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The Future Challenges of Food and Agriculture: An Integrated Analysis of Trends and Solutions

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Abstract: The availability, access, utilization and stability of food supply over time are the four pillars of food security which support nutrition outcomes. Addressing the issues raised globally around these pillars remains a challenge. The Food and Agriculture Organization of the United Nations (FAO) 2017 report "*The future of food and agriculture: trends and challenges*" outlined the challenges which will have to be addressed in order for sustainable agricultural services to cost-effectively meet the growing food demand of the world population. In this study, we systematically analyzed the future challenges of the agriculture and food systems by focusing on (1) their root causes and trends; and (2) the interlinkages among the solutions proposed to address the challenges using social network analysis tools. It found that, if trends leading to extreme poverty are reversed, several other challenges will also be partially addressed and that climate change has the highest impact on the network of trends. Improving food security would have positive impacts on food access and utilization. The clear outline of the qualitative relationships among challenges presented and insights will help their prioritization by decision makers. However, additional in-depth quantitative analysis is necessary before measures identified to tackle the challenges could be effectively implemented.

Keywords: food security; sustainable agriculture; future agrifood sector; climate impacts

1. Introduction

Food availability, access, utilization and stability over time have been identified as the four pillars, or dimensions, of food security [1]. Meeting global food security needs remains a challenge, as food and protein demand increases at a rate even faster than the population growth. The rising stress on food security and demand for high-quality nutritional food such as from animal products must be addressed sustainably by minimizing environmental impacts and maximizing social opportunities [2]. In this respect, investment will be necessary especially in low- and middle-income countries where population growth and stress on the agricultural systems will mainly occur. In order to receive the maximum benefit from these investments, tackling the systemic challenges will be of particular importance to ensure food security [3]. Business-as-usual investments in agriculture are unlikely to deliver sustainable solutions in a rapidly changing world [3]. The Food and Agriculture Organization of the United Nations (FAO) report entitled "*The future of food and agriculture: trends and challenges*" [4] identified

the requirements for the provision of adequate and affordable food supplies through sustainable agricultural services, in order to meet the growing demands of the increasing world population.

The complexity of the agriculture and food supply system, together with the opportunities and challenges that will have to be faced for its sustainability, has been emphasized [5]. Prioritization of the means to develop a viable, less resource intensive, and a more beneficial mechanism will be necessary given the economic and resource constraints. Therefore, this analysis of the interlinkages between the various challenges helps guide the critical decision-making processes in order to come up with scenarios that would reverse any negative trends.

The objective of this study was to systematically analyze future food stability, availability, access, and utilization, as well as the challenges in food and agriculture value chains, and to reveal the integrated nature of their causes, and potential solutions. Inter-linkages between the various challenges to be met in agriculture and food systems were identified to provide insight on how to address them holistically and give some indication of prioritization of possible solutions.

2. Background

2.1. Root Causes of Challenges: The Trends

The world is undergoing changes that will shape the livelihood of millions of people in the coming years. Understanding the root causes of the various trends (Box 1) and the relationship between them will aid manage the demand in solutions for future food security and sustainable livelihoods for everyone, in the changing world. Variables to describe the trends that cover both environmental and socio-economic aspects [4] are outlined in Table A2 in the Appendix A. This section further describes the reason behind the uncertainty of future food and agricultural systems, providing quantitative evidence on the broad range of interlinked factors and trends, (e.g., resource availability and productivity; climate change; productivity and technological change; conflicts, crises and natural disasters; population dynamics; the behavior of producers and consumers, and trade and policy responses).

Box 1. Trends relating to future agriculture and food systems [4].

1. A rapidly increasing world population marked by growth "hot spots," urbanization, and aging.
2. Diverse trends in economic growth, family incomes, agricultural investment, and economic inequality.
3. Greatly increased competition for natural resources.
4. Climate change impacts from extreme weather effects, droughts, floods, crop diseases etc.
5. Plateauing of agricultural productivity for many crops and animals.
6. Transboundary pests and diseases.
7. Increased conflicts, crises and natural disasters.
8. Persistent poverty, inequality and food insecurity.
9. Dietary transitions affecting nutrition and health.
10. Structural changes in economic systems and employment implications.
11. Increased migration.
12. Advanced food production systems and resulting impacts on farmers' livelihoods.
13. Persisting food losses and waste.
14. New international governance mechanisms for responding to food and nutrition security issues.
15. Changes in international financing for sustainable development.

Despite the decrease in the population growth rate at the global level, Africa and South Asia will still witness a remarkable increase in the coming years. This growth will cause increased competition for already-scarce land and water resources [6]. Furthermore, the competition for natural resource inputs for food, energy use [7], and national bioeconomy strategies [8] will likely increase, especially when countries also seek renewable energy and material alternatives to fossil-based economy. Apart from the stress on land resources, over 40% of the rural population worldwide currently experiences water scarcity, due to agricultural, industrial and urban demands on water [9]. Considering that 80% of the freshwater resources are used for irrigation worldwide, the scarcity and further declines in water

availability will cause challenges when the non-agriculture competition over water increases, which in turn might also bring inequalities regarding the access to water, perpetuating poverty [10].

Poverty, inequality, and food insecurity are among the key challenges of our time [9]; yet, improving food availability is not enough to eliminate poverty and hunger. Actions to permanently reduce poverty and hunger go beyond agriculture and include social protection policies and safety nets to eliminate food insecurity. On a global level, a decreasing trend is evident for extreme poverty, and currently about 350 million extremely poor live in Sub-Saharan Africa and about 300 million in South Asia [11]. Despite a reduction in inequality among countries (regarding income, consumption and gross capital formation), there is an increase in inequalities within low- and middle- countries, and high-income countries alike [12]. These inequalities may lead to more undernourished populations, especially under business-as-usual (BAU) scenarios. For example, food access may be hampered due to inequalities which limit facility access for cooking and storage, as well as health and education services related to nutrition. Therefore, the goal to end hunger might not be attained by 2030 [13].

Not only the population growth but also dietary transitions to higher nutritional levels will drive up agricultural demand as a result of country food system transformations [14]. Ultimately, despite the fact that there are adequate resources on the world to provide sufficient food for even the growing population, the triple burden of malnutrition (undernutrition, micronutrient deficiencies, and obesity) still has an impact over a large population worldwide, as availability of food does not imply a balanced intake of nutritional elements [14]. On the other hand, balanced diets not only would provide significant positive impacts on the health and wellbeing of the public but also on the environment by entailing lower greenhouse gas (GHG) emissions and lower resource intensity associated with the prevention of the overconsumption of animal-derived protein sources [14,15].

To meet the growing demand, the agricultural sector productivity should increase, as one of the premises of sustainable intensification [16]. In 2050, the productivity will need to be almost 50% more than that of 2012 [11]. Even more agricultural output would be needed under a scenario of increasing food waste, inequalities in income and food distribution and exacerbated climate change [17]. However, improvements in agricultural efficiency are not enough to maintain a sufficient increase in crop yields, as they are impeded by climate change, degradation of natural resources and the associated loss of biodiversity. Climate-smart agriculture and other resource-conserving practices can further favor increases in productivity, but they are hampered by climate change, natural resource degradation, and biodiversity loss. The outbreaks of transboundary pests and diseases affecting both animals and plants are increasing with globalization and climate change jeopardizing the food security of the affected areas. Meanwhile increased anti-microbial resistance, partly due to antibiotic use in livestock production poses a threat to human health [18].

Climate change is jeopardizing all dimensions of food security; yet, agriculture is one of its major causes. Agriculture, forestry and other land use (AFOLU) sectors contribute to an estimated 21% of annual greenhouse gas (GHG) emissions globally, and energy inputs for the agrifood chain contribute an additional 10% [19,20]. In addition, deforestation is expected to continue, in order to expand agricultural areas [21]. Climate change deteriorates livelihoods and poses direct risks on food security, and leads to decreased employment opportunities and poverty, and limits social protection access [12]. It also has strong links with social trends and population dynamics, as it is one of the key causes of recent migration patterns, together with conflicts, war, increasing resource scarcity and degradation. These trends cause an increase in migration, and it has been estimated that international migration will increase from 244 million in 2015 to over 400 million by 2050 [12].

