



The need for cost-effective, adaptable, and environmentally friendly food systems

Ghazanfar Ali Nasir*, Fahim Arshad, Muhammad Akram

Department of Botany, Govt. Islamia Graduate College, Civil Lines, Lahore, Pakistan

*Ghazanfar Ali Nasir

✉ ghazjun22@gmail.com

☎ Landline: +92(042)37300252

► Received: 03-03-2026 / Accepted: 02-04-2026 / Published: 03-04-2026

Abstract

Food production methods and sources should have as little of an environmental impact as possible. In a similar vein, water and production chemicals should be used in a way that promotes soil structure and texture. The food system's distribution channels must be optimal to guarantee that there is no food waste and that it reaches the consumer at the lowest feasible cost. It could result in all ethnic groups in society, from the most secluded to the most assimilated, having widespread access to healthy and affordable foods. Advanced food preservation, automation, and precision farming technology should be used to produce more food and reduce waste. Supporting tactics pertinent to the food supply chain, including farmers, food processors, distributors, retailers, and consumers, is ideal. Climate change-related products may impact crop health, drought, and current and future weather patterns. For customers to pick what they eat easily and confidently, growers, smallholder farmers in particular, must have the necessary resources and skills to practice lucrative and sustainable agricultural practices. Government and public policies about the sustainability of food systems and consumer awareness of nutritious foods must support food supply networks.

Keywords: Healthy food, novel food technologies, precision farming, resilient food system, sustainable food technology

Key message: Requirements for a sustainable food system for human beings

Abbreviations: NA

1. Introduction

1. Net-zero oriented

It refers to the process of bringing global greenhouse gas emissions down to a level where they are not contributing to climate change. This effort is essential to prevent the severe effects of climate change and ensure a sustainable future for future generations (IPCC, 2022; IEA, 2021; UNFCCC, 2021).

A comparison of the strategies and key approaches to address the benefits and challenges of food systems have been described in Table 1. Countries and companies must drastically cut their emissions using a variety of tactics to reach net zero, including:

1.1 Shifting consumer preferences



Copyright: ©2026 The authors. **Open Access** International Licensee: Plant Research Journal, Lahore, Pakistan. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license: <https://creativecommons.org/licenses/by/4.0/> While the work is simultaneously licensed under the CC Attribution 4.0, which permits others to share the work with a citation to the work's authorship and first publication in this journal, the authors retain copyright and grant the journal the right of first publication. With an acknowledgement of the work's original publication in this journal, authors can sign additional, independent contracts for the non-exclusive distribution of the journal's published version of the work. *Nasir, G.A., Arshad, F., Akram, M. (2026). The need for cost-effective, adaptable, and environmentally friendly food systems. Plant Research Journal, 02(01), 19-29.*

Table 1. Comparison of the strategies and key approaches to address the benefits and challenges of food system.

Theme	Key Approaches	Benefits	Limitations/Challenges	References
Net-Zero Strategies	Renewable energy, energy efficiency, carbon capture, low-carbon transport, circular economy	Reduce GHG emissions, improve efficiency	High cost, political barriers, slow adoption	IPCC (2022); IEA (2021); UNFCCC (2021)
Food System Resilience	Agroecology, local food systems, crop diversity, small-scale farmer support	Enhance soil health, climate adaptation, rural livelihoods	Requires training, market access issues	Altieri (2018); FAO (2019); Tilman & Clark (2014)
True Cost of Food	Internalizing environmental & social costs	Promotes sustainability, discourages harmful subsidies	Difficult to measure, resistance from industry	TEEB (2018); WWF (2020)
Analytical Tools	Life Cycle Assessment, FEW Nexus, Agent-based models, Scenario analysis	Assess trade-offs, policy guidance	Complex, data-intensive	ISO (2006); Hoff (2011); van Ittersum et al. (2008)
Equity in Food Systems	Fair labor practices, smallholder support, systemic inequality reduction	Improves justice, inclusiveness	Requires strong governance	Clapp (2021); IPES-Food (2016, 2017)
Novel Food Sources	Cultured meat, insects, vertical farming, functional foods	Reduced land use, new protein sources	Consumer acceptance, regulation, costs	Post (2012); van Huis et al. (2013); Al-Kodmany (2018)
Future Agriculture	Climate-smart, digital, organic, alternative farming systems	Higher efficiency, sustainable practices	Tech divide, yield gaps	Lipper et al. (2014); Rose & Chilvers (2018)
Food Waste Reduction	Prevention, recovery & redistribution, composting, innovation	Reduce losses, improve food security	Requires awareness, infrastructure	UNEP (2021); Gustavsson et al. (2011)

