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A 2023 Update

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ACRONYMS

| | |
|-------|---|
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| FAO | Food and Agriculture Organization |
| IFI | international financing institution |
| IFPRI | International Food Policy Research Institute |
| IPC | Integrated Food Security Phase |
| IPCC | Intergovernmental Panel on Climate Change |
| MSMEs | Micro, small,- and medium-sized enterprises |
| PES | Paid ecosystem services |
| SME | Small- and medium-sized enterprises |
| UNCCD | United Nations Convention to Combat Desertification |
| UNEP | United Nations Environment Programme |
| UNFCC | United Nations Framework Convention on Climate Change |
| UNIDO | United Nations Industrial Development Organization |
| WFP | World Food Programme |
| WHO | World Health Organization |
| ZEF | Centre for Development Research, University of Bonn |



FOREWORD

Resolving conflicts, increasing food security and reducing the impacts of climate change are among the top challenges which humanity collectively faces today. We need to recalibrate our global priorities to ensure a more sustainable future. If we cannot offer access to safe and nutritious food for all, then there can be no true global stability and catastrophic consequences are nigh unavoidable.

The current progress on achieving SDG 2 Zero Hunger provides little hope for reaching that goal by 2030 as the international community committed to do. Population growth, soil degradation, water scarcity, reduced global cooperation and of course climate change impacts are among the issues that must be dealt with. No other sector of the economy is as dependent on climatic conditions as agriculture.

Upon becoming the Director General of the United Nations Industrial Development Organization (UNIDO), my focus was to address these challenges with “Progress by Innovation” solutions for our Member States. I am sure that by working together with them, a world without hunger is indeed possible. We know what needs to be done. What we truly now need is the political will to mobilize the financial resources to finally create a world without hunger.

This report, Food Security and Climate Change – An Update for 2023, reveals that there are opportunities to significantly improve the situation. Three key aspects are:

1. Increasing the productivity of the 500 million smallholder farmers, with soil improvement playing a mayor role. Done right, this would contribute significantly to climate protection and generate huge financial flows.
2. Reducing food loss and waste, with special attention on post-harvest processes to increase food availability without further negative impact on the climate.
3. Improving the efficiency of the livestock sector can lead to reduced loss and waste, allowing enviromentally and socially more sustainable practices along the value chain.

In all three areas, the inefficiencies of the status quo in fact offer great opportunities.

Against this background, the report provides a brief overview of the interlinked challenges related to food security and climate change, and how UNIDO offers Member States solutions to create more resilient and innovative agri-food supply chains. We believe local solutions can have a transformative role on agribusinesses, addressing humanitarian aid and economic transformation.

As Director General, I can assure you that ending hunger remains a top priority for UNIDO, and we are committed to working together with all our partners and stakeholders in food systems transformation.

Gerd Müller

Director General, UNIDO

EXECUTIVE SUMMARY

This study describes the challenges of climate change and hunger and why a wider economic transformation is required to improve the status quo. Based on recent reports by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environment Programme (UNEP), it is evident that the world is **off track to achieve its targets in climate and food security**. Today, hunger is increasing again in an economically and socio-politically turbulent and unstable world. Current challenges are described by reviewing selected academic studies, offering an up-to-date perspective based on FAO's food system approach. The following points describe today's major challenges:

1. **Supplying 10 billion people with healthy food in 2050 is possible** in terms of quantity and quality of supply, despite continued population growth. However, the financing of the required transformation processes presents a major challenge.
2. **\$40-50 billion is required per year to end hunger by 2030**, according to the latest estimates from academia. Wider economic transformation within a holistic approach to the Agenda 2030 would require trillions of dollars.
3. **The true annual cost of food was estimated to be around \$28 trillion**: \$9 trillion for food expenditure, \$7 trillion for environmental cost, and \$11 trillion related to human life and health costs. A transformation of the food system at all levels is required for a more sustainable future. Nevertheless, relationships and trade-offs linked to a complex ecosystem might cause impediments in this process.
4. **Research and development (R&D) and innovation** can accelerate progress through on-farm practices such as yield gaps, agricultural inputs and mechanization, digitalization, locally adapted seeds, precision farming, and regenerative solutions for soil nutrient and plant and animal health protection management. Integration of new types of proteins and improved sectoral efficiency can reduce the current impact of the livestock sector on climate change.
5. **The productivity of 500 million smallholder farmers**, who currently supply half of humanity with food, can be doubled by 2050. This requires significantly empowering women. Innovative technologies will assist in engaging the next generation of farmers and developing urban agricultural production systems.
6. **Many opportunities exist to reduce food loss and waste** in the post-harvest stage (storage, logistics, processing, and distribution). Cooling chains can have cross-cutting implications from improved public health through more resilient supply chains to agro-industrialization. Consumer behaviour will play a major role in curbing growing demand and making more conscious choices.
7. **Soil restoration and regenerative management have several positive effects and provide a climate financing opportunity with multiple dividends**. Regenerated soils store more carbon, have higher productivity and value, improve water balance for greater resiliency against climate change impacts and contribute to food security. Beyond the social benefit of bringing producers out of poverty and producing more food on less land, regenerating soils can actively provide a scalable solution for greenhouse gas removal from the atmosphere and preserving biodiversity.

A matrix of intervention areas (see Annex 1) has been developed that are essential for wider structural transformation contributing to a more food-secure and environmentally sustainable future. From the perspectives of policy and regulatory frameworks, infrastructure, technology and innovation, skills development, and finance, UNIDO differentiates at three distinct levels to contribute to the goal of ending hunger and improving climate change:

- Food production
- Post-harvest practices
- And wider economic transformation





1 INTRODUCTION

Climate change has a causal relationship to food security and hunger, negatively impacting the lives of millions if not billions of people. This report reviews food security from this climate change perspective and analyzes how UNIDO technical expertise and tools for sustainable industrialization can help Member States. A number of resources were examined, including the Food and Agricultural Organization (FAO) food systems approach¹ and a detailed literature review of recent publications of United Nations (UN) development agencies, supplemented by practitioners and decision-makers from the field of agriculture.

