

Bottom-Up Transformation of Agriculture and Food Systems

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Abstract: The global agenda for sustainable development includes the alleviation of poverty and hunger by developing sustainable agriculture and food systems. Intensive farming systems and its variations, such as sustainable intensification or ecological intensification, are currently being promoted as technologies that can improve agricultural productivity and reduce environmental impacts. However, these are focused only on per-hectare productivity with growing negative impacts on local culture and the environment. This study identifies the negative impacts of crop- and livestock-based farming systems on the Indo-Gangetic plains, as well as in the USA, China, and South America as an example of key challenges in global agriculture. These impacts are classified into environmental, social, economic, and health impacts. An alternative paradigm is proposed to overcome some of the shortcomings of current global agriculture. This new bottom-up paradigm is based on three indicators that are fundamental to achieve the environmental, economic, and social sustainability of agriculture and food systems. These are divided into technical, geographic, and social indicators and have been analysed for four farming systems—low-input, high-input, organic, and desired farming systems. Seven global geographic regions have been analysed in terms of their socio-economic indicators and status of agriculture in order to develop pathways for the implementation of the new paradigm. The pathway for change suggested in this paper includes a focus on research and training, policy and institutional changes, and an evaluation of the costs and benefits, and changes in production models that consider scale and sustainability metrics and include innovations in consultation with all stakeholders. This new paradigm has the potential to direct global efforts towards more local and regional solutions, which are community driven and constitute a ‘bottom-up’ approach.

Keywords: agroecology; human capital; natural capital; social capital; sustainability agriculture



Citation: Sandhu, H. Bottom-Up Transformation of Agriculture and Food Systems. *Sustainability* **2021**, *13*, 2171. <https://doi.org/10.3390/su13042171>

Academic Editor: Adesoji O. Adelaja

Received: 21 January 2021

Accepted: 14 February 2021

Published: 18 February 2021

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1. Introduction

The transformation of agriculture and food systems is vital to eradicate poverty and hunger, and to achieve sustainable development goals as envisioned by Agenda 2030 of the United Nations [1–5]. Six decades ago, a call for alleviating hunger and poverty in the global south was supported by a ‘silver bullet’ solution widely known as the ‘green revolution’ that included germplasm improvement, the use of synthetic fertilizers and pesticides, and the mechanization of farms [6,7]. Some parts of world; for example, the Indo-Gangetic plains and parts of China; responded well by adopting these practices rapidly. This led to a doubling of productivity and improved food availability in those areas inhabited by large human populations. These efforts were supported by government policies with a focus on increasing per-hectare productivity. The demand for more diverse types of food has outpaced the productivity potential in those regions, and this is a growing trend worldwide [1]. Moreover, these regions are facing major environmental challenges such as the depletion of groundwater on the Indo-Gangetic plains (the food bowl of South Asia) and the loss of soil on the Yangtze river plains in China. Despite sufficient calories being produced by global agriculture, there are over 800 million hungry people today and over 2 billion do not have regular access to nutritious food [1]. Addressing these challenges requires a coordinated and global effort much like the green revolution of 1960s [8], but

with more careful consideration for the environment and society [9]. There is not much room for oversight on the impacts of current agriculture on the environment and people's health, which are growing concerns for wider society and governments around the world.

It is being argued in the scientific and policy literature that the current focus on intensive agriculture can be improved to achieve the global goals of producing more food using less resources, thereby achieving the desired productivity and environmental sustainability [8]. A wide spectrum of technologies is often suggested, and some are currently in practice in many parts of the world to bring this change. Some of the common technologies or variations of high input-based agriculture include diversified agriculture, ecological and sustainable farming, and organic or chemical-free farming, whereas peasant-driven initiatives are grouped as agroecological farming [10–17].

Other than the lack of consideration for the environmental impacts, there was also a lack of attention to the local biodiversity and social aspect of agriculture during the green revolution [18–20]. The technology was sold to the global south as a 'top-down' approach and on the premise that the technology is applicable to all regions for its rapid uptake. There was complete disregard of local diets, biodiversity including agro-biodiversity, and impacts on livelihoods and rural communities [21]. Even if the multitude of technologies that are being suggested and promoted for global agriculture are adopted, they are going to answer only one of the three key critical lines of enquiry—to grow more food. To answer the questions of what, where and how to grow warrants further attention by scientists and policy-makers alike. Therefore, the aim of this paper is to propose an alternative paradigm for the transformation of agriculture and food systems.