Consumer preferences are shifting away from fossil fuels and toward renewable energy sources like hydropower, wind, and solar.

1.2 Energy efficiency

Energy efficiency reduces energy consumption in companies, automobiles, and buildings, thereby increasing production and reducing emissions (IEA, 2021; IPCC, 2022).

1.3 Carbon capture and storage

Removing carbon dioxide from emissions produced by factories and power plants and storing the captured emissions underground to prevent them from returning to the atmosphere (Haszeldine, 2009; IPCC, 2022).

1.4 Low-carbon transportation

Encouraging the use of electric vehicles and other forms of mobility to reduce transportation emissions and improve walking and bicycling (Sims et al., 2014; IEA, 2021).

Various mindful activities may be adopted to reduce carbon emissions and maintain healthy routines (Fig. 1).

1.5 Land-use changes

Control of changes in land use, emissions from forest degradation and deforestation, and afforestation and reforestation (Rockström et al., 2009; FAO, 2019).

1.6 Circular economy

Establishing and expanding the circular economy concept aims to reduce waste production and promote more sensible product consumption, re-use, and re-manufacturing.



Figure 1. Mindful activities help people reduce low-carbon emissions in the environment.

Offsetting carbon, paying for programs that can reduce the amount of greenhouse gases in the atmosphere, such as afforestation and the financing of renewable energy projects, to offset emissions from other sectors. Although achieving net zero will require political will and ongoing funding, it is essential to preserving the environment and building a brighter future for all (Geissdoerfer et al., 2017; UNEP, 2021).

2. Improvement of food systems' resilience and flexibility

Considering climate change and other adverse effects, it is critical to increase the stability of food supply chains to ensure that people have access to enough and healthful food. The following tactics can be applied to improve food systems' resilience and sustainability:

2.1 Promote agroecological practices

Agroecology is a farming style emphasizing ecological principles to enhance agricultural infrastructure. This includes promoting ecological balance on farms and reducing the use of chemicals in farming operations. Adopting agroecological techniques will improve soil health, crop resilience to climate change, and hydration status (Altieri, 2018; Gliessman, 2015).

2.2 Invest in local food systems

One strategy to reduce greenhouse gas emissions from food production and sales is to support localized food supply chains. This entails supporting local agricultural practices and the consumption of locally produced food, decreasing the waste associated with food, and establishing structures and institutions such as farmers' markets and other food co-operatives (FAO, 2019; IPES-Food, 2017).

2.3 Increase crop diversity

Additionally, they eradicate diseases, pests, and climate change, which helps to diversify crops and reduce the likelihood of food system failures. This means promoting the production of enhanced, environmentally friendly agricultural varieties and traditional ones like heirlooms (Tilman & Clark, 2014; Khoury et al., 2014).

2.3 Reduce food waste

Several strategies exist to reduce food waste and increase food utilization, diminishing the impact on the environment. These include promoting the use of high-quality, environmentally friendly packaging, properly preserving food to ensure that it reaches its destinations undamaged, and using food waste for animal feed or compost (Gustavsson et al., 2011; UNEP, 2021).

2.4 Support small-scale farmers

Due to their susceptibility to these conditions, declining livelihoods and climate change impact on their food security. Ad hoc interventions that would allow small-scale farmers to access markets, high-quality inputs, and financial facilities would significantly improve food security and the food systems' resilience to shocks (FAO, 2019; IPES-Food, 2016).