The origin, transit, and final destination countries both benefit and suffer due to the consequences of migration [22]. A large proportion of international migrants are male, between 15 to 34 years old, with rural backgrounds. Along with the globalization of food and agricultural systems migration of rural males is among the main reasons behind the increase in the agriculture sector feminization in many parts of Africa, Asia and Latin America [12]. Global remittance flows of those who migrate back to their countries of origin supply cash of around USD 500 billion per year, which in turn increases the

insurance levels against crises and shocks, and the investment opportunities for both agricultural and non-agricultural activities [4,23].

The increased number of conflicts in the last decade has also led to greater food insecurity and malnutrition [24] as the intersection between fragile socio-economic structures, and their vulnerabilities to climate change elevate the potential conflict risks [24]. In addition, without sufficient employment opportunities, especially in rural areas, global population growth may result in accelerated rates of urbanization and migration, and consecutively, potential conflicts.

Urbanization causes a shift of labor out of the food and agricultural systems, and may entail a decline in agricultural productivity in land-restricted communities [25]. On the other hand, in most low- and middle-income countries, these trends are coupled with population growth that increases the demand for agricultural products. Agriculture and food systems supplying urban and peri-urban areas are progressively characterized by vertical coordination. The trend towards coordinated, capital-intensive agrifood chains can create severe barriers to small-scale producers and agro-processors in local, national and global markets.

The increase in agricultural demand will, in turn, promote further investments in food and agricultural systems. However, it is estimated that BAU investment structures and social protection expenditures would leave hundreds of millions of people under-nourished by 2030. Therefore, investments will need to be accompanied by sustainable social policies. Additional investments estimated in USD 265 billion per year for social protection programs and activities which are pro-poor are needed to meet the target of eradicating extreme poverty and hunger by 2030 [13].

2.2. The Challenges for the Agriculture and Food Systems

The key challenges which will be faced by the food and agricultural systems over the near future (Box 2) can be grouped into three clusters [4]: (1) challenges related to food stability and availability, (2) challenges related to food access and utilization, and (3) systemic challenges. This section provides an analysis of the challenges mentioned above, as plausibly determined by selected trends which represent their root causes. Possible actions to address the mentioned challenges are also highlighted. A synopsis of the challenges, their original clustering, and plausible causal linkages between trends and challenges are provided in Figure 1.

Box 2. Challenges for the agriculture and food systems in the mid- to long-term [4].

Challenges for food stability and availability
1. Sustainably improve agricultural productivity to meet increasing demand.
2. Ensure a sustainable natural resource base.
3. Address climate change and intensification of natural hazards.
4. Prevent transboundary and emerging agriculture and food system threats

Challenges for food access and utilization
5. Eradicate extreme poverty and reduce inequality.
6. End hunger and all forms of malnutrition.
7. Improve income-earning opportunities in rural areas and address the root causes of migration.
8. Build resilience to protracted crises, disasters and conflicts.

Systemic challenges
9. Make food systems more efficient, inclusive and resilient.
10. Address the needs for coherent and effective national and international governance.

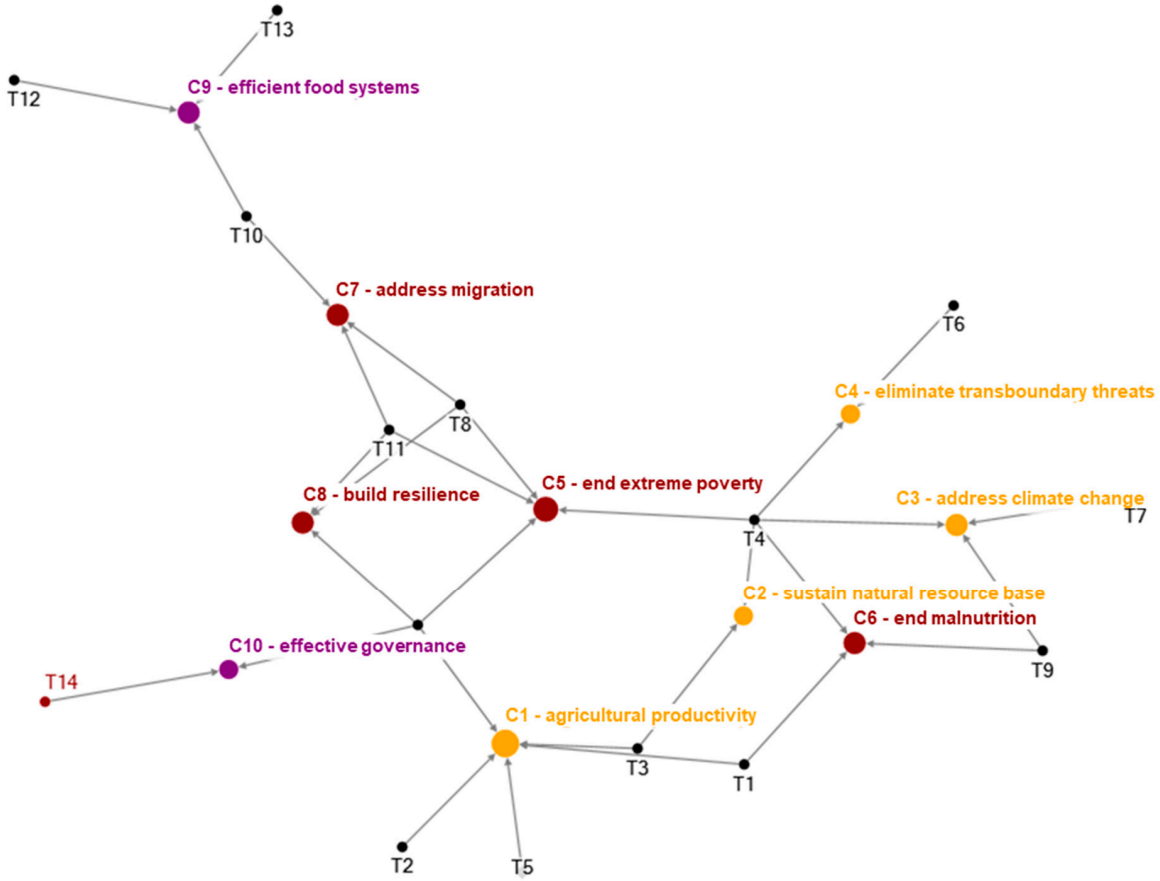

Figure 1. Network graph showing linkages between the trends (Box 1) and challenges (Box 2, challenges of food stability and availability (orange), food access and utilization (red), and systemic challenges (purple) for the food and agricultural systems (based on the FAO report [4]). Arrows represent causal linkages. *Note: T1 = Population growth, urbanization, and aging; T2 = Global economic growth, investment, trade and food prices; T3 = Competition for natural resources; T4 = Climate change; T5 = Agricultural productivity and innovation; T6 = Transboundary pests and diseases; T7 = Conflicts, crises and natural disasters; T8 = Poverty, inequality and food insecurity; T9 = Nutrition and health; T10 = Structural change and employment; T11 = Migration and agriculture; T12 = Changing food systems; T13 = Food losses and waste; T14 = Governance for food and nutrition security; T15 = Development finance. Table A1 further explains the information reported in this figure.*

2.2.1. Challenges for Food Stability and Availability

Challenge 1: Sustainably Improve Agricultural Productivity to Meet Increasing Demand

Urbanization, population growth and per capita income increases will change the nature of the demand for food and agricultural goods thus impinging on the way such goods are produced (Trends 1, 2 and 5). Furthermore, although the demand for food is increasing, the increases in crop yields started to plateau (Trend 5). These patterns will pose stress on natural resources and all together will bring up the necessity for increasing the resource use efficiency.

Intensive use of chemical inputs also causes negative impacts on the environment. Therefore, requiring the adoption of sustainable food systems is necessary to tackle this challenge. Climate-smart agriculture can help increasing resilience. Furthermore, more coherence in agricultural subsidies will also be required (Trend 15).

Challenge 2: Ensure a Sustainable Natural Resource Base

It has been projected that the pressure on agricultural land, water, forests, fish capture, and biodiversity will increase, as discussed in Section 2.1. Although the demand for agricultural land in high-income countries will decrease, the opposite trend will be observed in low-income countries.

