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Review

Assessment and Principles of Environmentally Sustainable Food and Agriculture Systems

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Abstract: Feeding the world depends on protecting our valuable ecosystems and biodiversity. Currently, increasing public awareness of the problems posed by the current industrialized food system has resulted in increased support for the creative market for economically, socially, and ecologically sustainable food production systems and enhanced demands for variations in agricultural policies and regulations. In food production, the restoration and protection of ecosystems and sustainable food systems must be given priority, which requires a forward-looking rational management strategy and fundamental changes in patterns and practices of economic development, product, and production. Food systems should be redesigned to have a neutral and positive environmental impact, as well as ensure healthy nutrition and food safety, and low environmental impact strategies should become a priority. This review paper aims to discuss, build, guide and evaluate sustainable food systems, principles, and transition strategies such as agroecological, organic, biodynamic, regenerative, urban, and precision agriculture, which are imperative visions for the management of agriculture and food production. To this end, we analyzed the evolution of the established strategies to develop sustainable agriculture and food systems, and we created assessment of key sustainability issues related to food, environment, climate, and rural development priorities and resource use practices.

Keywords: environmental sustainability; sustainable agriculture; local food systems; biodiversity in agroecosystems; sustainable farming; food safety

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1. Introduction

Sustainable food systems address the principle that improving production and processing the food supply needs of the present must be met without compromising the health of the planet and the ability of future generations to meet their needs. Overall, a socially, economically, and ecologically sustainable food system has been defined as a system capable of adapting and mitigating the impact of climate change, maintaining the health of ecosystems, reversing biodiversity loss, and producing adequate, healthy, safe, and nutritious food [1,2]. According to the definition used in FAO, a sustainable food system is "deliver food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" [3]. This system ensures food safety and nutrition by considering the components of production, processing, distribution, and consumption of food, and makes food accessible for everyone [4]. On the other hand, it is humane and just and protects farmers, workers, consumers, and communities. This system focuses on increasing the quality of life of all individuals with profitable production and food systems, protecting and improving resources, using nonrenewable and on-farm resources in the most efficient way, and producing food and other agricultural products at low costs by reducing total energy use [5,6].

Agriculture not only contributes to climate change and global warming [7] but also causes more carbon dioxide, methane, and nitrous oxide emissions, acidification, eutrophication, nutrient releases, fertilizer residues, and carbon emissions and negatively affects water supplies through runoff and wasteful irrigation systems [8–10]. Modern industrial agriculture has increased yields and food availability and achieved remarkable growth over time, but existing food systems have also led to many problems, such as pollution and degradation of soils, nitrogen and phosphorus pollution, loss of biodiversity and global habitat, destruction of habitat, rendering agricultural landscapes less resilient, reduction in human health and farm incomes, and shrinkage of water storage and distribution capacity, which have come at a staggering cost to the environment [11–13]. However, over time, the benefits and gains of monocultures have decreased due to the inability to balance the advantages and disadvantages [14], and as a result, the main agricultural systems are directed to an unsustainable trajectory. While increasing environmental pressures on farmland as well as financial pressures on farmers due to land scarcity and speculation [15], the increasingly centralized food system commercializes food; the economy plays a dominant role and can provide food at a low cost, but it underperforms in meeting criteria for food quality and social and environmental sustainability [16]. Today, while the problem of food insecurity is shifting from rural areas to cities, urbanization is becoming one of the important challenges faced by societies in terms of food safety and sustainability.

The ecological environment encompasses the size and quality of soil, water, climate, and living resources essential to life. While food systems deplete the natural resources on which they rely and diminish the availability of resources needed for other activities, irrigation use disturbs river flow, alters water quality, and modifies regional climates. At the same time, fertilizers leach into surface- and groundwater and cause algal blooms; human-made materials and substances can lead to contamination and create unforeseen problems, affecting air, water, and soil quality. Wildlife habitats, wetlands, land, and water biodiversity are increasingly threatened by the current food production system based on chemical inputs, which have effects such as disruption of biochemical cycles, climate change, pH change, water pollution, and habitat destruction. Moreover, large natural areas have been converted to farmland, fragmented habitats have reduced biodiversity, and industrial agriculture has contributed to reducing agrobiodiversity and thus the resilience of ecosystems, wetlands, and wildlife habitats [17,18] and is a cause for concern due to its lack of respect for life [19]. Monoculture practices directly affect the quality and health of the soil, deplete nutrients, and cause the degradation and pollution of ecosystems and decrease their services [20].

Agricultural systems can use natural resources more efficiently and sustainably, reduce the environmental impact of use inputs more efficiently, and achieve a multitude of benefits. It is necessary to maximize production, minimize pollution, avoid uniform fertilizer and pesticide applications, encourage site-specific practices, increase nutrient use efficiency, and reduce nitrogen application, as well as protect the natural resource-based agriculture.

In this regard, high agricultural productivity should be achieved with low environmental impacts, special emphasis should be placed on improving efficiency in less efficient systems, and new technologies and management techniques should be developed to increase agricultural input efficiency [21]. Achieving sustainable agricultural development requires protecting the ecological capacity, the efficient use of natural, human, material, and energy resources, turning to radically transformative specific innovation policies, and achieving a balance between agricultural development and environmental protection [15,22].

An economically sustainable system is one that can produce goods and services in accordance with the principles of continuity without harming agricultural and industrial production and without creating sectoral imbalances [23]. Additionally, agricultural sustainability requires investment in ecosystem management and sustainable innovation. While sustainability can be analyzed by considering environmental, economic, social, and generational visions [24], sustainable agriculture aims to meet these objectives simultaneously. Growth, development, and productivity have been proposed as important criteria for economic sustainability, along with equity, participation, accessibility, sharing, cultural identity, and stability for society [25]. Moreover, sustainability in farming is driven by three interrelated principles, economic viability, social fairness, and environmental friendliness [26]. Reducing transportation and food waste and loss, improving water management, and healthier and more sustainable food production practices were evaluated as indicators of environmental sustainability [16]. It is becoming increasingly important to develop innovative approaches to the study, evaluation, creation, and redesign of the agricultural system, which is an important part of high living standards.

2. Sustainable Food, Agriculture, and Agroecosystems

The ecological environment encompasses the size and quality of soil, water, climate and living resources essential to life. Sustainable agricultural practices are based on more efficient use of natural resources, reducing the environmental impact of agriculture, improving the capacity to adapt to climate change and variability, and providing adequate and nutritious food for all. Sustainability focuses on the overall viability and health of ecological systems and aims to maximize revenue while maintaining the stock of assets. Sustainable agriculture and crop production's key goals are to include a healthy environment, economic profitability, and social and economic equality in the production process [27], while its basic principles are social inclusion, economic development, and environmental sustainability [28]. Sustainability performance enhanced by the adoption of technology and the integration of economic, social, and environmental dimensions [29], could be defined as a potential generator of competitive advantage [30].

According to FAO recommendations, sustainable agriculture should be environmentally, economically, and socially responsible and contribute to the availability, access, use, and stability of food security, while sustainable development is defined as "management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations" [22]. FAO [22] emphasized five basic key principles for sustainable food and agriculture (Table 1). Sustainable agricultural systems of the future must be technically appropriate, productive, economically viable and efficient, socially fair and acceptable, and environmentally friendly, as well as protecting soil, water, plant, and animal genetic resources [22]. Therefore, sustainability strategies comprise much more than not harming the environment and protecting the natural resource base. The methodological principles for "Sustainability Assessment of Food and Agriculture systems" (SAFA) recommended by FAO [7,31] are relevance, holistic, rigor, simplicity, efficiency, goal orientation, continuous improvement, performance orientation, adaptability, transparency, and accessibility.