3. Limitations in measuring the real cost of food production

It encompasses all the environmental, social, and economic expenses of producing food, such as the costs of carbon, water, soil, and the cost of human illnesses. Although many of these costs do not feature in the price that consumers pay for food, they are incurred at the societal and environmental level.

A primary limitation within the true cost of producing food is the exorbitant task of assigning or estimating the impacts of various internal and external factors involved in producing food. This may consist of the costs of services, like soil erosion, deforestation and water pollution, which are usually left out of the market price of food (TEEB, 2018; WWF, 2020).

Another well-known problem is overburdening the most disadvantaged people: small farmers in developing countries, underserved consumers from the population, and other affected communities. For instance, due to climate change, adverse effects are likely to affect the small-scale farmers since they are likely to be affected by frequent incidents of poor weather and other conditions affecting agricultural production (FAO, 2019; IPES-Food, 2016).

Furthermore, consumers lack awareness of the actual cost per food production, including the influence it has on the environment and other people. Because of this, it becomes challenging to build a market for sustainably grown food, which proves disadvantageous to sustainable farmers.

Lastly, the actual cost of producing food is also not clearly considered, mostly due to subsidies and other government interferences in the production of food. For instance, aid oriented to huge commercial farming has negative impacts of promoting destructive agricultural practices such as growing crops of a single kind referred to as monoculture in addition to overuse chemicals, for instance, pesticides and fertilizers.

4. Tools for studying food interactions and compromises

Here are some examples of commonly used models and methodologies: Here are some examples of commonly used models and methodologies:

4.1 Life cycle assessment (LCA)

LCA is a technique that measures the effect of a product or a process across its life span from manufacturing to end-use. LCA can be applied to assess the environmental effects of various food production systems—mainly, emissions of greenhouse gases, soil and water use, and loss of biodiversity (ISO, 2006; Notarnicola et al., 2017).

4.2 Food-Energy-Water (FEW) Nexus

The FEW Nexus approach is an approach that looks at the interactions and balance between the food, energy, and water systems. It can be applied to assess the vulnerability of food systems and potential methods for decreasing the utilisation of resources and increasing resource productivity (Hoff, 2011; Biggs et al., 2015).



Figure 2. Orthodox and protein-rich food sources.

4.3 Agent-based modeling

Agent-based modeling is a simulation method which considers activity of agents, including farmers or consumers in the analyzed system. The structures created with this approach can be used to analyse the selection dynamics of food systems and how policy change and other external factors affect them (van Ittersum et al., 2008; Robinson et al., 2007).

4.4 Scenario analysis

Scenario analysis, on the other hand, entails the creation of real-like models that will help to analyze different prospects to arrive at definite results and associated compromises. This approach can be used to estimate the effect of various policy interferences of food system sustainability and its resilience.



Figure 3. Food wastage places and their environmental impacts.

4.5 Participatory modeling

Participatory modeling requires the involvement of relevant stakeholders, including farmers, policy makers and consumers, among others. Thus, this approach can also aid in the completeness of the modeling process since consideration is given to the varied opinions of different investors (Voinov & Bousquet, 2010; Reed et al., 2013).

Through applying these models and methodologies, the scholars and policymakers can comprehend and indicate the tradeoffs and complexity of the food system.