Analysis was conducted at three levels:

- The production side in agri-food system (including smallholder farmers).
- The downstream side in food supply chains (as an opportunity to reduce post-harvest losses).
- The socio-economic macro environment, which includes the inter-connected system of markets, regulatory and policy environment, technology and innovation, such as energy access, digitalization, precision agriculture.

All three levels represent opportunities for interventions to reduce hunger and, at the same time, mitigate or adapt to the impact of climate change. Overarching and cross-cutting topics are climate, nature and planetary system integrity. It is also vital to mention that vulnerable groups, particularly youth and women, are highly impacted by food insecurity and climate change and, therefore, special attention is needed to them during different interventions.

¹ Cf. FAO (2018).

2 ANALYSIS OF 2020 POLICY RECOMMENDATIONS

As part of the Decade of Action to achieve the Sustainable Development Goals by 2030, two earlier, 2020 studies on overcoming hunger were prepared as input to the Food Systems Summit 2021 (FSS2021).²

1. Laborde, D., Murphy, S., Parent, M., Porciello, J. & Smaller C. (2020). Ceres2030: Sustainable Solutions to End Hunger - Summary Report. Cornell University, IFPRI and IISD.
2. ZEF and FAO. (2020). Investment costs and policy action opportunities for reaching a world without hunger (SDG2). Rome and Bonn.

Both studies offered comprehensive analyses and recommendations on needed investments. One study was undertaken by Ceres, a novel partnership among research organizations, civil society, and economists. The studies focused on improving the practices of smallholder farmers, but did not cover several key areas: post-harvest supply chain efficiency and resilience; framing of the socio-economic system, including markets and conditions of trade; social systems with an economic basis; and required agricultural and infrastructural services for agro-industrialization, which remain a challenge for many low- and middle-income countries facing food security issues. Overall, the Ceres study had limited references to post-harvest practices, which prevented considering food security and climate change from an economic transformation perspective.

2.1 Analysis of Ceres recommendations

According to the study, implementing 10 recommendations would prevent 490 million people from experiencing hunger, double the incomes of 545 million smallholder farmers and their families, and limit greenhouse gas emissions for agriculture to the commitments made in the Paris Agreement.

These primarily considered practices of smallholder farmers as a central issue for food security, differentiating between “Empowering the Excluded” and “On the Farm”. The report also elaborated on post-harvest value chains in a chapter entitled “Food on the Move”. The economic system as subordinate to those different stages of food systems was only partially considered in the study.

² *The UN Food Systems Summit set the stage for global food systems transformation to achieve the Sustainable Development Goals by 2030.*

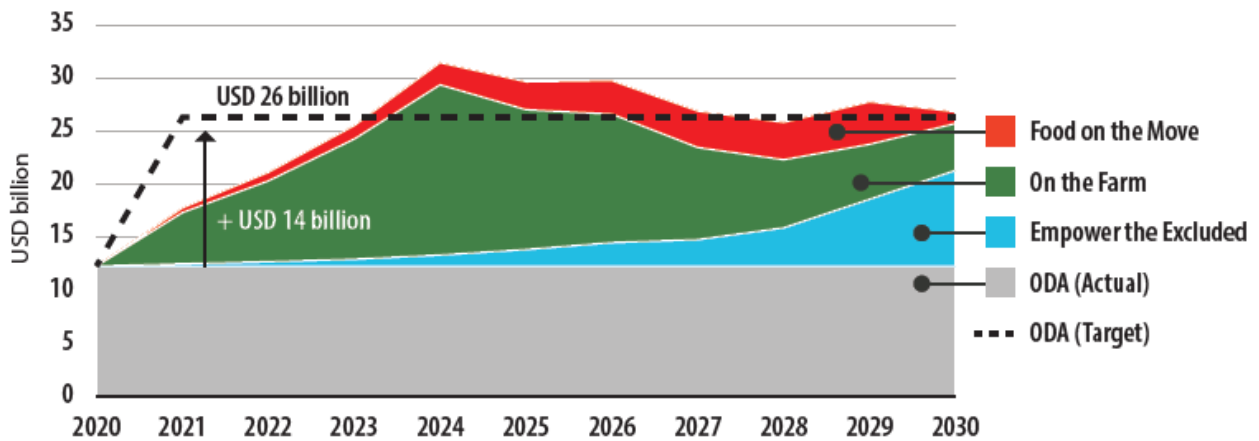
Figure 1. 10 CERES recommendations

| | |
|--------------------------------|---|
| Empowering the Excluded | 1. Enable participation in farmers' organizations. |
| | 2. Invest in vocational programmes for rural youth that offer integrated training in multiple skills. |
| | 3. Scale up social protection programmes. |
| On the Farm | 4. Investment in extension services, particularly for women, must accompany research and development (R&D) programmes. |
| | 5. Agricultural interventions to support sustainable practices must be economically viable for farmers. |
| | 6. Support adoption of climate-resilient crops. |
| | 7. Increase research on water-scarce regions to scale up effective farm-level interventions to assist small-scale producers. |
| | 8. Improve the quantity and quality of livestock feed, especially for small and medium-scale commercial farms. |
| Food on the Move | 9. Reduce post-harvest losses by expanding the focus of interventions beyond the storage of cereals, to include more links in the value chain, and more food crops. |
| | 10. Invest in the infrastructure, regulations, services and technical assistance needed to support SMEs in the value chain. |

Ceres estimated the average cost for this at \$33 billion per year, split between public spending (\$19 billion) and donor contributions (\$14 billion). About 80 per cent would contribute to improved production capacities of smallholder farmers, with the remaining 20 per cent invested in post-harvest supply chains. According to the study, public funds identified for the investments would attract additional private funding in the range of \$52 billion.

Given the current period of economic crisis, hyperinflation and increasing debts, the additional \$14 billion from donor countries might not be sufficient, since governments in low- and middle-income countries will probably not be able to raise the \$19 billion.

Figure 2. The Official Development Assistance donor funding gap over time and by category of intervention



Source: CERES2030: Sustainable Solutions to End Hunger

2.2 Analysis of ZEF and FAO recommendations

As with the Ceres study, the Centre for Research Development at the University of Bonn (ZEF) and the Food and Agricultural Organization (FAO) synthesized the outcomes of multiple previous studies. The marginal cost curve (MaCC) econometric tool was used to identify the most cost-effective policy and economic interventions to reduce hunger.