Therefore, the constraint is not the land availability, but rather the lack of access resulting from poor infrastructure and disconnection from the main markets, or the vulnerability to outbreaks of diseases. Moreover, the available land is concentrated in a limited number of countries, where these resources will be under environmental and social stress (Trend 3). In addition to land availability, water stress is also concerning for the future food and agricultural systems. The shifts in water demand, as well as the fluctuations in temperature and precipitation, will also cause variations in water availability, as an additional cause of water stress (Trend 4).

Challenge 3: Address Climate Change and Intensification of Natural Hazards

Climate change leads to multiple concerns related to the future of food and agriculture: it damages and leads to agricultural production losses; degrades soil, forests, water, and other natural resources, and adds pressure on the ecosystem (Trend 4). Climate change also impacts crop yields, fish stocks, and animal health, thus putting the availability and stability of food supply at risk. Food access is also negatively impacted, due to the detrimental impact of climate change on the incomes and livelihoods of the farmers.

In the short period (until 2030), globally, the impact of climate change will only slightly outweigh the benefits as plant growth is expected to increase due to higher temperatures (Trend 4). However, after 2030, the negative impacts of climate change, such as droughts and floods, will intensify in most parts of the world leading to reduced yields and increased losses (Trends 4 and 7). These trends are expected to jeopardize food security beyond 2030 increasingly. For example, an additional 120 million people are estimated to be at risk of undernourishment by 2050 due to climate change [4]. Almost 50% of this increase would be concentrated in Sub-Saharan Africa (Trends 4 and 9).

Challenge 4: Prevent Transboundary Pests and Diseases

Due to the increases in the intensity and number of transboundary outbreaks of animal and plant pests and diseases, the food and agricultural systems are under threat, which in turn causes food safety issues and risk of radiation events. One main reason for this increase is climate change (Trend 4). Overall unsanitary conditions and unsafe water used in processing, handling, and storage of food threatens its safety as well. These challenges are amplified by the risk of antimicrobial resistance, associated with the prevention and treatment techniques of a range of diseases and infections. However, at present, the international community lacks the capacity and coordination to prevent, control, and eradicate transboundary diseases. Integrated pest management helps prevent the spread of these pests and diseases, reduces yield losses in agriculture, and improves productivity.

2.2.2. Challenges for Food Access and Utilization

Challenge 5: Eradicate Extreme Poverty and Reduce Inequality

Poverty and hunger are most evident among people in rural areas, earning from agriculture, forestry, and fisheries. Poverty reduction; however, is dependent on several factors broader than only agriculture as it implies access to education, the ability to diversify the economy to non-farm activities and to have mechanisms for social protection in place as well as to support job creation. The eradication of extreme poverty would need measures to support productivity as well as the profitability of agriculture, linking farmers to markets. Especially in rural contexts, women tend to experience greater barriers than men and receive unequal treatment in terms of economic opportunities and often do not participate in decision-making (Trend 11).

Tackling the challenge mentioned above requires essential investments, and due to the low level of capital formation in low-income countries and their limited 'fiscal space', international financial cooperation is needed to support such investments (Trend 15).

Challenge 6: End Hunger and All Forms of Malnutrition

In the coming decades, tackling the triple burden of malnutrition (undernutrition, micronutrient deficiency and overweight) will remain to be a difficult task for countries with high levels of food insecurity and a growing population, even if growth in average per capita income should lead to a positive nutritional outcome.

Changing diets associated with increased incomes (Trend 1 and 9), as well as population growth, will put pressure on agriculture and food systems. Increasing food production to meet increasing demand must be coupled with improving supply chains to link farmers to urban markets and with measures such as tariff policies and social protection to facilitate access to good food at affordable prices for consumers.

The transition to diets rich in milk and meat, particularly ruminants, can have heavy environmental footprints, due to the increase in carbon dioxide due to the conversion of forests into pasture, enteric methane emissions, and nitrous oxide originating from the production of animal feed. In terms of resources use, dietary shifts toward processed foods can have high environmental burden, unless energy and water resources are managed sustainably. (Trend 4 and 9).

Challenge 7: Improve Income-Earning Opportunities in Rural Areas and Address the Root Causes of Migration

In low-income countries, the youth often experiences prevalent inequalities, leading to poverty and hunger (Trend 8). The lack of rural employment opportunities and social services (especially on health and education), forces them to migrate (nationally or internationally) (Trends 8, 10, and 11). In many regions, low-productivity of agriculture is accompanied with significant setbacks in resource access (Trend 10). A more inclusive rural society, including rural-urban connections, is an important challenge in the upcoming decades.

Population growth necessitates integration of the young population into the labor market, especially in South Asia and in sub-Saharan Africa. However, the population is growing more quickly than new job creation in many low- and middle-income countries and urban areas have not been able to offer a non-agricultural jobs opportunity to former agricultural workers. This challenge implies that a large share of the new jobs will have to be created in rural areas. In addition, it was found that poverty rates could decline faster for female-headed households by non-farm income opportunities in rural areas [26].

Moreover, globalization, climate change and political conflicts will accelerate migration. Improving social protection and increasing in both destination and origin countries are essential in managing migration in the near future.

Challenge 8: Build Resilience to Protracted Crises, Disasters, and Conflicts

Protracted crisis is currently affecting nearly 500 million people, mostly in African, spanning across more than 20 countries (Trend 7). The majority of these people rely on agriculture and related sectors to derive their food, income and well-being. Protracted crises, along with other conflicts disasters, impact agricultural livelihoods and food security negatively and trigger migration (Trend 11).

Protracted crises last on average eight or more years, and they are driven by different causes, including anthropogenic factors, natural disasters, conflicts, prolonged food crises, as well as weak governance and institutions to deal with them (Trend 15). Intensity and frequency of conflicts and disasters have increased globally in recent decades. In order to stop and solve these increasing trends inclusive and equitable resilience and development processes are fundamental.

2.2.3. Systemic Challenges

Challenge 9: Make Food Systems More Efficient, Inclusive and Resilient

Vertically integrated modern food and agricultural systems are driven by global supply to meet large-scale demands based on large-scale distribution (e.g., supermarkets) are growing worldwide. These systems may be more efficient than traditional food systems, but are linked to several negative trends and concerns: high energy intensity and ecological footprint (Trend 4); plant disease and animal health issues (Trend 6); high-caloric but low-nutrient food (Trend 9); the reduced access of small farmers and producers to markets (Trend 10); and the high level of food wastage (Trend 13). Moreover, modern distribution systems are often oriented toward urban centers and large producers, since they are concentrated in more affluent urban areas and the strict requirements of supermarkets regarding uniformity and regular supply are difficult to be met for small producers.

Still, domestic production meets up to 90% of food consumption in rural areas of low-income countries; therefore, local food systems remain important. Investment in traditional local food systems and support to linkages between farms, and growing markets and urban consumers can instead be an important driver of growth in these countries.

Challenge 10: Address the Needs for Coherent and Effective National and International Governance

The challenges that food and agriculture systems are facing are interconnected, and addressing them requires integrated policy approaches at all levels. Such approaches are not easy to design, and generally, past sector-specific policies did not perform well; therefore, highlighted deficiencies in governance mechanisms at all levels, including in terms of regulation, monitoring, and accountability (Trends 14 and 15). The 2030 Sustainable Development Agenda and the relevant global agreements also recognize the need to combine cross-sectorial actions to achieve multiple objectives, maximizing synergies among the Sustainable Development Goals (SDGs) and their targets. This outlook will inevitably place new demands on policy-making processes and trigger novel institutional organizations and improved coordination at various levels.

A key challenge here is ensuring the rights of poor people (including informal rights) to access natural resources (land, water, forests, fisheries, biodiversity) and adequate food. This is especially true in areas with fragile institutions, vulnerable to climate change and conflicts.

Since agricultural sectors depend on several transboundary resources and rapid changes in the environment inevitably lead to changes in resource availability, an unintended consequence will be the migration of people, plants and animals, and modifications in human activities. In order to deal with climate change, policies for the prevention and management of climate-related risks will need to move away from their local focus and be more supported by international cooperation mechanisms.

According to the FAO report, other areas where improved governance is needed include financing for inclusive agriculture development; employment and migration; the multilateral food and commodity trading regime; and open data and statistics to support decision-making in governance.

3. Methodology

The network perspective considers any system as a set of interrelated actors [27], and has been widely used as a tool in behavioral sciences, and policy network studies. For example, social network analysis has been used for the determination of the interrelations between SDG targets [28]. In another study, researchers applied social network analysis to map out the relationships between smoke-free policies in Europe [29]. Therefore, in this study, the trends and challenges of the future of food and agriculture, as well as their solutions, were considered as a network, and have been analyzed as such as described in this section. The conceptual framework of the network analysis has been provided in Figure 2.