Here, a brief review of the major farming systems across the globe is presented to highlight some of the challenges in the current and future agriculture. To overcome these challenges, I put forward an alternative and inclusive paradigm than relying on various technologies that are largely the focus of current global agriculture to achieve food and nutritional security. This new concept is based on three pillars that are fundamental for the environmental, economic, and social sustainability of agriculture and food systems. It has the potential to direct our global efforts towards more local and regional solutions, which are community driven and represent a 'bottom-up' approach. Transformed local agriculture and food systems will be a better outcome for the environment and society at-large. This new paradigm responds to all three critical considerations—to grow larger quantities of more-diverse food where it is required, and to use technologies that are not damaging to the environment and human health.

2. Challenges to Major Farming Systems

Global agriculture and food systems are mired in challenges ranging from climate change-related risks to market volatility and also its impact on biodiversity. Agriculture is the single largest modified ecological system, but it fails to connect sufficiently with the social aspect of farming and food systems [2]. Since the green revolution of the 1960s, it is being promoted as a part of the economic engine that can help to stimulate the economy. One good cropping season leads to higher productivity and the economic engine is turned over making giant leaps for the rest of the economy. It has become segregated from the cultural and social responsibility that was once the pillar of agriculture and food systems since human settlements started to emerge, consolidate, and flourish. More so in the recent past, farms are seen as a fixed-capital asset to churn out commodities, and not just food. Any surplus food that is traded in the market is a 'win' under the current paradigm. It is important to understand that the farm is a living ecological system that operates under the natural functions performed by soil microbes, plants, and animal species on and around the farm, managed by humans. It is being downgraded from a healthy and functioning living system to an artificial system, by increasing the intensity of fossil fuel-based inputs, high energy use, wastefulness, deterioration of biodiversity, and the toll on farm workers and farming families. Some of the major farming regions are examined here to understand various challenges (Table 1).

Table 1. Summary of intensive crop and livestock farming systems in major agriculture producing regions and their impacts.

Farming Systems	Region	Environmental Impacts	Social Impacts	Economic Impacts	Health Impacts
Rice–Wheat intensive cropping system	Indo-Gangetic plains	Groundwater depletion, N in water sources, soil health deterioration, herbicide and pesticide resistance, loss of biodiversity, climate change [22–24]	Loss of farm employment due to mechanization, loss of livelihoods from small and marginal family farms [22–24]	High energy cost, productivity decrease after initial increase, accumulated farm debt [22–24]	Poisoning incidences in humans, toxins in groundwater that is used for drinking, respiratory diseases from air pollution due to crop residue burning [22–24]
Intensive animal feeding operation	USA	N and antibiotics in water, methane from enteric fermentation, and N ₂ O emissions from manure, climate change [25–28]	Disappearance of mixed farms and local employment [25–28]	Subsidies to grain growers, federal farm bills let grain prices fall [25–28]	Increasing health impacts due to meat consumption, air and water pollution impacts [25–28]
Intensive poultry farming	China	Manure leakage in water bodies, eutrophication, soil degradation, solid and liquid waste, GHG emissions, range of pollutants, pathogens, natural and synthetic hormones, veterinary antimicrobials, and heavy metals entering local farmland soils, surface water, and groundwater during the storage and disposal of animal waste, climate change [29]	Loss of local livelihoods, and employment [29]	Financial subsidies for the manure treatment [29]	Air pollution results in health impacts, gaseous pollutants and bio-aerosols pose direct and indirect human health risks [29]
Soybean farming	South America	Loss of biodiversity and rainforests, grazing land, N pollution, clean drinking water polluted by fertilizers, climate change [30,31]	Disappearance of small diversified farms, ranches [30,31]	Subsidies for biofuel drive soy expansion [30,31]	Drinking N polluted water increases health risks [30,31]

2.1. Intensive Wheat and Rice Cropping Systems in Indo-Gangetic Plains

The Indo-Gangetic plains host about 900 million people in an area that stretches between the Indus river in Pakistan to the delta of the Ganges and Brahmaputra in the east. Rice and wheat crops have been grown in the region for over 1000 years in this region, but not in rotation with each other. Since the green revolution of the 1960s that introduced intensive farming practices, such as high-yielding seed, and irrigation, accompanied by mechanization, has resulted in the dominant rotation of the rice–wheat cropping system [22,23]. The rice–wheat-based farming system is the single largest system, practiced across about 24 million hectares (Mha) spread over the Indo-Gangetic Plains in South Asia [24].

