Chapter

Global Food System Transformation for Resilience

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Abstract

Our world is incredibly diverse and beautiful, everything we do has an impact on the environment, and our actions are intertwined. Recognizing how our actions affect the Earth on a global scale means, we need to change the way we do things. We must ensure that the value society derives from our actions comes at a low cost to the environment. A sustainable strategy to establish a resilient food system is to ensure that human demand for the Earth's resources for food is kept within the supply of these resources. While more than 800 million people worldwide suffer from chronic malnutrition, our food systems emit roughly a third of all greenhouse emissions. Also, over 80% of our biodiversity gets lost. Hence, scaling up food system is simply not an option to feed nine to ten billion people by 2050 as we will need to produce more food in the next four decades than all of history's farmers have harvested in the last eight thousand years. Therefore, rather than upscaling, the global food systems require transformation. Four critical aspects of this transformation include: "Boosting the small; Transforming the Big; Losing Less; and Eating Smarter." Examining these four areas more deeply, it becomes evident that, while new technology will be critical to the transformation, government involvement, as well as better financial and behavioral change from residents and consumers, will be required. This chapter focuses on these four pillars that make up the global food system transformation for resilience.

Keywords: food system, resilience, livelihoods, global food system transformation, sustainable diet, boosting small, losing less, eating smarter

1. Introduction

Food, a crucial element of our everyday lives is essential to our health and well-being. It forms a part of our identity and culture, and a key component, if not the focal point, of many of our social activities. As a result, it is no surprise that food security (i.e., the availability of food for people) has shaped and continues to shape nations' economies, politics, and histories [1]. However, the current food production system and consumption create a variety of diseases, wreak havoc on the ecosystem, and obliterate the planet's safe operating zone. Transforming our food systems would help achieve a number of development objectives; including health, inclusion, safety, sustainability, efficiency, and resilience (HISSER) [2]. The existing food system is failing while also damaging the environment and jeopardizing human health [3]. Goals 2 (end hunger), 3 (improve health), 8 (decent work

and economic growth), 12 (responsible consumption and production), 13 (climate action), 14 (life below water), and 15 (life on land) are all deeply intertwined with the global food system [3]. Global food system is made up of several types of structures, such as contemporary, mixed, and traditional food systems. To achieve long-term sustainability, deep transformations in food system design are required. Widespread adoptions of sustainable agricultural techniques, environmental conservation and regeneration, dietary adjustments, decrease of food loss and waste, and advances in economic and social justice along food supply chains are a few examples [4].

Food system encompasses all processes, players, and activities related to food production and consumption, from growing and harvesting to transporting and consuming [5]. According to the EC FOOD 2030 Expert Group [6] Food systems "encompass the entire range of actors and their interconnected value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry, or fisheries, as well as parts of the broader economic, societal, and natural environments in which they are embedded, ". This includes the environment, comprehensive networks of people, processes, infrastructure, and institutions, as well as the consequences of their actions on our society, economy, landscape, and climate [7, 8]. (See **Figure 1**). Food environments shape consumers' capacity to obtain food and influence dietary preferences by forming the physical, economic, and social context of their interactions with the food system [10]. Food system structure is not static; rather, its components are influenced by a number of biophysical and socio-economic factors. Therefore, the importance of concentrating not only on individual elements but on all elements of a food system and the various feedback processes between them is crucial, especially in view of global environmental change [4].

According to Bart de Steenhuijsen et al. [11], the resilience of food systems is understood as the ability of food systems to achieve desired results in the face of shocks and stressors. The concept of resilience has its origins in ecological stability theory which explains the ability of ecosystems to return to their original state

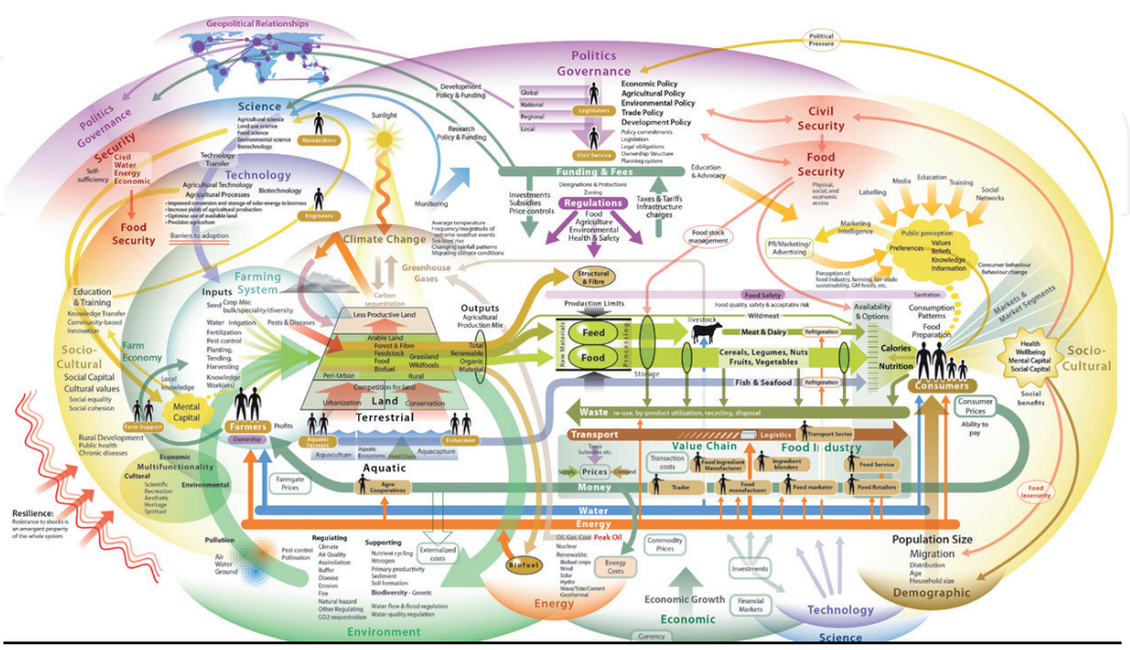

Figure 1.
Complexity of global food systems and multiple interactions source: ShiftN; Belchior., et al. (2016); [9].

after a disturbance [12], as cited in [11]. Increasing resilience, as defined by the IPCC [13], is the ability of a system and its components to anticipate, cater, absorb, or recover from the effects of a dangerous event in a timely and efficient manner, including by ensuring the maintenance, restoration, or improvement of the system's essential structure and functions is a primary component of adaptation. With regard to food systems, resilience thinking has been applied to address the complex interactions between nature and society, with an emphasis on maintaining human wellbeing within planetary boundaries [14]. Sustainable food system is one that provides food security and nutrition for all in such a way that the economic, social and environmental foundations for creating food security and nutrition for future generations are not compromised. This means that a sustainable food system must be economically viable, have broad benefits for society and have positive or neutral effects on the natural environment. Itebinul, et al. (2021) viewed a sustainable food system as one that is capable of providing adequate, healthy, safe and affordable nutrition, which is the basis for a healthy life and the prerequisite for every individual's successful participation in society and, at the same time, a clean and healthy planet that recognizes it as the basis of all life on earth.

A food system must be viewed in the context of rapid population growth, urbanization, growing prosperity, changing consumer habits and globalization, as well as climate change and the depletion of natural resources. To achieve the SDGs, the global food system must be transformed so that it is more productive, more inclusive of poor and marginalized populations, environmentally sound and resilient, and is able to provide healthy and nutritious food to all. The focus on increasing food production is now deeply anchored in food policy. However, food security and sustainability are more than just the production, provision and consumption of food. Environmental sustainability and resilience of food systems are essential to ensure food security for all by 2050. Developments in food systems have produced many positive results, especially over the past three decades in developing countries. These outcomes include expanding non-farm employment opportunities as the food industry evolves and expanding food choices beyond local staples, thereby satisfying consumer preferences for taste, shape and quality. However, the associated rapid structural change has also led to increasing and considerable challenges, with potentially far-reaching consequences for food security and nutrition. These include the many highly processed, high calorie, and low nutrient foods that are widely available and consumed today; limited access of small producers and agribusinesses to viable markets; high levels of food loss and waste; increased cases of food safety and health problems in animals and humans; and increased energy intensity and ecological footprint associated with the elongation and industrialization of food supply chains. Hence, a better understanding of how different food systems work is critical to ensure that these systems evolve in such a way that their negative effects are minimized and their positive contributions are maximized. A food systems approach is a way of thinking and acting that looks at the food system in its entirety, taking into account all of the elements, their relationships, and their implications. It takes into account all relevant causal variables of a problem and all social, environmental and economic effects of the solutions in order to achieve transformative systemic changes.