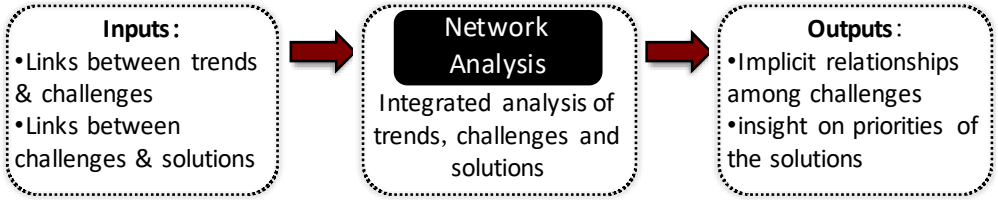

Figure 2. Conceptual framework of the study.

3.1. Analysis of Links between Challenges in Terms of Their Root Causes (Trends)

In order to define the relationships between challenges, their links with the root causes, i.e., the trends, were analyzed. These links were identified through bi-modal analysis of the links between the trends and the challenges. The relationship among two given challenges was determined in terms of the total number of common trends that led to both of the challenges. Therefore, the link was unidirectional. The calculated number was used to weight the edge (i.e., the link) between the

given two challenges. The obtained matrix of the relationship among challenges was visualized using the software NodeXL, version 1.0.1.381. The conceptual framework of the network analysis has been provided in Figure 2.

3.2. Analysis of Implicit Relationships among Trends

Links among trends were laid out to reveal the explicit and implicit causalities comprehensively. When possible, the impacts of one trend on another were determined in quantitative terms as used in the FAO report to describe the trends (Table A1, Appendix A). These were used to detect how one trend can affect others, either negatively or positively (related trends can become worse, or one trend can contribute to solving another). When available, the links were derived from various sections of the report. When not, information from the literature was used to strengthen the justification of the proposed linkages. The implicit links between trends identified during this analysis were used for network analysis and visualization of the links among challenges. All graphic distributions were performed using the Harel-Koren Fast Multiscale layout algorithm.

Once a comprehensive web of interlinkages among trends were established, the outcomes of the process were processed through unimodal Network Analysis (NodeXL, version 1.0.1.381). Trends were treated as vertices and connected using directed edges, taking into account the causality. Due to the complex nature of the trends, in many cases reciprocation was identified among trends (i.e., both trends have a causality relationship with each other), which have been accounted for by doubling the strength of the link. Trends were then manually grouped under challenges (Figure 1) as stated in the report.

The links between challenges, trends, and food security dimensions (i.e., food stability, availability, access, and utilization) as identified by the report is presented in Table A1 in the Appendix A.

3.3. Analysis of Proposed Solutions and Their Links to Challenges

Proposed solutions to the challenges were primarily extracted from the FAO report [4], yet, the identification of potential positive impacts of one solution on other challenges was determined by analyzing implicit relationships among trends, as well as through the literature, when necessary. Although the list of solutions was derived from the report, their consequences were investigated for all challenges. For this purpose, the report was systematically analyzed, and if no explicit connection was suggested, the literature was used.

The links between challenges in terms of the proposed solutions were subjected to bi-modal network analysis. The number of common solutions between two given challenges was calculated for each component of the solutions-challenges matrix. Again, the graphic distributions were performed by Harel-Koren Fast Multiscale layout algorithm using NodeXL.

4. Results and Discussion

4.1. Analysis of the Links among Challenges

There are links among challenges in terms of the commonality of their root causes (Figure 3). The clustering of challenges related to food stability and availability, and food access and utilization have been minimal, and the challenges were rather scattered along the map space without clustering. For example, *ending hunger and all forms of malnutrition* (Challenge 6) is in shorter proximity to the challenges related to food stability and availability, rather than the other challenges of food access and utilization, which is conceptually reasonable. This observation shows the complexity of the links among trends and challenges. Identification of the indirect effects of trends on challenges would also increase the strength of the links and degree of clustering. However, the results show that *ending extreme poverty* (Challenge 5) has the highest number of common trends with other challenges. This implies that reversing the trends leading to extreme poverty will partially address several other challenges as well.

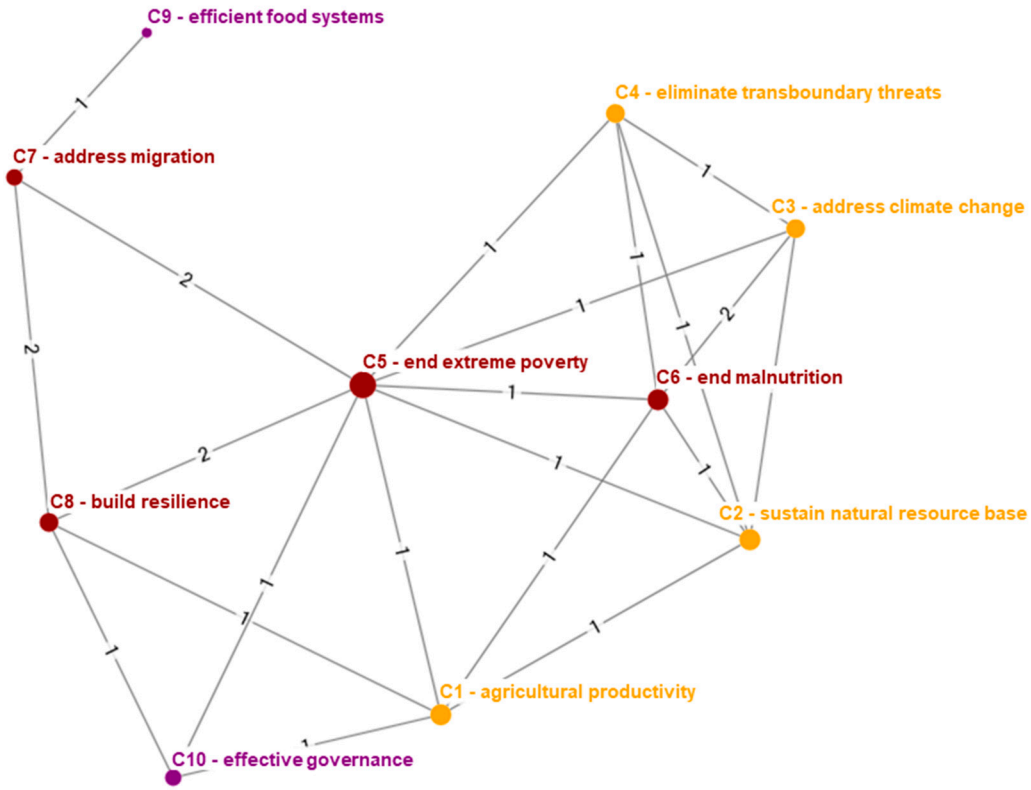

Figure 3. Interlinkages among the challenges of food stability and availability (orange), food access and utilization (red), and systemic challenges (purple) in terms of common leading trends. The *radii* of the challenge nodes are proportional to their degree values. The numbers indicate the number of common trends the challenges share, as originally provided in the FAO report.

Ending extreme poverty and reducing inequality (Challenge 5) has the highest common centrality value, implying the highest control over the network of challenges, which is constructed for their interlinkages in terms of their common root causes (trends) (Table 1). Another challenge with high level of control over the network is to *improve income-earning opportunities in rural areas and address the root causes of migration* (Challenge 7). When the solutions to these challenges are realized, the highest impact on the whole food security network would be achieved, in terms of tackling the challenges.

Table 1. Network analysis of the interlinkages between challenges in terms of root causes (trends).

Vertex	Degree	Betweenness (Centrality)	Closeness (Centrality)
C1—Agricultural productivity	5	2.0	0.07
C2—Sustain natural resource base	5	0.7	0.07
C3—Address climate change	4	0.0	0.07
C4—Eliminate transboundary threats	4	0.0	0.07
C5—End extreme poverty	8	16.7	0.10
C6—End hunger and malnutrition	5	0.7	0.07
C7—Address migration	3	8.0	0.07
C8—Build resilience	4	2.0	0.07
C9—Efficient food systems	1	0.0	0.04
C10—Effective governance	3	0.0	0.06

4.2. Implicit Links among Trends

Given that the trends are also interlinked, tackling the trends that lead to one challenge, could have potential benefits on overcoming another challenge. The map of the trends for food and agriculture is

shown in Figure 4. The fifteen trends are represented as circles of differing *radii*, scaled according to the magnitude of their out-degrees; i.e., the number of other trends they influence.

