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Catalyzing transformative futures in food and farming for global sustainability

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This perspective article highlights the need for transformation in food and farming at three scales to promote a food system that meets UN Sustainable Development Goals. Food insecurity is still a persistent problem globally because of how food and farming sector is currently organized vs. how it should be organized if cultural traditions, environmental concerns, and nutritional needs of the world's growing population were foregrounded. The article argues that system-wide transformations are needed at different scales: landscape (macro), species (meso) and genes (micro). It suggests alternatives available for food and farming sector and identifies transformative pathways that are more sustainable in cultural, social and environmental terms. A better management of farming landscapes; diversification of the food system to include a wider range of species; and better use of neglected and underutilized species, varieties and cultivars of plants, and breeds of animals, in the food system can help to catalyze such a transformation. This can go a long way in promoting global sustainability by achieving three key UN Sustainable Development Goals: 2 (Zero Hunger), 3 (Good Health and Wellbeing) and 15 (Life on Land).

KEYWORDS

agriculture food and nutrition, environmental sustainability, food security, health and wellbeing, UN Sustainable Development Goals

Introduction

Global food security is seen as the challenge of feeding more than 9 billion people by 2050 (Godfray et al., 2010; Strange, 2015; Fróna et al., 2019). A natural response to this challenge is to increase food production and some estimates suggest that the world will need to produce over 50% more food by 2050 than we currently do (e.g., Searchinger et al., 2019). The last 60 years of the so-called "Green Revolution" has increased food production dramatically. However, the Green Revolution has not only harmed the environment through excessive use of agrochemicals to enhance food production, but it has also failed to solve the problem of hunger and malnutrition in the world. Global food insecurity has progressively worsened year on year and in 2021 over 2 billion people were still food insecure, i.e., without access to safe, nutritious and sufficient food (FAO et al., 2021). Also, it has become increasingly clear that global food and nutrition security is not a matter of increasing food production alone, but of the "four betters"—better production, better nutrition, better environment and better life—as identified in

FAO's (2021) Strategic Framework 2022–2031. What are the key concerns in feeding the growing population of the world and how can we rethink agriculture and food security to address those concerns?

In this Perspective, I suggest that the global food insecurity is still a persistent problem because of how the food and farming sector is currently organized vs. how it should be organized if cultural traditions, environmental concerns, and nutritional needs of the world's growing population were foregrounded. The popular literature over the last decade has articulated the need for paying attention to cultural traditions, environmental concerns, and nutritional needs when thinking about global food security. It is suggested that the current focus of food and farming is on commercial mass production at the cost of the severance of food from cultural traditions of farming and agriculture (Shiva, 2016). The lack of recognition of environmental harms caused by the intensification of agriculture and the impact of heavy use of agrochemicals on soils under such forms of agriculture have also been discussed in the popular literature (e.g., Monbiot, 2022). It has also been suggested that the long-held attraction of technological solutions (Huesemann and Huesemann, 2011) such as the use of genetically modified organisms to "fix" the global food system has ignored the diversity that nature presents. Collectively, this popular literature has suggested that the problem of food insecurity has been addressed through ever-more production rather than approaching food and farming in a manner that is sensitive to cultural traditions, environmental concerns, and the nutritional needs. But what scientific evidence is there that the alternatives available to food and farming sector can be more sustainable in cultural, environmental and nutritional terms? Here I present my analysis of why the transformation in food and farming is needed at three scales, how it can be conceptualized in the context of global food insecurity, and how we can develop pathways for transformative futures to produce better outcomes for global sustainability (Figure 1).

First *the landscape-scale transformation* (macro-scale). The industrial agriculture claims vast landscapes and uses advanced technologies to increase food production primarily of cereal grains. On the other hand, 80% of food is produced on family farms by smallholder farmers (FAO and IFAD, 2019) and these farms are known to make more efficient use of land to produce a wider variety of food that is also nutritious. This calls for a better management of farming landscapes (Fischer et al., 2017; van Noordwijk et al., 2018). Such management can help with the transformation from farming methods currently used for commercial food production toward more sustainable options available to produce food.