However, there is growing recognition that long-term food security cannot be achieved without improving the resilience of food systems [15]. This requires producers and consumers to be able to adapt to unexpected changes in the (natural and political) environment through diversification strategies for livelihoods, nutrition and markets, which enable flexible and timely responses to global change [16]. In order to ensure resilience and a functional link with the circular economy, these strategies must also contribute to the long-term satisfactory functioning of the food

systems by providing nutritional, environmental and livelihood benefits in the production, provision, consumption and disposal/recycling of food provide different levels and across different types of food systems [16]. The main reason for the growing interest in the transformation of the food system has to do with the recognition that the multiple problems of poverty, malnutrition, environmental degradation and climate change are combined and cannot be remedied with individual interventions, but instead a fundamental change in the dynamics of food systems [17, 18]. In response to the triple challenge of malnutrition, hunger, micronutrient deficiency and obesity, comprehensive strategies must be defined to support the availability, access, safety, affordability and attractiveness of food.

Food systems transformation occurs when significant and intentional changes are made to any of the food system's components [19], resulting in increased resilience to causes of food insecurity and malnutrition, as well as higher affordability of healthy diets [7]. The urgent need for this transition has become a focal point of a worldwide discussion aimed at tackling some of the most pressing issues facing sustainable development, particularly the challenge of eradicating hunger, food insecurity, and malnutrition in all forms by 2030. A number of significant drivers have had progressively detrimental consequences on food security and nutrition outcomes throughout the world as a result of their impact on food systems. Conflict, climatic variability and extremes, and economic slowdowns and downturns, which are exacerbated by poverty and inequality, are all major factors. Despite these obstacles, if food systems are transformed to be more resilient to the identified drivers, and incentives are put in place to encourage food systems to provide affordable healthy diets in a sustainable and inclusive manner, they can become a powerful driving force in ending hunger, food insecurity, and malnutrition in all forms – and put us on track to achieve SDG 2, while also triggering important synergies for other SDGs [7]. This transformation of food systems necessitates innovative systemic changes, which must be accompanied by an enabling environment of institutions, policies, laws, regulations, and investments that are aligned and complementary across sectors [20]. In addition, to achieve the necessary transformation, small-scale gradual transitions and larger-scale structural changes to institutions, laws, and standards are required – all in a coordinated and integrated manner [21].

The World Research Institute's (WRI) study on how to create a sustainable food future identified 22 solutions that are divided into five broad categories: (1) reduce demand for food and other agricultural products; (2) increase food production without expanding agricultural land; (3) protect and restore natural ecosystems; (4) increase fish supply; and (5) reduce GHG emissions from agricultural production [22]. All of these measures must be implemented simultaneously to close these gaps [22]. Similarly, FAO et al., [7] identified six pathways to global food system transformation, including integrating humanitarian development and peace building policies in conflict-affected areas; scaling up climate resilience across food systems, strengthening the resilience of the most vulnerable to economic adversity; intervening along food supply chains to lower the cost of nutritious foods; tackling poverty and structural inequalities, ensuring interventions are pro-poor and inclusive; improving the food environment and influencing consumer behavior to encourage eating patterns that are good for human health and the environment. However, Richardson, Christensen, and the Sustainability Science Center [23] identified four crucial parts of this transformation: Boosting the small; Transforming the big; Losing less; and Eating smarter, all of which require new technology, government intervention, and behavioral change from citizens and consumers. It is these four pillars of global food system transformation that are discussed in this chapter.

1.1 A brief overview of our food System's history

Historically, Lynda [24] identified six food systems, namely: Food System 1 (hunter-gatherer approach to food); Food System 2 (transition from nomadic life to settlement and development of agriculture); Food System 3 (selection of desirable traits in plants and animals and optimizing of food production for taste, climate, and pest protection); and Food System 4 (agricultural adaptation based on automation, fertilizer, and pesticides, with the selection of higher yielding and pest resistant plants); Food System 5 (convenience, shelf life stability, logistics, and economic optimization). Food system 5 has posed numerous challenges, including marginalization of primary growers, producers, and ranchers, limiting consumer purchasing decisions, increased inequity and lack of parity for critical stakeholders, and, most importantly, the production of processed foods lacking essential nutrients for human health [24]. "As a result, the time has come to rethink our existing food system and usher in humanity's sixth Food System - one that is optimized for the integrated and comprehensive priority of planetary and human health." This system will need to take into account the interrelationships between all stakeholders in the food system, as well as a holistic view of farm viability, sustainable ecosystems, healthy communities, and justice, and equity - features and parts of food production that have been overlooked by food systems 5″ [24].

1.2 The need for change in the food system

Despite the global efforts toward ending food insecurity and all forms of malnutrition by 2030, food insecurity is on the rise [25] because there has been no progress toward achieving either the SDGs target of "ensuring access to safe, nutritious, and sufficient food for all people all year round or eradicating all forms of malnutrition" [7]. "720-811 million people in the globe suffered hunger in 2020, up to 161 million higher than in 2019," according to the 2021 issues of the state of food security and nutrition in the world study. In 2020, about 2.37 billion people lacked appropriate food, an increase of 220 million individuals in only one year" [7]. Hence, considerable efforts and attention on increasing food production at both the global and regional levels notwithstanding, around 3 billion people in every part of the globe lack access to a good diet due to the high cost of a healthy diet, chronic poverty, and widening inequalities [7]. These factors place the entire world at a "critical juncture," not only in terms of overcoming the enormous challenge of food insecurity, ending hunger, and eliminating all forms of malnutrition, but also in terms of exposing the global food system's fragility and the need to build food system resilience through transformation [7]. "The current covid-19 epidemic and other zoonotic illnesses, the negative effects of climate change (e.g. frequent and severe floods, droughts, storms), pests and plant disease (e.g. locusts), conflicts and wars illustrate how vulnerable food systems are," according to LEAP4FNSSA [26]. These call for urgent need for transformation to systems that can adapt to future shocks, such as pandemics and natural disasters [27].

Similarly, the current status of agricultural and food systems has been dubbed a "triple catastrophe," in which climate change, undernutrition, and obesity are wreaking havoc on human and planetary health [25]. Unhealthy eating habits have made dietary hazards the third greatest cause of mortality worldwide, and malnutrition a prominent cause of healthy life years lost [28]. Non-communicable diseases (NCDs) caused by poor diet, such as cardiovascular disease, diabetes, and certain malignancies, are on the rise worldwide, with an estimated 40 million deaths per year [29]. These trends are compounded by the fact that when people

become wealthier, their diets move substantially toward more sugar, animal, and fat products, at the expense of traditional and often more sustainable diets.

The global food system, particularly food production, is a key driver of global environmental change, causing huge changes in terrestrial and marine ecosystems. More than 70% of the world's ice-free land is directly affected by human activity, and estimates suggest that up to one-third of terrestrial net primary production is consumed for food, feed, wood, and energy ([30] a). More terrestrial, coastal, and offshore area is being taken up by aquaculture [31], and forecasts suggest that without substantial fisheries reforms, over 80% of world fish stocks would be overfished and below critical biomass by 2050 [31]. Industrialized agriculture is highly reliant on external inputs, contributes to chemical pollution through the use of pesticides and herbicides, alters nitrogen and phosphorous cycles through synthetic fertilizer additions, and has an impact on freshwater stocks through irrigation [32]. It is also energy demanding, contributing to climate change by producing about one-third of all greenhouse gases, including methane [33].