This cropping system with intensive practices has resulted in gaining food self-sufficiency in the region. However, it has resulted in various social, environmental, and economic impacts that threaten food and ecological security in the region [22–24]. Some of the impacts are summarised in Table 1.

2.2. Intensive Animal Feeding Operations in the USA

The USA describes intensive animal feeding operation (AFO) as an animal production system where a large number of animals are confined to a closed area and are fed with concentrated feed. There are over 450,000 such AFOs in the US (<https://www.cdc.gov/healthywater/other/agricultural/afo.html>). The livestock industry promotes these systems as more efficient than the crop and livestock mixed systems to gain higher output per unit area in a relatively short period of time. Such systems lead to a higher production to meet the growing demand of protein from consumers. However, they come with high environmental, social, and economic impacts, as summarised in Table 1 [25–28].

2.3. Poultry Farming in China

The poultry industry in China is worth USD 119 billion annually. Growing demand for protein by the increasing population in China has fueled growth in the livestock and poultry industry. Traditionally, backyard poultry was based on kitchen waste as a feed. However, in recent decades, the industry has scaled up by emulating the concentrated animal feeding operations (CAFO) in the USA [29]. These systems are industrial operations that include high-quality nutrient-balanced feed and comprehensive disease prevention measures. Consequently, they result in environmental pollution and increased risks to human health, as summarised in Table 1.

2.4. Soybean Production in South America

Soybeans are one of the largest-traded commodities in the world. The top soybean producers and exporters are found in Brazil, Argentina, and Paraguay, with China as the top importer [30]. It has a variety of uses, such as for food products (e.g., tofu, soybean sauce), vegetable oil, biofuel, and livestock feed. An increase in soybean production in South America has resulted in land-use change from pastures to cropping. In more recent years, deforestation has increased to make way for soybean cultivation, especially in Amazon ecosystems. Such deforestation and intensive practices have both social and environmental impacts [31] (Table 1).

3. Current Alternatives

To overcome some of the above challenges in the current food systems, two major alternatives are being promoted by the global agriculture.

3.1. Sustainable Intensification

Sustainable intensification is an outcome-based set of practices that are aimed to achieve food security by increasing the per-hectare productivity while reducing the environmental impacts. It also includes increasing resource-use efficiency. Given the current trends in agriculture and increasing human population, there is a need to cultivate more land to fulfil the food demand. However, sustainable intensification avoids any expansion of land. There has been some recent success in applying sustainable intensification worldwide [16]. However, many concerns remain unaddressed in defining sustainable intensification.

Sustainable intensification is not focused on all three dimensions of sustainability. It focuses on production and reducing some environmental impacts; social and ecological dimensions are not the focus. There is need to include social aspects, such as the focus on networks, farming groups, support for sustainable and reliable markets, fair trade, access to environmental funds, equitable distribution of food, empowerment of people, etc. Ecological sustainability includes improving natural capital such as land, water, and biodiversity, and enhancing ecosystem functions and services.

Achieving food security cannot be realised by focusing only of production practices; it needs to be more inclusive and must include society and the environment as the key stakeholders. There is need to integrate various parameters that are essential to achieve food security, such as good governance, the climate resilience of farms, empowerment of farmers,

fair trade practices, sustainable farming practices, fair distribution of food, addressing poverty, health, etc. This sustainable intensification does not provide a pathway for sustainable and just agriculture and food systems as its current focus is only on increasing food productivity whilst reducing some environmental impacts.

3.2. Agroecology

Agroecology is defined as the interaction between farm, people, and other living species by using the principles of ecology. Agroecology is not a particular set of farming practices. However, it is people's movement that defines and modifies local farming according to the availability and condition of natural resources and the needs of rural communities. It has 10 basic elements: diversity, synergy, recycling, efficiency, resilience, circular economy, co-creation of knowledge, responsible governance, human and social values, and culture and food systems.