Table 1. Assessment of some sustainable food and agriculture systems and some related themes in terms of some dimensions.

Sustainable Farming Approaches	Dimension/Strategic/Practices/Principles and/or Goals	References
Agriculture green development	***Subsystems***: Green crop production system/Integrated animal–crop production system/Rural environment and ecosystem services/Green food products and industry	[32]
Sustainable plant production	***Main principles:*** Economic development/Social inclusion/ Environmental sustainability ***Systems approach:*** Sustainable seeds and varieties/Diversified farming systems/Minimal pesticide use/Water conservation/Nurturing soil health Innovations: Biotechnology and genetic engineering/Remote sensing and big data/New forms of fertilizers	[28]

Table 1. *Cont.*

Sustainable Farming Approaches	Dimension/Strategic/Practices/Principles and/or Goals	References
Sustainable agriculture	***Main benefits:*** Enhancement of soil quality, fertility, and production, and amelioration of soil physicochemical characteristics/Improvement in plant physiological status and reduction in plant disease incidence/Increase in the abundance, functionality, and diversity of soil biota/Re-establishment of the trophic balance and increase in soil–plant compatibility/Preservation of natural resources, environmental protection	[33]
Conservation agriculture	Minimizing soil disturbance (minimal or reduced tillage)/Maintaining soil cover (cultivation of cover crops and permanent organic cover over soils)/ Managing crop rotation	[22]
Regenerative agricultural practices	***Objectives/Outcomes:*** Regenerate the systems/Enhance and improve soil health/Reduce environmental externalities/Increase biodiversity, yields, farm profitability, carbon sequestration, and crop health/Improve ecosystem health and resilience, soil carbon, soil fertility, and soil physical quality/Optimize resource management/Improve nutrient cycling/Improve the ecosystem/Alleviate climate change/Improve water quality, availability, percolation, and retention/Improve food nutritional quality and human health/Improve food security, safety and access, and economic prosperity/Improve the social and economic well-being/Reduce greenhouse gas emissions and waste	[34,35]
	Principles: Minimize or eliminate agrochemicals/Maintain permanent cover of the soil, ideally with living roots/Minimize soil disturbance/Maximize functional biodiversity/Adapt to context-specific design	[36,37]
	Activities: Minimize external inputs/Use of manure and compost/Mixed farming/Minimize tillage/Crop rotation/Use of perennials/Other soil activities	[35]
	Processes: Use cover crop, crop rotations, plant diversity, organic methods, organic fertilizers, and inputs/Restore natural habitats/Use ecological, natural principles/Focus on localism and regionality, and small-scale systems/Changes land preparation, fertility management, and land use	[34]
Permaculture	Improve soil and water quality/Integrated land and pest management/ Involved crop rotation/Diversify ecosystems	[14]
Sustainable intensification	***Redesign:*** Producing more per unit of input/Preserving essential ecosystem services/Resilience to shocks and stresses caused by climate change/Integrated pest management/Agroecological system and habitat/Redesign/Conservation agriculture/Integrated crop and biodiversity redesign/Pasture and forage redesign/Trees in agricultural systems/Irrigation water management/ Intensive small and patch systems ***Practices:*** Drawing from integrated approaches/Agroecology/Organic farming/Precision farming/Urban farming/Genetic improvement methods	[36,38]
Ecological intensification	***Goals:*** Biodiversity conservation/Improved soil fertility management/Reduced pest and disease infestations/Farming system resilience ***Practices:*** Mixed cropping systems, crop rotation, cover crops, and mulch-based cropping systems/Conservation tillage/Integrated pest management/Improved fertilizer and nutrient management/Biodiversity preservation and promotion of positive allelopathic effect	[39]
Climate-smart agriculture	***Goals:*** Increasing agricultural productivity, incomes, and food security sustainably/Adapting and building resilience to climate change/Reducing and/or removing greenhouse gases emissions/Food security and preserve natural resources	[7,31]
	Adaptation and mitigation actions: Use of less pollution and energetically efficient machinery/Investment in the improvement in irrigation infrastructure/Change in crop/Zero-tillage management/Introduce improved and resistant seed/Organic agriculture/Adaptation of the sowing calendar/Use of renewable energy	[40]

Table 1. *Cont.*

Sustainable Farming Approaches	Dimension/Strategic/Practices/Principles and/or Goals	References
Principles of agroecology	Recycling/Input reduction/Soil health/Animal health/Biodiversity/Synergies/Economic diversification/Cocreation of knowledge/Social value and diets/Fairness/Connectivity/Land and natural resource governance/Participation	[41,42]
Direction and principles of more sustainable agroecosystems	Use of inputs such as water and nutrients efficiently/Keep soil covered throughout the year/Select species and varieties well suited to the site and to conditions/Reduce tillage in a manner consistent with effective weed control/Diversify farming enterprise to spread agronomic and economic risk/Rotate crops to enhance yields and facilitate pest management/Diversify crop and cultural practices to enhance the biological and economic stability of the farm/Manage soil appropriately and use cover crops, composts, mulches, and green and/or animal manure to build soil quality and fertility/Protect water quality/Develop ecologically based pest management programs/Integrate crop and livestock production/Increase energy efficiency in production and food distribution/Maintain profitability/Take into account farmers' goals and lifestyle choices	[5,43]
Basic agroecological strategies	Increase in planned and associated biodiversity (functional agrobiodiversity)/Prevention and control of pests and diseases (natural control and crop diversification)/Restore soil fertility and biological activity (regenerative soil management)/Restoration of natural resources (minimize losses of energy, water, and nutrients)	[18,44,45]
Ten elements of agroecology for the transformation of agriculture and food systems	Diversity/Cocreation and sharing of knowledge/Synergies/Efficiency/Recycling/Resilience/Human and social values/Culture and food traditions/Responsible governance/Circular and solidarity economy	[46,47]
Nature-based solutions	Resilient food production/Mitigating climate change/Enhancing nature and biodiversity	[48]
	Reforestation/Targeted land protection/Land use change from farmland to pastureland/Riparian buffer strips/Aquifer recharge/Reconnecting rivers to floodplains/Establishing flood bypasses/Wetlands restoration/Conservation/Construction of artificial wetlands/Ponds and basins/Forestry best management practices	[49]
Decision support systems	Farmers' decision making about adopting agroecology/Impact assessment of the applied methods/Standardization and regulation of efficient approaches/Communication between farmers and other actors/Track market trends	[18,50]
Mitigation strategies in the agro-food sector	***Environmental:*** Agro-food waste management and efficient use of waste/Reduction in climate change, ozone depletion, and greenhouse gas emissions/Energy production as a strategy to reduce the environmental load/Improved organic fertilizer management and environmental protection ***Economic:*** Environmental credits due to the production of electricity from a renewable source/Raw material management for biogas production	[51]
Food systems transformation	Enable all people to benefit from nutritious and healthy food/Reflect sustainable agricultural production and food value chains/Mitigate climate change and build resilience/Encourage a renaissance of rural territories	[52]
Sustainable development goals	Ensuring access to safe and nutritious food for all/Shifting to sustainable consumption patterns/Boosting nature-positive production/Advancing equitable livelihoods/Building resilience to vulnerabilities/Shocks and stresses.	[53]
Principles for sustainability in food and agriculture	Improving efficiency in the use of resources/Conserving, protecting, and enhancing natural ecosystems/Protecting and improving rural livelihoods, equity, and social well-being/Enhancing resilience of people, communities, and ecosystems/Promoting good governance of both natural and human systems	[22]