To secure a more equitable and sustainable future, it is clear that a significant structural transformation in food production and use is required [3]. The nature of the sustainability challenge necessitates a reconsideration of previously dominant ways of doing things and understanding the world [3] in order to make room for knowledge systems that can deal with accelerating change, increasing complexity, contested perspectives, and inevitable uncertainty.

1.3 Food systems transformation: Drivers and barriers

The current spike in hunger and halting progress in eliminating all types of malnutrition is due to conflict, climatic variability and extremes, and economic slowdowns and downturns (exacerbated by the COVID-19 pandemic). These key drivers are distinct, but not mutually exclusive, in that they wreak havoc on food security and nutrition by causing many, worsening effects across our food system [7]. Conflicts, for example, have a detrimental impact on nearly every part of the food system, from production, harvesting, processing, and transportation to raw material availability, finance, marketing, and consumption. Direct repercussions can include the loss of agricultural commodities and livelihoods, as well as major disruption and restriction of commerce, goods, and services, with severe implications for food supply and costs, especially healthful foods. Similarly, climate fluctuations and extremes have a wide range of repercussions on food systems, which are becoming more pronounced. They have a detrimental impact on agricultural productivity as well as food imports as countries strive to compensate for lost local output. Climate-related disasters have the potential to disrupt the whole food value chain, resulting in severe effects for sector growth and the food and non-food businesses [7].

Economic slowdowns and downturns, on the other hand, largely influence food systems by reducing people's access to food, including the cost of healthy eating, since they result in increased unemployment and lower salaries and incomes. This is true whether market fluctuations, trade conflicts, political turmoil, or a worldwide epidemic like COVID-19 are to blame. These significant global drivers and underlying structural variables impair food security and nutrition through interrelated and cyclical impacts on other systems, including environmental and health systems, in addition to their direct effects on food systems [7].

When the food system is transformed by making it more resilient to climatic variations and extremes, war, and economic lag and downturns, it becomes a major driving force in the elimination of hunger, food insecurity, and malnutrition in all forms for all people [7]. Therefore, objective of food system transformation is to create a future in which everyone has access to a healthy diet that is produced in a

sustainable and resilient way, restores nature, and produces just and equitable livelihoods [34]. Considering the diverse perspectives and arguments toward achieving food system transformation ([35], 202; [36–38]), in the following sections we discuss global food system transformation for resilience based on the concept of the four pillars of food system transformation of "Boosting the Small; Transforming the Big; Losing Less; and Eating Smarter" developed by Richardson, Christensen and Sustainability Science Center, University of Copenhagen, Denmark.

2. Boosting the small

There is a risk that two constituencies may be left behind as food systems change. On the one hand, there are approximately half a billion self-employed smallholders in rural areas, including farmers, shepherds, and fishermen [39], and approximately two billion men and women who work in the informal economy and are currently unable to secure economic access to basic food supplies [40, 41]. Healthy nutrition, on the other hand, is out of reach for at least three billion people in both the global north and the global south [42, 43]. This number has risen dramatically as a result of the COVID-19 problem [44]. In the future decades, resolving the contradiction between enhancing smallholder livelihoods and guaranteeing an adequate and healthy food supply will be critical to boosting the food system's overall resilience [16].

2.1 Increasing know-how

By 2050, the globe will need to feed an extra 2 billion people, with Africa hosting the majority of them. Despite the fact that Africa possesses over 200 million hectares of uncultivated land, yearly food imports are predicted to rise from $35 billion to $ 110 billion by 2025 [23]. To strengthen the resilient of the people living there to the effects of climate change, the continent has huge food production potential that needs to be harnessed. Farmers with only a few hectares of land are critical to feeding the future population. There are anticipated to be 750 million smallholders in the globe by 2030. To begin with, these farmers require better understanding about best practices, both in terms of increasing productivity and in terms of improving soil quality. According to FAO et al., [7], a best practice is one that has been demonstrated to work, has produced positive outcomes after a thorough examination, and is thus suggested as a model for scaling. This entire compendium, or all of these "best practices," allows farmers to reap a bumper crop [23].

2.2 Better financial access and livelihood adaptation

Inequality affects access to food. Around 80% of the world's poorest people reside in rural regions, where poverty rates are three times greater than in cities [7]. Policies, investments, and legislation are needed to address the underlying structural inequities that disadvantaged communities in rural and urban regions face, while also boosting their access to productive resources and new technology can help to alleviate severe poverty and structural inequalities by hastening the transformation of pro-poor and inclusive food systems. Lack of access to productive resources and inadequate market integration worsen rural poverty among smallholders in Southeast Asia, which is compounded by climate-related and economic shocks, as well as frequent outbreaks of plant and animal diseases [45]. In this region, public-private producer partnerships (PPPPs) have aided the integration of poor smallholders into the food value chain, which offer opportunities to alleviate

poverty and structural inequalities, especially when bolstered by improved governance mechanisms and multi-stakeholder platforms [7].

The adaptation process, which the IPCC describes as "the adaptation to the present or predicted climate and its impacts," is the primary way of mitigating the danger of climate change to rural livelihoods. Adaptation in human systems aims to reduce or eliminate damage while also taking advantage of possibilities. The skills, assets, and activities required for a livelihood that allows individuals to reach a minimal degree of wellbeing are referred to as livelihood. Climate change poses a danger to these livelihoods, necessitating systematic and transformational adaptation, which in turn need more and inventive funding. As the food system transforms, adequate finance is vital to achieving successful transformational adaptation for resilient livelihoods in the agri-food industry. This entails not just increasing the availability of financial resources, but also ensuring that those resources are available to individuals who need them and that suitable finance channels are employed to make them available.

Hence, "dismantling barriers to just and equitable livelihoods, such as lack of access to productive resources requires institutional changes, policy support and investment to empower those whose livelihoods are tied to food systems" [34]. As a result, policy solutions should consider the role of women in agri-food systems and guarantee that their unique requirements as household food security keepers, food producers, farm managers, processors, merchants, wage employees, and entrepreneurs are effectively met [7]. More so, Youth, especially in less developed countries, where more than 80% of youth reside [46], provide a significant potential for revolutionary change in food systems [47]. Young people (aged 15-24) account for around 16 percent (1.2 billion) of the world's population, and as prospective young entrepreneurs, they represent the future agents of change. Unlocking their entrepreneurial and creative potential requires strengthening their skills and agency through training, positive role models, and mentorship [48]. As a result, particular initiatives to increase young people's access to productive resources, financing, markets, and connections, as well as decision-making, are required as part of larger efforts to encourage responsible investing. Social conventions that may inhibit rural young people, particularly vulnerable groups such as young women and indigenous youth, from taking advantage of new possibilities must also be addressed [49].

2.3 Sharing economy

The sharing economy has long existed in many regions of the world, but the widespread availability of low-cost Android devices has created new possibilities for small farmers to hire a tractor for a certain period of time, giving them access to automation that would otherwise be prohibitively expensive. In the crop production cycle, mechanization is crucial for farmers. It has the potential to boost and affect farmer yields and profits in a variety of ways [23].

2.4 A more fair trade system through good governance

Many innovative strategies can help smallholder farmers enhance their agricultural output. However, reforms to the trade mechanisms are also essential to truly overhaul the food systems. Farmers in developing nations compete with industrialized countries' subsidized produce. Subsidies from wealthier countries lower prices in poorer countries, discouraging domestic manufacturing. At the same time, agricultural products are subject to high tariffs of up to 50% in both north–south and south–south commerce. This complicates things even further. It will be significantly more difficult for developing nations to disrupt trade patterns as a result of

this [23]. Smallholders require more knowledge and green expenditures in order to enhance their output in a sustainable manner. As a result, maintaining excellent governance through a fair trade system is critical to achieving a beneficial food system transformation. Fanzo et al. [34] "proposed a working definition of governance for positive food system transformation as the mode of interaction among the public sector, private sector, civil society and consumers to identify, implement resource and monitor solutions for achieving healthy sustainable, resilient, just and equitable food system without leaving anyone behind".

