause 5.2 million deaths in the Western Pacific by 2030*, Retrieved from. https://www.who.int/japan/news/detail/13-06-2023-antimicrobial-resistance-expected-to-cause-5.2-million-deaths-in-the-western-pacific-by-2030 (Accessed Nov 2023)

WHO (2023). *Noncommunicable diseases: key facts*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (Accessed Sept 2023)

WMO (2023) *Global Temperature set to reach record high*. Retrieved from https://public.wmo.int/%E2%80%A6/global-temperatures-set-reach&#8230 (Accessed July 2023)

World Meteorological Organisation (2022). *Scientific assessment of ozone depletion: 2022 Executive Summary*. Report No. 278, 56 pp.; WMO: Geneva. Retrieved from: https://digitallibrary.un.org/record/4000934 (Accessed Nov 2023)

World Wildlife Fund, *Networks of support in the Amazon*, Available at: https://www.wwf.org.uk/success-stories/networks-support-amazon (Accessed Nov 2023)

WWF (2022) *Press release: Transform UK farmland to boost food resilience and tackle nature crisis – WWF*, Available at: https://www.wwf.org.uk/press-release/transform-uk-farmland-boost-food-resilience-tackle-nature-crisis, (Accessed Nov 2023)

Wunderling. N., et al. (2021). Interacting tipping elements increase risk of climate domino effects under global warming. *Earth Syst. Dynam*. 12, 601-619 https://doi.org/10.5194/esd-12-601-2021

Xiaoming. X., et al. (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. *Nature Food*. 2. 724–732. https://doi.org/10.1038/s43016-021-00358-x

Xu, C., et al. (2020). Future of the human climate niche, *PNAS*, 117 (21) 11350-11355, https://doi.org/10.1073/pnas.1910114117, https://www.pnas.org/doi/10.1073/pnas.1910114117

Xu, X., et al. (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. *Nature Food*. 2, 724–732. https://doi.org/10.1038/s43016-021-00358-x

Yang, M. (2023) *"Over 100 children illegally employed by US slaughterhouse cleaning firm"*, The Guardian, Feb 17, Retrieved from: https://www.theguardian.com/law/2023/feb/17/underage-child-labor-working-slaughterhouse-investigation (Accessed Nov 2023)

Zuidema, P.A., et al. (2022). Tropical tree growth driven by dry-season climate 37 variability. *Nature Geoscience*, 15(4), pp.269-276. https://www.doi.org/10.1038/s41561-022-00911-8

Appendix I

The Plant Based Treaty

R1 | Relinquish

Stop the problem increasing

No land use change, including deforestation, for animal agriculture

- No building of new animal farms
- No building of new slaughterhouses
- No expansion or intensification of existing farms
- No conversion of plant-based agriculture to animal agriculture
- No conversion of any land for animal feed production
- No clearing of forests or other ecosystems for animal grazing, animal rearing or animal farming of any kind
- No new fish farms or expansion of existing aquaculture farms
- Protection of Indigenous Peoples; their land, rights and knowledge
- Ban all live exports
- No new large-scale industrial fishing vessels.

R2 | Redirect

Eliminate the driving forces behind the problem

Promotion of plant-based foods and actively transition away from animal-based food systems to plant-based systems

- Declare a climate emergency – join the 1,900+ local governments in 34 different countries that have already done so
- Address the methane emergency: According to the United Nations, a 0.3°C temperature rise could be averted by 2045 if methane emissions were cut by 45% this decade. As the leading source of human-caused methane emissions, a transition away from animal agriculture to a sustainable plant-based food system would help us meet these goals as soon as possible
- Food security should be placed as a priority for all nations, with a focus on ending poverty and hunger and making nutritious food accessible for all
- Acknowledge and support the pivotal role small farmers have in feeding the planet; support them to maintain (or restore) autonomy over their lands, water, seeds and other resources
- Shift away from monoculture-based arable farming that depletes soil, decreases biodiversity and is reliant on external inputs such as animal manure and agrochemicals towards towards diversified, agroecological, veganic (vegan and organic) farming using regenerative, permaculture and natural principles that restore soil and ecosystems, enhance food security and provide nutrient-dense foods
- Calculate greenhouse gas emissions based on consumption and prioritize a switch to plant-based foods in Climate Action Plans
- Update government food and dietary guidelines to promote wholefood, plant-based food
- Design public information campaigns to raise awareness about the climate and the environmental advantages and health benefits of plant-based food, nutrition and cooking
- Aim to reduce the public's consumption of animal-based food through education in schools
- Transition to plant-based meal plans in schools, hospitals, nursing homes, prisons and government institutions
- Mandate honest labelling of food products including carbon labelling and cancer warning labels on all processed meats which have been declared carcinogenic by the World Health Organization
- Introduce a meat (including fish) and methane tax with proceeds funding restoration of land destroyed by animal agriculture
- Subsidize fruits and vegetables to make a wholefoods, plant-based diet more affordable and end food deserts that hurt low income communities
- Redirect government subsidies for animal agriculture, slaughterhouses and industrial fishing to environmentally-friendly production of plant-based food
- End government subsidized advertising for the meat, dairy and egg industry
- Create green bonds to fund a transition to a plant-based economy
- Provide financial support and training for farmers, ranchers and fisherpeople to move away from animal production to diversified agroecological, plant-based (veganic) systems.

R3 | Restore

Actively healing the problem while building resilience and mitigating climate change

Restore key ecosystems and reforest the earth

- Reforestation projects to be rolled out in appropriate ecosystems using native tree species to restore habitats to a previously similar state
- Reforestation and restoration of the oceans is prioritised by designating additional areas of the oceans as zero fishing Marine Protected Areas (known as Highly Protected Marine Areas – HPMAs)
- All existing Marine Protected Areas should be declared strictly no fishing zones and converted to HPMAs
- Active programs rolled out to replant critical carbon absorbers in the oceans, such as seagrass beds
- Restore key degraded ecosystems which are essential for carbon sequestration cycles: mangroves, peat bogs, forests, some types of grassland
- Focus shift on nature-based solutions for climate change mitigation and adaptation
- Subsidies made available for farmers and landowners who practise good land stewardship and are actively restoring the land and the associated ecosystem services (such as carbon sequestration, biodiversity, flood defence, general climate change resilience)
- Subsidies made available for rewilding and reforestation projects
- Incentivised subsidies / grants for farmers to switch from animal agriculture to diversified plant production
- Cities: increase trees and wildflowers, increase green community projects, wildlife corridors, green rooftops, local growing schemes, work towards biodiversity increases
- Enhance food justice by providing access to healthy food for all, especially low-income communities of color
- Repurpose available land freed up from animal grazing and animal feed production for: rewilding, reforestation (if appropriate), returning land to Indigenous people, nature reserves, hiking zones, community growing, allotments (if appropriate), agroecological veganic food growing (where possible)
- Shift of some land ownership into community hands so the land can be repurposed for reforestation, green space and community food gardens and allotments.

Action Checklist

- [ ] **Sign the Plant Based Treaty**
  www.plantbasedtreaty.org/endorse

- [ ] **Share this report**
  Download at: www.vegandonuteconomics.org

- [ ] **Ask your local representatives to endorse and implement the Plant Based Treaty**

- [ ] **Read our free PBT Playbooks**
  Practical guides on best practices for schools, universities, city councils, care homes, healthcare and more.
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