Table 1. *Cont.*

Sustainable Farming Approaches	Dimension/Strategic/Practices/Principles and/or Goals	References
Indicators of climate-resilient sustainable agriculture	***Ecological:*** Crop and livestock biodiversity/Rainfall deviation/Soil organic carbon/Cropping intensity/Drought, flood, and forest frequency/Net irrigation area/Soil depth/Water productivity/Groundwater table/Fertilizer usage/Agriculture waste/Organic/Conservation agriculture/Fertilizer use efficiency/Soil drainage	[54]
	Environmental: Integrated water, land, and pest management/Soil fertility management/Biodiversity/Plant rotation/Mixing of traditional and modern innovative methods/Ecological systems and environmental degradation ***Societal:*** Education and training facilities/Social involvement/Farmers' knowledge and awareness/Food self-sufficiency/Food security and distribution/Participation in cooperative/Sharing knowledge and experience/Labor migration/Population density ***Economic:*** Net farm return/Land productivity/Target economic viability/Sufficiency of cash flow/Cost saving/Firms overall value/Advanced technology/Agricultural employment/Per capita food supply/Gross value added from crops and livestock	[54,55]

The 10 elements proposed by the FAO [46,47] and management practices and principles recommended by researchers can be used to plan, analyze, manage, protect, develop, research, and evaluate transitions to sustainable agri-food systems (Table 1). Despite the site-specific nature of sustainable agriculture, there are principles to help farmers choose good management techniques to create more sustainable agroecosystems [5,43]. Sustainable agriculture and agroecosystems aim for high yield and quality production to meet current and future needs, while keeping resource input and especially nonrenewable resource use as low as possible. These systems optimize the use of renewable resources while reducing adverse impacts on soil fertility, water and air quality, and biodiversity from agricultural practices and enable local communities to protect and enhance their well-being and environment.

Large-scale monoculture-based systems, food security, land degradation, water scarcity, climate change, and a growing population are interlinked challenges and key issues for sustainable agriculture [56]. Agri-food production and consumption require radical changes [57], as existing food systems are responsible for nearly one third of global greenhouse gas emissions [10], as well as leading to biodiversity loss and eutrophication. The processes of economic, social, and environmental unsustainability originate in part due to the food system, which is a complex system involving many human–nature interactions [1].

Even though the objectives of agricultural systems have expanded and diversified, sustainable food security remains the ultimate goal and requires the development of strategies via smart choices to achieve these multiple objectives. Key points in promoting sustainable farming systems are better use of natural resources such as water, biodiversity, and soil and the implementation of new resource-saving technologies [58]. In addition, new strategies should be developed that ensure multifunctional synergies between species and systems to increase input efficiency and resource availability, as well as locally adapted science-based agroecological methods. A sustainable food system should focus on practices such as the adoption of sustainable manufacturing practices; recognizing the integrity of nature and agroecosystems; promoting an efficient energy system; strengthening the capacity to adapt to disasters such as climate change, extreme weather, and drought; establishing short food supply chains; minimizing losses and waste of food; and ensuring food security for all generations [16,19,24,58]. These practices and goals, which require fundamental changes, should be adopted by policy makers, researchers, and all stakeholders and be promoted through public policies. A synergy is needed between market, sustainability, and agricultural policies in terms of the appropriate use and conservation of resources.

Different sustainable agricultural innovations and techniques, such as evergreen agriculture, conservation agriculture, perennializing grains, rainwater control, agroforestry in farm and pasture systems, and tree-based agroforests, should be developed for different environments. Improved soil organic matter as a result of using green manure; keeping the soil covered throughout the year; and mulching and recycling cover crops, crop residues, and manure will increase the water-holding capacity of the soil and its ability to keep rainwater. Sustainable production systems also have the potential to become self-sufficient in nitrogen through the recycling of farm manures and crop residues and reducing nutrient losses and biological and economic stability due to the diversification of crops and cultural practices, legumes, bio-fertilization, and intercropping rotations.

The redesign of agriculture and food systems should create diversified and synergistic systems with combinations of annual, perennial, cover crops, drought-resistant crops, multi-cropping, polycultures, livestock, and trees, as well as crops with different harvest times and different climate and stress response characteristics [20,28,46]. Crop rotations are crucial for sustainable agroecosystems and food security because they affect the physical, chemical, and biological properties of the soil and improve its structure. Management alternatives and green manure and legume integrations have been able to reduce the negative effects on the environment and increase farm income through efficient use of resources and the productivity and sustainability of cropping systems by improving the carrying capacity of the crop system and availability of nutrients [59,60].

3. Climate Change Mitigation and Adaptation Strategies

Climate change induced by human activities, not relying on appropriate production strategies and better resource management, increases the frequency and intensity of heavy rainfall, droughts, extreme heatwaves, sea level rise, and floods. It is estimated that climate change is a threat to global food and nutrition security which will reduce the ability of natural resources to feed the global population [7], could make food more expensive to produce [13], and will reduce food production by 30%, which will exacerbate food insecurity and hunger problems. Climate change poses many risks, both direct and indirect, to agricultural production systems, from physical impacts to ecosystems, agroecosystems, water availability, pests and disease, pollinators, land degradation, agricultural production, food chains, incomes and trade, livelihoods, food security, and nutrition [31]. Climate change associated with global warming remains a dangerous obstacle to sustainable development, with profound economic, environmental, and social impacts, especially in vulnerable rural areas.

Agriculture, which is dependent on weather and climatic conditions, is adversely affected by climate change [61], to which it contributes significantly, and extreme weather events and increase in temperature may reduce agricultural production in sensitive areas and affect food security depending on the time period [61,62].Industrial agriculture entails an increase in greenhouse gas emissions and contributes to the exacerbation of climate change, which affects agricultural production and is directly linked to food insecurity [63]. Intensive farming practices, biodiversity, nutrition, land degradation, and climate change are closely linked. Agriculture could play a role in reducing agricultural emissions and mitigating climate change [64], and sustainable agriculture and food systems require investment in climate-smart agriculture and successful water management. Therefore, it has been proposed to reduce the mutual influence of climate change and agriculture and food systems on each other to contribute to sustainable agriculture and food systems [65], since long-term climate change will develop faster [66].

Climate-smart agriculture is defined as agriculture that focuses on or achieves a sustainable increase in agricultural productivity and incomes, improving food security and development goals, promoting resilience, and adapting to climate variability, and reducing greenhouse gas emissions [67,68]. Climate-smart agriculture is agricultural management developed to increase sustainable food production and adapt to and mitigate climate change. Research has shown that climate-smart agriculture can improve productivity, incomes, profit efficiency, and food and nutritional security, promote efficient and equable water use, and mitigate climate change and greenhouse gas emissions [6,68,69]. Due to reasons such as the increase in extreme weather events, sustainable agriculture in the future requires measures such as improving the biotic and abiotic stress tolerance and nutritional quality of important plant species, the domestication of wild and semi wild species and naturally stress-resistant neglected and orphan plants, increasing the fertilizer and water use efficiency of plants, and reducing the loss of productivity [70,71].