Of the 24 measures considered to eradicate hunger and malnutrition in terms of the Sustainable Development Goals (SDG) 2 targets, the following 10 were ranked as highest in terms of average annual incremental investment cost per person saved from hunger:

1. Agricultural R&D efficiency enhancement
2. Agricultural extension services
3. ICT - Agricultural information services
4. Small-scale irrigation expansion in Africa
5. Agricultural R&D
6. Female literacy improvement
7. Social protection - Scaling up existing programmes
8. Crop protection – Insects
9. Social protection - Establishing new programmes
10. COVID-19 - Social protection

Overall, the G7 Official Development Assistance (ODA) funds for 2018 (\$17 billion) would have to be increased by at least \$14 billion annually. This is in line with the Ceres numbers for additional donor contributions.

2.3 A sad truth: Limited contribution to the Decade of Action

In 2019, the UN Secretary-General called on all sectors of society to mobilize for the Decade of Action at three levels: global, local and among people.

In the past three years, various unplanned events had a negative impact on food access and availability to required agricultural inputs and food. The COVID-19 pandemic and Ukraine conflict contributed to food supply chain disruptions and more protectionist trade policies of countries, increasing the number of people facing hunger. Even if the overall economic conditions and their negative impact had been more favorable and there had been fewer crises, smallholder farmers would not have been able to significantly improve their situation.

So despite the valuable 2020 interdependent group of recommendations, these were never implemented consistently and across the breadth of areas. Progress can only be measured based on estimates provided by FAO and the UN World Food Programme (WFP). Collaborative international efforts will be required among governments, industry and consumers to address the challenges ahead.

3 STATUS QUO IN THE FIGHT AGAINST HUNGER AND EMERGING DEVELOPMENTS

This chapter describes the current status in the fight against hunger based on the most recent data and information. It also elaborates on further developments and trends. All eight targets of the Sustainable Development Goal (SDG) 2 to End Hunger are addressed³

3.1 The fight against hunger

Hunger and food security remain a global challenge and humanitarian issue. While there was steady progress reducing the number of people facing acute hunger in the early 21st century, down to less than eight per cent in 2014, the numbers remained relatively stable between 2014 and 2019.⁴

Today, the causes of hunger are complex and include wars, conflicts and disasters, economic and financial crises, poor governance, unfair land distribution, climate change, and social exclusion to unfair international trade agreements. Insufficient resilience of the food system contributes to crises and disasters. The COVID-19 pandemic led to people in poverty losing parts or even all their income opportunities. Particularly among many industrializing countries, financial rescue packages and social security systems were non-existent, resulting in food security issues. Further exacerbating the food crisis, the armed conflicts in Ukraine have contributed to further inflation, food price spikes, and increased costs of agricultural inputs such as fertilizer.

In 2022, about 735 million people faced hunger, disproportionately affecting women and girls.⁵ On the other hand, more than 333 million people are facing acute food insecurity in 2023, around 200 million more than before the COVID-19 pandemic.^{6,7} A total 47 million people across 54 countries are in “emergency” or worse levels of hunger.⁸

In addition, 3.1 billion people could not afford a healthy diet in 2022, with 2.4 billion of them lacking reliable access to healthy, safe and sufficient food throughout the year.⁹ This group consists mainly of people in rural areas, especially women. Eighty per cent of the people who go hungry worldwide are food producers.¹⁰

To address these issues, the G7 issued the Elmau Pledge in 2015 to free 500 million people from hunger by 2030, but implementation is below expectations.¹¹ To better coordinate actors involved in the eradication of hunger, the Global Alliance for Food Security was launched in 2022. In this context, the G7 pledged an additional \$4.5 billion above the Elmau Pledge to protect the most vulnerable

³ Cf. UN (2023).

⁴ Cf. FAO et al. (2023).

⁵ Cf. FAO et al. (2023).

⁶ Cf. WFP (2023).

⁷ Cf. WFP (2019).

⁸ Cf. WFP (2023).

⁹ Cf. FAO (2023).

¹⁰ Frick, M. (2023)

¹¹ Cf. BMZ (2022c).

people from hunger and malnutrition, and actually ended up making available \$4.9 billion as of December 2022. The latest development within the G7 is the Hiroshima Action Statement for Resilient Global Food Security and the announcement of further efforts to combat worldwide hunger.¹² The statement suggests a holistic policy approach to food security to expand agricultural cultivation in low- and middle-income countries, empower women, and consider the impact of biodiversity losses and climate change on nutrition. The G7 acknowledges that only climate-adapted, sustainable agriculture that preserves biodiversity can ensure a long-term supply of healthy food for all people.

