Planet-proofing the global food system

Without a great food system transformation, the world will fail to deliver both on the United Nations Sustainable Development Goals and the Paris Climate Agreement. There are five grand challenges to be faced, by science and society, to effect that transformation.

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Food is failing us. The global food system is the single largest greenhouse-gas-emitting sector in the world[1], and by far the largest cause of biodiversity loss, terrestrial ecosystem destruction[2], freshwater consumption, and waterway pollution due to overuse of nitrogen and phosphorus[3]. It holds a firm grip over the stability of the Earth system and the future of humanity. Unhealthy food is the world's biggest killer, with diet-related chronic disease estimated to be responsible for 11 million premature deaths in 2017 alone[4]. Meanwhile, increasing numbers of people — more than 900 million — are undernourished. This increase is due in part to armed conflict, but climate change and the water–food–environment nexus are increasingly identified as amplifiers of social instability[5,6].

The global food system is a prime driver — and generally the first victim — of the Anthropocene. A swift global food transformation towards healthy diets from sustainable food systems is necessary, and without such a food transformation the world will not meet the targets set in the United Nations Sustainable Development Goals (SDGs) and the Paris Climate Agreement[7]. Scalable solutions do exist, but the food sector lags 30 years behind the energy sector (despite the inertia in decarbonising the global energy system) in concerted efforts to transform the system towards a safe operating space on Earth.

Food and the state of the planet

Modern agriculture was able to develop through the benign climatic conditions and abundant biodiversity of the Holocene. In the Anthropocene, however, the food system is the primary driver of our current Earth trajectory, which follows a path at risk of creating a cascade of interacting non-linear processes that propel the planet towards a radically different climatic state. Where certain tipping points lie is not yet well understood, but it is now increasingly established that warming beyond 1.5 °C places us dangerously close to those red lines[8]. The world has already warmed by 1 °C above pre-industrial levels; at 1.5 °C, tropical coral reefs are very likely to collapse; at 2 °C, Arctic summer sea ice would disappear and the Greenland Ice Sheet could tip towards disintegration; several glaciers of the West Antarctic Ice Sheet might already have passed tipping points, contributing over two metres of unstoppable sea-level rise in the long-term[9]. The oceans have buffered the effects of global warming by absorbing more than 90% of human-caused excess heat. However, social and environmental costs are mounting and, as oceans grow warmer, more acidic and less productive, coastal extreme events and sea-levels are on the rise[9]. Under climate change, the diversity of species and ecosystems is declining faster than at any time in human history[2]. Increasing evidence shows that tipping elements are connected and can trigger cascading effects[10], for example, Arctic sea-ice melt amplifies regional warming, accelerating Greenland ice sheet melt, which in turn may have contributed to the recent 15% slowdown in the Atlantic Meridional Overturning Circulation (AMOC)[11]. The AMOC itself is connected to both regional rainfall dynamics in the Amazon and the West African monsoon[12], with a further slow-down potentially triggering drought, amplifying global warming and risking food shortages. Without a major transformation across sectors and scales, we risk crossing points of irreversibility that threaten the Earth system as we know it.

There is a critical need to scientifically define and move towards a safe operating space for food within planetary boundaries. This is a completely new positioning of the food system — a shift from the conventional focus on reducing environmental impacts at the 'farming system' scale towards defining science-based targets for food at the planetary scale, recognizing the global force that food constitutes today. A first attempt at this definition has recently been made for the planetary boundary processes directly associated with food — namely land, water, biodiversity, nutrient loading and climate change[7]. Globally, food transgresses all five of these planetary boundaries (Fig. 1).

Grand food challenges

Food production and environmental conservation have traditionally, and falsely, been pitted against each other. Food production, dietary health and environmental sustainability have, at best, been advanced as separate, siloed disciplines with limited explorations of synergies and trade-offs. Food-system science, policy and action continue to largely be pursued as local or regional concerns, despite food's role as a global driver of planetary instability. Transforming food across the world might be our best bet in meeting the Paris Climate Agreement and the SDGs. The challenges we face call for rapid but thoughtful actions along five primary axes.