It does not recommend one practice over another in growing food. It promotes four dimensions of food sustainability: environmental, economic, social, and agronomic. There is a focus on the diversification of food systems to improve soil health and biodiversity. The global agriculture system adopts some principles of agroecology by integrating ecological knowledge into intensive practices. It is practiced as ecological intensification. It focuses on increasing productivity by improving ecosystem functions and services. However, all 10 elements of agroecology are not being included in such practices. Therefore, there is a need to develop future agriculture and food systems that include all social, economic, and ecological dimension of sustainability. In addition to this, there are some limitations, such as a lack of policy and market support in the current global agriculture and food systems that prohibits the scaling up of agroecology.

Current approaches discussed above are limited in regard to balancing productivity and sustainability. Hence, there is a need to reconcile the tension between increasing the productivity and efficiency of natural resources. Increasing efficiency is not sufficient to shift global agriculture and food systems towards sustainability. There is a need to develop sustainable production models by greater emphasis on sustainable consumption. There is growing scientific literature that shows pathways to achieve efficiency and environmental performance [32–34]. These approaches provide a useful theoretical underpinning that can be used to develop models for sustainable agriculture and food systems.

4. New Paradigm

The recent focus on sustainable agriculture and food systems has been supported by existing frameworks that build on natural and social capital, and also on human capital as advocated by the United Nations-led Inclusive Wealth Report and promoted by the study known as the Economics of Ecosystems and Biodiversity for Agriculture and Food [2,4]. While it is an advancement to examine agriculture and food systems more holistically, the ultimate challenge is to design farming systems that are appropriate for the specific location, respond to the needs of the local community, are culturally sensitive, and can be adopted by the farming community without impacting environmental and human health. Multi-dimensional assessments help in understanding the impacts of farming, but decisions about managing the rural landscape to address food production, poverty, and other sustainable development goals require further understanding of the context in which farms operate [35]. There is a need to shift the paradigm from the market-driven, 'per-hectare-productivity' type of farming to the agriculture that builds on three key parameters—technical, geographic, and social indicators [2]. This shift has the potential to develop and sustain long-term social, economic, and environmental sustainability and also to improve livelihoods and the well-being of society.

The top-down approach (Figure 1) is depicted by the current focus of agriculture and food systems on 'per-hectare productivity' to meet the growing need for food. In this approach, food is considered a commodity for global trade. The top 10 commodities in the world include coffee, corn, sugar, cotton, and wheat amongst crude oil, natural gas,

Brent oil, gold, and silver. Farming systems are directed to supply food as a commodity to global markets by practicing intensive agriculture using high-input technology and support from policy with appropriate investment.