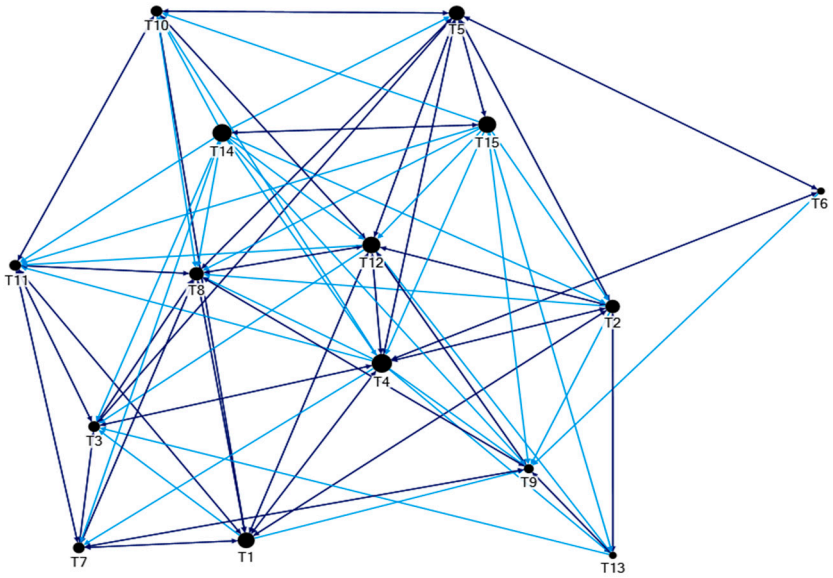

Figure 4. Network map of the trends in food and agriculture. Two-way causality links are represented with navy lines, whereas unreciprocated (one-way) links are represented with cyan lines. The sizes of the trend bullets are in proportion with their out-degrees; i.e., in proportion to other trends they have influence on. *Note: T1 = Population growth, urbanization, and aging; T2 = Global economic growth, investment, trade and food prices; T3 = Competition for natural resources; T4 = Climate change; T5 = Agricultural productivity and innovation; T6 = Transboundary pests and diseases; T7 = Conflicts, crises and natural disasters; T8 = Poverty, inequality and food insecurity; T9 = Nutrition and health; T10 = Structural change and employment; T11 = Migration and agriculture; T12 = Changing food systems; T13 = Food losses and waste; T14 = Governance for food and nutrition security; T15 = Development finance.*

There are several synergies between the trends. For instance, migration (Trend 7) is strictly connected to population growth, urbanization, competition for natural resources, conflict, crisis and natural disasters. *Poverty, inequality and food insecurity* (Trend 8), *nutrition and health* (Trend 9) are affected by most of the other trends.

In other cases, tackling a trend is likely to have a positive impact also on related trends. For instance, *climate change* (Trend 4), *governance for food and nutrition security* (Trend 14), and *development finance* (Trend 15) are related to almost all other trends, which has further been supported by the out-degrees reported for these trends on Table 2. Therefore, positively addressing these trends is likely to reduce many other (negative) trends. For instance, addressing climate change can affect positively Trends 1, 2, 3, 5, 6, 7, 8, 9, 10, 11 and 13.

Some trends have a systemic dimension and the potential to shape other trends: *investment in agriculture* (Trend 2), *changes in food systems* (Trend 12), *governance for food and nutrition security* (Trend 14) and *development finance* (Trend 15), if well managed, can become tools for addressing present and future challenges in agrifood chains.

The highest out-degree, along with the highest betweenness centrality of the *climate change* (Trend 4) reveal the strong influence of this trend on the others (Table 1). It also shows that climate change would have the highest control over the network of trends. Considering these outcomes, mainstreaming climate change mitigation options that reduce GHG emissions per unit of produced food would be logical. Increasing the resilience of agriculture to climate change would therefore also produce synergetic outcomes on global food security.

Table 2. The metrics of the network analysis of the trends in food and agriculture.

Vertex	In-Degree	Out-Degree	Betweenness (Centrality)
T1—Population growth, urbanization, and aging	7	9	3.18
T2—Global economic growth, investment, trade and food prices	7	7	2.6
T3—Competition for natural resources	9	5	4.3
T4—Climate change	8	12	19.4
T5—Agricultural productivity and innovation	9	8	6.5
T6—Transboundary pests and diseases	2	3	0.29
T7—Conflicts, crises and natural disasters	7	5	0.8
T8—Poverty, inequality and food insecurity	12	7	5.8
T9—Nutrition and health	10	4	9.7
T10—Structural change and employment	7	5	1.1
T11—Migration and agriculture	9	5	2.2
T12—Changing food systems	9	10	6.4
T13—Food losses and waste	5	3	0.9
T14—Governance for food and nutrition security	1	11	4.9
T15—Development finance	2	10	4.0

Figure 5 shows interlinkages among implicit links between trends and challenges of food stability and availability, food access and utilization, and systemic challenges. It can be seen that taking into account the implicit link among challenges enhances the clustering in terms of food security pillars. In other words, the challenges related to food stability and availability, food access and utilization, and systemic challenges are grouped distinctively and share similar root causes within each group.

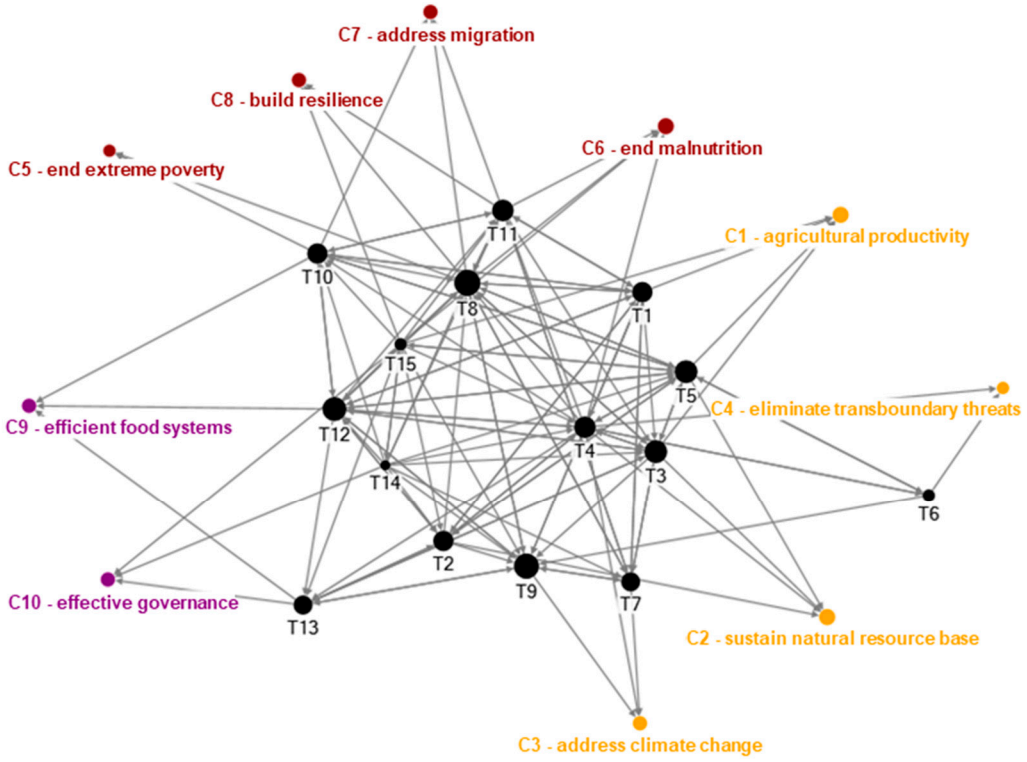

Figure 5. Implicit links between trends and challenges of food stability and availability (orange), food access and utilization (red), and systemic challenges (purple). The sizes of the challenge bullets are in proportion with their in-degrees; i.e., proportional to the number of trends they are affected by. *Note: T1 = Population growth, urbanization, and aging; T2 = Global economic growth, investment, trade and food prices; T3 = Competition for natural resources; T4 = Climate change; T5 = Agricultural productivity and innovation; T6 = Transboundary pests and diseases; T7 = Conflicts, crises and natural disasters; T8 = Poverty, inequality and food insecurity; T9 = Nutrition and health; T10 = Structural change and employment; T11 = Migration and agriculture; T12 = Changing food systems; T13 = Food losses and waste; T14 = Governance for food and nutrition security; T15 = Development finance.*

4.3. Analysis of Proposed Solutions and Their Links to Challenges

Figure 6 depicts the map of the proposed solutions and the challenges that they lead to betterment. The solutions have been listed in Table A4 in the Appendix A. A very distinct clustering is evident in terms of the solutions of food stability and availability, and food access and utilization. Most of the solutions which would tackle the challenges related to food stability and availability would solve or address the challenges of food access and utilization as well.