Second, *the species-scale transformation* (meso-scale). A large proportion of calories consumed in the world come from only a dozen or so plant and animal species (Bioversity International, 2017). On the other hand, there are hundreds of thousands of species that are suitable for human consumption. This calls for diversification of the food system to include a wider range of species from which food comes (e.g., Bisht et al., 2018; Islam et al., 2018). Such diversification can help with the transformation from the small number of species that global food supply is dependent on toward the large number of species that are potentially suitable for more sustainable supply of food.

Third, *the genes-scale transformation* (micro-scale). Genetically modified organisms are seen as a cure for "fixing" the problem of providing food to the growing population of the world. Yet, there are vast numbers of local cultivars of crops and breeds of animals—known as "agrobiodiversity"—that have been long known to protect genetic variation (FAO, 1999). This agrobiodiversity is a product of selection and breeding over thousands of years of history of food and farming. This calls for better use of neglected and underutilized varieties and cultivars of plants, and breeds of animals, in the food system (Padulosi et al., 2013; Joshi et al., 2020). The use of such neglected and underutilized species can help with the transformation from commonly promoted technological solutions for food security toward the vast pool of genetic traits that are potentially suitable for more sustainable food and farming.

Catalyzing system-wide transformation at three scales

I suggest that the system-wide transformation can be achieved through a reorganization of food and farming sector in ways that heed cultural traditions, environmental concerns and nutritional needs. I will illustrate with examples pathways for such transformation. I will conclude by suggesting that the consideration of issues at landscape, species and genetic scales is important for achieving the 2030 UN Sustainable Development Goals, particularly Goals 2 (Zero Hunger), 3 (Good Health and Wellbeing) and 15 (Life on Land).

The landscape-scale transformation

Although the intensification of agriculture over the last 60 years has produced vast agricultural landscapes, often cultivated with monocultures of cereal grains, there are many examples of multifunctional landscapes where farming and biodiversity thrive (Bhagwat et al., 2008; McGranahan, 2014; Montoya et al., 2020). These multifunctional landscapes provide numerous other benefits to people defined by the 2005 Millennium Ecosystem Assessment as "ecosystem services" (MEA, 2005). A more recent assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) articulates this as Nature's Contribution to People (NCP) which highlights the value of multifunctional landscapes to human wellbeing (Diaz et al., 2018). One iconic example of such multifunctional landscapes

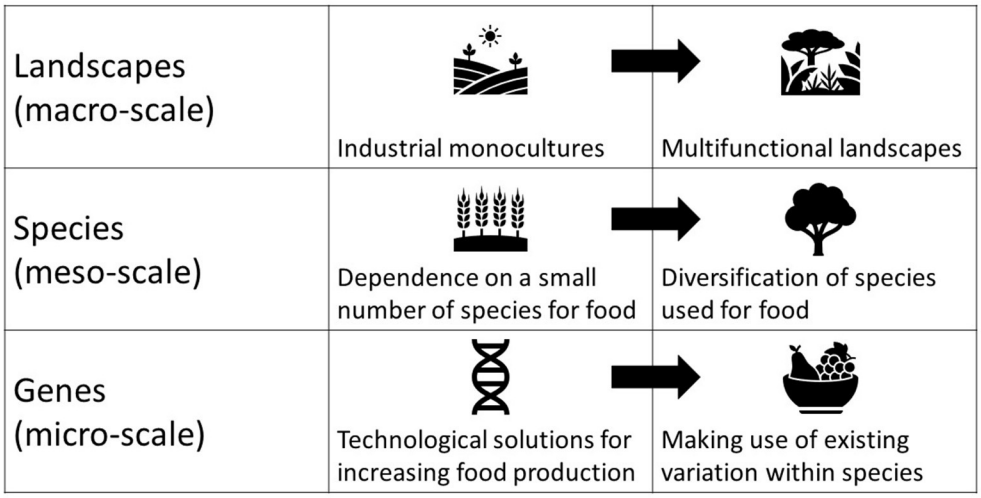

FIGURE 1
Schematic representation of the transformation in food and farming sector at three scales. The arrows indicate alternative pathways to promote a food system that is more sustainable in cultural, nutritional and environmental terms.

is culturally protected forests which are often situated at the heart of traditional agroforestry landscapes (Bhagwat et al., 2005; Tscharntke et al., 2011; Roux et al., 2022). These forests are common across the world, are found on every single continent, and are instrumental in supporting biodiversity (Bhagwat and Rutte, 2006). These forests are typically embedded in agricultural landscapes and they also provide a range of different ecosystem services such as groundwater storage, carbon sequestration or pollination of crops (Box 1).

