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Ensuring Access to Safe and Nutritious Food for All Through Transformation of Food Systems

- A paper on Action Track 1 -

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A paper from the Scientific Group of the UN Food Systems Summit

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ENSURING ACCESS TO SAFE AND NUTRITIOUS FOOD FOR ALL THROUGH TRANSFORMATION OF FOOD SYSTEMS

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Abstract

Action Track 1 of the Food Systems Summit offers an opportunity to bring together the crucial elements of food safety, nutrition, poverty and inequalities in the framework of food systems in the context of climate and environmental change to ensure that all people have access to a safe and nutritious diet. Achieving Action Track 1 goal is essential to the achievement of the goals of the other Action Tracks. With less than a decade left to achieve the Sustainable Development Goals (SGD), most countries are not on target to achieve the World Health Organisation's nutrition targets and SGD 2 targets. The COVID pandemic has exacerbated malnutrition and highlighted the need for food safety. The pandemic has also exposed the deep inequalities in society and food systems. Yet, future food systems can address many of these failings and ensure safe and nutritious food for all. However, structural change is necessary to address the socio-economic drivers behind malnutrition, inequalities and the climate and environmental impacts of food. Adopting a whole-system approach in policy, research and monitoring and evaluation is crucial to manage trade-off and externalities from farm-level to national scales and across multiple sectors and agencies. Supply chain failures will need to be overcome and technology solutions adopted and adapted to specific contexts. A transformation of food systems requires coordinating changes in supply and demand in differentiated ways across world regions: bridging yield gaps and improving livestock feed conversion, largely through agro-ecological practices, deploying at scale soil carbon sequestration and greenhouse gas mitigation, reducing food losses and wastes, as well as over-nourishment and shifting the diets of wealthy populations. Global food systems sustainability also requires halting the expansion of agriculture into fragile ecosystems, while restoring degraded forests, fisheries, rangelands, peatlands and wetlands. Shifting to more sustainable consumption and production patterns within planetary boundaries will require efforts to influence food demand and diets, diversify food systems, careful land-use planning and management. Integrative policies need to ensure that food prices reflect real costs (including major externalities caused by climate change, land degradation and biodiversity loss, and public health impacts of malnutrition), reduce food waste and, at the same time, ensure safe and healthy food affordability, decent incomes and wages for farmers and food system workers. Harnessing science and technology solutions and sharing actionable knowledge with all players in the food system offers many opportunities. Greater coordination of food system stakeholders is crucial for greater inclusion, greater transparency and more accountability. Sharing lessons and experiences will foster adaptive learning and responsive actions. Careful consideration of the trade-offs, externalities and costs of not acting is needed to ensure that the changes we make benefit to all and especially the most vulnerable in society.

1. Introduction

Action Track 1 of the Food Systems Summit offers an opportunity to bring together the crucial elements of food safety, nutrition, poverty and inequalities in the framework of food systems in the context of climate and environmental change to ensure that all people have access to a safe and nutritious diet. These elements are embedded in the fundamental human rights, including the right to food, the rights to safe water and sanitation (essential for safe food), as well as the right to be free from discrimination.

Food systems provide a framework to advance access to safe and nutritious food for all (including all crops, fish, forest foods and livestock). Food systems encompass all the elements and activities that relate to the production, processing, distribution, preparation and consumption of food, as well as the output of these activities, including socio-economic and environmental outcomes (HLPE, 2020). Ensuring access to safe and nutritious food for all underlies the other Summit Action Tracks (Figure 1).

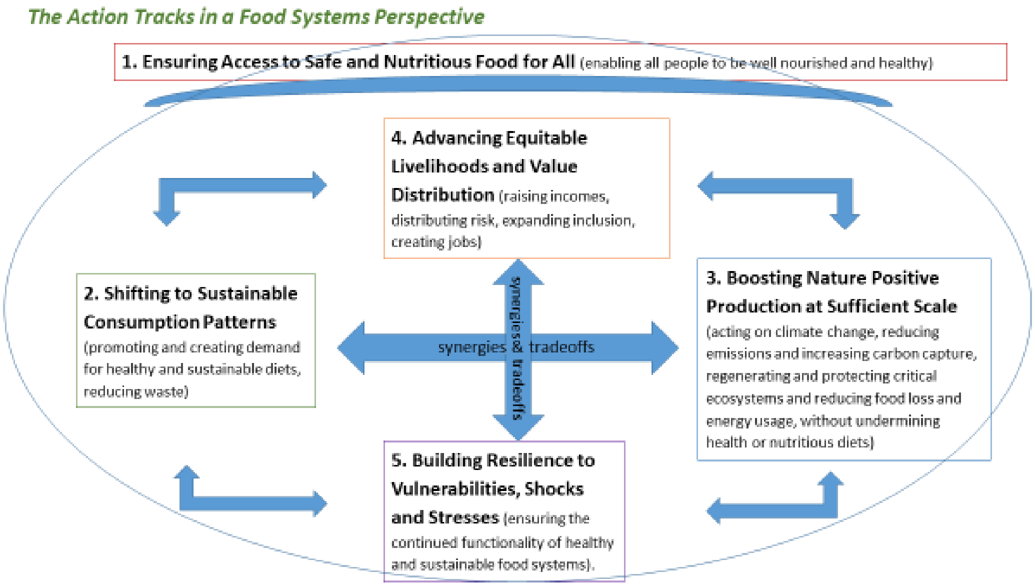

Figure 1: Action Tracks of the UN Food Systems Summit in a Normative Systems Perspective (von Braun et al., 2021).

2. What is a safe and nutritious diet?

A safe and nutritious diet is a healthy diet – a diet that "is human health-promoting and disease-preventing. It provides adequacy (without an excess of nutrients) and health-promoting substances from nutritious foods and avoids the consumption of health-harming substances" (Neufeld et al., 2021). A nutritious food "provides beneficial nutrients (e.g., protein, vitamins, minerals, essential amino acids, essential fatty acids, dietary fibre) and minimises potentially harmful elements (e.g. anti-nutrients, quantities of sodium, saturated fats, sugars)" (Neufeld et al. 2021, drawing on GAIN (2017), Drewnowski (2005) and Katz et al. (2011)). Safe food promotes health and is free of foodborne diseases caused by microorganisms, including bacteria, virus, prionics, parasites and chemicals, as well as foodborne zoonoses transferred from animals to humans and other associated risks in the food chain (WHO, 2013).