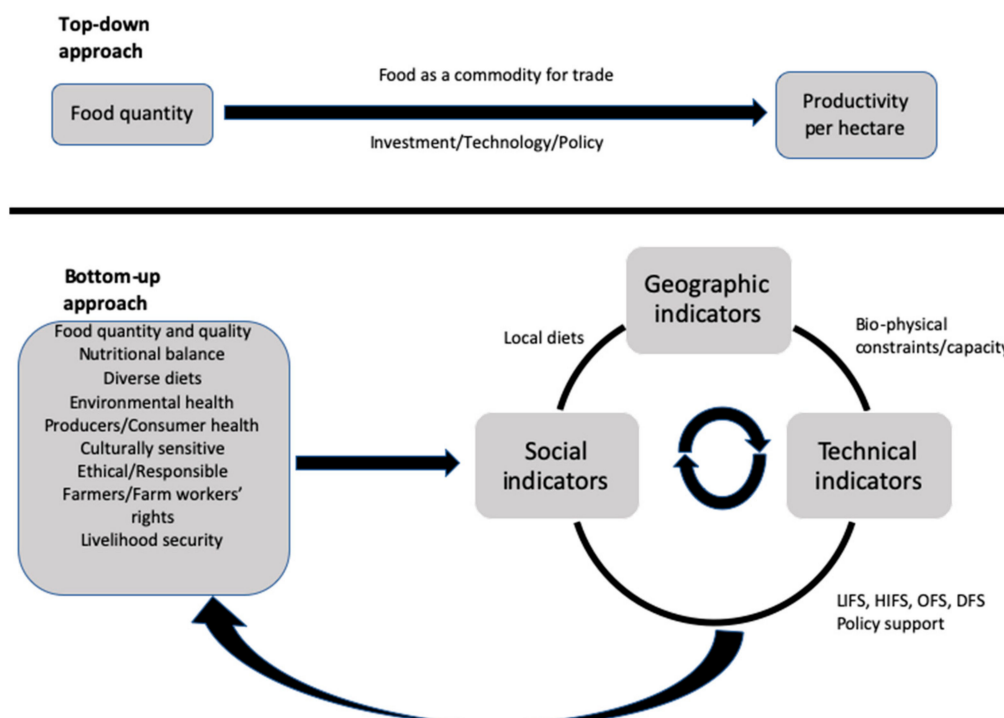


Figure 1. The current top-down approach and an alternative bottom-up paradigm for global agriculture and food systems with key parameters.

The bottom-up approach (Figure 1), however, is based on a multi-dimensional focus that includes food and nutritional security considerations, a focus on human and environmental health, ethics, and responsible production and consumption, and is likely to be determined by the geographic indicators, social norms, and other bio-physical parameters. Technology can be appropriately modified from low-input to sustainable intensification or the most desired system where resource use efficiency is increased with minimal impacts on the environment. The three parameters of this new paradigm are described below.

Technical indicators encompass on-farm and off-farm technology. These include a management system that further involves the type of enterprise—single crop, multiple crops, crop–livestock mix, agroforestry systems, etc. The right kinds of crop rotations with cereals followed or under-sown by legumes are an example, whereas mixed-enterprise includes livestock—sheep, cattle, goats etc. raised with multiple crops. The management of tillage (no-till, stubble management etc.), nutrients (addition of synthetic inputs or organic matter recycling and pest management by chemicals vs integrated or biological pest/disease control), irrigation requirements (flood, drip vs rain fed) are integral to technical indicators. It also involves energy use either in tillage operations, sowing, harvesting, or irrigation. Technical indicators are mostly cost-driven and require training, investments, and policy support. Terrace farming, pastoral farming, and rotations are all forms of local technologies that supported farming before the advent of modern technologies. There is a need to emphasise traditional technologies, which are often overlooked without scientific investigation or methodological analysis. Currently, the majority of the research and development is targeted to intensive agriculture technologies—biotechnology, germplasm development, synthetic fertilizers, pesticides, irrigation, market support, etc.—whereas community driven farming in many parts of the world does not get any investment or R&D focus. There are globally important agricultural heritage sites that are given special

status by UNESCO [36]. These sites conserved farming practices for centuries. The only reason people survived in those regions was due to their ability to use limited natural resources to develop a food production system that could be sustained indefinitely. Such systems supported local food production and also provided livelihoods. Communities grew around these sites. In contrast, many parts of the world where the green revolution was introduced in the 1960s are now facing an environmental crisis within six decades of introduction [37,38]. Clearly, this introduction of green revolution technologies did not consider local needs or geographic indicators such as bio-physical constraints, and only focused on improving output with high inputs, which was largely driven by demand for commodities in the global markets.

Geographic indicators include the centre of origin of the diversity of agrospecies—crops and livestock—and their adaptation to the climatic conditions [39]. Farming is predominantly determined by common location-specific indicators such as soil type, water availability, terrain, environmental conditions, etc. Various regions around the world started a certain set of farming practices based on the geographic constraints or advantages. For example, the globally important agricultural heritage sites around the world indicate the strong influence of various bio-physical indicators that have shaped farming over centuries in those regions. These sites showcase how natural farming was integrated into other livelihood activities and the local environment. People managing these now are still practicing ancient heritage practices to grow food, which are specifically institutionalized in their cultures.

Social indicators include cultural and economic indicators. The availability of the market either to buy inputs or sell produce defines particular types of agriculture systems. Agricultural policies and resultant well-being are also integral parts of this indicator. Economic indicators also contribute towards the adaptation of crops/agriculture in a particular region. The cultural needs of the people also define the type of agricultural systems that develop with regional attributes. The culture of people defines the type of farming. Diets have been part of the cultural fusions or experiments by earlier societies. There are numerous types of diets—vegetarian, meat-based, Mediterranean, etc.—which are the result of the continuous availability or lack of certain food-types in the areas where they were naturalized or evolved.