Such "cultural landscapes" are also known to be the guardians of "biocultural diversity," the diversity of life in all its manifestations within a complex social-ecological system (Maffi, 2007; Pungetti and Bhagwat, 2012). The UNESCO World Heritage Convention attributes special significance for cultural landscapes, many of which are also places of outstanding natural beauty (UNESCO, 2022). If industrial agriculture claims vast stretches of such landscapes consisting of forests and other natural vegetation, their ability to provide ecosystem services can be significantly compromised. Landscapes where cultural norms are upheld can produce food more sustainably whilst also supporting human wellbeing.

BOX 1 Ecosystem services from church forests in Ethiopia.

Church forests in Ethiopia (Eshete, 2007) are purposefully protected and nurtured by people are associated with the Ethiopian Orthodox churches in rural landscapes. Based on the modeling of pollination services provided by these church forests (Marks et al., 2022) suggest that church forests provide pollination services to nearly all of the cropland in South Gondar region of Ethiopia. In other words, without these pollination services, the small-scale farming in Ethiopia cannot function and as a result the farming communities in this region will become far more food insecure than they currently are. The church forests exist today because of cultural norms and if these norms are removed, then a collapse of agriculture is not inconceivable. On the other hand, if the cultural norms are recognized, they will continue to provide vital ecosystem services (e.g., LoTemplio et al., 2017). The example of Ethiopian Orthodox church forests is good reminder that such landscapes are ultimately 'cultural landscapes' shaped jointly by humans living in their environment. Such cultural landscapes can be the key to catalyzing the landscape transformation.

The species-scale transformation

The global food supply comes from a relatively small number of species. Out of the estimated 390,000 plant species globally, there are at least 7039 edible plant species, 417 of which have been considered crops. Worryingly, however, only 3 crops—rice, maize and wheat—provide 50% of world's calories from plants, and only 12 plants and 5 animals provide 75% of the world's food (Antonelli et al., 2020). This dependence on a small number of species for food points to the vulnerability of the global food system which is underpinned by large scale and commercial production of food. In contrast, 9 out of 10 farms are family farms and they produce over 80% of food in the world (FAO and IFAD, 2019). Family farms are also very important for protecting the varieties of plants and animals that provide unique ingredients in world's cuisines that make food

BOX 2 An example of non-native invasive species used for food to illustrate unconventional ways in which food supply can be diversified.

North American Crayfish or signal crayfish (*Pacifastacus leniusculus*) was introduced in the United Kingdom in 1976 and it soon spread throughout the British waterways driving out the native crayfish (Chadd and Eversham, 2010). The trapping of this crayfish is legally permitted by the UK Environment Agency. One environmental campaigner, Crayfish Bob, has been supplying potted crayfish at pop-up restaurants, music festivals, and other events across the United Kingdom (Crayfishbob, 2022). Making use of invasive species in this way not only solves the problem of non-native invasive species, perceived as one of major environmental problems today, but it also helps make our food diverse and possibly more nutritious. Although this is an unconventional and controversial solution to diversifying the food supply, there is an increasing number of examples to suggest that where natural resource managers have 'given up' on controlling non-native invasive species, 'consuming' them can provide a potential solution to keep their populations under control (Bhagwat et al., 2012; Hoag, 2014; Cerveira et al., 2022).

BOX 3 Genetically modified cotton vs. traditional variety of "tree cotton".