5. Impartiality in the food system

It is one of the prerequisite measures to contribute to the development of stable and shock-resistant food chains. Here are some key strategies for achieving the goals of fairness across the food systems: Here are some key strategies for achieving the goals of fairness across the food systems:

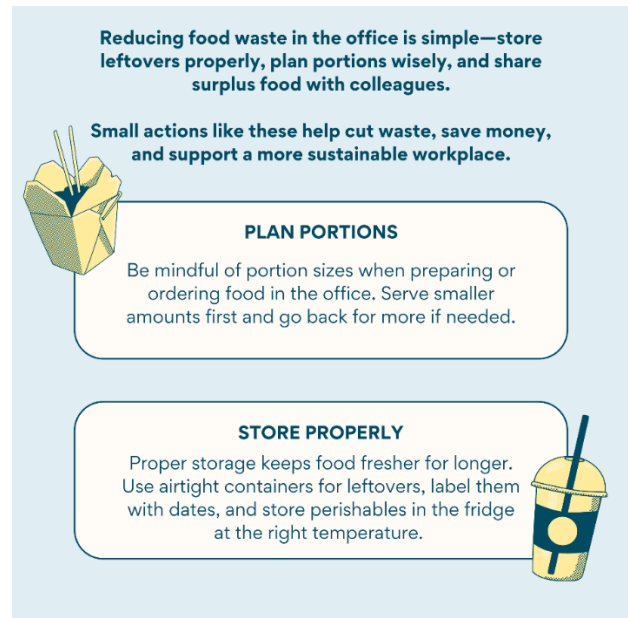


Figure 4. Some useful information about reducing food waste.

5.1 Addressing food insecurity and malnutrition

Availability of health or better still, nutritious foods to those who are in need are very crucial to meet the goal of food system equity. This can include policy and program changes to promote healthy foods, for example, buying and selling of fresh foods in remote areas or ensuring expansion of school feeding programs.

5.2 Supporting small-scale farmers

With this method of production, small-scale farmers are disadvantaged within food systems due to issues such as market access and requirements. This is because of the availability of, for example, markets to sell their produce, access to appropriate technology, and markets where the small-scale farmers can get access to affordable and quality input, which can go a long way in providing fairness to farmers in the food system (FAO, 2019; IPES-Food, 2016).

5.3 Promoting fair labor practices

A significant number of employees in the food chains like farmers and Restaurant employees, are paid very low wages and are not protected by employment laws like access to healthcare, paid sick days, or unions. Advocating for remunerated labor can assist in guaranteeing that employees are treated fairly and offered safe and advanced working environment (Clapp, 2021; IPES-Food, 2017).

5.4 Addressing systemic inequalities

Patriarchal and racially influenced oppressive power relations are part of the reason for unfair food systems. These disparities can be rectified through the employment of procedures and essentials that ensure fairness and complete non-discrimination at the economic frontier, or, for instance, providing women and colored farmers with subsidies and/or preventing discrimination in employment (IPES-Food, 2016; FAO, 2019).

5.5 Engaging in community-led initiatives

It is about equity and fairness within communities with local ideas like community garden or food cooperatives that are locally managed, to enhance affordable healthy food sources.

Thus, applying these methods would help the Commission and other stakeholders develop the fundamental principles for constructing more just and fair food systems that would provide everyone in the world with proper nourishment and resources they may require to lead healthy lives.

Politics in the food system and managing accountability among the actors for the food system. Here politics, governance and accountability are key components in the development of better and sustainable food systems. Here are some key considerations for each of these areas:

- **Food politics:** Food politics then describe the use of power and authority, especially in the context of the food systems. This involves corporate and government actions that shape the food system policies and actions. The task of making food politics open, fair, and responsible will contribute to the support of the future population and future generations.
- **Governance:** They are the system that defines the approaches to making and executing decisions regarding the food system. A strong government system used in a country can assist

in the implementation of food systems, influencing policies and practices in line with sustainability and equity. This might include using strategies in nutrition and dietetics and food security, including the support of sustainable and equitable food choices, for example, the adoption of sustainable agriculture or food choices.

- **Accountability:** Accountability defines how actors involved in the food system are supposed to be made answerable or are answerable for their actions, the decisions they take. Some of these can be in the form of certification, compliance and monitoring, evaluation and that decision making processes must be made available. This paper has shown that for a more sustainable and fair food system, food system actors must be made to answer for their actions.
- **Food system actors:** Food system participants include producers, manufacturers, suppliers, regulatory authorities and the customers. All these actors hold a responsibility for contributing to the equitable and sustainable food systems. For instance, farmers can employ sustainable farming, policymakers can embrace policies and legislation that support sustainable food systems within society and consumers can select products and services that are sustainable and priced.