The important systemic challenges that lay ahead were categorized as: making food systems more efficient, inclusive and resilient (Challenge 9); and addressing the need for coherent and effective national and international governance (Challenge 10). Reasonably, the solutions to systemic challenges, when resolved, would have impacts on all pillars of food security. Means of addressing the systemic challenge of making food systems more efficient, inclusive and resilient (Challenge 9) would have the positive impact mostly on the food access and utilization challenges, considering that Challenge 9 is clustered very closely with these challenges. Similarly, on the other hand, building resilience to protracted crises, disasters and conflicts (Challenge 8) appear to equally address the challenges related to food access and utilization, as well as food stability and availability. This observation could be due to the cross-cutting nature of resilience. Indeed, increasing resilience of the food systems would require solutions beyond technological advancements and a broader focus than only increasing agricultural productivity, also considering the trade-offs with the changing environment systematically [30].

The interrelation between the trends and challenges addressed in Sections 4.1 and 4.2, along with the dimensions of food security, and the three pillars of sustainable development, notably economic, social and environmental sustainability require a systemic approach to increase the overall sustainability of food and agricultural systems. In the very short term, efforts should be focused on investment in social protection to achieve food security and improved nutrition outcomes. But in order to improve the food security sustainably, middle and long-term plans must include investments in productive activities which are pro-poor to improve their income-earning potential, as the solutions to the systemic challenges suggest.

Given the rising number of young people in low- and middle-income countries, employment opportunities must be generated both in urban and rural areas where small-scale, non-farm enterprises can create employment if legal and financial constraints are addressed [31]. Youth employment requires developing human capital through effective primary and secondary education. Public investment in public goods is fundamental to favor to pro-poor investment. Proper agricultural and food price policies can incentivize private investment in agriculture and private banking institutions (including cooperatives) to increase their coverage in rural areas, thus strengthening farmers' resilience and risk-coping capacities.

Globally, smallholder farms under two hectares produce 30–34% of the world's food supply from 24% of the gross agricultural area and account for greater crop diversity [32]. Therefore, business models, institutions and policies which provide incentives and support services to link smallholders to markets are much needed.

Significant amount of food produced globally is lost or wasted, yielding a high environmental burden and inefficient use of resources due to the associated waste inputs of energy, water, and natural resources [33]. Efficient food systems would entail solution to this problem. Food loss reduction has a multiplier effect, which tends to be more significant in value chains with more intermediaries and value addition (such as the milk chain, as compared to the rice or vegetable chains) [34]. Farms over 1000 ha have the most significant proportion of post-harvest losses [32]. On the other hand, high-quality local foods linked to traditions and culture can contribute significantly to the global food supply and nutrition, with a lower ecological footprint. However, these indigenous food systems compete with large-scale practices especially following Green Revolution and require research and adaptation for scaling up with comparable productivity [35].

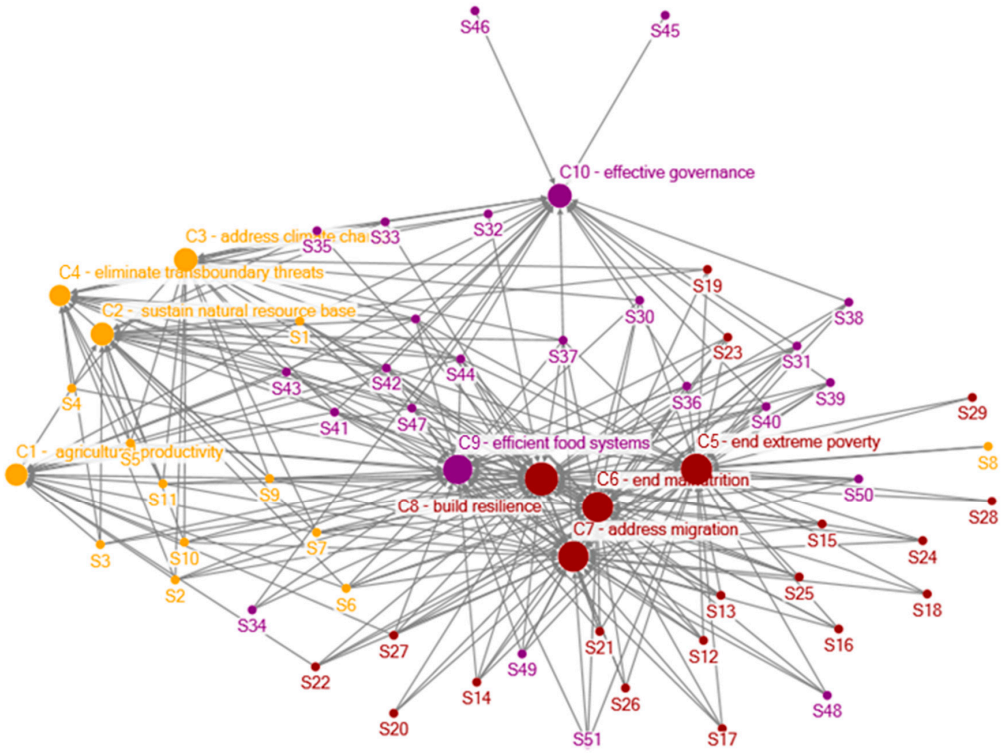

Figure 6. Interlinkages among selected solutions and challenges of food stability and availability (orange), food access and utilization (red), and systemic challenges (purple). The sizes of the challenge bullets are in proportion with their in-degrees; i.e., in proportion to the number of solutions proposed to address each.

5. Conclusions and Recommendations for Further Work

Our analysis, moving from the relations between challenges and trends identified by the FAO report "The future of food and agriculture: trends and challenges" [4], highlights that ending extreme poverty (Challenge 5) and end malnutrition (Challenge 6) have the highest number of common trends with other challenges (Figure 3). This implies that if trends leading to extreme poverty are reversed with appropriate interventions, several other challenges will also be partially addressed. This is not particularly surprising since these two challenges have important overlaps and synergies with others and could be considered key challenges.

In terms of trends, on the basis of the explicit linkages mentioned by the FAO report, and the implicit linkages identified in our study, it is evident that acting on *climate change* (Trend 4), *changing food systems* (Trend 12), *governance for food and nutrition* security (Trend 14), *and development finance* (Trend 15) can have a significant impact on several other trends. In particular, the highest out-degree, along with the highest betweenness centrality of climate change (Trend 4) reveal the strong influence of this trend on the others (Table 1). This observation also shows that climate change would have the highest control over the network of trends. However, the most relevant trends to be tackled in order to have a systemic impact (highest out-degree) appear to be the *investment in agriculture* (Trend 2), *changes in food systems* (Trend 12), *governance for food and nutrition security* (Trend 14) and *development finance* (Trend 15).

The analysis of interlinkages among trends presented in this paper went one step forward, identifying the non-explicit (or implicit) interlinkages between trends, and how these would impact overcoming the challenges ahead. In fact, the complex nature of the interlinkages between trends should be taken into account considering implicit linkages. These implicit linkages were identified on the basis of expert opinion and are presented in Table A3 of the Appendix A. By taking into consideration also the implicit linkages, the results show that key trends to tackle are *persistent*

poverty, inequality and food insecurity (Trend 8), *dietary transitions affecting nutrition and health* (Trend 9), *advanced food production systems and resulting impacts on farmers' livelihoods* (Trend 12), *greatly increased competition for natural resources* (Trend 3) and *plateauing of agricultural productivity for many crops and animals* (Trend 5). These trends include poverty and food insecurity and production efficiency, highlighting the need to address both types of trends at the same time. In fact, the 2030 Agenda for Sustainable Development also highlighted the complexity and interlinks among the food and agricultural system challenges. This acknowledgement is promising in nature, as the integration of international and national approaches will ultimately be needed to tackle these challenges, rather than policy developments on a sectoral basis.