Science-based targets. The 'planetary health diet'[7] is the first attempt to provide scientific targets for healthy diets from sustainable production systems. They provide a set of universally applicable scientific boundary conditions within which all diets should operate for both human health and Earth sustainability. Following the Paris Climate Agreement, there are 285 companies that have adopted science-based targets (SBTs) for climate through the SBT initiative. Now, there is a growing momentum to widen that initiative to set SBTs for the entire Earth system — that is, to establish quantitative science-based targets for all planetary boundaries to support business transformations towards sustainable development. Similar efforts are needed for cities and national governments. Food systems across the world can be the first sector to adopt system-wide SBTs for planetary health. Making the SBTs for food operational across scales, sectors and agents will require further development of the planetary health diet and major methodological advancements. Immediate challenges include defining the food boundary for atmospheric aerosol loading (air quality), and novel entities such as the contamination of land and water with plastics, antibiotics and biocides.

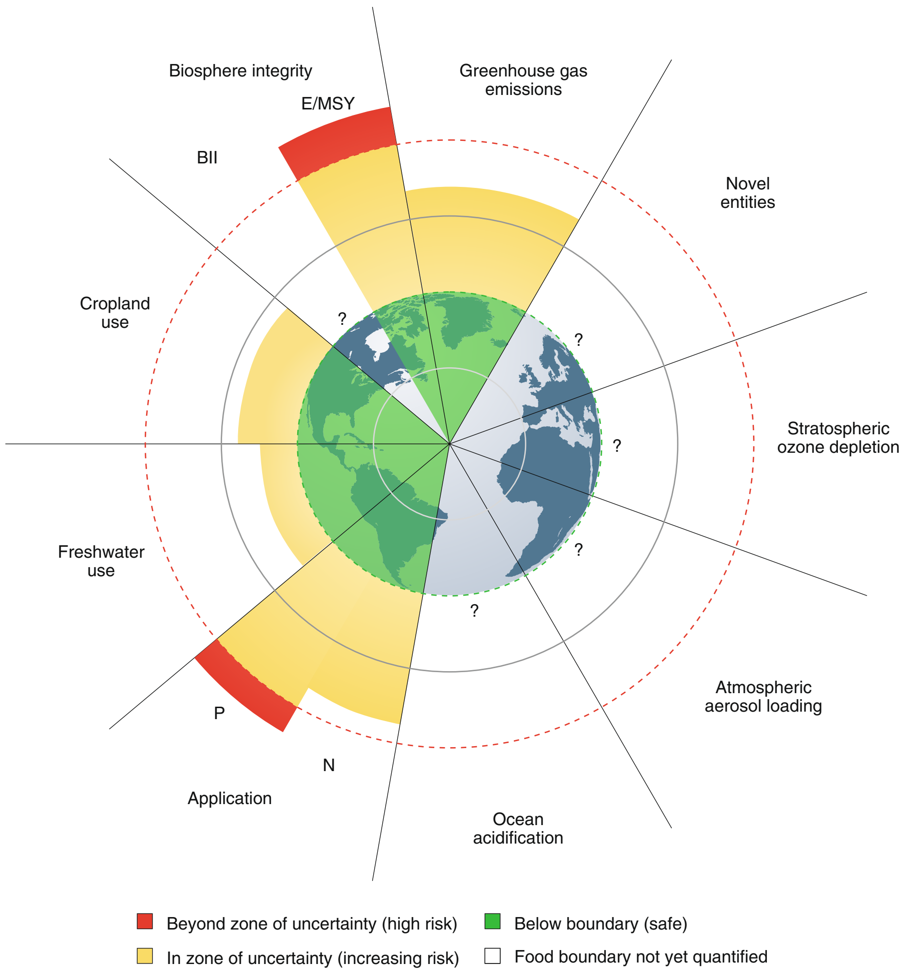

Fig. 1 | An estimate of the global food system's transgression of planetary boundaries. Here, the safe operating space (green) provides an estimate of the food-related share of the planetary boundaries, that is, not the entire planetary boundary space for all sectors in the world economy. The zone of uncertainty (yellow) defines dangerous risk, whereas high-risk (red) indicates where production has exceeded the assessed uncertainty range in science. The range of uncertainty originates both from quantitative assessments and from expert judgement. Control variables have been normalized for the zone of uncertainty; the centre of the figure therefore does not represent zero values for control variables. Processes for which the food system contribution or the planetary boundary itself have not yet been quantified are highlighted with a question mark. E/MSY, extinctions per million species-years; BII, Biodiversity Intactness Index; P, phosphorus; N, nitrogen. Values are based on Fig. 6 of ref. [7]; image credit: PIK, 2019.