Consequently, more attention should be given to politics of food, as well as governance and responsibility of the actors involved in the networks to develop reliable innovative systems fit for the purpose.

6. Managing changing dietary demands and gaps in the world

It is an important element in constructing stable food chains to supply human needs. Here are some strategies for addressing these issues:

6.1 Promote healthy and sustainable diets

Therefore, to meet the emerging future dietary requirements and sustainable food systems, it is crucial to promote healthy and sustainable dietary consumption. This may include raising awareness on the importance of taking healthy and sustainable meals and putting in measures that encourage consumers to take healthy meals that are sustainable.

6.2 Address food waste

That is why it is possible to conclude that combating food waste can be an essential component in tackling the negative aspects of food systems' inequities. This can include adoption of strategies that enable food to be rescued from being wasted or even changes in food production processes that lead to minimum wastage of the same (Gustavsson et al., 2011; UNEP, 2021).

6.3 Promote food system resilience

Influencing food resilience can benefit the issue of inequality in food systems because it will enable all groups of people to access food that is healthy for them despite the circumstance. Some of the intervention areas might entail applying sustainable agricultural practices in a region, developing effective systems for food supply, or creating food systems that are led by community members.

6.4 Address global food inequalities

The inclusion of aspects that address food inequalities in the global society is important in ensuring that food systems run on fairness. This can be exercising courtesy through buying local farming products and supporting farming in the developing world or buying fair trade products and supporting food security within the affected nations.

6.5 Foster international cooperation

Thus, the pursuit of international cooperation is required because food systems are interconnected and must become more sustainable and equitable. It may encompass the process of cooperation with other countries in areas of concern, including climate change, trade relations, and food security, among others.

Thus, understanding how consumers require food that meets their new demands and analyzing inequality in a globalized world to build a new and fairer food system is possible.

7. Modern food sources and techniques

Orthodox and new food sources entail the techniques of food production that are different from the conventional practices of food production (Fig.2). Some of these are novel protein sources, plant proteins and

analogs, in vitro meats, insects as food and feed, and functional foods, among others.

Here are some examples of novel food sources and technologies (Granato et al., 2020; Roberfroid, 2000).

7.1 Alternative protein sources

New types of proteins for consumption have surfaced in the market as the market grows and expands, where plant proteins, algae, and fungi proteins are slowly becoming widespread. The above sources of protein can be considered as more friendly to the environment and can be produced with fewer inputs than animal proteins.

7.2 Cultured meat

Download Scientific Theme Cultured meat, or scientifically referred to as lab-grown meat, is derived from tissue samples from an animal and grown in a laboratory. Cultured meat has benefits such as reduced effect on the environment as well as on the welfare of the animals (Post, 2012; Stephens et al., 2018).

7.3 Edible insects

Beef is also a good source of protein, but it requires more input than insects do to produce. Foods like crickets, mealworms, and grasshoppers have come into the limelight as being a potential source of protein (van Huis et al., 2013; Payne et al., 2016).

7.4 Vertical farming

Vertical farming is also known as vertical agriculture and this is a method or technique of growing crops whereby the plants are stacked in layers one on top of the other. Its usefulness can be attributed to the fact that this method can be applied to the production of food in urban regions where space is a limiting factor, and this reduces the number of resources used in food production (Al-Kodmany, 2018; Despommier, 2013).

7.5 Functional foods

Functional foods are those foods that have value besides the basic nutritional value of the food. For instance, there are probiotics, prebiotics, and foods enriched with beneficial ingredients that improve digestion (Granato et al., 2020; Roberfroid, 2000). Thus, new food sources and technologies are promising to

meet the increasing global demand for food; however, their existence is not without drawbacks. Some of these are the regulatory system, acceptance from the consumers, and the impact on the environment. Therefore, expansion of knowledge and development of new foods and related technologies that promise safety, nutritional quality, and environmental compatibility ought to be given topmost importance.