It should be noted that the analysis of interlinkages among trends, challenges and between trends and challenges, is based on a 'snapshot' of the current trends as reported by the FAO report. A more comprehensive dynamic study, closer to the real picture would also be possible and would further improve the analysis.

Our study also assessed the relevance of a number of solutions (presented in Table A4 of the Appendix A) to overcome the challenges, as identified in the FAO report. A more comprehensive analysis of the available technologies and possible solutions could be taken into account for future studies. Given that such a practice would be very intensive, it could be performed for a specific category rather than for the entire food security dimensions.

The analysis shows that most solutions that address challenges related to *food stability and availability*, would also address *food access and utilization* (Figure 6). In addition, solutions that tackle directly *making food systems more efficient, inclusive and resilient* (Challenge 9), *addressing the need for coherent and effective national and international governance* (Challenge 10) and *building resilience to protracted crises, disasters and conflicts* (Challenge 8) have an indirect (systemic) impact on all aspects of food security (Figure 5) and should therefore be prioritized.

In 2018, FAO published a follow-up publication focusing on the possible future pathways of food and agriculture [17]. This last publication largely confirms the results of our analysis, highlighting the strong interlinkage of climate change with other trends in the food and agriculture sector, the urgent need of developing efficient, inclusive and resilient food systems (including agriculture intensification, avoiding land degradation, using water more efficiently, etc.), and of reducing inequalities through coherent and effective governance. In addition, it gives a likewise prominent role to solutions to modify the food demand, which were not very prominent in the set of solutions mentioned in the FAO report [4] and which were considered for our analysis. An interesting exercise for future research would be to extend the systemic approach presented here to include the new solutions presented in the 2018 FAO report [17].

It should be also noted that this study focused on the links in terms of qualitative relationships identified in the FAO report, but a mathematical relationship and a more complex model could be built by analyzing the trends and challenges in a more quantitative manner (i.e., taking in consideration also the relevance or rapidity of trends).

This study suggested the trends which would produce the highest positive outcome if reversed, on the related key challenges and prioritized the solutions to tackle these challenges. However, given the dynamism of nature, food demand and technologies of our food system, it is clear that new international governance mechanisms for responding to food and nutrition security issues must follow iterative, bottom-up, problem-solving and experimentalist approaches. Efforts to achieving the SDGs require global and national governance frameworks focused on reducing between- and within-country inequality within the environmental constraints posed by climate change [4].

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Appendix A

Table A1. Links between challenges, trends and food security.

Challenge	Related Trends	Food Security Component
Sustainably improving agricultural productivity to meet increasing demand	Trends 1, 2 and 5 Trend 3 Trend 15	Challenges to food stability and availability
Ensuring a sustainable natural resource base	Trend 3 Trend 4	Challenges to food stability and availability
Addressing climate change and intensification of natural hazards	Trends 4, 7, 9	Challenges to food stability and availability
Eradicating extreme poverty and reducing inequality	Trends 8 and 11 Trends 4 and 15	Challenges to food access and utilization
Ending hunger and all forms of malnutrition	Trends 9, 1, 4	Challenges to food access and utilization
Making food systems more efficient, inclusive and resilient	Trends 10, 12, 13	Systemic challenges
Improving income earning opportunities in rural areas and addressing the root causes of migration	Trends 8, 10, and 11	Challenges to food access and utilization
Building resilience to protracted crises, disasters and conflicts	Trends 7, 11 and 15	Challenges to food access and utilization
Preventing transboundary and emerging agriculture and food system threats	Trends 4 and 6	Challenges to food stability and availability
Addressing the need for coherent and effective national and international governance	Trends 14 and 15	Systemic challenges

Table A2. Trends and Variables.

Trend	Variables
Population growth, urbanization, and aging	Total population Population annual increase Growth in global urban and rural populations Urbanization trends
Global economic growth, investment, trade and food prices	Growth in GDP per capita Growth in GDP Gross Fixed Capital Formation (GFCF) in agriculture Investment rates Agricultural investment orientation ratio Agricultural net capital-output (value added) ratio Additional income and investment to eradicate hunger by 2030 Total and agricultural international trade volume (USD) Percentage of net food imports in domestic food supply in total calories FAO real food price index (RFPI)
Competition for natural resources	Agricultural and forest land use Net forests conversion Freshwater withdrawals as a percentage of total renewable resources Total land equipped for irrigation
Climate change	Annual greenhouse gas emissions from Agriculture, Forestry and Other Land Use (AFOLU) Annual greenhouse gas emissions from all sectors Projected changes in crop yields owing to climate change

Table A2. *Cont.*

Trend	Variables
Agricultural productivity and innovation	Increase in agricultural production Projected demand for agricultural production Annual average crop yields Sources of growth in agricultural production Real growth of public spending on agricultural R&D Agricultural research intensity (ARI)
Transboundary pests and diseases	Reported outbreaks of lumpy skin disease Global spread of crop pests and pathogens
Conflicts, crises and natural disasters	Prevalence of undernourishment and protracted crises Climate-related disasters Agricultural production losses after medium- to large-scale disasters in low-and middle-income countries, by cause and region
Poverty, inequality and food insecurity	People below the poverty line (PPP) of USD 1.90 per day Per capita gross capital formation Per capita income Per capita consumption GDP per capita projections in low- and middle-income countries as a share of high-income countries Number of undernourished
Nutrition and health	Undernutrition Micronutrient deficiencies Overweight and obesity Per capita calorie intake by source Per capita protein intake by source Greenhouse gas emissions by diet type
Structural change and employment	Sectoral contributions to aggregate GDP, by region Sectoral employment shares, by region Estimates of the population aged 15–24 years
Migration and agriculture	Numbers of international migrants, by origin and destination International migrant stock, by destination International migrants in destination countries Remittances to low- and middle-income countries compared with other financial inflows Female share of economically active population in agriculture
Changing food systems	Share of the food retail trade, by channel and region
Food losses and waste	Distribution of food losses and waste along the supply chain
Governance for food and nutrition security	-
Development finance	Financial flows to low-income countries Composition of financial flows to low-income countries Tentative estimates of annual incremental investments needed in energy, agriculture and food security for sustainable development (USD billions) Investment in agriculture in low- and middle-income countries, by source

Table A3. Implicit and explicit relations among trends.

#	Trend	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Population growth, urbanization, and aging	-	Δ	Δ	◊	-	-	Δ	◊	Δ	Δ	Δ	◊	-	-	-
2	Global economic growth, investment, trade and food prices	Δ	-	-	Δ	Δ	-	-	◊	Δ	-	-	Δ	Δ	-	-
3	Competition for natural resources	-	-	-	Δ	Δ	-	Δ	Δ	-	-	Δ	-	-	-	-
4	Climate change	◊	Δ	Δ	-	Δ	◊	Δ	Δ	Δ	Δ	Δ	Δ	◊	-	-
5	Agricultural productivity and innovation	-	Δ	Δ	Δ	-	Δ	-	Δ	-	◊	-	◊	-	-	Δ

Table A3. *Cont.*

#	Trend	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6	Transboundary pests and diseases	-	-	-	Δ	Δ	-	-	-	Δ	-	-	-	-	-	-
7	Conflicts, crises and natural disasters	◊	-	Δ	-	-	-	-	Δ	◊	-	Δ	-	-	-	-
8	Poverty, inequality and food insecurity	Δ	-	◊	-	◊	-	Δ	-	Δ	-	Δ	◊	-	-	-
9	Nutrition and health	-	-	-	-	-	-	Δ	◊	-	-	-	Δ	◊	-	-
10	Structural change and employment	Δ	-	-	-	Δ	-	-	Δ	-	-	Δ	◊	-	-	-
11	Migration and agriculture	Δ	-	Δ	-	-	-	Δ	Δ	-	Δ	-	-	-	-	-
12	Changing food systems	Δ	Δ	◊	Δ	Δ	-	-	Δ	Δ	Δ	Δ	-	Δ	-	-
13	Food losses and waste	-	Δ	Δ	-	-	-	-	-	◊	-	-	-	-	-	-
14	Governance for food and nutrition security	-	Δ	Δ	Δ	Δ	-	Δ	Δ	Δ	Δ	Δ	Δ	-	-	Δ
15	Development finance	-	Δ	-	Δ	Δ	-	-	Δ	Δ	Δ	Δ	Δ	Δ	Δ	-

Δ: Explicit links in the report; ◊: Implicit links in the report.