2.5 Boosting innovative and transformative entrepreneurs

Given that the current industrial food system is responsible for greenhouse gas emissions, environmental and soil degradation, animal welfare abuses, public health, and labour crises, a wide range of business efforts are required to assist in the resolution of the various problems that the food system faces. Training, promoting, and engaging young innovative and transformational youth and women to take advantage of more mindful and holistic food chain management that considers the connections between people and parts at every level and how they cannot be improved but can be transformed [24]. The rising emphasis on food system transformation by academic institutions and corporate organizations' evaluation of the influence of stakeholders on their business has resulted in a massive rush of innovation and entrepreneurs into the food system [24, 50].

As a result, these new business groups will require assistance in developing and scaling solutions that challenge / distort existing conventional practices and legacy players throughout the food and agriculture value chain, thereby creating value that is based on both the planet's capacities and consumer needs. These revolutionary technologies and entrepreneurs encounter hurdles in their attempts to disrupt the existing actors in the food and agricultural systems, but their novel solutions are more sustainable for planetary resources and have high customer preference and demand. Lynda, [24] also advocated for productive collaboration between bigger incumbents and smaller businesses that does not dilute or eliminate the fundamental value created by innovators. Huge sums of money have been invested in these entrepreneurs all across the world, and they are projected to increase as the new food system matures and iterates.

3. Transforming the big

Large, multinational food firms confront sustainability difficulties that are vastly different from those encountered by smallholder farmers. They must, figure out how to develop in a sustainable manner. However, they are also confronted with the task of revamping an existing production plant that has a significant environmental impact. Agriculture, along with transportation, was one of the most essential activities not included in the Kyoto Protocol's quota system. As a result, agriculture has been overlooked in many efforts to reduce greenhouse gas emissions [23].

3.1 Goal-based planning and shared vision

In order to determine priority guidelines and desired objectives in all subject areas of the food system transformation, a shared vision refers to integrative, participative procedures [7]. The agriculture industry in Denmark is responsible for around 20% of total Danish greenhouse gas emissions. The majority of these emissions originate from livestock, with cows accounting for 63% and pig

production accounting for 32%. These astounding figures are mostly attributable to two additional greenhouse gases: nitrous oxide (laughing gas) and methane, rather than CO_2 emissions from equipment. Nitrous oxide (laughing gas), which is mostly emitted by liquid manure and fertilizers, has a greenhouse impact over 300 times larger than CO_2. Methane has a 25-fold greater warming effect than CO_2, and it is also released by manure. Burps from ruminants like cows and sheep also release methane into the atmosphere. It is critical to address these various emissions in order to meet both the Paris Agreement and the SDGs [23].

Therefore, Denmark's cattle industry has set lofty ambitions for the future: Danish Crown, Europe's largest pork producer, plans to cut greenhouse gas emissions in half by 2030 and achieve CO2 neutrality by 2050 [23]. This might be accomplished by implementing mixed agriculture, biogas usage, sustainable slaughterhouse management, and individual animal treatment, all of which are necessary for reducing environmental and climate consequences. Individualizing treatment for each animal not only extends the animal's life expectancy, but it also allows for more sustainable antibiotic use [23].

3.2 Sustainable soils

Another issue that plagues industrial agriculture is soil deterioration. Land use, climate, water usage, biosphere intensity, and pollution are the key environmental systems and processes that interact with the food system, and they all alter and are impacted by the Earth system [34]. Agriculture dominates global land usage, with 14.5 billion hectares of arable land used for cultivation and 3.5 billion hectares used for grazing ([34]; Mboro et al., 2019). Around 12.5 percent of agriculture in Europe is thought to be subjected to moderate to severe erosion. This amounts to an area greater than Greece's whole territory [23]. According to FAO and ITPS [51], a third of the world's peaks have been degraded due to highly chemical-induced agriculture, global warming, and deforestation, leaving just sixty years of topsoil on the planet. As a result, the present food and farming system has damaged the topsoil where 95% of our food is grown, necessitating quick action to transform the industrial agricultural production paradigm into regenerative agriculture [24].

Regenerative agriculture, according to Lynda [24], is a farm and food system rehabilitation and conservation approach that focuses on regenerating the topsoil, strengthening the health and vitality of agricultural soil, increasing biodiversity, improving ecosystem services, improving the water cycle, increasing the focus on climate change resilience, and supporting bioequestration. Composted manure created from biodegradable waste is used in regenerative agriculture, as is reusing as much agricultural waste as feasible. Deforestation and land conversion must be stopped in order to minimize greenhouse gas emissions, enhance water cycles, and safeguard biodiversity. This operation has the ability to dissolve between 200 and 300 gigatons of carbon dioxide [30, 34].

3.3 Closed-system farming

Precision farming under controlled conditions allows for a more personalized approach to plant care. Precision farming is not just for indoor farming anymore, as new types of sensors and data processing are being developed. As a result, digital agriculture and precision agriculture are two of the most essential strategic future themes. Machine learning in crop production is another example of how current innovations will influence future food systems. To manage pests in these crops, greenhouses and precise engineering in water usage, fertilizer use, and the application of numerous biological control agents. One part of this diverse agricultural

method in the Netherlands is the use of LED lights to impact not only plant growth but also, for example, insect resistance and hence pesticide use in plant production in the greenhouse is lowered thereby affecting the product's quality [23].

Plants having helpful traits have been selected for further breeding by humans for as long as they have grown plants. These features represent naturally existing genetic variants and may lead to higher yield, disease resistance, or resilience to environmental stress, among other things. Plants that have been genetically modified (GMOs) are those that have had their genomes altered in a laboratory rather than via breeding. Plant genetic alterations have mostly been used to improve pest resistance and herbicide tolerance. As a result, the use of genetically modified organisms (GMOs) in agriculture has been linked to unsustainable, highly industrialized monoculture agricultural methods. More than 93 percent of maize and soy farmed in the United States has been genetically engineered in some form.

Vertical farming is another specialty in greenhouse production. It is seen as a solution to the urbanization problem: People are increasingly relocating to large cities, and there are now numerous cities in the globe with populations exceeding 10 million. They live in a limited region, and their food is imported from all over the world, but an increasing number of people demand fresh, locally produced food. Vertical farming is frequently based on hydroponics, aquaponics, or aeroponics, which are soilless techniques of growing plants. The advantages of vertical agriculture include a high production rate, the use of less area for food production, the use of very little water, the use of very few nutrients, and the use of fewer pesticides, all of which result in extremely high scores on many sustainability criteria. On the other hand, it is pricey, and consumes a lot of energy – lighting, which contributes to the price. As a new technology, there is still much to be improved and refined in future to reduce costs [23].

3.4 Food system synergy and policy monitoring

Existing national, regional, and global policies, plans, legislation, and investments are divided out into multiple conversations, which is a major barrier to sustainable food system transformation. These issues may be addressed by developing and implementing cross-sectorial policy, investment, and legislative portfolios that fully address the negative effects of diverse elements impacting agricultural systems on food security and nutrition [7]. Given that most food systems are impacted by several factors, each of which has a varied impact on food security and results, broad portfolios of policies, investments, and laws can be developed in multiple ways at the same time. This will allow them to maximize their collective effect on food system reform, take advantage of win-win solutions, and avoid undesirable tradeoffs. Coherence in the formulation and implementation of policies and investments in the food, health, social protection, and environmental systems is also required to create synergies that lead to more efficient and effective food system solutions that ensure affordable, healthy nutrition in a sustainable and inclusive manner [7].