Since climate change is one of the important obstacles to sustainable agriculture and food security, especially in vulnerable arid and semiarid regions [72], climate-sensitive agriculture and different mitigation technologies have emerged as an approach to increase farm resistance against the effects of climate change. As a major contributor to climate change, agriculture could also play a role in reducing agricultural emissions and mitigating climate change. As an efficient way to create healthy, safe, and sustainable food systems [73], agroecology could offer solutions in regions where climate change poses a threat to agriculture and food security. Measures such as the protection and restoration of natural ecosystems, increasing the efficiency of input use, restoring degraded land and dried-up areas, reducing food losses, increasing carbon sequestration in soils, and reducing direct on-farm, crop cultivation, and livestock emissions could contribute to climate change mitigation. Sustainable agriculture and extreme events bring greater use and development of diverse, perennial grain-cropping systems and wild species. Productivity and sustainability should be preferred and focus on climate change adaptation strategies such as the conservation of agricultural resources, soil and water management, using efficient and less-polluting machinery, changing and applying crop, variety and planting dates, and testing and promoting resistant plant varieties [40,74].

Nature-based solutions are essential for mitigating climate change in agricultural production systems, building ecological resilience against extreme weather events, and improving nature and biodiversity [48]. Improved plant management systems, such as increasing soil organic matter and residue; improved water; precision fertilizer; integrated pest management, agroforestry, and perennial farming; co-cropping; and crop diversification, contribute to climate change mitigation, adaptation, biodiversity, and livelihoods [75]. Long-term, large-scale food system applications have been stated to reduce soil and water quality and adversely affect natural resources and climate change [76]. While the globalization of food options through industrial agriculture negatively affects the sustainability of traditional farmlands, mixed crop–livestock systems based on biodiversity are seen as the key to climate change resilience and the sustainability of small-scale farming agroecosystems [26].

4. Environmental, Food, and Agricultural Security

Biobased products; extreme weather- and climate-related events; food and nutrition security; health; environment; natural resources and biodiversity; ecosystem services such as pollination, rural livelihoods, and the role of landowners; technology; soil; and water are the core issues or themes affecting food and agriculture systems. Currently, water, food, the environment, climate change, deforestation, pollution, genetics, and natural resources are becoming increasingly important in all relationships. The importance of the conservation and sustainable use of biodiversity, sustainable food, and agriculture systems, food and nutrition security, and environmental sustainability is increasing daily. The environmental notion of security extends by considering risks such as climate change, deforestation, soil degradation and erosion, depletion of water resources, desertification, loss of biodiversity and ecosystem services, air, land and water pollution, chemical runoff, ocean acidification, and disruption of the nitrogen and phosphorus cycles posed by environmental change [77,78]. The widespread use of chemical fertilizers and pesticides brought about by agricultural expansion has led to the loss of ecosystem services and biodiversity due to eutrophication and habitat destruction, increased climate change and uneven distribution of precipitation, and atmospheric changes, which have begun to affect food security [71]. Environmental protection and security encompass access to essential natural resources as well as food, energy, and economic security [77].

Food security can be defined as communities' sufficient access to safe, culturally acceptable, nutritionally adequate, and healthy food that maximizes self-confidence and social justice through a sustainable food system [79]. Food and agricultural security are important elements of healthy living, access to safe and nutritious food, and sustainable development. Sustainability is a prerequisite for maintaining food security based on availability, stability of supply, access, and utilization. Sustainability, which refers to the resilience of systems, is an integral component and precondition of food security and nutrition.

Food security focuses not only on the quantity but also on the quality of food but also covers malnutrition, yield and demand for food products, income and production capability of food producers, and proper use of biodiversity resources. Although agricultural production systems have expanded and diversified, they continue to play a strategic role in improving food availability and ensuring food security, and sustainable food security remains the ultimate goal. Today, food security and the effects of industrial agriculture and humans on climate and ecosystems are becoming increasingly complex [64,80], and food insecurity is increasing. Long-term food sustainability and security is the sustainable provision of nutritional security and the quality, value, and diversity of the food produced without compromising the preservation of regional balance and ecosystem health. Existing agricultural systems fail to solve the world health nutrition problem, creating and exacerbating environmental damage and social injustices [81]. Moreover, the cost of the manufacturing process, processing, and distribution of food, as well as the increasing inequalities in these channels, are increasing the living costs of urban residents.

Food security and environmental sustainability are essential to the progress and development of economies and societies worldwide. Food security is the physical, social, and economic access of people to sufficient and safe food that meets their preferences and nutritional needs for a healthy life. While the sustainability and resilience of agricultural production and ecosystems are important for food security, human well-being, and environmental protection [82], agricultural food systems must consider agroecology to ensure sustainable food security and nutrition. To guarantee food security, it should not be overlooked that increases in yield should not further erode the natural resources on which agriculture depends [83]. Most of the population will reside in urban areas in the future, which increases food security issues.

5. Food Systems, Nutrition, Health, and Environment

Nowadays, there is a greater demand for sustainable food systems, as well as a growing awareness of the health and future protection of individuals and the global community. Food and nutrition security, the protection and sustainability of resources and the environment, and the pollution of water resources are closely related to food production and rural development. SAFA proposes themes for social welfare such as decent livelihoods, fair trade practices, equity, human health and safety, cultural diversity, economic resilience such as investment, vulnerability, local economy, product quality, and environmental integrity such as atmosphere, water, land, and biodiversity [7,31].

Since adequate nutrition requires a regular intake of a variety of foods, local diversity should be considered, which can contribute to sustainability rather than uniformity and monoculture [19]. Including reducing food losses and waste, it is necessary to promote and strengthen cooperation between food system stakeholders, create enabling environments for sustainable food systems, and raise awareness by better connecting the food and agriculture sector with science, media, and education. For a more sustainable food system, reliable and sustainable communication on food products, investment, and financing, as well as information platforms regarding these systems, should be encouraged. Redefining efficiency as the efficient use of all resources, preserving natural resources, reducing emissions and waste with improved process and closed loops, and strengthening sink capacity by improving ecosystem services and social support networks have been proposed to repair economic models [66].

Agri-food systems play an important role in mitigating and adapting to climate change, as well as protecting and restoring biodiversity and ecosystems [84]. Sustainable food security depends on agroecology, sustainability, and ecological intensification, increasing production while maintaining soil health. The process of transformation to sustainability in food systems should consider agroecology, which can reduce producers' vulnerability to economic risks to achieve food security and nutrition [85]. Strategies have been proposed for sustainable food systems, such as social changes to reduce food consumption, innovations to improve resource use efficiency in all farming systems, and incentives for switching to alternative farming techniques [86].

Achieving more sustainable, just and equitable, healthy, and resilient food systems in the future requires the integration of methods and agricultural techniques from different disciplines, innovation with analytical and integrated approaches, and cross-sectoral policy analysis and participation. Ensuring both food and nutrition security requires designing rotational and intercropping systems, using innovative technologies and cropping practices, integrating alternative cropping models, creating a green eco-environment framework, and collaborating with all stakeholders [32,60,87].

6. Agricultural Biodiversity and Diversification

Biodiversity, which generally refers to genes, species, habitats, and ecosystems, in the narrow sense, describes the functional, genetic, taxonomic, or phylogenetic diversity among species in a region. As an essential component of a safe food supply, agricultural biodiversity is the result of the interaction between genetic resources, the environment, and management systems and includes genetic resources for food and agriculture and ecosystem services. As a result of natural selection, management, and practices, agricultural biodiversity includes the food and agro-related components of biodiversity, as well as those that make up the agroecosystem [88], and includes sociocultural, economic, and environmental aspects. Biodiversity creates habitats with different flora and fauna species of special importance and increases the resistance of agroecosystems against abiotic and biotic stresses. Increasing agrobiodiversity, which is essential to the productivity and adaptability of species, global food production, food security, and sustainable agricultural development, is key to strengthening resilience in food systems. It has been noted, for instance, that more crop diversity alters microbial populations, which can promote plant growth and increase agricultural output [89]. Agricultural ecosystems have a great impact on biodiversity and natural resources, and the protection of biodiversity is important for agriculture. Biodiversity is an important regulator of the agroecosystem in meeting the needs of farmers and society, as well as increasing sustainable food and agricultural production.