Malnutrition includes undernourishment, micronutrient deficiencies and overweight (including obesity). Malnutrition increases susceptibility to foodborne diseases, creating a vicious cycle for health, reducing productivity and compromising development. The COVID-19 pandemic is expected to increase the risk of all forms of malnutrition (Headey et al., 2020).

Recent reports draw attention to the affordability of a healthy diet (FAO, IFAD, UNICEF, WFP and WHO, 2020); Masters et al., 2018). The pandemic has exposed long-standing inequalities in our food and health systems that affect access to safe and nutritious food as well as income to enable this access (Laborde et al., 2020). Shocks (including health shocks such as COVID-19 that increase the need for a nutritious diet) make healthy diets less accessible and affordable.

While the definitions of an adequate diet and safe food are established and widely accepted, there is debate in the literature about what constitutes a sustainable diet. Each proposed diet has trade-offs in terms of affordability, climate and environmental impacts. These trade-offs are discussed in the sections that follow.

3. We are not on track to meet international targets for ensuring safe and nutritious food for all by 2030

Despite some progress in reducing the rate of extreme poverty, with only ten years to go to 2030, the world is not on track to meet nutrition-related targets. Table 1 presents a summary of the international targets related to ensuring safe and nutritious food for all. While the proportion of the population that is undernourished, stunting, low birth weight and anaemia among women of reproductive age have declined, the reductions are not sufficient to meet the global targets. The experience of food insecurity (FIES, a survey that consists of eight questions regarding people's access to adequate food) as measured by FAO et al. (2020) has increased somewhat. Moreover, the numbers of overweight children and adults is rising.

No country is exempt from the scourge of malnutrition. Undernutrition coexists with overweight, obesity and other diet-related non-communicable diseases (NCDs), even in poor countries. UNICEF et al. (2020) report that 37% of overweight children reside in low and middle-income countries. Likewise, fragile and extremely fragile countries are disproportionally burdened by high levels of all three forms of malnutrition compared to less-fragile countries (GNR, 2020).

While some progress has been made in certain countries and in some regions, the 2020 Global Nutrition report shows that no country is 'on course' to meet all WHO’s global nutrition targets (GNR, 2020). Although the health and behavioural actions required for reducing all forms of malnutrition are well documented (Lancet report, various WHO guidelines) as are the benefits (Hoddinott, etc.), progress is far too slow. Inequalities in society and the food system make affordable and healthy diets inaccessible to the most vulnerable populations. There is an urgent need to transform food systems to deliver on nutrition outcomes. Unless nutrition-specific (direct) and nutrition-sensitive (indirect) interventions are implemented at scale and in a sustainable way (see Box 1) with complementary services (such as regular deworming of children), the impact will be suboptimal (Ruel et al., 2018). In addition, urgent action is necessary to minimise the impact of the Covid-19 pandemic on children's nutrition (Ruel et al. 2020).

Box 1: Sustainable food systems

“Sustainable food systems are: productive and prosperous (to ensure the availability of sufficient food); equitable and inclusive (to ensure access for all people to food and to livelihoods within that system); empowering and respectful (to ensure agency for all people and groups, including those who are most vulnerable and marginalized to make choices and exercise voice in shaping that system); resilient (to ensure stability in the face of shocks and crises); regenerative (to ensure sustainability in all its dimensions); and healthy and nutritious (to ensure nutrient uptake and utilization)” (HLPE, 2020).

Table 1: Taking stock

	Element	International target/s	Base-line year	Baseline estimate	Latest assessment year	Latest global estimates (with population estimates where available)	Change to date (global)
Nutrition	Hunger (Proportion of the population that is undernourished, PoU)[1]	SGD2: By 2030, end hunger and ensure access by all people, in particular, the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2004-2006	12.5% (FAO et al., 2020)	2017 - 2019	PoU = 8.8% (690 Million) (FAO et al., 2020)	Down 3.7%
	Prevalence of food insecurity (Food Insecurity Experience Scale, FIES) measured as the number of people living in households where at least one adult has been found to be food insecure (FAO et al., 2020)[1,2,3]		2014-2016	Severe – 8.1% Moderate – 22.7% (FAO et al., 2020)	2017-2019	Moderate FIES = 25% or 2 billion, including 9% with severe food insecurity (FAO et al., 2020)	Severe: up 0.9% Moderate: up 2.3%
	Wasting (being underweight for height)[4, 6]	WHO target: Reduce and maintain childhood wasting at less than 5% by 2025 and less than 3% by 2030 (WHO & UNICEF, 2017)	2012	8%	2019	6.9% (moderate and severe) or 47 million children (UNICEF et al., 2020)	Down 1.1%
	Stunting (being short for age)[4, 5, 6]	WHO target: 40% reduction in the number of children under five years of age who are stunted by 2025 and 50% by 2030 form 2016 (WHO & UNICEF, 2017)	2012	24.6% (UNICEF et al., 2020)	2019	21.3% (moderate and severe) or 149 million children under five years of age (UNICEF et al., 2020)	Down 3.3%
	Overweight children (children <5 years with a Body Mass Index (BMI) over 30 – calculated as weight/heigh^{t2})[4, 5, 6]	WHO 2025 target: No increase in child overweight (WHO & UNICEF, 2017)	2012	4.9%	2019	5.3% or 38.3 million under five years of age are overweight (FAO et al., 2020).	Up 0.7%
	Obesity (Adults with a BMI over 30)	WHO 2025 target: Halt the rise in levels (WHO & UNICEF, 2017)	2012	11.8%	2016	13.1% or 677.6 million obese adults (GNR, 2020).	Up 1.3%
	Low birthweight (less than 2500g) [6]	WHO 2025/2030 target: 30 % reduction in low birth weight (WHO & UNICEF, 2017)	2012	15%	2015	14.6% (FAO et al., 2020)	Down 0.4%

	Element	International target/s	Base-line year	Baseline estimate	Latest assessment year	Latest global estimates (with population estimates where available)	Change to date (global)
	Anaemia (iron deficiency)	WHO 2025/2030 target: 50 % reduction of anaemia (iron deficiency) in women of reproductive age (WHO & UNICEF, 2017)	2012	30.3%	2016	2016 32.8% (FAO et al., 2020)	Up 1.5%
Food safety	Foodborne Disease Burden	None established	2010	Unsafe food caused 600 million cases of foodborne diseases and 420 000 deaths equivalent to 33 million years of healthy lives are lost WHO Foodborne Disease Burden Epidemiology Reference Group (FERG 2007-2015)	Not applicable (N/A)	N/A – only baseline available	Unknown – only data for 2010 published
Poverty and inequality	Poverty	SGD1: By 2030 eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.90 a day (World Bank, 2018).	2015	10% or 734 million (World Bank, 2018).	2019	8.2% (UN, 2021)	Down 1.8%
	Affordability	None	2019	% population that cannot afford an energy-sufficient diet = 4.6% FAO et al., 2020) % population that cannot afford a nutrient- adequate diet = 23.3% (FAO et al., 2020) % population that cannot afford a healthy diet = 38.3% or 3 billion (FAO et al., 2020)	-	N/A – only baseline available	Unknown – this is a new indicator without historical data