Fanzo et al. [34] presented a science-based surveillance framework / method to measure and monitor the performance of food system operations globally, which might help achieve real progress, establish priorities, set clear targets for action, and align food system players make a list of trade-offs. According to the authors, such a mechanism can assist "food system actors and other stakeholders (e.g. civil society, governments and international organization) actionable evidence to hold government, consumers and other private sector accountable for food system transformation". The authors have used various food systems frameworks to illustrate the confluence and interrelationships between the components of the food system (see **Figure 2**), in order to address five thematic areas for the food system monitoring mechanism that comprises of (1) nutrition, nutrition and health (2) environment

and climate (3) livelihoods, poverty, and justice (4) governance and (5) resilience and sustainability with indicators, domains and tables.

Similarly, Hebirick et al. [52] developed a sustainability compass for political navigation in the transformation of food systems, based on four interrelated,

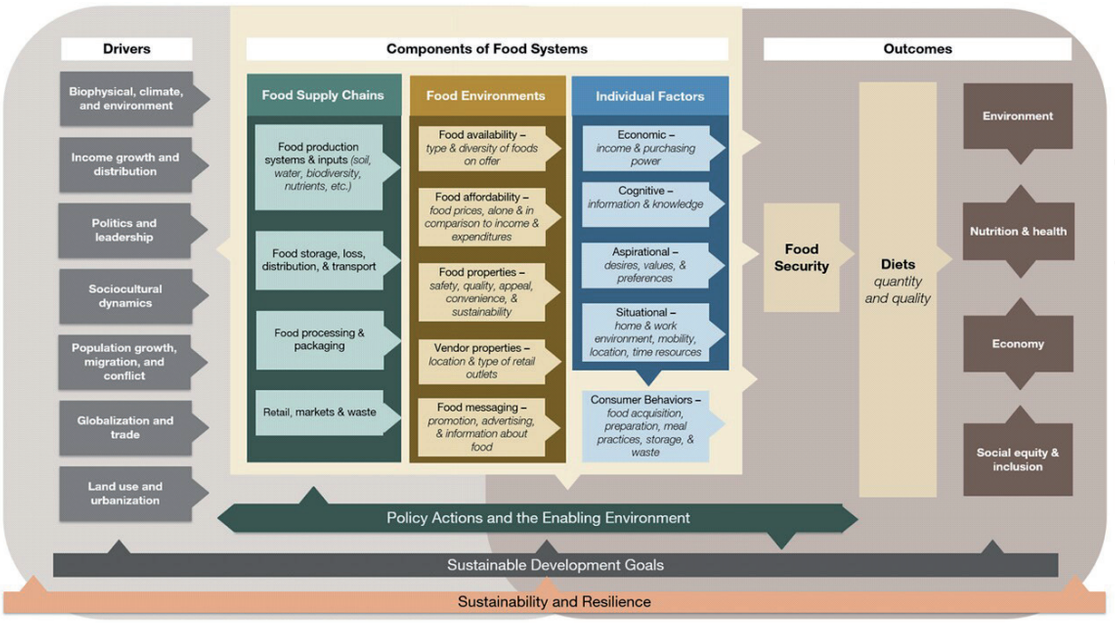

Figure 2.
Food system components, drivers, and outcomes. Source: Fanzo et al., [34].

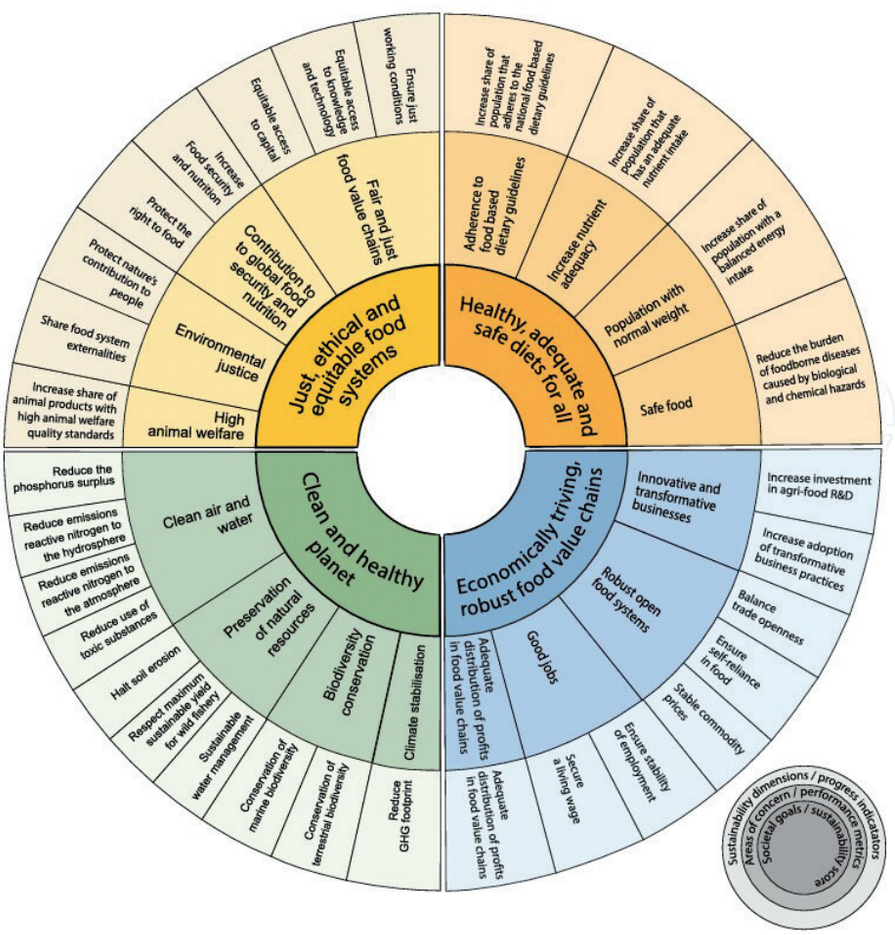

Figure 3.
A sustainability compass for policy navigation to sustainable food systems. Source: Hebinck et al.,[52].

desirable societal perspectives: healthy, adequate, and safe nourishment for all; a clean and healthy world; and a fair, ethical, and fair food system. The compass (see **Figure 3**) provides an all-encompassing framework for assessing sustainability that allows for an integrative and transparent political discussion and can deliver practical findings. The compass may be utilized at many levels of policy development to promote inclusive multi-stakeholder discussions and assure reflective and thorough evaluations, setting the framework for building integrated policies that deal with trade-offs in a reflexive manner [52].

4. Losing less

While the problem is obvious, the narrative that we must feed the globe legitimizes present production systems erroneously [23]. Even though food production is already high, a third of it is lost or wasted. Inevitably, this implies that a large portion of the resources utilized in food production are squandered, as are the greenhouse gas emissions associated with producing food that is lost or wasted. These losses occur at several points along the food supply chain, including harvesting, processing, shipping, marketing, and consumption, and they could feed 2 billion hungry people each year. Food loss and waste costs the economy $940 billion each year.

Losing less therefore, is critical to fulfilling the needs of an expanding population while also driving production in a more sustainable path. Food losses are defined as a reduction in the mass of edible food in the segment of the supply chain that leads to edible food for human consumption. Food losses occur in the food supply chain during the production, post-harvest, and processing phases [53]. Food losses at the end of the food chain (retail and final consumption) are more likely to be labeled as waste, which has to do with retailer and consumer behavior [53].

Food is obviously wasted more at the consumption level in industrialized nations, that is, it is thrown away even while it is still fit for human consumption. Developing countries have higher post-harvest agricultural losses, which mean that considerably less food is wasted at the consumer level. One-sided investments in agricultural resources are to blame for the substantial post-harvest losses in underdeveloped nations.

4.1 Circular food systems

Food system transformations are interactive processes that need adaptive skills in order to respond properly to unanticipated obstacles. Food system development is not a linear process, and various trends occur at the same time [16]. Diverse sorts of food systems have different and unique means of delivering nutritious, economical, safe, and long-term nourishment, necessitating customized solutions. The move to circular systems based on resource recycling, on the other hand, benefits all types of food systems by enhancing resource responsiveness and efficiency. A thorough understanding of the major leaks underpins the promotion of circular food systems [16]. Post-harvest losses and waste (PHL) must be reduced, which necessitates physical infrastructure and food management expenditures. Recycling and reusing materials can help to improve material balances. Many perishable items can have their shelf lives prolonged by adopting upstream drying or fermentation techniques to improve food integrity downstream in the food system [54]. Local indigenous food improvement strategies that focus on resource recycling can also help foster youth employment and women's entrepreneurship [54]. Because global food production is the leading cause of environmental deterioration, methods for making the best use of biomass from plant-based systems, as well as approaches for reducing

pressure on forests and biodiversity, and opportunities to improve feed conversion and circularity within animal husbandry systems are all given special attention.