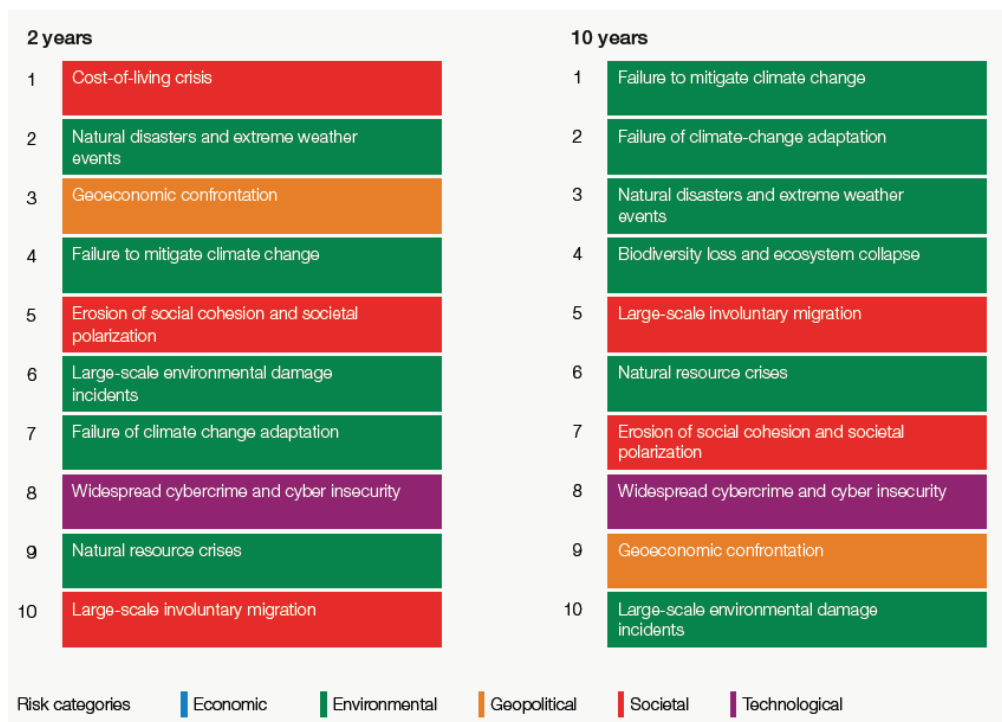
3.2 Emerging developments and trends

The world population is expected to increase from eight billion people today to about 10 billion people by 2050.¹³ The highest increase will occur among industrializing countries, particularly areas where the food situation is most critical.

Since the COVID-19 pandemic, an increase in the cost of living has been observed worldwide, stimulated in particular by shortages such as fertilizer, inflation, and armed conflicts. For the poorest, this means that they can no longer afford food.

The world is facing geopolitical confrontations and the formation of new political and trade blocs, exacerbating non-cooperation and conflicts. There are twice as many armed conflicts today as ten years ago, which also leaves its mark on the food security crisis. Armed conflicts are just one reason for increasing involuntary migration. According to the United Nations High Commission for Refugees, more than 100 million people were displaced at the end of 2022, more than ever before. Climate change and changing agroecological zones will push more people to move to cooler areas. In general, refugees are particularly at risk of hunger and malnutrition.¹⁴

Figure 3: Global risks ranked by severity over the short and long term



Source: WEF Global Risks Report 2023)

¹² Cf. G7 (2023).

¹³ Cf. UN DESA (2022).

¹⁴ Cf. UNHCR (2023).

There is an increasing risk of ecosystem collapse, which would have severe consequences for the environment, humankind, and economic activities, particularly in the fields of agriculture and forestry. Figure 3 ranks top global risks by severity over the short and long term.¹⁵ Climate change and collapsing ecosystems will increasingly dominate development and increase the numbers facing hunger.

3.3 The negative impacts of climate change

From a global perspective, climate change is a very influential high-risk trend, in particular for agriculture and food systems. It is one of the major drivers of food insecurity due to shifting agroecological zones and more frequent and intense extreme weather conditions. Although there may be positive local exceptions, such as expanding new fruit-growing areas,¹⁶ those suffering from hunger today will continue to be negatively affected by climate change.¹⁷ Agriculture is the economic sector that is most impacted by the consequences of climate change and, therefore, its adaptation to these new conditions must be addressed. Cross-sectoral experience shows that change requires substantial support, and is especially difficult when it has to happen under time pressure.

Food systems are highly vulnerable to shocks and disruptions arising from climate variability and extremes. Impacts on soil and the water balance are just two examples. Changing distributions of plant and animal pathogens and transmission vectors are of concern. Similarly, the loss of predictability of cropping seasons is challenging for farmers. The intensification of weather extremes like droughts, heavy rainfalls and heatwaves are moving the world further away from the SDG 2 targets.

An indirect risk is the destruction of infrastructure for transport, energy and warehouses during extreme weather events. Climate change also contributes to urbanization, worsening the economic conditions of people who work in rural agriculture. Urbanization is strongly increasing in developing and emerging countries, in particular. This trend increases the number of people who are no longer food self-sufficient, and requires a massive redesign of food supply chains.

These developments threaten to intensify in the future. Even though the Paris Climate Agreement includes the goal of limiting global warming to 1.5°C, this target appears to be unattainable. The massive difference between countries' pledges to cut emissions and the amount of cutting needed could result in warming the earth by almost 3°C by the end of the century.¹⁸ This assessment is confirmed by many sources, including the Intergovernmental Panel on Climate Change in its recent *Nationally Determined Contributions (NDC) Synthesis Report*.¹⁹

It should be noted that agriculture, forestry, and land use are responsible for a considerable proportion of global emissions,²⁰ possibly more than a third of the total greenhouse gas (GHG) emissions.²¹ This means that all future changes to the food system should also be considered in terms of their climate impact.

Because the global community is not succeeding in tackling climate change, low- and middle-income countries are threatened with drastic economic collapses and severe public health issues. If current trends continue, their average gross domestic product (GDP) will be reduced by 20 per cent

¹⁵ "Global risk" is defined as the possibility of the occurrence of an event or condition which, if it occurs, would negatively impact a significant proportion of global GDP, population or natural resources, cf. WEF (2023).

¹⁶ Cf. Beise, M. (2023).

¹⁷ Cf. FAO et al. (2023).

¹⁸ Cf. UNEP (2022a); Sognaes et al. (2021).

¹⁹ Cf. UNFCCC (2022).

²⁰ Cf. FAO (2021).

²¹ Cf. Crippa et al. (2021).

by 2050 and by 64 per cent by 2100. Even if the 1.5°C target was to be met, these countries face a 13 per cent drop in economic output by 2050 and a 33 per cent drop by 2100.²²

This GDP reduction is particularly high because agriculture and forestry are very important economic sectors. In global terms, these account for just under five per cent of world GDP,²³ contributing around \$4 trillion. While the share of agriculture and forestry in GDP is low in high-income countries, it is much higher in low- and middle-income countries and crucial for their economic well-being. For example, the share in Sierra Leone is 60 per cent and in Chad 54 per cent,²⁴ directly affecting livelihoods.

3.4 Outlook

By 2030, the UN expects more than 600 million people to be suffering from hunger – a number that surpasses that of 2015 estimates, when the SDGs were approved by the world community.²⁵ Given the current megatrends, the risk of hunger among all five IPC groups is expected to rise. It is clear that SDG 2 to End Hunger will not be met.