One example where genetic modification technology has come under sharp focus is cotton farming in India where genetically modified cotton (*Gossypium hirsutum*) has been linked to farmers' suicides (Gutierrez et al., 2020). Bt cotton is a genetically modified pest resistant variety that produces an insecticide to combat bollworm (*Helicoverpa armigera*). In this type of cotton, strains of a bacterium called *Bacillus thuringiensis* are introduced to produce Bt toxins harmful to insects. As a water-thirsty plant, cotton is heavily reliant on irrigation. Bt cotton does well where farmers have access to irrigation, but it does not do so well where artificial irrigation is unavailable. Studies have shown that Bt cotton increases the risk of farmer bankruptcy, and therefore suicides, in smallholder rainfed cotton farms (e.g., Gutierrez et al., 2015). However, a traditional variety of deep-rooted 'tree cotton' (*Gossypium arboreum*) does very well in environments where water is scarce. It is these kinds of traits that can help farmers, as opposed to traits that seek to maximize profit through, for example, the introduction of pesticide resistance in order to promote commercial interests through the increased sale of pesticides in cotton farming.

rich and diverse. Conservation of neglected and underutilized species has other benefits such as their role in fighting hunger and malnutrition during "lean" periods when the harvest of staple crops has been consumed (e.g., Li et al., 2020). The dietary diversity that these species offer can also promote nutrition, health and wellbeing in parts of the world where malnutrition and hunger are prevalent (e.g., Chivenge et al., 2015; Li and Siddique, 2018).

Beyond the currently neglected and underutilized species, there is also potential in non-native invasive species to provide sources of food. These species pose a serious problem for environmental managers because once they take hold they are difficult to control or eradicate. Although an unconventional, controversial and "outside the box" solution, their use as food can potentially help the environment as well as diversifying the food supply (Box 2). This so-called "frontier food" holds promise as an important component of global sustainability alongside better use of neglected and underutilized species. A global food system that does not depend on a small number of species can become more resilient to shocks and also offer environmentally more sustainable options for global food and nutrition security.

The genes-scale transformation

As opposed to applying technological solutions to the challenge of increasing global food production and or fortifying food with nutrients, it is important to recognize the genetic variability and diversity that already exists in nature. Hundreds of varieties and cultivars of plants and breeds of animals that exist today are a product of thousands of years of selection and breeding by people (Bioversity International, 2017). This rich "agrobiodiversity" is important for food and nutrition security of a large proportion of the world's farming population. Yet, technological solutions such as genetically modifying crops pay very little attention to this already existing diversity. Gene editing tools, for example, are used to generate changes to the native genetic material to introduce commercially desirable traits. Similarly, the technologies that produce genetically modified organisms, introduce novel configurations of genetic materials typically derived from other organisms. These technologies are used to generate commercially attractive traits such as pesticide resistance (e.g., Qaim and Zilberman, 2003). Yet, traits such as drought resistance are, arguably, far more useful to farmers than pesticide resistance (Box 3). Such useful traits are common among wild relatives of cultivated plants as well as among the cultivars of plants and breeds of animals that have been produced through careful selection and breeding (e.g., Mammadov et al., 2018). Biotechnology is seen as an important part of food and farming, as exemplified by EU's Farm to Fork strategy (Purnhagen et al., 2021). However, it is important to recognize that technologically-driven approaches do not undermine the genetic variation that exists naturally.

Conclusion

In conclusion, this Perspective suggests that a system-wide transformation in food and farming at landscape, species, and genes scales will go a long way in achieving global food and nutrition security. The revitalization of cultural traditions of farming and agriculture and moving away from commercial mass production toward multifunctional food landscapes can help with the landscape-scale transformation. The introduction

of a greater diversity in the food system and making use of neglected and underutilized species as well as exploring the uses of non-native invasive species in food can help with the species-scale transformation. Moving away from technological solutions to increase food production and adopting the already existing varieties, cultivars and breeds that are better adapted to local environments can help with the genes-scale transformation. The status quo in the food system currently compromises the possibility of achieving the 2030 UN Sustainable Development Goals (SDGs) 2, 3, and 15. SDG2 pledges to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture". The system-wide transformation in food and farming can reduce the environmental harms from agriculture as well as producing sufficient and nutritious food for those facing hunger. SDG3 strives to "ensure healthy lives and promote well-being for all at all ages". Such transformation can also help reimagine the modern-day relevance of traditional practices in food and farming for health, wellbeing and better quality of life. SDG15 commits to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Such transformation can promote the conservation of cultural landscapes and biocultural diversity dependent on such landscapes. Food is the building block of life and an important part of our society. If we get the food right, then we would have made good progress toward global sustainability.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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