Notes to Table 1:

[1] Regional estimates were included when more than 50 percent of population was covered. To reduce the margin of error, estimates are presented as three-year averages (FAO et al., 2020).[2] FAO estimates of the number of people living in households where at least one adult has been found to be food insecure (FAO et al., 2020).
[3] Country-level results are presented only for those countries for which estimates are based on official national data or as provisional estimates, based on FAO data collected through the GallupR World Poll, for countries whose national relevant authorities expressed no objection to their publication (FAO et al., 2020).
[4] For regional estimates, values correspond to the model predicted estimate for the year 2019. For countries, the latest data available from 2014 to 2019 are used (FAO et al., 2020).
[5] For regional estimates, values correspond to the model predicted estimate for the year 2012. For countries, the latest data available from 2005 to 2012 are used (FAO et al., 2020).
[6] Wasting, stunting and overweight under 5 years of age and low birthweight regional aggregates exclude Japan (FAO et al., 2020).

WFP has predicted that the number of people facing acute food insecurity in low and middle-income countries will nearly double to 265 million by the end of 2020 (WFP, 2020). Children are disproportionately affected, with likely intergenerational consequences for child growth and development. The pandemic's impact could have life-long implications for education, chronic disease risks and overall human capital formation (Martorell, 2017).

Approximately 600 million people fall ill through the consumption of contaminated food each year, with considerable differences among sub-regions; with the highest burden observed in Africa (WHO, 2020). More than 420 000 die every year, equating to the loss of 33 million Disability-Adjusted Life Years (WHO, 2015). Foodborne diseases disproportionately affect children, accounting for 40% of the foodborne disease burden. The consumption of unsafe foods cost low- and middle-income countries at least US$ 110 billion in lost productivity and medical expenses annually (Jaffee et al., 2019). With a large proportion of emerging human infectious diseases originating from animal sources (zoonotic diseases), there is also an increasing need to consider both animal and human health as a 'One Health' issue.

Devleesschauwer et al. (2018) report that food safety is a marginalised policy objective, especially in developing countries. The scale of foodborne outbreaks has become more extensive and has affected more countries since 2004 (INFOSAN, 2019), representing a constant threat to public health and an impediment to socio-economic development. However, updated data is not available regarding progress on reducing the incidence of foodborne diseases, presenting a major obstacle to adequately addressing food safety concerns (Devleesschauwer et al., 2017).

A recent innovation is the assessment of the adequacy, affordability and access to healthy diets included in the 2020 SOFI report (see Affordability, Table 1). If continually updated, this indicator could become a comprehensive proxy for monitoring progress on ensuring safe, nutritious food for all.

4. Interconnected food systems drivers that affect the access to safe and nutritious food for all

Several interconnected socio-economic and biophysical food systems drivers affect access to safe and nutritious food. Nutrition is both a health and food system concern. While some drivers of food systems are global (e.g. trade liberalization, climate change), others are regional, national and sub-national (e.g. conflicts). At the same time, many are differentiated across geographies (e.g. poverty, demography, technologies, land degradation). Below, we provide a brief overview of the main drivers, depicted in Figure 2. At the centre of the diagram is the food system, driven by socio-economic, supply chain and climate change and land-use drivers (depicted by the segmented circle). The drivers and the food system are influenced by globalisation and the global COVID-19 pandemic. In certain contexts, the drivers and the food system are also affected by conflict and fragility.

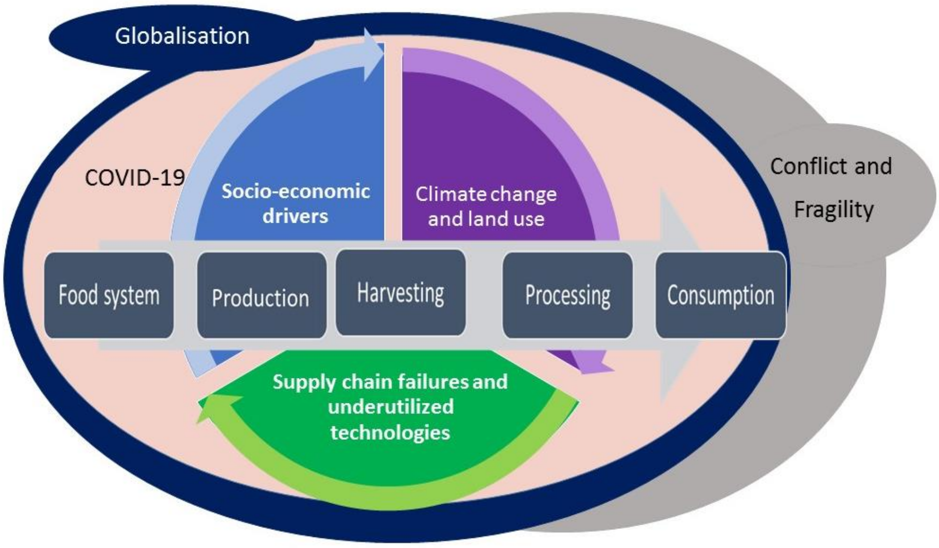

Figure 2: Food system context and drivers related to Action Track 1.

a) Socio-economic drivers

There is a vast array of socio-economic drivers that increase the global food demand, including population growth (Gerten et al., 2020), westernization of diets, increased food waste and overweight (including obesity) (Hasegawa et al., 2019), increased demand for animal-sourced foods in diets leading to increased demand of feed from arable crops (Mottet et al., 2017), and rapid urbanisation (van Vliet et al., 2017). These trends could cause a doubling of food demand by 2050 and will require a mean global increase of crop yields by over 30% from 2015 for a range of scenarios without climate change (FAO, 2018), a value lower than in previous projections that were assuming rapid economic growth (Alexandratos and Bruinjsma, 2012).