The international community should prepare for an increase in food emergencies, and expand interventions to overcome logistical challenges and save lives. The availability of drinking water is a parallel issue, and so are health care and immediate medical intervention. To feed the 10 billion people expected by 2050,²⁶ biodiversity and climate concerns have to be addressed simultaneously. This is an existential challenge requiring focus, intelligence, and determination.

The true annual cost of food was estimated to be around \$28 trillion. \$9 trillion for food expenditure, \$7 trillion for environmental cost, and \$11 trillion related to human life and health costs. A transformation of the food system at all levels is required for a more sustainable future. Nevertheless, relationships and trade-offs linked to a complex ecosystem might cause impediments in this process.²⁷

22 Cf. *Andrijevic, M., & Ware, J. (2021).*

23 Cf. *Statista (2022).*

24 Cf. *Destatis (2022).*

25 Cf. *UN (2023).*

26 Cf. *UN DESA (2022).*

27 Cf. *Hendriks et al. (2023)*

4 PRINCIPAL REQUIREMENTS TO IMPROVE THE FOOD SECURITY SITUATION

To feed a growing world population, the global community needs to improve the availability and quality of food, including animal-based products and seafood. This huge global challenge must be addressed in a way which avoids negative environmental impacts.

4.1 The global food security situation

Previous studies assumed an average increase in food demand of just under 50 per cent between 2010 and 2050.²⁸ Without changes in farming practices, this requires 50 per cent more cropland. There are physical limits to increasing good cropland and despite emerging technologies, like vertical or hydroponic farming, these cannot be changed. However, Africa has arable land that could be investigated for agricultural production. On top of that, many additional sustainability requirements in all dimensions and resulting land use conflicts have to be taken into account and they might act as additional constraints for dealing with the challenges ahead.

Between 1.6 and 3.3 million hectares of prime agricultural land is actually lost every year due to urbanization.²⁹ By the end of the century, it is expected that the rapidly urbanizing Nigeria will become one of the most populated countries in the world. Yet Africa has huge areas of arable land not being used today for various reasons, among them unclear land use rights, ownership issues, and the sometimes passive attitude of owners. Additionally, about one-third of the global agricultural land is degraded, affected by erosion, depleted soil health, salination, or desertification.³⁰

In times of economic transition, smallholder farmers might lose their land, pushing them to acquire new skills and find new jobs. This would happen in a period when agriculture is becoming less attractive to youth. In some countries, smallholder farmers are not able to compete with larger agribusinesses, which drive them out of business. Before meaningfully addressing these issues, certain countries might shift part of their agricultural production to organic agriculture without a proper transition process or building up the required knowledge. This can lead to a loss in yields and more working hours for smallholder farmers. A recent experiment in Sri Lanka where a fast decision on a complete ban on fertilizer and pesticides led to low productivity, the collapse of the political regime, and additional financial problems. Thorough planning utilizing scientific evidence must drive dialogue and policy.

At the same time, the very productive food systems in high-income countries such as Europe, Japan, Russia and the United States are at their limit of productivity from an environmental and social perspective. Around \$470 billion³¹ is spent annually by these countries on agricultural subsidies and various forms of energy inputs via fertilizer and mechanization. The output is unlikely to increase further and has also distorted the food market with uneven competition against low- and middle-

28 Cf. Van Dijk et al. (2021).

29 Cf. UNCCD (2017).

30 Cf. FAO (2020). *Global Symposium on Soil Erosion*. Food and Agricultural Organization of the United Nations (FAO).

31 Cf. UNEP, UNDP, FAO (2021)

income countries.³² Recognizing these challenges, many industrialized countries are reducing the agricultural use of areas. Over the next decades this strategy might need to be further monitored to avoid unintended consequences.

4.2 Hunger is also a humanitarian issue

Ending acute hunger is above all a humanitarian task, which is mandated to the UN World Food Programme. Emergency interventions will not solve any of the root causes of hunger but should remain a short term-objective for a food-secure future. Rapid response to unexpected, short-term food security challenges cannot be overlooked, even in a hunger-free future.

Urgent emergency interventions today are needed for some 400,000 people for which the required financial resources are available. Unfortunately, many of the people in urgent need cannot be reached because of war and conflicts.

Temporary emergency interventions are also needed for 258 million more people, for the smallholder farmers who face famine occasionally, and in this sense, live in permanent food insecurity.³³

4.3 Key guiding areas to improve the food supply

Three guiding areas should drive future development:

- 1. Increase productivity in the food system**, primarily among smallholder farmers in low- and middle-income countries. The industrial sector can provide solutions for higher yield. Increased productivity of smallholder farmers coupled with improved efficiency of supply chain should increase the dollar per hectare value and raise incomes as well as food production.
- 2. Reduce the loss and waste of food.** An estimated 13 per cent of the world's food is lost in the downstream value chains after harvesting, called post-harvest losses.³⁴ This issue particularly affects the global south, where up to 21 per cent of the harvest is lost. A further 17 per cent of food is wasted in households, food services and retail, particularly in high-income countries.³⁵
- 3. Promote international standards and the use of 'best available techniques' for the livestock sector.** The livestock sector has been criticized for the level of greenhouse gas emission, in addition to other wastes, originating from animals or the processing of different products. In the past decades, the invention and spread of new technologies led to cleaner and more circular practices, valorizing by-products for developing other food or feed products and wastes for energy generation. Given the magnitude of challenges in our food systems, it will be vital to consider these best practices and identify opportunities for promoting and making these technologies available globally.

³² Cf. Smil, V. (2022).

³³ Cf. FSIN & Global Network against Food Crisis (2023).

³⁴ Cf. FAO (2022).

³⁵ Cf. UNEP (2021).