4.2 Transport and storage

Food loss and waste is a worldwide issue, yet while it affects people everywhere, the issues are different in each country [55]. Several studies suggest that investment in rural transportation and communication infrastructure helps farmers and merchants minimize transaction costs, improve the quality and freshness of local products, and boost output [56]. Dorosh et al. [57] show that in Sub-Saharan Africa, agricultural yield and adoption of high-input technologies are greater when farmers reside closer to metropolitan areas, emphasizing the relevance of accessibility.

Both pre-harvest and post-harvest infrastructure, such as collecting centres, (refrigerated) storage, distribution, or processing centres, are critical. Farmers who have access to storage space might boost their revenue by taking advantage of seasonal price changes if they can wait [58].

4.3 Connectivity: Connecting producers and consumers

The type and strength of the interactions between the various components of any system is referred to as Connectivity. Connectivity at the neighborhood, business, and national levels helps people build resilience and protect themselves from negative repercussions. The food system's resilience may be improved by tying rural and urban populations together [55] and expanding agricultural and non-agricultural job options to absorb surplus labour. Investing in small and medium-sized businesses for local processing, storage, and retailing produces crucial new job possibilities, encourages value creation, and allows for cyclical resource usage [59]. Connecting farmers and consumers to dependable and transparent informal and formal markets has the potential to improve access to inexpensive and good nourishment, as well as boost nutrition, inclusiveness, and sustainability, as well as increase food supply stability [60].

Therefore, improved agricultural value chain connectivity increases a food system's ability to respond to shocks and stresses, as well as its adaptive and transformation capacities. As a result, food waste is not only a technological issue, but also a question of enhancing the interaction between producers and consumers [23]. Prices in European supermarkets and businesses do not frequently change during the day. Too Good To Go is an app that helps consumers avoid wasting food by linking them with establishments that have leftover foods at the end of the day. This allows these customers to reserve food at the store at the end of the day, and after the store closes, the customer will pick up those items and take them home to eat instead of the business throwing them away. There are several benefits to this, the most notable of which is that the shop does not have to waste out food, and the consumer receives a wonderful dinner at a reasonable price [23].

The problem of date marking is one of the political concerns that the app handles with similar success in both Denmark and France. According to research conducted by the European Union, up to ten percent of all food thrown out in Europe each year is due to a misinterpretation of the date marking on everyday items like breakfast cereals or rice. Basically, people get the two date labels 'best before' and 'use by' mixed up ahead of time and use them interchangeably [23]. That is, when food passes its best before date, consumers just toss it away. Consumers who frequently use the app to assist in the battle against food waste will be able to understand this in a very relevant way. Additionally, food makers can frequently add 'often good after' to their best-before date, indicating that the product has passed its best-before date but is still edible days or weeks afterwards [23].

4.4 Decreasing food miles

By 2050, emerging nations will account for 97 percent of the world's increase population with 70 percent of the new population settling in cities. As a result, there is a significant gap between where food is produced and where it is consumed. Farmers must relocate further from cities in order to feed this rising population, while rural residents must relocate further from farms to cities thereby increasing food miles. As a result, real food markets are critical for connecting rural production with urban demand. Cities in Sub-Saharan Africa are planning and constructing markets, or retrofitting existing ones with proper sanitation, storage, and lighting [61]. Investing in informal market infrastructure and spatial design is thus at least as essential as investing in official markets. Understanding how to effectively preserve these informal market connections is also important, yet this information is frequently absent [62].

4.5 Food wastage resilience through agroecology, insurance, and agroforestry

Strategies which guarantee that less food is lost in the food chain, is critical to build resilience. Building resilience to ensure higher food production and reduced loss necessitates the implementation of a food production system that respects the natural environment by making the best use of the limited land area available, particularly for animal production. The adoption of agrocology, agroforestry, and insurance is a sustainable strategy to buffer shocks and stressors in the food production and supply chain, preventing post-harvest losses and securing the livelihood of food system operators [23].

Agroecology is an alternative that advocates a variety of ecosystem-based ideas that encourage natural processes to minimize dependency on chemical inputs and cut production costs [63]. Anderson et al. [64] highlighted six key areas in agroecological transformation that must be considered: (1) access to natural ecosystems; (2) knowledge and culture; (3) trade systems; (4) networks; (5) equality; and (6) discourse.

It is not enough to adjust agricultural methods to climate change to boost the overall resilience of food production. Farmers should be insured not only for the food they have already produced, but also for their whole operation. Steps to better adapt to climate change for farmers go hand in hand with insurance preparation for extreme weather events, as on-farm activities come with premiums. In this approach, decreasing food waste and loss is about strengthening farmers' resilience as well as enhancing storage, transportation, and the relationship between producers, sellers, and consumers [23].

4.6 Diversity

While efficient, dependable, and sustainable food production is still critical, focusing only on agricultural output has resulted in certain unforeseen and unpleasant consequences that are not all insufficient [16]. Furthermore, the manner in which the intensification was carried out has generated environmental issues [17], and the food system's 37 percent contribution to greenhouse gas emissions necessitates a significant decrease to satisfy the Paris Agreement and mitigation demands [15]. Diversification is important for strengthening the food system's resilience. Diverse diets will only benefit nutrition and health if they are supported by greater affordability and accessibility to nutrient-dense foods [65]. Diversification of food production can enhance rural livelihoods while also promoting biodiversity and natural resource landscape management.

Diverse systems make up resilient systems. The loss of one resource can be compensated for by another. An excess elsewhere can compensate for a shortfall. According to studies on environmental resilience, biodiversity contributes significantly to system stability and continuity [66]. More varied agricultural systems have a better capacity to absorb the effects of shocks and stresses, which helps to stabilize food supply as they travel through value chains to consumer markets [67].

4.7 Peace building

During times of violent conflict, entire food systems are frequently disrupted, making it difficult for people to get nourishing meals. Food security, as defined by FAO [68] and WHO (1996), is all people having physical and economic access to safe and nutritious food that meets their dietary preferences at all times for an active and healthy lifestyle. Economic growth and social progress, as well as political stability and peace, are all linked to food security [69]. Wars, political unrest, insecurity, insurgency, banditry, and terrorism limit access to food, resulting in increased hunger, malnutrition, and loss of livelihood, all of which wreak havoc on the food system's resilience. Conflicts are causing a rise in the number of displaced people in many regions of the world, who are living in risky situations and unable to satisfy their food and nutritional demands. In Africa, the number of wars grew by 90% in the fourth quarter of 2020 compared to the fourth quarter of 2019, causing more economic disruption [70].

In addition, ending wars and promoting peace should be a regional and global priority. The combination of humanitarian, development, and peace building initiatives in conflict zones, according to FAO et al., [7], is critical. It is vital to remember that the majority of chronically hungry people, as well as many undernourished people, live in nations plagued by insecurity and violence. As a result, conflict-sensitive policies, investments, and actions to alleviate acute food insecurity and malnutrition must be implemented concurrently with conflict-reduction measures and reconciled with long-term socio-economic development and peace initiatives [67]. Policy actions backed by institutional and legislative changes should strive to minimize and, if feasible, avoid these underlying causes' consequences on food systems, food security and nutrition, and the economy as a whole [7].