Globalisation. Lockdowns caused by the COVID-19 pandemic's of zoonotic origin have disrupted the production, transportation, and sale of nutritious, fresh and affordable foods, forcing millions of families to rely on nutrient-poor alternatives (Foreet al., 2020). International food trade can increase the diversity of diets and has established a global standard food supply, which is relatively species-rich in regard to measured crops at the national level, but species-poor globally (Khoury et al., 2019). Globalized food trade can also contribute to unsustainable water use (Rosa et al., 2019) and to land degradation (IPCC, 2019). The availability of cheap, high-energy, fatty and, sugary foods, the high price of nutritious fresh foods and the demand for more 'westernised' and often obesogenic foods increases the incidence of nutrition-related non-communicable diseases (NCDs) (Chaudhary et al., 2018). Nevertheless, globalized supply chains support the wide distribution of food, reducing shortages in import-dependent regions (Janssens et al., 2020), improving seasonal availability and often reducing food loss through technological advances in processing, packaging and storage (Zilberman et al., 2019).

Demography and urbanization. Although population growth has slowed globally, the population in the 47 least developed countries (mostly in Africa and Asia) is projected to double between 2019 and 2050. By 2030 the number of youth in Africa will have increased by 42 per cent. Nevertheless, in 2018, for the first time in history, the proportion of older persons (above 65) outnumbered children under five years – a trend that is predicted to continue (UNDESA, 2019). A growing proportion of older people will put a strain on the health system and change nutritional needs and dietary preferences. Ageing is accompanied by multiple physiological changes that affect diets and nutrition. This may include a lower sense of taste and/or smell; reduced appetite; poor oral health and dental problems; lower gastric acid secretion that may affect the absorption of minerals and vitamins; loss of vision and hearing and reduced mobility that may limit mobility and affect elderly people's ability to shop for food and prepare meals (WHO, 2015b). Moreover, by 2050, 68% of the global population could be urban, shifting the proportion of producers to consumers, changing consumption patterns (demand), driving land take and putting extra pressure on soil resources (Barthel et al., 2019, van Vliet et al, 2019).

Poverty and inequality. Poverty traps millions in poor nutrition, depriving them of their potential (Victoria, 2008). The prevalence of undernutrition and overweight adults are directly linked with relative food prices (Headey and Alderman, 2019). Healthy diets cost between 60 and 400% more than nutrient adequate and energy sufficient diets, respectively (FAO et al., 2020). More than 1.5 billion people cannot afford a nutrient-adequate diet and over three billion cannot afford even the cheapest healthy diet (FAO, 2020). Food system disruptions caused by COVID measures aggravate this situation (Headly et al., 2020). The out-of-pocket costs on health care spent by the poorest billion due to non-communicable diseases and injuries may be high, accounting for 60–70% of the public health care costs in low-income and lower-middle-income countries (Zuccala and Horton, 2020). In total, it has been estimated by the World Bank that under and malnourishment costs 3% of global GDP and overweight and obesity another 2% of GDP (Jaffee et al., 2018).

Women play a key role in multiple components of food systems and in decisions over food choices. Still, inequalities and barriers related to access to farming opportunities and services such as extension, credit, digital platforms for knowledge and market access constrain their participation relative to men (Quisumbing, 2011). Inequalities and barriers also affect the nutrition and health of minorities and off-farm and food system workers (including migrants and undocumented workers), which is a barrier to food system and societal transformation (CFS, 2020).

Conflict and fragility. Conflict can be an outcome and cause of food insecurity. Increased competition for natural resources leads to conflict and political fragility, exacerbated by the failure of traditional conflict resolution mechanisms to adapt to the new governance system of communities (SOFI, 2017). Government and political institutions (municipalities, legal systems and political party structures) have not adapted to the social fabric they presently govern, constraining development and also affecting development and the delivery of humanitarian aid.

While widespread famine has largely been eradicated, the nature of food crises has changed in recent times. FSIN (2020) reports that in the year 2019, about 135 million people were affected by crisis levels of acute food insecurity – an increase of 11 million people over the previous year (FSIN Food Security Information Network, 2020). While these crises are largely driven by conflict and economic downturns, they have a severe effect on the ability of people to access food. The provision of food transfers in emergency situations may alter the food preferences of communities, leading to changes in production and consumption past-conflict.

The largest numbers of acutely food-insecure people are in Africa, where extreme weather events in the Horn of Africa and Southern Africa have led to widespread hunger. In many parts of the world, armed conflicts, intercommunal violence and other localised tensions create insecurity (FSIN, 2020). Adverse climate events and stresses compound violence, displacement and disrupted agriculture and trade. Often those affected by crises flee to neighbouring countries, putting additional stress on the international humanitarian response system and on the food systems of the host countries. Women and girls are disproportionately affected by crises. Populations in crisis are disproportionally vulnerable to the impact of the COVID pandemic and have little capacity to cope with the health and socio-economic aspects of the shock (FSIN, 2020). WFP predicts that the number of people in LMICs facing acute food insecurity will nearly double to 265 million by the end of 2020 (WFP, 2020). Moreover, fragile and extremely fragile countries are disproportionally burdened by high levels of malnutrition compared to non-fragile countries (GNR, 2020).

b) **Supply chain failures and underutilized technologies affecting the supply of food**

The focus of food supply has shifted over the past few decades from ‘feeding the world’ to ‘nourishing the world’, but technological advancements still lack behind and many supply-side factors and failures affect the ability of the food system to sustainably (see Box 1) ensure access to safe and nutritious for all. In many developing countries (especially in Africa), supply chain failures and the under-utilization of technology are major constraints to the transformation of food systems to achieve this access. More than half of the calories consumed by humans are provided by three major cereal crops (rice, maize, and wheat) with a high-calorie output and current research investments are positively correlated with the energy output of crops, with a number of crop species (e.g. sweet potato, potato, wheat, broad bean, and lentil) under-researched relative to their contribution to healthy human nutrition (Manners and Van Etten, 2018). Orphan crops that are usually well adapted to low-input agricultural conditions have received little attention from researchers (Tadele, 2019). There is a growing recognition the development of perennial versions of important grain crops and grasses could expand options to ensure food and ecosystem security (Glover et al., 2010). Viable high biomass perennial grain crops could be further developed in agroecosystems that regenerate soils and capture other important ecosystem functions (Crews and Cattani, 2018). In the same way, this lack of research applies to some fruit and vegetable crops and local livestock local breeds, especially for small ruminants as well as fish.