These three parameters are critical for the development of new or existing farming systems. They define the type of farming that can be developed specifically in a specific region.

In summary, four types of farming systems (see Table A1 in Appendix A) have been compared for each of these three indicators, as shown in Table 2. This comparison of three current systems and one speculative futuristic farming system, that can be developed by following the paradigm discussed in this paper, offers the scientific and policy community guidance to fix the current unjustified agriculture and food systems.

Table 2. Key indicators and their focus (H: High, M: Medium, L: Low) under four different types of farming systems. LIFS: Low-input farming system, HIFS: High-input farming system, OFS: Organic farming system, DFS: Desired farming system.

Indicators of Sustainable Food System	LIFS	HIFS	OFS	DFS
Technical				
Single/multiple enterprise	M	L	M	H
Crop rotations	M	L	M	H
Livestock management	L	L	M	H
Tillage management	L	M	M	H
Nutrients management	L	H	H	H
Crop pest/disease/weed management	L	H	M	H
Cost of inputs	L	H	H	L

Table 2. Cont.

Indicators of Sustainable Food System	LIFS	HIFS	OFS	DFS
Energy use and cost	L	H	H	L
Resource use efficiency, greenhouse gas emissions,	L	H	H	L
Recycling	M	L	H	H
Outputs	L	H	M	H
Sustainability, environmental payments	M	L	M	H
Geographic				
Centre of origin	L	L	M	H
Climatic adaptation	M	L	L	H
Natural resources	M	L	M	H
Agrobiodiversity	L	L	M	H
Social				
Diets	H	L	L	H
Subsidies	L	H	M	L
Cultural needs	M	L	M	H
Well-being	M	L	M	H
Livelihoods	H	L	M	H
Markets	L	H	H	L
Policies	L	H	M	H
Relevance	Primitive	Current	Current	Desired

5. Pathway for the Future

The combination of these three parameters can help develop appropriate farming systems that can meet the growing demand for diverse types of food and protect the environment whilst being considerate of farm workers' rights and respectful of the cultural norms of the society.

There are seven main geographic regions, as summarised in Table 3. In each region, one country with high GDP and one with low GDP is mentioned. It also shows the land area and area under agriculture and organic farming. The contribution of agriculture in GDP is also provided [40]. Given the model of development that many fast-growing economies have adopted, the small countries are more likely to follow that path to modernize their agriculture sector. There is an opportunity to develop appropriate farming systems that are defined by the three parameters, so that agriculture and food systems can fulfil the requirement for food security and also for the overall development of those countries. This way, new and modified farming can support long-term sustainability with better outcomes for society and the environment in those countries.

It can help to avoid situations such as the short-lived success and sudden failure of the 'Green Revolution of Malawi'. Malawi was offered a linear top-down approach that resulted in an increase in productivity of maize with the use of highly subsidised agrochemical inputs and improved seed between 2006 and 2007 to increase agricultural productivity and reduce hunger [41]. This approach did not consider other social, political, and geographic features of agriculture in Malawi. Moreover, it promoted monoculture, thereby ignoring the diverse diets that people need for their nutrition and general well-being. Dependency on costly external inputs led to a cycle of debt for small hold farmers and natural resources quickly started to decline [42]. Soon, other external events such as erratic rainfall and economic uncertainty resulted in the demise of this success.

Table 3. Examples of two contrasting economies in each of the seven geographic regions of the world [40].