Modern, intensive conventional agriculture and the conversion, degradation, and loss of habitats reduce and deplete agricultural biodiversity, which is the result of the interactions among genetic resources, natural selection processes, the environment, and the management systems and methods used by farmers. Food production is the primary cause of biodiversity loss globally, with impacts such as adversely affecting freshwater wildlife, reducing habitat quantity and quality, intensifying agricultural production, decreasing the availability and quality of wild food, affecting climate change, and converting forests and land [90–92]. Biodiversity in agroecosystems is under significant pressure due to intensified farming and land abandonment, and the combined impact of climate change and biodiversity reduces resilience to shocks and makes agricultural systems vulnerable.

Biodiversity loss contributes to numerous problems, such as threatening ecosystem functionality and sustainability, negatively affecting the climate, and undermining sustainable development goals, including food, water, and energy security [91]. Loss of genetic diversity makes food systems less resilient and threatens food security, and agricultural growth leads to loss of biodiversity [92,93]. Biodiversity loss adversely affects the services of pollinators, which causes yield decreases. Diversity at the ecosystem, species, and genetic levels provides many benefits to agricultural production, and the scope and distribution of diversity in production systems may vary depending on the characteristics of the system. The diversity and ecosystems needed to increase productivity and improve ecosystem functions [88] could be enhanced by increasing habitat diversity, restoring aquatic ecosystems and wetlands, and improving water quality and reliability with nature-based solutions [48].

The methods of biodiversity are crop diversity and crop rotation approaches, as well as enhancing genetic diversity. Diversity is a central principle of agroecology necessary to increase and maintain productivity and resilience, enhance ecosystem functions, and ensure adaptability [18,88]. Furthermore, diverse crop rotations and diversification are required to improve long-term sustainability and productivity [94]. Biodiversity provides a buffering and stabilizing insurance effect against environmental changes, leads to yield stability, and contributes to a stable food supply [95]. Furthermore, research shows that higher crop diversity supports more agricultural employment [96]; provides continuity in agricultural yield [97]; increases in crop yield, pollinators, yield stability, nutrient recycling and uptake, and weed and pest suppression [98]; enhances farm income [99]; encourages optimal levels in wildlife for ensuring basic natural processes [18]; and promotes and stabilizes ecosystem services [83]. Diverse agroecological systems are generally more resilient [18]; improve soil health [100]; contribute more to ecosystem services, biodiversity conservation, and food security [101]; reduce environmental and human exposure to pesticides and chemicals [102]; enhance yield stability and food security [103]; and play an important role in meeting health and nutrition goals [104]. While increased plant diversity can lead to changes in microbial communities and increased production, soil microbial diversity, which mediates the positive effects of diversity [89] and soil biodiversity [33], promotes a sustainable food system. Soil microbial diversity has been found to be associated with soil functionality, which is important for sustainability.

Effectively protecting wild biodiversity in agricultural areas, using sustainable agroecological practices, and reducing the use of fertilizers and chemicals will require more research, policy coordination, and strategic support for farming communities and conservationists. The investigation and identification of abiotic conditions that benefit biodiversity, along with basic environmental functions and processes, key habitats and species, community-based natural resource management principles, and sustainable agricultural practices, are essential for monitoring agricultural biodiversity in ecosystems [105]. As in-field precision protected areas, ecological refuges can function to host biodiversity, habitat management, and ecosystem services.

Agricultural diversification is the addition of functional biodiversity to agricultural systems to support biotic interactions and create ecosystem services [101]. Diversified farming systems may include polycultures, mixed cropping systems, cover cropping, multiple cropping, intercropping, agroforestry, living fences, seminatural habitats, hedgerows, low-input management practices, and varieties of a given crop, as well as natural or seminatural plant and animal communities. Functional biodiversity can be enhanced by increasing crop and non-crop species diversity and promoting beneficial microorganisms. Agricultural diversification practices provide benefits as a strategy to contribute to biodiversity and therefore to achieve sustainable development and food safety goals [101].

Agricultural diversification practices also contribute many ecological, social, and economic benefits, such as better crop performance [106], helping to enhance the sustainability of agriculture, and improving soil quality [107], leading to the stability of food systems [95], improving income and providing food security [108], and contributing to biodiversity and food production outcomes [109]. Agricultural diversification has positive effects on biodiversity and a multitude of ecosystem services, such as farm profitability, pollination, yield stabilization, climate regulation, pest control, nutrient cycling, nitrogen fixation, C sequestration, resource use efficiency, soil fertility, and water regulation, without compromising plant yields [101,109,110].

7. Approaches for Sustainable Agricultural Production

Sustainable food production requires alternative farming practices that have less impact on the environment, as agriculture depends on the natural environment for resources such as water and nutrients but also transforms the environment. Many approaches, practices, and agricultural systems for sustainable production, environmental protection, and ensuring food safety have been proposed by researchers, such as agroecology, organic farming, biodynamic agriculture, nature-inclusive agriculture, high-nature-value farming, precision agriculture, conservation agriculture, permaculture, regenerative agriculture, sustainable intensification, climate-smart agriculture, low-external-input agriculture, agroecological agriculture, diversifying farming systems, ecological intensification, integrated nutrient management, pest management and farming systems, mixed cropping, intercropping, and relay cropping [6,28,41,43,111,112]. Sustainable production practices should consider soil, climate, and topographic characteristics, availability of inputs, producer objectives, appropriate variety selection and soil management, protection and rehabilitation of soil health and productivity, efficient use of inputs, and diversification of cultural practices, along with supporting activities.

Many supporting factors contribute to and play a role in sustainable farming approaches, such as genetic improvement, integrated farming tools, integrated pest management, precision farming, mixed farming systems, agroforestry, landscape- and ecosystem-based approaches, agritourism, urban farming, and community-supported agriculture [36]. In terms of sustainable agriculture, climate-smart agriculture, diversification of crop systems, diversified farms, and location-specific integrated farming systems have shown encouraging performance and increased economic efficiency and profitability [60].

Food systems need to be better managed to promote healthy eating patterns, reduce food waste, collaborate nutritionists with other sectors and disciplines, ensure land use sustainability, and mitigate the effects of climate change and biodiversity loss [53]. Studies have found that relay cropping and sequential double-cropping systems promote food safety, profitability, and environmental sustainability, including increasing crop productivity, soil fertility, economic returns, land use and nutrient cycling efficiency, and pest control [113]; balancing high crop production and agricultural sustainability [114]; increasing the efficiency of land and nitrogen [115]; reducing reliance on external inputs and tillage; and improving weed control [116].

Biodynamic agriculture is an environmentally and sustainable holistic alternative system specific to climate zones and conditions, uses natural production methods, considers all living systems and ecological principles, and contributes to long-term sustainability [117,118]. The integrated farming system, which is based on combining crop and livestock systems, foresees the use of appropriate technology for long-term farming and food security [6]. These systems aim to improve resource use and biodiversity by reducing competition for water, nutrients, and space by using mixed cultivation, crop rotation, crop combination, and co-cropping, as well as by applying environmentally friendly practices.