Closing yield gaps on underperforming lands and increasing cropping efficiency would have considerable potential to meet an increasing food demand (Foley et al., 2011). One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield-enhancing seeds or cropping techniques, including mechanization, precision and digital agriculture. Moreover, a lack of access to extension services, to formal credit and cooperative membership often limits technology adoption, which is associated to positive household welfare effects (Wossen et al., 2017). While efficiency and substitution are steps towards sustainable intensification, system redesign may be essential for agro-ecological intensification through e.g. integrated pest management, conservation agriculture, integrated crop and biodiversity, pasture and forage, trees, irrigation management and small or patch systems (Pretty et al., 2018).

Currently, 25-30% of total food produced is lost or wasted (IPCC, 2019), equating to about one-quarter of land, water, and fertilizer used for crop production (Shafiee-Jood and Cai, 2016). Food losses and food waste occur throughout the food chain. They constrain food system sustainability due to their adverse effects on food security, natural resources, environment, climate and human health (e.g., toxic emissions from incineration) (Xue et al., 2017).

Plant biotechnologies are mostly used for fibre and animal feed, less often for food because of regulatory constraints and intellectual property rights barriers (Barrows et al., 2014). New and innovative technologies such as biotechnologies, precision agriculture and digital agriculture, alternative protein sources, underutilized food sources and the use of biomass for bioenergy and green chemicals need to be harnessed to improve food systems (reviewed below). However, such advances can also drive negative food system changes. For example, biofuel production based on grains from food crops, can drive up staple food prices and compete for land, exacerbating inequalities.

c) Climate change, land-use change and natural resource degradation

Climate change, including increases in frequency and intensity of extremes, has adversely impacted food security, affecting the yields of some crops (e.g., maize and wheat) and on pastoral systems in low latitude regions (IPCC, 2019). Climate change may aggravate food system problems in countries with delicate food security balances and relatively high levels of vulnerability to climate change due to the large-scale use of scarce resources (water, land, etc.) for feed and food production for exports, particularly in the case of mono cropping. Diets and cropping patterns may change as climate factors constrain the production of traditionally grown crops.

With increasing warming, the frequency, intensity and duration of heatwaves, droughts and extreme rainfall events are projected to increase in most world regions, increasingly threatening the stability of food supply (IPCC, 2019). For example, Gaupp et al. (2020) found an estimated 86% probability of losses across the world's maize breadbaskets with warming of 4 °C, compared to 7% probability for 2°C warming under business as usual conditions and without considering crop adaptation to climate change. Likewise, in a business-as-usual scenario, Alae-Carew et al's. (2020) review of predicted changes in environmental exposures has reported likely reductions in yields of non-staple vegetables and legumes. Where adaptation possibilities are limited, this may substantially change their global availability, affordability and consumption in the mid- to long-term (Alae-Carew et al., 2020; Scheelbeek et al., 2018). The nutritional quality of crops may also be affected by rising atmospheric CO_2 levels through reduced proteins and micro-nutrients contents (IPCC, 2019). Labour productivity is also likely to reduce with increasing temperatures (Watts et al., 2021).

The global food system (from farm inputs to consumers) emits about 30% of global anthropogenic greenhouse gases (GHG), contributes to 80% of tropical deforestation and is a main driver of land degradation and desertification, water scarcity and biodiversity decline (IPCC, 2019). About a quarter of the Earth's ice-free land area is subject to human-induced degradation and about 500 million people live within areas undergoing desertification (IPCC, 2019). By 2050 land degradation and climate change could lead to a reduction of global crop yields by about 10% with strong negative impacts in India, China and sub-Saharan Africa resulting in the displacement of up to 700 million people (Cherlet et al., 2018). Around 2 billion people live within watersheds exposed to water scarcity and this number could double by 2050 (Gosling and Arnell, 2016). Future agricultural productivity in the tropics is also at risk from a deforestation-induced increase in mean temperature and the associated heat extremes and from a decline in rainfall (Lawrence and Vandecar, 2015). Over half of the tropical forests worldwide have been destroyed since the 1960s, affecting the lives of 1 billion poor people whose livelihoods depend on forests and equalling a mass extinction event if tropical deforestation continues unabated (Alroy, 2017).

5. Transforming food systems is key to safe and nutritious food for all

Business as usual is not an option with the future of food and nutrition security in jeopardy (FOFA, 2018). Changing the path of our future will demand a structural transformation (transitioning from low productivity and labour-intensive economic activities to higher productivity, sustainable and skill-intensive activities) of food systems. This will require changes in the allocation of resources and research attention to factors beyond production will be necessary to transition to more sustainable patterns of production and consumption (CFS, 2020). More concerted effort is needed to coordinate activities, monitor progress more closely and greater accountability from all players across the food system. Priority should be given to the establishment of functional problem-solving institutions which address the core challenges facing each of the various components of the global food systems.

A global social compact (an implicit agreement among the members of a society to cooperate for social benefits) is needed to manage the demand and consumption drivers and harness science, technology and innovation to improve the sustainable production of enough food to ensure access to affordable, safe and nutritious foods for all (Figure 3). The sections below identify some of the levers for change.

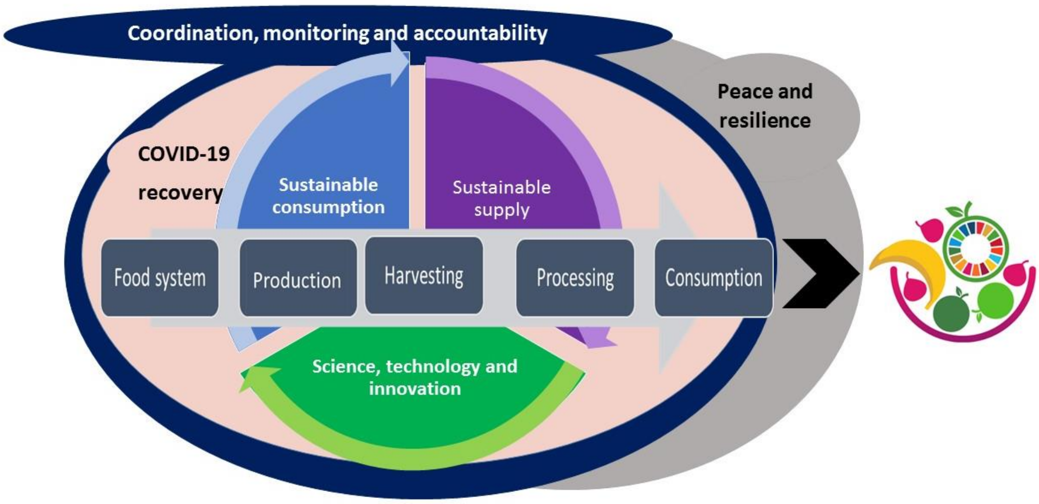

Figure 3: Food system transformations and solutions related to Action Track 1.