4.8 Sustainable food safety practices and management

Inadequate food safety and quality endangers food production, distribution, and consumption [71]. Foodborne illness lowers the quality and amount of agricultural produce, lowering food availability and access for communities whose livelihoods are dependent on its sale [72]. When people are on the verge of starving, they will eat whatever food is available, even if it is dangerous. Food safety is a critical component of successfully transforming food systems, strengthening supply networks, diversifying value chains, and fostering the circular economy. As a result, there is no food security without food safety, and food that is not safe is not food [73–77]. Climate change and extremes, agricultural intensification, and the evolution of antibiotic resistance are all issues that can impact food safety at the production level. Changes in food processing, value creation, and packaging are being driven by technological advancements, research, and creativity, all of which necessitate careful attention to food safety. Furthermore, if not carefully handled, globalization, new digital distribution networks, e-commerce, and informal markets might have an impact on food safety [73–77]. Food safety, as a component of food security, is also a key component of the Sustainable Development Goals (SDGs), since the FAO/WHO estimates that over 600 million instances of foodborne illness and 420,000 fatalities

result from contaminated food intake each year [36, 69, 73–77]. Apart from the fact that SDG2, which covers a wide range of themes such as eliminating hunger, establishing food security, enhancing nutrition, and supporting sustainable agriculture, can only be realized if food is available and safe to eat [69]. Similarly, Nwiyi and Elechi [72] argued that in order to safeguard a people's food, the food system's safety and nutritional-physiological characteristics must be assured at all times, regardless of how primitive, cultural, indigenous, traditional, contemporary, or technically sophisticated it is.

Strengthening high-level political involvement for food safety, prioritizing sustainable investments in effective national food control systems, and mobilizing enough public and private resources within dynamic systemic change are all important, according to FAO [73–77]. With the declaration of June 8 as World Food Safety Day and the recent establishment of a dedicated food safety and quality department by FAO in recognition of the urgent need for sustainable food safety management, with the mission of supporting science-based governance and food safety decisions, improving food safety management along the food chain to reduce disease and trade disruption, and evaluating new technologies to improve food safety and protect public health [69, 73–77].

4.9 Reducing global postharvest skill technology gaps

There are technological deficits, particularly in poor countries, as a result of the loss of post-harvest investment. To overcome this problem, we urgently require more sustainable post-harvest initiatives as well as new technologies. The "World Food Preservation Centre" meets this need by training young post-harvest scientists from developing countries in advanced food preservation technologies that are appropriate for their countries, as well as conducting research and developing innovative food preservation technologies that are suitable for developing countries.

4.10 Building food systems climate resilience

Humans and environment can survive and prosper in a climate-positive future if we change the way we produce food and utilize natural resources [78]. This is significant not just because environmental degradation and climatic events have an impact on food systems, but also because food systems influence the status of the environment and are key drivers of climate change. These initiatives are centered on protecting the environment, managing current food production and supply systems sustainably, and restoring and rehabilitating natural habitats [7]. Stronger partnerships and multi-year, substantial funding are needed to support (among other things) integrated disaster risk reduction and response programs, climate change adaptation strategies, and short-, medium-, and long-term practices [19] to mitigate the effects of climate variability and extremes, such as persistent poverty and inequality. The adaptation and upgrading of instruments and interventions such as risk monitoring and early warning systems, emergency preparedness and response, measures to reduce vulnerability and measures to build resilience, shock-active social protection mechanisms, risk transfers (including climate risk insurance), and forecast-based funding, as well as strong risk governance structures in the environment, are all required for the implementation of climate resilience policies and programs. Climate-Smart Agriculture (CSA), has shown triple success in the transformation of food systems, is a proven approach to building climate resilience. CSA builds resilience in a variety of ways through climate-sensitive and socio-economically advantageous approaches that boost agricultural production and incomes while also strengthening climate change resilience and reducing greenhouse gas emissions [79].

5. Eating smarter

It is not only a question of cost and affordability to have access to nutritious meals and a balanced diet. Culture, language, culinary traditions, patterns of knowledge and consumption, food preferences, attitudes, and values all have an impact on how food is sourced, produced, and consumed [7]. Dietary habits have shifted, with both beneficial and harmful consequences for human health and the environment [8]. Most food systems today neglect the hidden costs to human health and the environment. Because they are not frequently quantified, they are not taken into consideration and are not included into food pricing, putting the sustainability of food systems in jeopardy. As a result, action, legislation, and investment are required, depending on the specific country context and current consumption patterns, to create a healthier food environment and empower consumers to follow nutritious, healthy, and safe eating patterns with a lower nutritional impact on the environment [74].

5.1 Ensuring diet biodiversity through local foods

Many family recipes have been passed down for centuries. According to McCouch et al., [80], 80 percent of human caloric intake is reliant on less than a dozen of the world's 300,000 flowering plant species. As a result, the vast genetic variety that each of these 300,000 species contains is largely untapped. According to McCouch et al., [80], a more concentrated worldwide effort is needed to better use agrobiodiversity in the global food supply.

Local foods, defined as foods produced and/or processed in close proximity to where they are consumed [81], are an important part of the food system: rural and urban communities in many developing countries are reliant on endogenous, locally available vegetable and food products as well as animal resources [82]. There is evidence that improving urban inhabitants' awareness of the economic and health benefits of buying locally grown vegetables, fruits, and grains may aid rural communities by increasing demand for these items [55, 83].

5.2 Using unconventional food

When it comes to environmental sustainability, adding local wild plants in the diet not only serves to diversity the plate, but it also helps to promote environmental sustainability by lowering dependency on commercially farmed veggies and connecting people to nature. On farms, in urban parks, and even in backyards, wild edible plants abound. On agricultural ground, these plants can be found growing along the borders of fields, in hedges, or in small woods. Even in the lean months leading up to the yearly harvest, they can supplement food and nutritional needs and provide seasonal alternatives, especially in low-income nations where agriculture is dependent on rainfall and seasons influence. It is critical that arable land maintains biodiversity in many low-income nations where people still rely on edible wild plants for subsistence [84]. Wild edible plants, on the other hand, are prevalent in the British countryside. Some of these unusual food sources include algae, fungus, insects, invading species, and weeds. These resources can assist in achieving long-term nutrition and meeting the 2050 target of feeding 9-10 billion people.

5.3 Replacing meat

Despite the advantages of meat eating and livestock production in poorer nations, farm animal food contributes significantly to climate change, habitat

damage, and biodiversity loss [30]. Non-communicable illnesses claim the lives of 41 million people each year, accounting for 71% of all fatalities globally. 18 million of these fatalities are caused by cardiovascular disease, which is linked to our food in many cases [23].

Artificial meat or meat derived from the culture of animal cells, has attracted a lot of research investment and has the potential to drastically reduce the cost of meat. However, because this process consumes a lot of energy right now, it's unknown how essential such items will be in the shift to more sustainable food systems.

In several European nations, plant-based meat replacements are already available in supermarkets. Consumers accept plant-based meat replacements easily; however they lack nutritional value when compared to actual meat. Insects, on the other hand, have sparked widespread attention as a food source due to their high protein content and fatty acid composition present in many insects. Up to 2 billion people worldwide are estimated to eat insects in some form or another [23]. Insects are a rich source of vitamins that are otherwise difficult to receive through a vegetarian diet and can only be gained in adequate quantities through a carnivorous diet. In recent years, various ecological arguments have been made for eating insects, claiming that insects have an extraordinarily efficient nutritional turnover compared to cows and pigs. Insects are also better at turning food into weight than humans. That implies we will use less land and resources to generate the same amount of food energy, which is a good thing [23].

Insect output must be enhanced if insects are to become a viable source of food on a global scale. This necessitates ethical, economic, and health considerations: one of the most difficult challenges in developing a food system that can produce insects, is to increase production; and for that, we need some knowledge; it is said that many insects thrive particularly close to one another, and mealworms thrive in dark and narrow spaces; thus, having many of them in one place in the production system is beneficial. We also need to figure out how to automate the process because this would be a costly production. Some argue that one of the benefits of insects is that they are significantly different from humans, implying that they have a lesser risk of spreading diseases known as zoonoses when consumed. In addition, the EU has decided to legalize the consumption of insects, as well as the production of insects as animal feed in all EU nations [23].