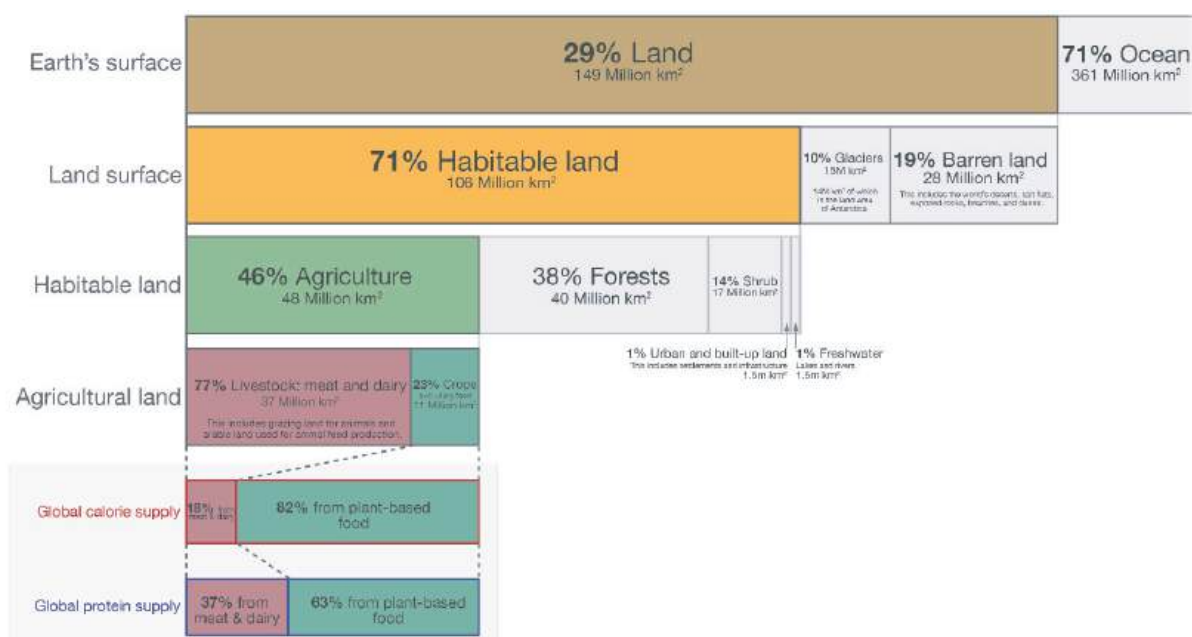
5 POSSIBLE SOLUTIONS FROM FARM TO FORK

This chapter describes essential concepts for solutions to simultaneously addressing hunger and climate change, starting with the underlying numerical framework, and then details approaches to increase production and reduce post-harvest losses in the downstream side.

5.1 Underlying numerical framework

The world consists of about 132 million km² of ice-free land, of which 48 million km² is agricultural land.³⁶ About 75 per cent or 32 million km² is used to produce food of animal origin on permanent meadows and pastures. Meat contributes 18 per cent of calories used and 37 per cent of proteins of the global diet, but considerable cultural and socioeconomic variation exists.³⁷ The agricultural production of 10 million km² is used for a variety of crops around the globe. Globally, 49 per cent of the yield is used for food, 36 per cent for animal feed, 11 per cent for industrial uses such as biofuels, and 4.4 per cent for processing.

Figure 4. Global land use for food production



Data source: UN Food and Agriculture Organization (FAO) [OurWorldinData.org](https://www.ourworldindata.org) – Research and data to make progress against the world's largest problems.

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Source: Ritchie, H., Roser, M. Our World in Data (2019)

Only about a third of agricultural land (16 million km², of which 14 million km² is arable land and two million km² permanent crops like trees) is used to produce plant-based food. Twenty-one per cent of top agricultural land is under irrigation,^{38,39} used for intensive cultures such as potatoes and vegetables that can contribute to a healthy diet.

36 Cf. FAO (2021).

37 Cf. Our World in Data (2019).

38 Cf. FAO (2021b).

39 Cf. FAO (2020).

The remaining 10 million km² of cropland produce cereals such as maize, wheat, rice and soya⁴⁰, in total 2.8 billion tons a year.⁴¹ These calorie-rich products (about 4000 per kg) are easy to store and handle and therefore they are traded in huge volumes around the globe. These provide 70 per cent of the daily calories for eight billion people, and are the primary food used in humanitarian interventions.

These soils also produce 700 million tons of oil seeds such as sunflowers and rapeseed.⁴² Cereals and oilseeds are more important than other agricultural products when it comes to overcoming hunger. Producing these for eight billion people requires less than 50 per cent of the current available agricultural capacity.

Cereals are the most important food group in the diet of all regions.⁴³ Cereals can contribute to up to 70 percent of daily energy intake in low- and middle-income countries, particularly in Africa and parts of Asia. Around 1.6 billion tons of cereals are needed for eight billion people, which is less than 50 per cent of the total production.

Agricultural practices have degraded croplands,⁴³ particularly in Canada, Europe, Russia and the United States. However, some countries have increased their cropland, such as Argentina, Brazil, Indonesia and Nigeria. Other countries have untapped reserves – about 0.19 hectare per person in sub-Saharan Africa, 0.22 hectare in Europe and 0.47 hectare in the US.⁴⁴ Fortunately, soil can be improved considerably by building up and protecting humus.

Some studies estimate the need for a 50 per cent increase of food by 2050.⁴⁵ This would have to happen under severe additional constraints. The resulting requirement to expand cropland by 50 per cent is not reachable, but increasing productivity of cropland could do the same.

Other studies estimate that climate change will require a 50 per cent increase in cropping areas. This also need not be a necessity but increasing cropping areas to a certain extent is an option. Food waste might nearly double by 2050 without further intervention.

The challenge is in executing the right interventions and not allowing these shortfalls to happen. Following are details on ways to implement the three recommended actions to improve the capacity for food production.

5.2 Approaches to increase productivity in agriculture sector

Smallholder farmers feed 50 per cent of the global population today (80 per cent in low- and middle-income countries). So doubling their productive volume could increase food production (“farm to fork”) and bring 500 million farmers and their families out of poverty. The reviewed studies have estimated a -10year time period and about 15\$ billion per year in funding to implement these changes.⁴⁶

⁴⁰ Horsch, M. (2023)

⁴¹ FAO (2023).

⁴² Horsch, M. (2023).

⁴³ Cf. FAO (2021).

⁴⁴ Cf. World Bank (2023).