8. Scaling up and adoption

This area also includes the constants regarding the production of novel food sources and food technologies in regard to their environmental implications, safety, and nutritional quality. Moreover, there could be a lack of well-formulated and clearly defined regulatory provisions regarding some of the new food sources and technologies, which causes a certain level of uncertainty and restricts market entrants.

Another major challenge is the acceptability of new sources of food and technologies by consumers. This could be a barrier because consumers cannot easily experiment with the new foods, especially if these are qualitatively perceived to be novel and unappealing. Also, people's perception of cultural and religious aspects of food may be positive or negative.

To address these trials, it is pertinent to emphasize pulling research and development of new types of foods and technologies that have been accredited for their safety, nutrient values, and ability to sustain the environment. Awareness creation is another method of making the consumer change so that he or she is willing to accept unfamiliar foods and thus end long-time stigmatization. Also, public-private partnerships can create the right policies and structures that would encourage the scaling up of new food sources and technologies in the fight against hunger.

In conclusion, novel food sources and technologies contain a lot of potential in helping to feed the world, but the challenges of how to upscale and increase acceptability are threatening, and these are the ways that require strategic investment, education, and collaboration.

9. Outlook on agricultural production and practices

This is another important field that generates discussion and concerns, as agriculture is a sector that must cope with multiple problems such as climate change, changes in customer preferences, transformation in knowledge, and so on. Here are some potential trends

and developments that could shape the future of agriculture.

9.1 Climate-smart agriculture

Related changes in climate are disrupting the yields of crops throughout the globe and the farmers' ability to feed themselves. As such, climate-smart agriculture is slowly transforming into a focus. Climate smart agriculture focuses on measures and activities to mitigate greenhouse gas emission, adapt to conditions that result from climate change, and increase agricultural productivity (Lipper et al., 2014; FAO, 2019).

9.2 Digital agriculture

Now technologies are already being incorporated in the way farmers conduct their business and this is set to expand in the future. Precision agriculture, remote sensing, and related machinery have potential to increase productivity while at the same time reducing input application and resource utilization (Wolfert et al., 2017; Rose & Chilvers, 2018).

9.3 Alternative farming systems

Organic farming, climate-smart agriculture, and even the use of hydroponics are considered to be the new rising stars in world agriculture as they are efficient and environmental-friendly farming practices that offer chances for the improvement of yields and the reduction of the negative impacts of farming on the environment and the soil (Lipper et al., 2014; FAO, 2019) (Reganold & Wachter, 2016; Seufert et al., 2012).

9.4 Farmer wellness and mental health

Agriculture entails hard work and might be dexterous both on the body and mind of the farmer. With the lowering of stress and depression levels in farmers, there is evidence that they wish to access material that enhances their mental and physical health. There's a sign of the struggling shift among the agriculture people; many farmers are more concerned with their well-being and mental health willing to seek help from the resources available to them.

9.5 Changing consumer demands

Consumers' requirements also already affect what farming will look like in the future. The food that

consumers are looking forward to consuming today is sustainable and from within their region with less or no use of chemicals. There is also an increasing consumer demand for protein from plant sources. Consumers have different demands in the food they require in their daily diet and farmers will have to change to meet these demands (Godfray et al., 2010; Tilman & Clark, 2014).

Thus, it can be stated that the future of farms, farmers, and farming is currently unpredictable and will have to be defined based on technological progress, the environmental and social issues, and the preferences of customers. Implementing the new changes in addressing food insecurity and meeting the consumers' need for fresh produce will demand innovation, cooperation, and sustainable and resilient agriculture.

10. Robust, sustainable food systems to reduce losses and food waste

The preservation of safety and accessibility of food through the mitigation of loss and waste is also another critical aspect to secure the food resource, cut down on carbon emissions and enhance food efficiency. Wasting food is a global crisis. There are various places where different food is generally being wasted with different proportions that have made environmental impacts (Fig.3).