5.4 Changing habits

Brouwer et al. [65] argues that influencing eating habits requires the application of social norms to promote a healthy diet. Social norms around healthy eating, as defined by culture and circumstance, might impact a person's food choices, implying that a code of suitable conduct exists [65]. In low- and middle-income countries, there are well-established societal norms and taboos, such as those around the feeding of young children (e.g., avoiding eggs) and the treatment of pregnant and nursing mothers. Understanding individual behavior and community reactions is critical for a system's overall resilience. Government policies may have a significant impact on a country's dietary patterns. Institutions that encourage sustainable consumption and nutrition are required. Dietary guidance is a fantastic illustration of how politics may play a role in this whole puzzle in the Nordic nations. Nudging is a psychological phenomena that may be utilized to alter eating habits on a personal and societal level. It can be used to get someone to consume something else in a tiny situation and foster healthy eating habits in a wider context, such as lowering in certain areas while growing in others. Another idea is to use smaller dishes in the cafeteria to prevent food waste [23].

5.5 Citizen-driven transformation

Nutrition democracy, according to Baldy and Kruse [85], is a notion that is gaining traction in nutrition policy research. It is about citizens reclaiming democratic control over the food system and allowing long-term change. Nutrition democracy research has thus far overlooked the potential of state-driven nutrition-related participatory procedures due to its concentration on civil society efforts. The authors looked at how local actors shape state-driven participation processes for long-term food system transformation along eight key dimensions of food democracy: mutual knowledge exchange, legitimacy and credibility of knowledge claims, transparent processes for generating ideas, common language for exchanging ideas, expectations and experiences with effectiveness, and role model.

5.6 Improving aquaculture

Today, fish remains a nutritious alternative to red meat. Between 1961 and 2016, the average yearly rise in worldwide fish consumption was 3.2 percent per year, outpacing population growth. Fish contributes over 20% of the average per capita animal protein consumption for more than 3 billion people. Whereas average per capita consumption in Central Asia is roughly 2 kg per year, it is around 50 kg per person in the Small Island Developing States (SIDS) [23]. Blue proteins would play a critical role in protein shifting. They are not spoken about as often as green ones, but they have a far less ecological imprint than red ones and come in a variety of sustainability levels [23]. In poor nations where red meat is not as readily available as it is in Europe, for example, Blue proteins are even more significant, as they have been connected to a slew of positive health benefits. Fish are high in vital nutrients, thus they should be included more in the protein shift discussion [23].

5.7 Lowering the cost of nutritious foods

Food supply chain interventions are needed to boost the availability and affordability of safe and nutritious food, particularly to make healthy eating more affordable. To accomplish these targets, this approach necessitates coordinated effort and investment from production to consumption focused at increasing efficiency and lowering food losses and waste [86]. Incentives should encourage, among other things, diversification of production in the food and agriculture sectors toward nutritious foods such as fruits, vegetables, pulses, and seeds, as well as foods of animal origin and bio-enriched plants, as well as investments in innovation, research, and expansion, and productivity increases. The nutritional content of food and drinks can be increased at various points in the supply chain by fortifying staple foods after harvest in accordance with international norms. Fortification and biofortification have been used to address micronutrient shortages while simultaneously improving the availability and affordability of healthy meals (WHO. 2016).

6. Case examples of global food system transformations

The facts and examples that illustrate that transformation of food systems is conceivable and is currently occurring are far more compelling. This section exemplifies efforts of global transformation for resilience as reviewed by FAO *et al.,* [7].

When the structural roots of conflict are connected to competition for natural resources, such as fertile land, forests, fisheries, and water supplies, deep economic crises can occur. The following scenario is for Somalia, where people have suffered from chronic food insecurity and hunger for three decades (including famine in 2011) as well as numerous harsh weather occurrences (mainly droughts and floods) [7]. Drought-related severe food insecurity and malnutrition affected up to 6 million people in 2017-2019, including acute malnutrition in 900,000 children (FEWS Net, 2019). Appropriate measures were taken in recent years to respond, for example, to the severe food insecurity and malnutrition caused by drought. In 2018, the FAO launched the Cash + nutrition-sensitive program, which combines unconditional long-term cash transfers with livelihood support to increase resilience to future shocks while sustaining production capacity and food supply networks [73–77]. Seeds and tools for home gardening were sent to farming households, and shepherds were given assistance in raising livestock, which boosted animal health and milk output. The initiative has increased access to food for families in need, improved the quality and diversity of their meals, and enhanced program members' nutritional awareness via nutrition and food safety education.

A landscape restoration initiative in Ethiopia from 2015 to 2020 not only increased agricultural output by protecting soil and water, but also effectively linked farmers to markets, improving their economic potential. Food security improved for households, average family income increased considerably, and minimum nutritional diversity levels increased [45]. In India, a 2012-2016 project to restore land and intensify crops combined traditional water storage systems with infrastructure investments and technology transfers, resulting in positive effects on degraded and rain-harvested soils: crop yields increased by 10 to 70% and average household income increased by 170 percent [7]. This method also allowed for groundwater recharging, which improved the long-term sustainability of water consumption.

Interventions that remove some of the age-specific limits on young people's capacity to be productive in agricultural and food systems can also benefit them [7]. Professional and life skills training significantly increased the likelihood of adolescent girls of working age participating in safe income-generating activities (by 48 percent), while also reducing teenage pregnancies (by 34 percent) and the likelihood of marrying or living together prematurely (by 62 percent) according to evidence from a youth empowerment and livelihood program in Uganda [87].

7. Conclusion

A transition is neither a gradual enhancement of an existing system nor a complete revolution. A transformation is the outcome of a large number of little changes occurring at the same time in various regions of the system. These desired changes or initiatives are self-contained, but they are all linked because they are all measured against the same challenge: How can 8 billion people coexist with the planet's natural resources while also making room for 2 billion more? We begin to believe that a transformation of the global food system is possible when we combine all of the elements we have examined, all of the actions, large and small, of people changing their habits, work, and way of thinking. According to the World Resources Institute's baseline scenario, with 10 billion people on the planet in 2050, greenhouse gas emissions from food systems will be 15 gigatons per year, measured in CO_2 equivalents.

These emissions only need to be 4 gigatons per year to keep global warming below 2 degrees Celsius. As a result, the change will need to save 11 gigatons of CO_2 from

our food systems. In 2050, we can save 5 gigatons of CO_2 emissions by lowering the demand for food and other agricultural goods. This is accomplished mostly by lowering food losses and waste by 50% and consuming 30% less ruminant meat than in the baseline scenario. We can save an additional 2 gigatons of CO_2 per year by improving food production on current agricultural regions using new technology. This, however, necessitates a 25% increase in productivity over the original condition. In addition, agricultural yields have improved by 56% since 2010. The next minor step is to boost fish supply by improving wild fisheries management and increasing productivity aquaculture. Cutting greenhouse gas emissions from agricultural output has a higher impact, such as reducing methane emissions from ruminants by 30%. Wet manure emissions are cut in half, reducing greenhouse gas emissions by 80%. A 50% decrease in energy emissions per agricultural unit and a reduction in nitrogen fertilizer consumption. All of these advances in agricultural productivity might result in CO_2 reductions of about 3 gigatons per year. In the end, 80 million hectares of previously unforested land will be totally reforested, resulting in significant CO_2 reductions when combined with an ambitious moor renaturation program.

Overall, improvements will cover an increase of 15 gigatons of CO_2 emissions from global food systems to a shocking 6 gigatons of the shortfall, allowing for land use changes. This entails altering the planet's appearance. And it demonstrates that transformation is not only essential, but also beautiful. In the countryside, there is less manure smell, whereas in the metropolis, there is more vertical green. A better quality of life with a healthier diet. And a world that is teeming with life. People with a variety of abilities from all over the world must adapt to this transformation. Political action, technical innovation, improved financial institutions, and behavioral improvements are all required. So let us get started on this transformation right now!

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Conflict of interest

The author declares no conflict of interest.

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