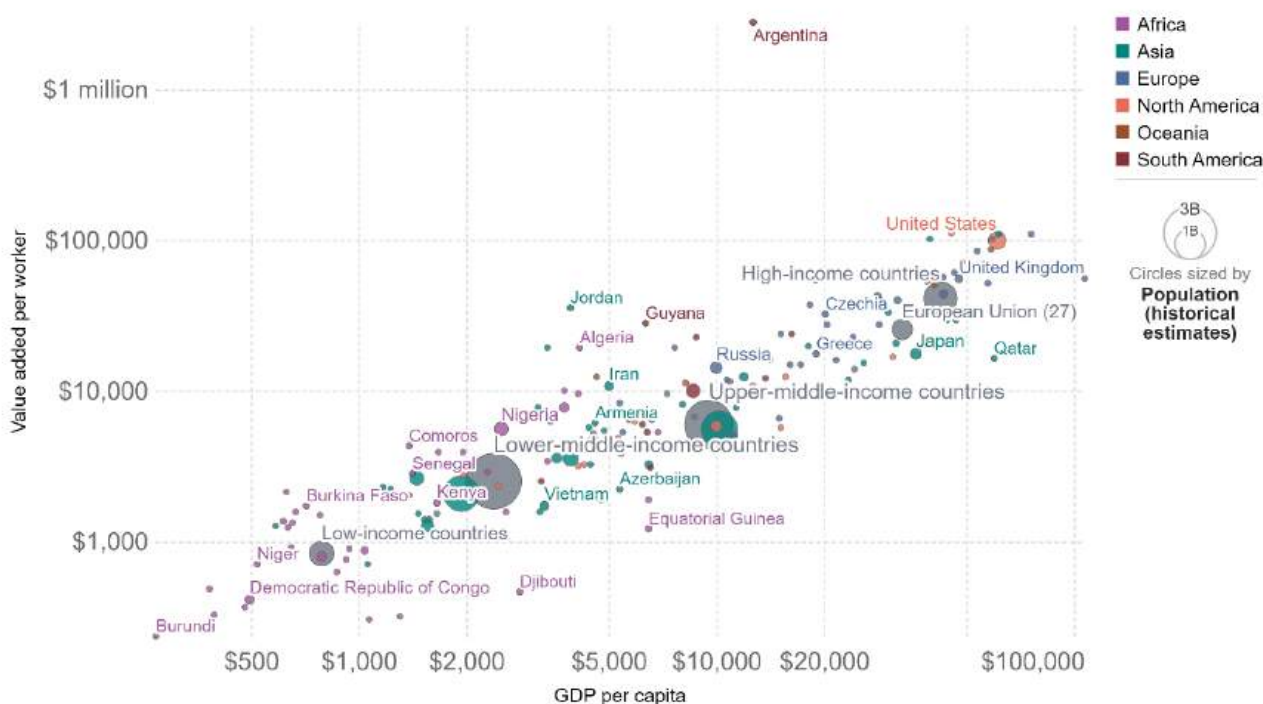
⁴⁵ Cf. Van Dijk et al. (2021).

⁴⁶ Cf. Laborde et al. (2020); FAO & ZEF (2020).

Smallholder farmers tend to produce food for human consumption. Policy measures on voluntary reductions of croplands were taken by some countries in the last 20 years, particularly in Europe, also impacting the livelihood of smallholder farmers. Agricultural productivity differs around the globe but even within continents. There is the “productivity per farmer”, and the “productivity per hectare” (yield). As per Figure 5, the productivity per farmer in high-income countries is up to 40 times higher than in low- and middle-income countries because they use significantly fewer workers for the same output. More essential, though, is the difference in yields, which in some parts of the world is lower by a factor of five or six. Double or multiple cropping and integrated production systems like agroforestry provide opportunities to amplify overall output per area unit.

Figure 5. Agriculture value added per worker vs. GDP per capita, 2019

Agricultural value added per worker* is calculated by dividing the amount of economic value generated from farming by the number of people that work in agriculture.



Data source: World Bank based on data from multiple sources

OurWorldInData.org/employment-in-agriculture | CC BY

Improving agricultural practices would also lead to important improvements: better seeds, the right crops, clever rotation strategies, proper using pesticides and fertilizers, correct application of biochar and compost as well as agroforestry systems. A reliable energy supply is a prerequisite for many activities.

New approaches reduce socio-economic cost and impact on the environment which includes regenerative agriculture such as non-tilling approaches. Precision agriculture applies fertilizers, herbicides, and pesticides in optimized doses, using data for improved decision-making.

Of particular importance is the potential to increase humus in soils. This helps the soil hold water and nutrients, increasing productivity and extending their carbon content. Nutrients in fertilizers used in conventional farming systems are often washed away and not available for plants.

This can reasonably be coupled with planting trees within and around fields. Agroforestry has huge potential to improve the 30 per cent of soil already heavily degraded. Biochar is a form of charcoal used to increase soil fertility and productivity.

Water usage for irrigation has to be intelligently adjusted to climate change. Desalination of water will gain in importance.

Finally, knowledge hubs provide knowledge, access to credits (including microcredits) and insurance against losses, such as climate insurance. These can help small- and medium-sized enterprises (SMEs) increase efficiency and add levels of value to the food production process.

To summarize, smallholder farmers can profit substantially from a market-oriented approach, strengthening of the private sector for partnerships, connecting agriculture with the fertilizers sector, and extending local value chains. These connections are, in many cases, already there but for the sake of selling fertilizers to the farmers. However, restoration of ecosystems and farmland can also mean reducing the number of chemical inputs, which may be in opposition to current business models.

In all these activities, more value creation will be shifted to industrializing countries. Smallholder farmers' competitiveness is crucial but only achieved with supportive industries and services locally available, and knowledge on the latest technologies and services on international best practices. These will provide jobs and improved incomes.

5.3 Approaches to reduce food loss and waste in downstream supply chain

Around one-third of food on farms is lost before it reaches people. This is often due to inadequate technologies and access to water and reliable electricity sources. Food preservation technologies can improve the shelf-life of products and in some cases the nutrient content. However, many small- and medium-sized enterprises require access to technology, know-how and financing solutions and credits to improve their food manufacturing and cold chain capacities.