a) Coordination, monitoring and accountability

The ambition of the CFS is to be "the most inclusive international and intergovernmental platform for all stakeholders to work together in a coordinated way to ensure food security and nutrition for all" (CFS, 2021). Moreover, UN agencies and their partners have converged through various mechanisms for food security coordination (e.g. FSIN, the Global Network against Food Crises, expanding the SOFI collaborators, the CFS Global Strategic Framework etc.). Strengthening the global governance and accountability with regards to safe and nutritious food for all and to sustainable food systems is key for meeting the challenges ahead and will require cross-sectoral integration of policies. Yet, agriculture, development and trade policies that affect access to food, as well as other dimensions of food systems, are often dealt with in separate fora (De Schutter, 2013). Therefore, improved coordination, monitoring and accountability across the food system and among all stakeholders is necessary, including sharing knowledge, building capacity, better measurement, updated data, better modelling for foresight, scenarios and case studies and access to documented success stories. Food systems bring together elements from various sectors of society: agriculture, consumer affairs, food processing, health, trade, water and sanitation, women's and child welfare etc., challenging the sectoral organisation found in most countries.

If we are to transform food systems to ensure safe and nutritious food for all from sustainable food systems, a concerted effort is needed to develop a global compact – a non-binding agreement to encourage the transformation of food systems - and appropriate accountability of all stakeholders to monitor agreed-on transformation targets. Integrated, science-based policies (health and nutrition, food and agriculture, climate and environment) would allow to reinforce accountability both at national and international scales.

Advances in information technology and data science play an important role in enabling rapid assessment of situations, monitoring and decision making and adaptive learning. An integrated global food system model is needed as existing models (see Valin et al., 2014;

Khanna and Zilberman, 2012) do not have consistent global coverage and are not designed to assess the impacts of all the elements of food systems. Strengthening national policy scenarios and foresight is also necessary (Schmidt-Traub et al. 2019). Moreover, improved indicators of food systems (see SOFI, 2020) are required (see Sukhdev et al. 2018, Chaudhary et al. 2018 for examples), that could provide more holistic measures that capture the four elements addressed by Action Track 1, namely safety, nutrition, inequality and sustainability.

Rigorous global monitoring systems require global collaboration, updated information, and investment with significant returns. The monitoring of underlying systemic risks (perhaps using artificial intelligence or machine learning) as well as food system indicators is essential to identify threats/pressure at an earlier stage. A task force charged with global monitoring and data collection opportunities about agri-food systems, could provide a clearinghouse for the multiple (often duplicated) data held by UN agencies and public and private organisations. While some effort has been made to coordinate international actions to address crises, access to food requires targeted interventions for the most vulnerable. Two-way real-time and artificial intelligence applications to collect information of systemic risks and food systems and disseminate information to various stakeholders and beneficiaries are needed in last-mile and crises situations and in regions disproportionately affected by the Covid-19 pandemic food system disruptions. This could include driving supply side demand through food banks, social grants, subsidised meals, vouchers and other food assistance (including through e-commerce systems) (WFP, 2017).

b) Influencing food demand and dietary changes

There are several ways to reduce demand on the global food system both in the short and long-term and make nutritious foods more available and affordable (see Herrero et al., 2021). Some of these ways may be by accelerating demographic transitions, increasing incomes, reducing food losses and waste and changing diets.

Household food waste is proliferating in emerging economies and is likely to increase without deliberate effort to curb waste (Barrera and Hertel, 2020). Halving food losses and waste is a target of SDG 12 that could help feed more people, benefit climate and the environment and conserve water (Kummu et al., 2012; Searchinger et al., 2018; IPCC, 2019). This requires changes along supply chains (agricultural production, food processing, distribution/retail, restaurant food service, institutional food service, and households) through improved logistics and processing technologies, economic incentives, regulatory approaches and education campaigns (Read et al., 2020; Barrera and Hertel, 2020). The amount of food waste/loss varies greatly from region to region, therefore, context specific interventions are crucial (Hodson et al., 2021).

Private investment is needed to develop food processing, refrigeration, storage, warehousing as well as retail markets to reduce food waste. Vertical integration of food chains can shorten chains to the benefit of smallholder farmers while trade can expand market opportunities. Compared to a business-as-usual scenario, a combined scenario targeting under-nourishment while also reducing over-consumption and food waste would reduce food demand by 9% in 2050 (Hasegawa et al., 2019).

Because of the strong associations between female education, fertility and infant mortality, alternative education scenarios alone (assuming similar education-specific fertility and mortality levels) lead to a difference of more than one billion people in the world population sizes projected for 2050 (Lutz and Samir, 2011; Samir and Lutz, 2017) and could therefore reduce the rise in food demand.

Balanced diets, featuring plant-based foods, such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds, complemented by animal-sourced food produced in resilient, sustainable and low-GHG emission systems present major opportunities for adaptation and mitigation of climate change while generating significant co-benefits in terms of human health (Springmann et al., 2018; IPCC, 2019, Jarmul et al., 2020). ‘Healthy sustainable diets’ can be defined by optimization procedures (Donati, et al., 2016). However, most diets have trade-offs between nutritional values, affordability and environmental issues (Headey and Alderman, 2019).

Populations with a high prevalence of undernutrition and micronutrient deficiencies (Fanzo, 2019) benefit from increasing the consumption of animal-sourced products due to the bioavailability of key micronutrients (Perignonet al., 2017). Many highly nutritious foods may simply be unaffordable to poorer populations and displaced by cheap, nutrient-poor foods. Moreover, a balance is necessary between meeting the demand for diversified, nutritious and affordable food and minimizing the time and energy to prepare meals.

Policies can create incentives for change. Urgent public policy action is needed to create incentives for creating healthy, sustainable food systems and delivering safe, nutritious and affordable foods for all. Policy options could be used to manage food demand, shift consumption patterns, reduce the environmental footprint of food systems and ensure equity across the food system. A wide range of well-established and relatively inexpensive policy options and interventions are available for improving nutrition at the individual level (Buckhman et al., 2020; Hawkes et al., 2020; Bhutta et al., 2008). Policies that enable healthy food environments (such as sugar taxes, educational food labelling, reducing salt, the prohibition of trans-fats and a reduction in the use of high-fructose corn syrup) are core to improving food environments and limiting the burden of non-communicable diseases. Increasing the diversity of food sources in public procurement, health insurance, financial incentives and awareness-raising campaigns can potentially influence food demand, reduce healthcare costs, contribute to lower GHG emissions and enhance adaptive capacity.