Table A4. List of Proposed Solutions to Address Challenges of Food and Agriculture.

Challenges→	**#**	**1**	**2**	**3**	**9**	**4**	**5**	**7**	**8**	**6**	**10**
Means to tackle challenge:	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
1. Sustainably improving agricultural productivity to meet increasing demand:	-	-	-	-	-	-	-	-	-	-	-
Climate-smart agriculture	11	Δ	◊	◊	◊	-	-	◊	◊	◊	-
Resource use efficiency	10	Δ	Δ	◊	-	-	-	◊	◊	◊	-
Adoption of sustainable production systems and practices	9	Δ	◊	Δ	◊	◊	◊	◊	◊	-	-
Address gender-specific needs	8	-	-	-	-	◊	-	-	◊	-	-
Realignment of implicit and explicit agricultural subsidies	7	Δ	◊	◊	-	◊	◊	◊	◊	-	-
2. Ensuring a sustainable natural resource base:	-	-	-	-	-	-	-	-	-	-	-
Improvements in productivity	6	◊	Δ	-	-	Δ	◊	◊	◊	◊	-
3. Addressing climate change and intensification of natural hazards:	-	-	-	-	-	-	-	-	-	-	-
Reducing agriculture's environmental and climate footprint	5	◊	◊	Δ	◊	-	-	-	◊	◊	-
4. Preventing transboundary and emerging agriculture and food system threats:	-	-	-	-	-	-	-	-	-	-	-
Maintaining the capacity of the planet's natural resource base to feed the growing population	4	◊	◊	Δ	◊	-	-	-	◊	-	-
Integrated pest management, which favors biopesticides and biocontrol agents	3	Δ	◊	-	Δ	-	-	-	◊	◊	-
Increasing food safety by safe water use, sanitary food production, adequate storage facilities.	2	◊	-	◊	Δ	-	◊	-	◊	◊	-
Enforce regulations for the above.	1	◊	◊	◊	Δ	-	◊	-	◊	◊	◊
5. End extreme poverty:	-	-	-	-	-	-	-	-	-	-	-
Link farmers to markets	29	-	-	-	-	Δ	-	-	◊	-	-
And provide efficient extension and agricultural advisory services	28	-	-	-	-	Δ	-	-	◊	-	-
Access to good quality education	27	◊	-	-	-	Δ	◊	Δ	◊	◊	-
Economic diversification to rural non-farm income generating activities	26	-	-	-	-	Δ	◊	◊	◊	-	-
Support for job creation	25	-	-	-	-	Δ	◊	◊	◊	◊	-
And adequate social protection mechanisms for extreme poverty	24	-	-	-	-	Δ	◊	◊	◊	-	-
External support to investment programs through international financial cooperation	23	-	-	-	-	Δ	◊	◊	◊	◊	◊
6. End malnutrition	-	-	-	-	-	-	-	-	-	-	-
Increasing farm production to meet the demand	22	◊	-	-	-	◊	Δ	◊	◊	-	-
Supply chains that connect farmers to urban markets	21	-	-	-	-	◊	Δ	◊	◊	◊	-
Measures such as pricing policies and social protection for malnutrition	20	-	-	-	-	-	Δ	◊	◊	-	-
National guidelines for responsible consumption	19	-	◊	Δ	-	◊	Δ	-	-	-	-

Table A4. *Cont.*

Challenges→	#	1	2	3	9	4	5	7	8	6	10
7. Improve income-earning opportunities in rural areas and address the root causes of migration	-	-	-	-	-	Δ	-	-	-	-	-
More inclusive rural transformations	18	-	-	-	-	◊	-	Δ	◊	-	-
Reconfiguration of rural-urban linkages	17	-	-	-	-	◊	◊	Δ	-	◊	-
Integrate hundreds of millions of young people into the labour market	16	-	-	-	-	◊	◊	Δ	◊	-	-
Building human capital through the provision of quality basic social services (particularly education and health)	15	-	-	-	-	◊	◊	Δ	◊	◊	-
Address root causes of migration and increase access to social protection	14	-	-	-	-	◊	◊	Δ	◊	◊	-
Employment opportunities in both origin and destination countries	13	-	-	-	-	◊	◊	Δ	◊	◊	-
8. Building resilience to protracted crises, disasters and conflicts	-	-	-	-	-	-	-	-	-	-	-
More risk-informed, inclusive and equitable resilience and development processes	12	-	-	-	-	◊	◊	◊	Δ	◊	-
9. Make food systems more efficient, inclusive and resilient	-	-	-	-	-	-	-	-	-	-	-
Strengthened linkages between farms, markets and consumers	51	-	-	-	-	Δ	◊	Δ	-	Δ	-
Find dynamic pathways that connect local food systems to growing urban markets and to seize market opportunities	50	-	-	-	-	Δ	◊	Δ	◊	Δ	-
Connecting small-scale producers and supermarket supply chains through contractual arrangements with mutually beneficial terms	49	-	-	-	-	◊	◊	◊	◊	Δ	-
Giving new impetus to the development of local food systems	48	-	-	-	-	◊	◊	◊	-	Δ	-
10. Meet the needs for coherent and effective national and international governance	-	-	-	-	-	-	-	-	-	-	-
Integrated policy approaches at national and international levels	47	◊	◊	◊	◊	◊	◊	◊	◊	◊	Δ
Combining instruments implemented at different levels of governance in ways that are mutually reinforcing	46	-	-	-	-	-	-	-	-	-	Δ
Containing inevitable trade-offs	45	-	-	-	-	-	-	-	-	-	Δ
Capitalizing on synergies among the Sustainable Development Goals (SDGs) and related targets	44	◊	◊	◊	◊	◊	◊	◊	◊	◊	Δ
Different sectoral policies	43	◊	◊	◊	◊	◊	◊	◊	-	◊	Δ
Diverse stakeholders at local, municipal, provincial, national, regional and international levels	42	◊	◊	◊	◊	◊	◊	◊	◊	◊	Δ
More inclusive governance will be needed to improve dialogue about the hard policy choices	41	◊	◊	◊	◊	◊	◊	◊	◊	◊	Δ
Avoid the marginalization of the poor	40	-	-	-	-	◊	◊	◊	◊	◊	Δ
Financing for inclusive food and agriculture development	39	-	-	-	-	◊	◊	◊	◊	◊	Δ
Ensuring the recognition of the poor's formal and informal rights of access to, and use of, natural resources	38	-	-	-	-	◊	◊	-	◊	-	Δ
Implementation of voluntary guidelines on the responsible governance of tenure of land, fisheries and forests	37	-	◊	◊	-	◊	◊	◊	◊	◊	Δ
Support to the realization of the right to adequate food	36	-	-	-	-	◊	◊	◊	◊	◊	Δ
Improved natural resource governance, based on the concepts of governance of tenure	35	-	◊	◊	◊	-	-	-	◊	-	Δ
Establish a flexible framework for mitigating and resolving conflicts over land, water, fisheries and forests	34	-	-	-	-	-	-	-	◊	◊	Δ
Protecting biodiversity, and ensuring ecosystem services	33	-	◊	◊	◊	-	-	-	◊	-	Δ
International cooperation and mechanisms for policies and institutions dedicated to the prevention and management of specific climate-related risks and vulnerabilities	32	-	-	◊	◊	-	-	-	◊	-	Δ
Financing for inclusive food and agriculture development	-	-	-	-	-	◊	◊	◊	◊	-	Δ
Meeting employment and migration challenges	31	-	-	-	-	◊	◊	◊	◊	◊	Δ
Addressing shortfalls in the multilateral trading regime in relation to food and agriculture systems	30	-	-	◊		◊	◊	◊	-	◊	Δ
Providing open access to data and statistics to enhance the role of all stakeholders in governance	52	◊	◊	◊	◊	◊	◊	◊	-	◊	Δ

Δ: Explicit links in the report; ◊: Implicit links in the report.

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