Here are some strategies for developing robust sustainable food systems that can help reduce losses and food waste (Gustavsson et al., 2011; UNEP, 2021):

10.1 Food waste prevention

There is nothing as efficient as avoiding food wastage in the first place, and this is the ultimate solution when it comes to the accumulation of food wastage. Small actions may be fruitful in reducing food waste as has been depicted in Fig.4. This can be attained by optimizing the supply chain, enhancing consumer awareness on the right ways of preservation and preparation of meals and giving value to food waste and other byproducts (Gustavsson et al., 2011; UNEP, 2021) (UNEP, 2021; Gustavsson et al., 2011).

10.2 Food recovery and redistribution

Despite such measures being put in place, there is still bound to be some level of wastage in food. Among the ways of reducing food waste and enhancing food security is through collecting edible food that was going

to be wasted and providing it to the needy populace (Gustavsson et al., 2011; UNEP, 2021).

10.3 Composting and recycling

Discarded food and other waste can be utilized by composting and this will aid in increasing the nutrient quality of the soil and availability of natural fertilizers. Most of the food waste can also be recycled even if it is not for human consumption either as animal feed or for biogas production (Kumar et al., 2017; Bernstad & la Cour Jansen, 2012).

10.4 Sustainable agriculture

There is provision made towards sustainable agricultural practices such as crop rotation, minimum tillage practices, integrated pest management among others to minimize losses on produce and enhance on yields.

10.5 Innovation and technology

Innovations in the field of precision agriculture as well as the application of blockchain, revolutionize the supply chain, encourage shared responsibility.

10.6 Collaboration and policy support

Food is another necessity that needs to be provided sustainably by involving the agricultural producers, processors, retailers and consumers. Measures that also focus on sustainable agriculture and food waste can also be used as policies that foster for sustainable food systems (Gustavsson et al., 2011; UNEP, 2021).

Lastly, it is important to establish strong effective, and sustainable food systems that will help in the fight against losses and waste of food. This involves food waste avoidance, collection and distribution and surplus reprocessing and recycling, waste management via composting and recycling systems, farming and food production, researching and investing in new technologies, and support and partnership along with policy implementation (Gustavsson et al., 2011; Bernstad & la Cour Jansen, 2012; Kumar et al., 2017; UNEP, 2021).

Acknowledgements All authors thank GICCL for the provision of placement for working activities.

Author(s) contribution Conceptualization, MA; methodology, MA; software, MA; validation, GAN;

formal analysis and investigation, MA; data curation, FA; writing—original draft preparation, MA; writing—review and editing, GAN; supervision, GAN. All authors have reviewed and approved the manuscript.

Conflict of interest The authors declare no conflict of interest.

Data availability All data supporting the findings of this study are available within the paper. We do not have any research data outside the submitted manuscript file.