Increased income can drive food demand, especially in terms of diversification away from staple crops to more diverse and nutrient-dense foods (diary, fruit, meat, nuts and vegetables). Likewise, income from social protection programmes can drive changes in dietary composition and quality (Alderman, 2016). The evidence reviewed in this paper indicates that subsidies on fortified foods can have positive nutritional effects, and in-kind transfers may limit food deficits during periods of currency or price volatility. The affordability of healthy diet can be improved with distribution of biofortified food in government schemes, cash transfers and nutrition programmes. However, price subsidies and in-kind assistance have complex interactions on markets and purchasing decisions with both negative implications and benefits (Alderman, 2016).

c) Shifting to more sustainable consumption and production within planetary boundaries

Nutrition outcomes in developing countries are affected by agriculture in several ways: as a source of food for household consumption and of income, through the role of food prices and agricultural policies, through the role of women’s employment in agriculture for nutrition, child care and child feeding and their own nutritional and health status (Gillespie and van den Bold, 2017).

There are more than 570 million farms worldwide, most of which are small and family-operated. Between 1960 and the turn of the century, average farm size decreased in most lower to middle-income countries, whereas it increased in most high-income countries (Lowder et al., 2016). The diversity of agricultural production diminishes as farm size increases (Herrero et al., 2017). Hence, as farm size increases, the production of diverse nutrients and viable, multifunctional, sustainable landscapes requires efforts to maintain production diversity (Herrero et al., 2019), which may lead to increased dietary diversity (Pellegrini and Tasciotti, 2014). Targeted policies that focus on the farmer may incentivise positive changes in landscapes, production diversity and dietary diversity.

In turn, diversification in the food system (e.g., implementation of agro-ecological production systems, broad-based genetic resources, combined with balanced diets) can enhance adaptation to increased climate variability under climate change (IPCC, 2019). Diversified agroecological systems can play a role in meeting health and nutrition goals while also reducing environment-related health risks caused by conventional agriculture through water and air pollution, and more specifically by pesticides, antibiotics and inorganic fertilizers (Frison and Clément, 2020). Compared to conventional agriculture, organic agriculture generally has a positive effect on a range of environmental factors, including above and belowground biodiversity, soil carbon stocks and soil quality and conservation, but it has weaknesses in terms of lower productivity and reduced yield stability (Knapp and van der Heijden, 2019).

Sustainable land management can bridge yield gaps and avoid deforestation while providing climate change adaptation and mitigation and land degradation co-benefits in croplands and pastures (Smith et al., 2020). This can be achieved by increasing soil organic carbon (Soussana et al., 2019), agroforestry, erosion and fire control, improved irrigation water and fertilizers management, heat and drought tolerant plants (Smith et al., 2020). For livestock, sustainable options include better grazing land management, improved manure management, higher-quality feed, and use of breeds and genetic improvement (Herrero et al., 2016). Under stringent global climate change mitigation policy, risks for food security would be increased (Hasegawa et al., 2018) through competition for land between food production, bioenergy and afforestation be it driven by local or foreign investment in land (Cotula, 2014). Nevertheless, increasing and valuing soil carbon sequestration on agricultural land would allow the reduction of these negative impacts by approximately two thirds (Frank et al., 2017). The large-scale deployment of bioenergy options such as afforestation, energy crops, carbon capture and storage has adverse effects on food security, but small scale projects with best practices may deliver co-benefits (Smith et al., 2020).

Increased demand for fish and seafood has threatened fisheries and the sustainability of ocean resources. Limited attention has been given to fish as a key element in food security and nutrition (HLPE, 2014). The aquaculture industry has emerged and increasingly fills the seafood supply gap to meet growing demand. Overfishing and relatively high waste (often due to catching under-sized fish) pose environmental and biodiversity challenges, threatening the long-term sustainability of fishery resources (HLPE, 2014). Additional challenges in production facilities such as marine feed supply, antibiotic use and in waste recycling need to be overcome to further develop aquaculture (Belton et. al., 2020). The impacts of activities such as oil drilling, energy installations, coastal development and construction of ports and other coastal infrastructures, dams and water flow management (especially for inland fisheries) affect aquatic productivity. The impact of these activities on the habitats that sustain resources (e.g. erosion and pollution) and the livelihoods of fishing communities - such as the denial of access to fishing grounds or displacement from coastal settlements - need to be carefully balanced with the growing demand for resources (HLPE, 2014).

Ensuring that food prices reflect real costs, including major externalities caused by climate change, land and water resources degradation and biodiversity loss is necessary to address artificial price distortions, reduce food waste, internalize the costs of externalities (including the public health impacts) and, at the same time, ensure decent incomes and wages for farmers and food system workers. However, a true costing of food would on average increase food prices. Food assistance policies that do not distort market and labour incentives can meet emergency food needs and improve access to food. Trade can help improve food availability, diversify diets and smooth price volatility (MacDonald et al., 2015).

d) Harnessing science and innovation and managing risks

Structural transformation to a more sustainable food system can bring about efficient and more rapid productivity growth through investment in research and development over the long term (Fuglie et al., 2020). Science should increasingly inform solutions and generate knowledge that is actionable to transform food systems and reach safe and nutritious for all (Arnott et al., 2020). Since policy agendas are largely set at national and local scales, the translation of global-scale scientific assessments into actionable knowledge at national and local scales is needed.

New and emerging technologies appropriate for one health, climate change adaption and mitigation, as well as disaster preparedness, could be game-changers for overcoming challenges and building system resilience. Still, their development should be guided by assessing their socio-economic, ethical and environmental impacts. Evidence-based assessment is needed of the risks and benefits associated with new technologies. Research is also needed to understand the diffusion modes of traditional knowledge and social innovations to support the conservation of common goods in more participatory, collaborative, inclusive and equitable ways.

Advances in science and technology such as genome editing (Khatodia et al., 2016), precision agriculture and digital agriculture (Basso and Antle, 2020), agroecology (Caquet et al., 2021), vertical farming, alternative protein sources (e.g. algae, insects), active packaging and blockchain technologies (Kamilaris et al., 2019), artificial intelligence and big data analysis (Wolfert et al., 2017) and whole-genome sequencing in food safety (Deng, Bakker, & Hendriksen, 2016) have the potential to meet a number of food system challenges. However, adapting these technologies to local conditions, making them accessible to farmers and retain much of the gain among consumers and the rural communities, is challenging, especially for developing economies, smallholder farmers and small businesses. Therefore, investments in science-based, participatory processes to map out realistic and equitable options are needed (Basso and Antle, 2020).