On the other hand, as a sustainable approach, conservation agriculture supports sustainable development as a result of its contribution to the protection of biodiversity and topsoil productivity, improvement in soil health, adaptation to climate change, ecosystem services, and food, water, and soil security [112,119]. Conservation agriculture contributes to numerous economic, environmental, and ecological benefits, such as being a sustainable alternative in arid and semiarid regions, promoting the synergy between food production and ecosystem protection, and increasing resilience and productivity to extreme stress conditions by using less energy and water, improving physical and biochemical properties, and increasing soil quality by reducing the breakdown of soil aggregates [120,121].

Sustainable agriculture should focus on conservation agriculture practices, the use of high-yielding varieties, integrated pest management, plant nutrition based on healthy soils, efficient water management, and the integration of crops, trees, pastures, and livestock. What is required is a rapid and safe transition from highly external, dependent, conventional, industrial, monoculture-based production to holistic and human-centered sustainable production systems that embrace agroecology and increase the productivity of small-scale farmers.

7.1. Agroecological Agriculture

Agroecological agriculture aims to design sustainable food systems with minimum dependence on external inputs, including environmental, social, and economic dimensions, by promoting agricultural diversification to support biological interactions and benefitting from synergies between the components of the ecosystem [41,111]. The role of agroecology science and practices is inevitable in making agriculture and food systems more sustainable. Agroecology or ecologically oriented agriculture, which can be regarded as the scientific basis of sustainable agriculture, bases agricultural research and practice on the principles and theories of ecology [122,123], applies them to human-age agricultural systems [124], creates a healthy relationship between people and food [19], and focuses on ecological solutions, community-based economic development, and the transition to a sustainable agricultural system [125], conservation practices [112,126], agroecosystems and the agri-food system [85]. Table 1 shows the principles of agroecology for sustainable food systems by setting "sustainable pillars" [41,42]. Agroecological practices for food production include the sustainable design and management of agroecosystems and their services, habitat and agricultural biodiversity conservation, and soil fertility management. The agroecology approach, which applies ecological and social principles to the design and management of food and agricultural systems [46], is among the agricultural policies of the future and is adopted for the sustainability of European agriculture, to reduce the negative effects of agri-food systems on the environment [57] and to benefit ecosystem services [127].

Agroecology, which regenerates agricultural ecosystems and foresees the efficient and sustainable use of natural resources [128], has a significant contribution to the support of small-scale farmers' livelihoods [129], sustainable rural development, and the sustainability of family farming by creating mobility in rural areas [85,130]. The principles of environmental health, economic viability of ecosystem management, social equity, and securing the right to food are proposed to assess the sustainability of local agroecological food systems [131]. Agroecological practices used by alternative farming methods could provide soil health restoration, sustainable food production and security, and nutritional and environmental benefits.

7.2. Agricultural and Sustainable Intensification

Agricultural intensification creates more stress on agricultural input resources and has also made food production more expensive, as energy prices rise and natural resources are strained. High-input, resource-intensive agricultural systems contribute to a multitude of environmental and ecological problems, such as adversely affecting ecosystem diversity and functioning [89], triggering environmental degradation by negatively affecting the balance and health of the planet [132], reducing biodiversity [90], and causing deforestation, water scarcity, soil depletion and biodiversity loss, and antimicrobial resistance to pests and diseases [12,13,20]. In contrast to agricultural intensification, sustainable intensification has been proposed to make agriculture more sustainable and to ensure food security by minimizing negative environmental impacts.

The sustainable intensification of agriculture is a management system that increases the productivity and sustainability of the agricultural sector by promoting and improving the sustainability of agricultural production, ecosystem services, social equity and nutrition, economic viability of agriculture, rural development, multi-functionality of the farming system, and quality of life of society, and produces more output by minimizing inputs and land and maximizing economic and resource use efficiency [39,133]. Sustainable intensification, defined as "producing more output from the same area of land without adverse environmental impacts" [38], has been proposed as a sustainable approach to increase the yield of crops, especially in regions with scarce resources [134]. Agricultural intensification is a solution for sustainable agriculture that contributes to food and nutrition security protection of the natural ecosystem and improves the economic conditions of farmers [135]. Sustainable intensification aims to transform the entire food chain into a fully sustainable procedure to reduce damage from agricultural activities and to utilize natural resources effectively through good management practices [136].

Sustainable crop production intensification has become increasingly important as a way of improving use efficiency while conserving resources, minimizing negative inputs on the environment, producing more from the same area of land and other natural resources, and improving the flow of natural capital and ecosystem services [137]. The sustainable intensification of agriculture has been proposed as a promising concept based on the application of a wide variety of technologies, focusing on increasing yields while simultaneously conserving land, other natural resources, and the environment, promoting a good quality of life, and preserving global food security [138]. This holistic approach has emerged as a promising solution to achieve sustainable food production and safety, in part by integrating food production, environmental protection, and socioeconomic well-being.

The degradation and destruction of natural ecosystems, salinization and degradation of soil fertility, increased resistance to pests and weeds, and loss of biodiversity constrain sustainable agricultural development and the stability of food systems [8,137]. For this reason, disseminating affordable sustainable agriculture technologies and maintaining environmental sustainability is crucial. Sustainable intensification enhances and maintains a protective organic cover on the soil, protects the soil, and minimizes its degradation. Six complementary components, "farming systems, soil health, crops and varieties, water management, plant protection, and policies and institutions", have been proposed to implement the "save and grow" model for the sustainable intensification of crop production, to produce more with less input, and to be more productive within carrying capacity [73]. Increasing eco-efficiency, input substitution, and system redesign are important in the transition to sustainable food systems [139].

7.3. Regenerative Farming Systems

Regenerative agriculture and permaculture are a semi-closed holistic sustainable system approaches designed to restore and protect natural systems such as soil quality, biodiversity, and ecosystem services, promoting natural ecosystems, improving livelihoods, optimizing interactions between soil and plant systems, and reducing or eliminating dependence on external inputs [14,140]. Adopting integrated permaculture alongside modern regenerative agriculture can improve soil health, biodiversity, sustainability, resource conservation, and food security [14]; increase resilience to environmental changes; improve farming systems; and reduce input costs [140,141]. Regenerative agriculture may include practices such as organic, biodynamic, agroecology, cover cropping, crop rotations, holistic management, integrated crop and livestock farming, biological pest control, reduced and conservation tillage, restoration ecology, diversity, and agroforestry [142,143].

An integrated approach, regenerative agriculture, can improve resilience to climate change, reduce negative impacts, reverse biodiversity loss, and improve soil health while promoting the use of natural processes rather than external inputs and maintaining or increasing profitability and food production per unit area [13,123]. Regenerative agriculture, which recreates the biogeochemical cycle and the resources they use and achieves higher productivity and profitability of the system, is an alternative way to achieve effective local sustainability goals in building the resilience of agroecosystems. Regenerative farming systems aim to protect and increase soil quality and biodiversity in agricultural lands while producing foodstuffs profitably. Research has found that practices used in regenerative agriculture promote soil biology, organic matter, and biodiversity, maintain soil fertility, provide more ecosystems and profitability, increase the resilience of the farming system [144], and improve soil health, water quality, vegetation, and local sustainability goals [34]. Sustainable food systems require evidence-based regenerative agriculture research, land conservation, and integrated food system approaches [76].

Apart from reforming industrial agriculture, regenerative farming practices should be used to increase the productivity of these farmers, as they are beneficial for small farming systems that do not have sufficient financial resources for intensive agricultural production systems [14]. Another regenerative system that provides food security as well as climate change mitigation and adaptation, ecosystem restoration, and higher productivity and profitability is organic agriculture.