Declarations

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

- Altieri, M. A. (2018). *Agroecology: The science of sustainable agriculture*. CRC Press.
- Al-Kodmany, K. (2018). The vertical farm: A review of developments and implications for the vertical city. *Buildings*, 8(2), 24.
- Bernstad, A., & la Cour Jansen, J. (2012). Review of comparative LCAs of food waste management systems—Current status and potential improvements. *Waste Management*, 32(12), 2439–2455.
- Biggs, E. M., Bruce, E., Boruff, B., et al. (2015). Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy*, 54, 389–397.
- Clapp, J. (2021). *Food*. Polity Press.
- Despommier, D. (2013). Farming up the city: the rise of urban vertical farms. *Trends in Biotechnology*, 31(7), 388–389.
- FAO. (2019). *The State of the World's Biodiversity for Food and Agriculture*. Food and Agriculture Organization of the United Nations.
- FAO. (2021). *The State of Food and Agriculture 2021*. Food and Agriculture Organization of the United Nations.
- Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy—A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.
- Gliessman, S. R. (2015). *Agroecology: The ecology of sustainable food systems*. CRC press.
- Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... & Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, 327(5967), 812–818.
- Granato, D., Barba, F. J., Kovačević, D. B., Lorenzo, J. M., Cruz, A. G., & Putnik, P. (2020). Functional foods: Product development, technological trends, efficacy testing, and safety. *Annual Review of Food Science and Technology*, 11, 93–118.
- Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). Global food losses and food waste: Extent, causes and prevention. FAO.
- Haszeldine, R. S. (2009). Carbon capture and storage: How green can black be? *Science*, 325(5948), 1647–1652.
- Hoff, H. (2011). *Understanding the Nexus*. Background paper for the Bonn2011 Nexus Conference. Stockholm Environment Institute.
- IEA. (2021). *Net Zero by 2050: A Roadmap for the Global Energy Sector*. International Energy Agency.
- IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change*. Intergovernmental Panel on Climate Change.
- IPES-Food. (2016). *From uniformity to diversity: A paradigm shift from industrial agriculture to diversified agroecological systems*. IPES-Food.
- IPES-Food. (2017). *Too big to feed: Exploring the impacts of mega-mergers, consolidation and concentration of power in the agri-food sector*. IPES-Food.
- ISO. (2006). *ISO 14040: Environmental management—Life cycle assessment—Principles and framework*. International Organization for Standardization.
- Khoury, C. K., Bjorkman, A. D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., ... & Struik, P. C. (2014). Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences*, 111(11), 4001–4006.
- Kumar, S., Smith, S. R., Fowler, G., Velis, C., Kumar, S. J., Arya, S., ... & Cheeseman, C. (2017). Challenges and opportunities associated with waste management in India. *Royal Society Open Science*, 4(3), 160764.
- Notarnicola, B., Sala, S., Anton, A., et al. (2017). The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. *Journal of Cleaner Production*, 140, 399–409.
- Payne, C. L., Umemura, M., Dube, S., & Van Itterbeeck, J. (2016). Chapter 11: Insects as food in Sub-Saharan Africa. *Insects as Food and Feed: From Production to Consumption*, 193–214.

- Post, M. J. (2012). Cultured meat from stem cells: Challenges and prospects. *Meat Science*, 92(3), 297–301.
- Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, 2(2), 15221.
- Robinson, S., et al. (2007). The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). IFPRI.
- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., ... & Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, 14(2).
- Rose, D. C., & Chilvers, J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems*, 2, 87.
- Seufert, V., Ramankutty, N., & Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. *Nature*, 485(7397), 229–232.
- Sims, R., Schaeffer, R., Creutzig, F., Cruz-Núñez, X., D'Agosto, M., Dimitriu, D., ... & Tiwari, G. (2014). Transport. In *Climate Change 2014: Mitigation of Climate Change*. Cambridge University Press.
- Stephens, N., et al. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends in Food Science & Technology*, 78, 155–166.
- TEEB. (2018). TEEB for Agriculture & Food: Scientific and Economic Foundations. UN Environment.
- Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, 515(7528), 518–522.
- UNEP. (2021). Food Waste Index Report 2021. United Nations Environment Programme.
- UNFCCC. (2021). NDC Synthesis Report. United Nations Framework Convention on Climate Change.
- van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). Edible insects: Future prospects for food and feed security. *FAO Forestry Paper* 171.
- van Ittersum, M. K., Ewert, F., Heckeley, T., Wery, J., Alkan Olsson, J., Andersen, E., ... & Wolf, J. (2008). Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS). *Agricultural Systems*, 96(1–3), 150–165.
- Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. *Environmental Modelling & Software*, 25(11), 1268–1281.
- Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big data in smart farming—A review. *Agricultural Systems*, 153, 69–80.
- WWF. (2020). Bending the curve: The restorative power of planet-based diets. World Wide Fund for Nature.

Publisher's note: PPSP remains neutral about jurisdictional claims in published data and institutional affiliations.