The importance of agriculture in producing non-food products (biofuels, chemicals, biomaterials) and in supporting ecosystem services is increasingly recognized in the context of the bioeconomy, which targets an increased reliance on renewable sources to address climate change (Zilberman, 2014). A circular bioeconomy envisions developments in industrial biotechnologies to generate co-products, by-products and waste recycling, thereby generating an overall increased input efficiency of agricultural systems producing bio-based products in diversified agroecological landscapes (Therond et al., 2017; Maina et al., 2017).

Global and regional data sharing systems (including machine learning) based on the FAIR principles (findable, accessible, interoperable and reusable data) (Mons et al., 2017) can advance food systems knowledge and enhance the accountability of all stakeholders of the food systems. The use of open-source platforms for data and code sharing should be encouraged to stimulate global learning.

Table 1 shows the fragmented nature of data related to this Action Track, with global reports focussing on single elements. National nutrition assessments are costly and infrequently conducted, constraining the monitoring of progress and the impact of interventions at scale. Even where the indicators have been included in the SDG indicator set, current data on foodborne diseases, some malnutrition indicators (such as wasting), poverty and inequality data are not updated or are missing comparative baselines. Very few sex-disaggregated indicators are available, constraining analysis and the tracking of progress towards gender equality. The upcoming *Countdown on Food System Transformation* mechanism may support the effort to bring together various indicators in a systematic framework for monitoring and evaluation.

Increasingly, risk assessment tools will be needed to drive food safety policy and standards and to optimize surveillance, detection and early warning systems of zoonotic diseases for both the formal and informal sectors (Di Marco et al., 2020) and crop diseases (Mohanty et al., 2016). Modernizing our food safety and biosecurity risk management systems is an integral part of the food system transformation required to meet food and nutrition security needs. This will require a science- and risk-based approach for production of safe food within a food systems approach.

6. Concluding messages

Action to address safety, malnutrition, poverty and inequality, as well as climate and environmental issues, through food systems transformation will undoubtedly bring large health, social, economic, ecological and development co-benefits and savings on public expenditure while supporting several interrelated SDGs. A range of priority actions to speed up progress towards international targets and scale up the solutions proposed in section 5 can be taken in the short-term, based on existing knowledge, while supporting longer, more sustainable responses with significant co-benefits. Future actions will have to be iterative, coherent, adaptive and flexible to maximise co-benefits and minimise trade-offs. Many recommended policy changes and interventions have win-win potential for food security, health and the environment. However, other choices will have adverse or unintended impacts on the interconnected drivers affecting food systems and their outcomes.

Adopting a whole-system approach in policy, research and monitoring and evaluation is crucial to manage trade-off and externalities from farm-level to national scales and across multiple sectors and agencies. Ultimately, context matters and comprehensive national action plans are crucial for setting out actions suited to the particular economic, agricultural, social and dietary preferences of the particular nation. Careful consideration of the trade-offs and co-benefits of any actions will be necessary at different levels (sub-national, national, regional and global). Likewise, there may be ‘winners’ and ‘losers’ in each action adopted to transform to more sustainable food systems. The losses and gains will vary depending on the context but could include a loss of income and livelihoods across the food system - such as would happen with a reduction in the production and consumption of animal-sourced foods or the implementation of seasonal banning of fishing to allow for the regeneration of marine resources. Such shifts could lead to the marginalisation and stigmatisation of people in the food system who have not yet been considered as vulnerable or marginalised.

Including all stakeholders in discussions, policy-making and evaluation processes is essential for the inclusive transformation of food systems at all levels. Strengthening collaboration between research, the private sector and policy-makers is pivotal in creating food environments and guiding consumers’ choice in practical and implementable ways. The elaboration and implantation of National Food Systems Plans will be essential instruments for bringing the relevant public sectors and diverse stakeholders together.

Adaptive learning and new knowledge must be shared globally to accelerate our capacities to meet existing and future challenges. Substantial public, private and international investment is necessary to faster progress towards the targets and recover from the setbacks of the Covid-19 pandemic. Improved international cooperation and coordination of the food system is necessary, including the establishment of a comprehensive monitoring, evaluation and early warning system with comprehensive indicators, transparency and commitments of all stakeholders. For example, bringing all the indicators in Table 1 into one annual food system monitoring report would facilitate cooperation among UN agencies. Creating a food system compass could be based on bottom-up pathways developed at national scale to reach food systems targets supporting an ensemble of global scale and integrative food systems models. Establishing such a system will require capacity development for comprehensive foresight, scenario and predictive modelling to better understand uncertainties, trade-offs and impacts of various change pathways. More research is needed to identify the most adequate, affordable, healthy and sustainable diets across different contexts. More frequently collected nutrition and poverty data are necessary to provide more data points for monitoring change and progress. Innovative indicators such as the affordability of adequate, nutritious and healthy diets are vital to bring the three elements of safety, nutrition and inequality together.

The costs of acting and not acting on the key drivers of diet and food system change and the impact of these changes and shits are required for effective decision making. For example, the cost of nutrition interventions is relatively low per unit compared to the long-term losses in human potential and incomes for poorer people. The cost of NCDs to the health system is significantly higher per unit that the cost of scalable interventions. Rapid reductions in anthropogenic GHG emissions across all sectors can reduce the negative impacts of climate change on food systems in the long term (similar for land and for water restoration).

Research and technology advances are essential to solve critical constraints and offer many opportunities to improve productivity, food safety and reduce food losses and waste, as well as GHG emissions. Capacity-building, property rights, technology development, transfer and deployment and enabling financial mechanisms across the food system can support livelihoods and increase incomes. Greater cooperation with regard to trade could overcome constraints and barriers.

Safe and nutritious food for all requires a transformation of food systems, changing both supply and demand of food in differentiated ways across world regions: bridging yield gaps and improving livestock feed conversion, largely through agro-ecological practices and agroforestry, deploying at scale soil carbon sequestration and agricultural greenhouse gas abatement, reducing food losses and wastes, as well as over-nourishment and changing the diets of wealthy populations. Global food systems sustainability also requires to halt the expansion of agriculture into fragile ecosystems while restoring degraded forests, fisheries, rangelands, peatlands and wetlands.

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