7.4. Organic Farming

Another regenerative system that provides food security as well as climate change mitigation and adaptation, ecosystem restoration, and higher productivity and profitability is organic agriculture. Despite the differences in the vision of sustainable agriculture, organic farming remains one of the key approaches and leading alternative farming systems to sustainable agriculture among researchers and farmers today. According to the principles of IFOAM [145], organic farming must be managed cautiously and responsibly to maintain and improve the health of ecosystems and organisms as a whole, to work with and help sustain the living ecological systems and cycles on which they are based, to build equitable environmental and life opportunities relationships, and to protect the health and well-being of present and future generations and the environment. The organic approach to sustainable development and producing high-quality and nutritious food is based on the four principles of health, ecology, care, and fairness [145,146].

Organic practices produce healthier food and reduce meaningless pollution by substituting synthetic inputs with organic inputs. Organic agriculture, which is a production system that protects soil, ecosystems, and human health, focuses on biodiversity, ecological and biological processes, renewable resources, local conditions, and organic inputs instead of industrial synthetic inputs that have negative effects. Compared to conventional agriculture, both organic and mixed farming systems promote biodiversity, affecting soil microbial diversity, which in turn supports ecosystem functions [147] and sustainable agriculture [83]. Organic farming has proven sustainability benefits, including improved soil quality, enhanced biodiversity, and reduced pollution [148], encouraged sustainable development [149], and developed small and self-sufficient farms, but its sustainability per unit product is sometimes questioned due to the lower yield [148,150]. Organic agriculture, which focuses on redesigning the whole food system to achieve ecological, social, and economic sustainability, will be able to contribute to smart farming systems in the future [146,151]. These organic regions are defined as systems where organic agriculture is common, moving towards agroecological approaches, inspired by and promoting sustainable rural development and the sustainable management of local resources, changing from bio-districts to becoming the target of local production and development strategies [152].

Organic farming is a method of food production that has little environmental impact; improves and promotes healthy ecosystems, biochemical and ecological traits, agricultural ecosystem health, biodiversity, natural biological cycles, soil biological activity, microbial richness, local production and distribution; and increases access to and the availability of wholesome food [146,151]. Sustainable management and use of land plays a key role in enhancing the biological capacity of soils, the functionality and diversity of soil biota, food production, and the sustainability of all ecosystems [33]. Research has found that practices used in organic agriculture encourage and improve agricultural ecosystems and soil health and related microbial communities [153], nutritional value, safety, quality and sustainability of food [154–157], soil biological activity activities and bacterial diversity [158], soil quality indicators, soil biological and enzymatic activity [159], soil organic matter, biodiversity protection, and agricultural sustainability, and increase soil fertility by using fewer external inputs and more effectively using local resources [146,151,160]. However, despite all these positive aspects and being less polluting, organic farming can contribute to sustainable agriculture and food security when it is economically viable for farmers and can support global sustainable productivity gains [148,150]. According to studies on the variables that impact the acceptance of sustainable farming methods, organic farms and pro-environmental attitudes are both highly associated with the use of sustainable farming methods [161].

7.5. Agroforestry

Agroforestry is a land use strategy that integrates perennial woody plants and applies ecological principles, increases ecological stability and water quality, can contribute to ecosystem diversification and processes, has the potential to improve sustainable production and food security, and combats climate change and biodiversity loss [162,163]. Agroforestry has many advantages, such as the restoration of damaged ecosystem services, the conversion of degraded lands, the protection of sensitive areas, and the diversification of production systems, especially when utilized in conjunction with an ecologically oriented management system [164], increasing sustainability in organic farming, protecting agroecosystems, and ensuring their long-term sustainability [165].

7.6. Regional Food Systems

Local food systems belonging to a particular geographic region are generally considered sustainable and environmentally friendly, partly because they are relatively close to consumers and away from homogenization, concentration, and industrialization. Local and organic food movements, selling farm products locally, and increasing farmer livelihoods, as well as increasing the rural economy, are characterized as the future strengths of small-scale agriculture [26]. Sustainable and healthy regional food systems contribute to the economic well-being of all residents and the region while maintaining local food-producing capacity. Local systems that encourage communities to eat healthy food improve the financial viability of local farmers and food processors, ensure equitable access to food, reduce waste in the food industry, and protect the ecological health of the environment and waters. For regional sustainability; protection and enhancement of the natural environment; embracing cultural vitality, economic prosperity, and social justice; creating social harmony; and providing for continuing prosperity and social solidarity are important principles.

Small-scale ecological farming methods focused on increasing diversity are key to ensuring resilience to climate change [19]. Since food systems develop depending on limited and scarce resources, for a sustainable ecosystem, natural resources should be protected, developed, and used efficiently in economically, environmentally, and socially sustainable ways, optimizing production and minimizing their negative effects on the environment. For sustainability transitions in agri-food systems, consideration should be given to designing sustainability and resilience to complement each other, as well as improving the resilience of regional food systems and their preparedness for crises and shocks [15]. Local food movements must balance protecting agroecosystems and meeting the growing needs of society by offering humane and flexible livelihoods for the rural population while providing economic benefits for farmers of small- and medium-sized lands. Small-holder farming could be made more sustainable and profitable by developing direct and local marketing strategies, providing improved market access for local agricultural products, promoting alternative food networks with short food supply chains, and promoting community-supported agriculture [19,26]. While agricultural productivity has directly affected poverty alleviation, labor-intensive farming in rural areas can benefit from increased production and lower the cost of basic foods. Regional food systems and agricultural development will continue to play a key role in poverty reduction, as most people living in poverty live in rural areas and make their livelihoods from agriculture.

7.7. Urban Agriculture

City district food systems, which are advocated to support ecological transition in urban and peri-urban regions and to guarantee food system resilience and nutrition security, are one of the most frequently proposed sustainable food system approaches [166]. It is described by the FAO and RUAF "as an approach aimed to foster the development of resilient and sustainable food systems within urban centers, peri-urban and rural areas surrounding cities by strengthening rural-urban linkages" [167]. Urban and peri-urban agriculture practices, which largely use local resources, systems, and ecologies in the city and its surrounding areas, are becoming increasingly widespread as a sustainable food production system in many areas from horticulture to milk production, which contributes to food safety and nutrition [168]. Multifunctional urban agriculture can become an effective strategy for creating more sustainable food systems and tackling food insecurity, extreme weather, ecological degradation, and economic crises [80]. This agriculture contributes to the world's food supply by reducing post-harvest losses, maximizing the use of limited resources such as land and water, and addressing issues with food security. It also helps satisfy shifting food demands. In fact, urban agriculture, whose water requirements can be supported and reduced as a result of the reuse of rainwater, will contribute more to urban sustainability [169]. Although limited research has observed the impact of urban agriculture on sustainable food security and it has not been adequately considered as a solution, it contributes positively to living standards, food quality and security, accessibility, and livelihood strategies [170].

While urban and peri-urban agriculture is unlikely to replace large-scale food systems, cities' vulnerability to complex crises and the need to support urban sustainability and resilience have revealed the need to support food-growing practices such as hydroponics, aeroponics, vertical farming or walls, aquaponics, home gardens, allotment gardens, experience farming, community gardens, community-supported agriculture, rain gardens, urban forestry, rooftop greenhouses, and green roofs [79,171,172]. Although food security is a major focus of urban agriculture [173], its advantages extend beyond regional self-sufficiency in food production [174] and include social, ecological, and economic factors.

To secure urban food security and access as well as to develop sustainable food systems, it is necessary to build urban and peri-urban food systems that will reduce the cost of food production and distribution, improve the resilience and sustainability of cities and the quality of life of their residents [79,175,176], and have low environmental, energy, and climate impacts [79]. As the identification and production of stress-resistant plants strengthen the resilience of agroecosystems by encouraging the diversification of urban food systems, this could mitigate the harmful effects of climate change and promote food and nutritional security and good health for all [18]. Urban agriculture also has the potential to lower social, economic, and environmental constraints and contribute to a more resilient local food supply, as well as increasing access to healthy and affordable food and local sustainable food production and distribution [177].