Regions	Country	Population (Million)	GDP (Billion USD)	Agriculture Share in GDP (%)	Total Land Area (M ha)	Agriculture Land (M Ha)	Organic Area (M Ha)
East Asia & Pacific	Australia	24.9	1432.2	2.6	769.20	371.08	27.15
	Myanmar	53.7	71.2	24.5	3.81	0.52	0.01
South Asia	India	1352.1	2726.3	14.4	297.32	179.72	1.49
	Bhutan	0.75	2.5	17.4	3.81	0.52	0.01
Sub-Saharan Africa	South Africa	57.7	366.9	2.1	121.31	96.84	0.01
	Angola	30.8	105.7	10	124.67	59.19	0.00
Middle East & North Africa	Saudi	33.6	782.4	2.2	214.97	173.62	0.02
	Yemen	28.4	26.9	4	52.80	23.55	0.68
Europe & Central Asia	Germany	82.9	3996.7	0.7	34.94	18.34	1.14
	Tajikistan	9.1	7.5	21.2	13.88	4.74	0.01
North America	USA	327.1	20494	0.9	914.74	405.86	2.03
	Bermuda	0.06	NA	0.7	NA	NA	NA
Latin America & Caribbean	Brazil	209.4	1868.6	4.3	835.81	283.55	0.75
	Haiti	11.1	9.6	17.7	2.76	1.84	0.01

Similarly, if such a top-down approach is replicated in Myanmar, which is a net food-importing country, then it is likely to lead to the same environmental and social issues that appeared in the regions that adopted the green revolution in the 1960s and also experienced in more recent times in Malawi. A linear approach is less likely to resolve and respond to multiple requirements. However, an integrated or bottom-up approach can show an alternative development pathway for agriculture in Myanmar.

One example of a bottom-up approach is the Zero Budget Natural (ZBNF) in India. The ZBNF is a peasant-led social movement to uplift debt-ridden farmers who adopted high-input chemical-based farming because of its instant productivity gains [43,44]. The gains obtained from this high input and output intensive farming declined over a period of time due to several social, economic, and environmental factors. These events led to the accumulation of debt for a number of farmers. To overcome these problems, bottom-up agroecological-based farming gained attention and is now being practiced by millions of farmers in Karnataka and Andhra Pradesh, two large states in India. The ZBNF became successful due to highly effective farming practices that are embedded in the local culture and are self-organized. Farmers grow sufficient and diverse types of food for their families by managing soil fertility by crop rotations and natural pest controls to manage diseases and pests.

In rich or larger countries, high-input farming can be incentivized to reduce some of the pressures on environment and human health by decreasing intensification; poor countries can be initially incentivized to uptake the best of the efficient farming systems with caution, and then gradually move towards reducing the intensification to optimize production with a balanced use of resources, and focus on improving the health of people whilst respecting local diets and culture.

In order to implement the new paradigm, the changes presented below will be required to shift the global agriculture towards social, environmental, and economic sustainability.

5.1. *Changes in Global Agriculture*

The success of the new paradigm depends on three critical elements: (i) research and training, (ii) policy and institutional changes, and (iii) evaluation of all costs and benefits of food systems. These are further elaborated below.

5.1.1. Research and Training

Such a novel system will require further research and training to develop skills and required technology to support its proliferation and adoption. It will require reforms in the agriculture research and development policies that have focused on inputs and markets. The new agriculture paradigm will need research to identify local and traditional agriculture and food systems: (i) production, improvement and multiplication of local seed and livestock; (ii) status of natural resources and improvement; (iii) nutritional requirements, now and in the future; (iv) market mechanisms to finance relevant technology and to support processing, distribution, packing and responsible consumption; and (v) waste management in the value chain.

5.1.2. Policy and Institutional Changes

Achievement of food security is the main policy in many countries around the world. This policy is focused on giving incentives and subsidies to agrochemical inputs and public distribution systems. National and global agriculture and food policies need to be modified to adopt the new paradigm shift in agriculture and food systems. Policy must expand its remittance to include support for local and traditional food systems and improve the focus on the health of producers and consumers, and subsidies should be directed to farmers and not to the agri-businesses. The transformation will also require new institutions that support new food systems. Such institutions must be inclusive and have include individuals from the farming community as key members.

5.1.3. Evaluation of All Costs and Benefits

Such a new paradigm must be tested for its efficacy. There is also a need to evaluate all of the costs and benefits of such local systems in terms of their outputs, and impacts on social, human, and natural capital [45]. There is a need to develop various scenarios to see how natural resources can be efficiently used under the new paradigm to meet the demand for diverse types of food for an increasing human population.