Practices and policies. Modelling analyses suggest[13] that it is biophysically possible to feed 10 billion people a healthy diet within planetary boundaries, and in ways that leave at least 50% of natural ecosystems intact. Success hinges on triple action at a global scale: shifting towards healthy diets; increasing productivity while transitioning to regenerative production practices; and reducing food waste and loss by 50%.

Major policy and investment shifts toward this global transformation are central to turning the food system from a primary threat to a primary solution space for human and planetary health. Grand challenges remain in how to accelerate and scale the pace of change, reconfigure food value chains from 'field to fork', and support shifts in consumption. Overall, there is a need to test the planetary health diet hypothesis — that we can feed 10 billion people healthily within planetary boundaries — on the ground. The universal recommendation allows alignment across sectors and scales. However, what it implies for national transformation pathways is not uniform, but relies on the emergence of culturally and agroecologically diverse solutions[14].

Human and natural capital. A recent assessment[15] 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. Today, food is an exceptionally subsidized and socially sensitive commodity. Not only is the planet subsidizing 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. The European Union's Common Agricultural Policy (CAP) is perhaps most prominent, currently accounting for 37.8% of the total EU budget. Shifting these types of subsidies to reward the production of public goods (such as carbon capture, habitat creation and improved water quality) presents a ready option for securing the global commons while supporting farming communities.

Food security, social instability and conflicts. The human pressures put on the entire Earth system are causing a rise in frequency and amplitude of extreme weather events[16] and a reduction in ecological resilience. Occurring simultaneously with decades of agricultural research and development that focussed on enhancing productivity over building resilience, this has resulted in heightened vulnerability as monocultures designed to operate efficiently under stable conditions are not adapted to handle shocks and stress amplified by global change.

Food production is the first victim of environmental pressures arising in the Anthropocene. Our immediate scientific preoccupation with this worrying trajectory has been on mapping impacts on food production and seeking strategies to build food-system resilience. This may not be enough. Real world examples are providing evidence, while still debated, of the amplifying role of food-system collapse on social conflict and migration, ranging from the Arab Spring to the Syrian war, the Sudanese crisis and the Sahelian instabilities[17–19]. This is an area in need of integrated analyses that couple big data and qualitative insights on social movements (physical and political), livelihood conditions, food security, and biophysical trajectories and shocks.

A new paradigm for our food future. Planetary boundaries for the food system define thresholds for the critical overuse of global commons. In the Anthropocene, when we are at risk of destabilising the Earth system, the global commons need to be expanded from including only global externalities (high seas, atmosphere, polar ice sheets) to also include all major biomes and element cycles, which together contribute to regulate the state of the Earth system[20]. This puts the onus on food, and requires an urgent shift in mindset to recognize agricultural ecosystems as possibly the Earth's largest biome — and the biome with the largest impact on the planet's elemental cycles: nitrogen, phosphorus, water and carbon.

A second major shift is to look beyond carbon and climate. Building resilient food systems requires a systems-approach integrating carbon, nitrogen, phosphorus, water, soils, biodiversity and biome stability; and taking a truly inter-disciplinary planetary health approach by addressing food cultures, nutritional security and geopolitical stability, as well as the role of governance, trade and equity. In light of the significant lag time to drive global progress on climate mitigation, we cannot afford to have succeeded in tackling climate before moving on to other planetary boundaries. Approaches must be developed and tested at a scale that operationalises a global commons framework for the stewardship of all food-related planetary boundaries. The social costs of our current global food system are unprecedented in both inter-temporal and inter-regional scales[15], providing crucial information for effective governance of the commons. Advanced methods of cost-benefit analysis and the application of the precautionary principle will allow the social costs of exceeding planetary boundaries for food to be used in the transition process of crafting and justifying government rules and interventions, such as agricultural subsidies and trade agreements, providing a new paradigm for navigating our 'Common Food Future'.

Gone are the days when it was enough to 'think global and act local'. All our actions aggregate and are interconnected with the global commons and the Earth system. The global food system transformation to a future where healthy, culturally appropriate and adequate diets are available for all, from food systems that operate within planetary boundaries, is one of the grand transformation challenges for humanity over the coming decades. We must act across scales and along the entire food value chain to enable a prosperous and equitable future for humanity on Earth. ❐

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Competing interests

The authors declare no competing interests.