Urban and peri-urban agriculture may offer a range of social, ecological, and economic advantages, including ensuring food supply and security [18]; mitigating and adapting to climate change [178]; enhancing ecosystem services, biodiversity, human well-being, and cultural and health concerns through food production [179]; securing food availability by supplying households with fresh food [180]; supporting community integration; and improving urban resilience and sustainability [79]. Moreover, urban agricultural activities can create employment opportunities and incomes, as well as stimulate the production of high-value foods such as poultry and mushrooms [180]. It is also clear that creating regionally organized city–regional food systems can support green, livable cities, while large-scale, highly productive, world-market-oriented agriculture might meet the high demands for sustainability [11]. In addition, regionally organized city–regional food systems can connect cities with regional food production, alleviating the food insecurity problems that cities may face, particularly those that depend on food produced outside their borders [181].

City–region sustainable food systems or community-supported agriculture practices, which are developed as an alternative to industrial conventional agriculture, are economically, ecologically, and socially sustainable, foresee food sharing, manage ecology and resources efficiently, reduce waste, aim to increase awareness and socialization about the environment and resources, and protect biodiversity and have been found to be important in the transition to a sustainable urban food system [15]. Urban agriculture not only helps to find ways to make cities and food systems more resilient and sustainable but also supports the mental health, cohesion, happiness, self-sufficiency, social benefits, social connection, better living conditions, sustainable lifestyle, and well-being of stakeholders [182–184].

As the issue of access to food and security becomes complex before, during, and after disasters such as earthquakes, a resilient food system is needed, and urban agriculture has been shown to improve recovery in such situations by providing social empowerment and safe assembly points, creating a sense of normalcy, and increasing food security [185,186]. As in the COVID-19 pandemic, the back-to-back destructive earthquakes of 7.7 and 7.6 magnitude in Kahramanmaraş (Turkey) on 6 February 2023, and similar disasters, showed the need to ensure that urban areas are not solely reliant on distant sources and the importance of local food production and urban agriculture for resilient food security. It is evident that these disasters not only necessitated the establishment of food supply bases around the cities but also elevated the significance of the local gardens and compelled that the city population and those in their surrounding area, heavily reliant on imported food, return to their rural roots. The environmental, economic, and social beneficial effects of urban agriculture include contributing to long-term food security and urban sustainability [187]; ensuring redundancy in the food system and creating disaster preparedness food [188]; providing social cohesion, healthy food, and the learning of new skills [185]; promoting psychological health, relief, and nutrition; sharing social and cultural identity [189]; and emerging cultures of cooperation and sense of community [190], all of which can contribute to recovery after a disaster. Research has found that urban agriculture can strengthen food systems and sustainability, have a positive impact on mental health [81], create jobs and strengthen the local economy [191], increase land productivity with very low environmental impact and cost [192], increase access to healthy food and food security, and provide social, ecological, and economic benefits [193]. The potential of producing disaster preparation food with a short shelf life required to maintain the physical health of disaster survivors from the time of the disaster until the time of life returning to normal will increase the importance of local food production and urban agriculture.

7.8. Precision Agriculture

Precision farming is a site-specific management approach that employs information technology for agricultural production decisions, gathering, processing, analyzing, and combining spatial, temporal, and individual data, as well as carrying out the appropriate action at the appropriate time and location [194,195]. The potential of precision agriculture to contribute positively to food security is very high. Based on the principle of combining precision agriculture technology and agroecological principles, production- and ecologically focused precision agroecology offer important solutions for sustainable food production [12]. It was noted that sensitive agroecological practices contribute to reducing inputs, replacing them with sustainable ones, incorporating biodiversity into the ecosystem, and establishing a fair food system [12]. Precision agriculture, which uses technological tools to collect data and apply it to management decisions to achieve the goals of agroecology and to create a productive, efficient, and sustainable agri-food system, can improve the efficient use of resources, productivity, profitability, quality, and sustainability of agricultural production and ecological and economic resilience, as well as reduce environmental impacts [12,194]. According to research, precision farming techniques could improve productivity and production stability, as well as resource allocation for inputs including herbicides, fertilizers, water, feed, and human labor [194].

While innovation is critical in terms of technological advancements, optimization, and efficiency of production systems for long-term sustainability [196], the integration of digital technologies contributes to the rapid industrial transformation of agri-food systems [197]. With this system, traditional food production systems could be transformed into agroecological systems by increasing input efficiency, productivity and ecological principles, ecosystem services, consumer–producer bonds, and sustainable input. Sensitive agroecological practices contribute to reducing inputs, replacing them with sustainable ones, incorporating biodiversity into the ecosystem, and establishing a fair food system [12].

Although the use rate in agricultural management processes is still low, digital agriculture and information technologies that are safe and adaptable to climate change have high efficiency for greater food security, stability, profitability, and sustainability of agricultural systems [194,198]. Moreover, it is still uncertain how digital agriculture will affect ecosystem services, agricultural production, and food systems and what its future will look like [199,200], and the evidence for its effects on ecosystem integrity is not yet certain [201]. However, the adoption rate of digital and precision agriculture is predicted to increase in the near future due to reasons such as technology becoming cheaper, faster connections, modeling capacity and integration of data into models, technology adoption rate, and labor cost increase [92]. Food production systems can move towards a more sustainable future by utilizing precision agriculture-like management and data without departing from the principles of ecology.

8. Conclusions

The goal of the society of the future is to have agriculture that improves social welfare, but how this will be achieved while limiting environmental degradation and the depletion of natural resources is clearly unclear. Additionally, the agricultural sector also has opportunities to conserve resources and ensure food security with high cost effectiveness. Sustainability strategies and sustainability policies for agriculture should be implemented in a way that promotes crop diversity, protects natural resources, does not harm the environment in the long run, and should be able to offer effective, practical, and scalable solutions. Transforming food systems in ways that support nature, biodiversity, climate change mitigation, and nutrition security without threatening natural processes on food security depends on and is needed for environmental, economic, health, and social reasons. Characteristics of a sustainable food system should be included with efficient energy, contribute to health and safety, raise awareness of food and agriculture, generate an economic source for farmers, and use creative water conservation strategies. The future of sustainable agriculture and food security faces many challenges, and for success, it must not be focused on one but on several strategies, and agriculture itself must be part of the solution.

Future studies should explore the relationship of product selection and variety to nutrition, affordability, sufficiency, and sustainability. Sustainable production systems will likely require the integration of organic and agroecological principles, as well as conventional and innovative farming techniques. Models that combine economics, ecology, and sustainability, promote the resilience and productivity of ecosystems, and optimize food production by using natural resources efficiently should be a priority. Cities should be redesigned as new socioecological areas that include sustainable agricultural practices. Urban and peri-urban agriculture can increase food security, lessen the effects of climate change, guarantee that the urban environment is more sustainable, support biodiversity and the environment, encourage healthy lifestyles, and provide new opportunities for food systems.

As nutritious, safe, and healthy food becomes increasingly important to the world's people, innovative technologies and methods need to be designed and locally adapted to protect soil, biodiversity resources, air, and water and to mitigate and adapt to climate change. While the use of cutting-edge technologies is inevitable for the future of sustainable food production, the potential negative technical and socioecological impacts of these technologies must be evaluated and mitigated.

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