5.2. *Changes in Production Models*

The dominant agriculture production models either promote intensive monoculture with high inputs and high productivity or promote increasing natural resource-use efficiency. There is growing resistance from consumers and environmentalists against intensive monoculture-based farming systems that were developed and practiced in developed countries in the last five or six decades. In many cases, such production models have been shifted or outsourced to developing countries. This shift in the production site has not helped sustainability of agriculture and food systems. There are three key elements in developing sustainable production models: (i) scale, (ii) metrics, and (iii) innovations.

5.2.1. Scale

As one size does not fit all, new production models based on the three parameters described in Section 4 need to be developed around the world. There is a range of scale that needs to be considered. For example, field to farm, from community gardens to urban and peri-urban farms, country to regional scale, etc.

5.2.2. Metrics to Measure Sustainability

Currently, there are a lack of a standardised metrics to assess the positive or negative impacts of different food production models. There is a need to develop metrics that can assess overall sustainability by including social, environmental, and economic indicators.

A comprehensive framework to assess farm sustainability will be required to classify and compare diverse types of production systems and models [46].

5.2.3. Innovations and New Markets

Innovations in agricultural technology and scientific advances in the methods and ways to produce food will need to be considered in the development of food systems. For example, the current demand for protein is showing new trends in the market, such as plant-based meat, cultivated meat etc. Milk is not necessarily confined to dairy alone; there are many types of milk available in the market, such as almond milk, soymilk oat milk, etc. The role of new innovations and their impacts, both positive and negative, on the livelihood of farmers, needs to be examined. Similarly, the changing behaviour of consumers needs to be factored into the responses of food producers and farmers.

Farmers, agricultural scientists, policy-makers and consumers in their respective regions around the world should play an important role in determining any changes in the global agriculture and food systems. Transparent and fair stakeholder consultation is the key to developing sustainable and desirable agriculture and food systems.

6. Conclusions

This is the beginning of a process with an alternative view that needs to be tested in the field by the scientific and policy community for its applicability and adoption potential. The global population is going to have an additional 2.5 billion people by the middle of this century. Food is a basic need for humans, and global agricultural systems must be prepared to respond to this demand for larger quantities of diverse types of food. The alternative paradigm discussed here provides an opportunity to consider a local consumption and production model that respects local diets, customs, and biodiversity to improve the well-being of all.

Author Contributions: Conceptualization, H.S.; methodology, H.S.; software, H.S.; validation, H.S.; formal analysis, H.S.; investigation, H.S.; resources, H.S.; data curation, H.S.; writing—original draft preparation, H.S.; writing—review and editing, H.S.; visualization, H.S.; supervision, H.S.; project administration, H.S.; funding acquisition, H.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All the data used in the study are provided in tables in the manuscript.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Definitions of food and farming systems.

Food Systems	This encompasses the entire range of actors and their interlinked value-adding activities involved in the production, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal, and natural environments in which they are embedded [47].
Low-input farming systems (LIFS)	Low-input farming systems (LIFS) are defined as traditional farming methods with low levels of input and output. The inputs are mainly seed, animal power for cultivation, simple machinery such as ploughs, and human labor. It has sustained populations in many countries for centuries by utilizing the principles of minimal inputs. It comprises a restorative phase of pasture or legumes between phases of crop cultivations. Such systems are unable to meet the growing demand for more food.

Table A1. Cont.

High-input farming systems (HIFS)	High-input farming systems (HIFS) are also described as conventional systems and are a specialized form of modern agriculture with high levels of input, such as pesticides, fertilizers, improved seeds, irrigation, and heavy machinery, while producing high levels of output. This intensive agriculture system is able to produce immense amounts of food and raw material for the growing world market. Its focus is on commodity markets and not diverse diets.
Organic farming systems (OFS)	Organic farming systems (OFS) involve the avoidance of synthetic fertilizers, herbicides, and insecticides. They depend on a few external inputs and regulate themselves to enhance soil fertility and biodiversity. Certified organic farming is mostly market-driven and increasing worldwide to meet the demand for chemical-free produce.
Desired farming systems (DFS)	Desired farming systems (DFS) may be defined as optimally diversified systems that have a high affinity to the geographic and social indicators backed up by appropriate technical aspects using agroecological techniques. These systems are more focused towards the overall well-being of producers and consumers and not just economic or environmental sustainability. DFS could be eco-technocentric with low management costs, a high provision of ecosystem services, and high outputs.

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