A similar amount of food reaches the table in high-income nations but eventually ends up as waste.⁴⁷ This is due to low consumer awareness on proper food handling and available social programmes addressing the matter. In addition, the World Health Organization estimates that 600 million fall ill after eating contaminated food and 420,000 die every year, resulting in the loss of 33 million healthy life years (DALYs).⁴⁸ Food safety is a shared responsibility among government, industry and consumers, having clear economic implications on business losses as well as food trade. Enhanced trade among countries has multiple benefits, including the positive socio-economic impact on people and ultimately economic growth.

5.4 Local value creation

A look at agricultural value creation in the post-harvest sector in the global south is sobering. In Africa, 80 per cent of processed food is imported from outside the continent.⁵⁰ The African Union Commission put the value of the imported goods at \$45 billion.⁵¹

To produce sufficient food to overcome poverty and hunger, enabling mechanisms should urgently be addressed. Africa has huge areas of fertile soil that could be cultivated. As described in Chapter 4, smallholder farmers alone could double the amount of food produced. Africa could feed itself and deliver food to the world. The economic system should stimulate that. From a technical point of view, bringing in more energy, such as through renewables and local grids, and putting more emphasis on digitalization would help.

⁴⁷ Frick, M. (2023)

⁴⁸ [https://www.who.int/news-room/fact-sheets/detail/food-safety#:~:text=An20%estimated20%20600%million%2%E20%93%80%2almost,healthy20%life20%years20%\(DALYs\).](https://www.who.int/news-room/fact-sheets/detail/food-safety#:~:text=An20%estimated20%20600%million%2%E20%93%80%2almost,healthy20%life20%years20%(DALYs).)

⁴⁹ *Our World in Data* (ND).

⁵⁰ Cf. ANUGA.

⁵¹ Cf. Sacko (2023).

The many and always extended requirements in the EU concerning food products might be interpreted as a means to complicate exports from Africa to Europe. Europe and other countries should instead put much more emphasis on local capacity building in Africa.

Trade with neighbors should be supported, but also with high-income countries – in an environment that is much fairer than today.

5.5 Levers in economic systems to facilitate transformative change

The “green and inclusive” economy is a paradigm that emerged out of the 2008/09 financial crisis. It was designed to integrate social and environmental needs into the global economic system. This fairer system that generates economic value within low- and middle-income countries has yet to be achieved. The world is now facing an economic slowdown as central banks in high-income countries are increasing interest rates, decreasing lending power and increasing inflation, including food prices.

Holistic and well-coordinated approaches to support the low- and middle-income countries’ economic development should be implemented, such as the Marshall Plan with Africa and the Compact with Africa. Substantial improvements of the macro, business and financing frameworks should increase the attractiveness of private investment and create jobs and prosperity.

5.6 Summary

The recommended interventions should increase the availability of food by increasing productivity and efficiency. They are designed to initiate new practices that will be self-financing after establishment, create more jobs for smallholder farmers and provide more equitable distribution of food across the globe.

The effects could be enormous. By combining the three interventions and utilizing levers in the economic system, the needed increases in food production by 2050 can be managed. The transition to feeding 10 billion people by 2050 could in part be mastered without any increase in food production. Parallel to this, the negative side effects of food production can be reduced. However, the main contribution is improving the climate situation. This will be discussed in more detail in the following chapter.

6 CLIMATE CHANGE AND THE DEGRADATION OF AGRICULTURAL ECOSYSTEMS: CHALLENGE AND OPPORTUNITY

Agriculture should at best be transformed from being a contributor to climate change and ecosystem degradation to being a positive contributor to the planet and public health. Today agriculture is a key contributor to climate change. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land, up to one-third of global greenhouse gas emissions are linked to today's food systems, as seen in Figure 6. Compounding the problem, around eight to ten per cent of GHG result from the production of food that is never eaten and ends up as loss or waste.⁵²

Figure 6. Global greenhouse gas emissions linked to food systems

- **9-14%: crop production and livestock on farms**
- **5-14%: land use**
- **5-10%: food production value chains**

Source: IPCC 2019

Current agricultural practices degrade the land, destroying ecosystems and reducing biodiversity. Climate change and ecosystem degradation are closely correlated and need to be addressed together. The longer these issues are neglected and treated independently from each other, the more difficult it will be to achieve food security. Climate protection and ecosystem restoration are not only prerequisites for food security. They must be considered together.

The power of innovation should not be underestimated, especially in biotechnology for introducing high yielding varieties, improved agricultural technologies, and climate smart agriculture practices.

6.1 Private sector awareness

While the need for effective contributions to climate change mitigation has long been widely recognized in the private sector, awareness of equally necessary ecosystem protection and restoration, and thus biodiversity conservation, is only recently beginning to grow.

The Vision 2050 of the World Business Council for Sustainable Development Nature (WBCSD)⁵³ states that 10 billion people can live well and within the limits of the planetary boundaries by 2050. It names three major urgencies that should guide private action: Climate Emergency, Nature in Crisis and Mounting Inequality. It is obvious that companies in the food sector are directly affected. Other sectors are also increasingly recognizing that not only climate change, but also the destruction of ecosystems and loss of biodiversity, pose serious risks.⁵⁴

⁵² Cf. UNEP, FAO (2022).

⁵³ Cf. WBCSD (2021).

⁵⁴ Cf. WEF (2023).

The mindset shifts that are mentioned in the vision to adequately address the three urgencies are reinvention, resilience and regeneration. Regeneration, in particular, is in the private sector's own interest to change the state of the world's food systems and, at the same time, the ecological and social systems for the better: "Business has to move beyond a 'doing no harm' mindset. It's time to unlock the potential of living systems – social and ecological – that business depends on, and build their capacity to regenerate, thrive and evolve."⁵⁵

Bringing this awareness to small and medium-sized enterprises and translating it into action is a central task for the years to come. It provides the opportunity to unfold the great potential of the private sector for overcoming existing challenges.

It is time for the huge potential of nature-based solutions to be finally tapped through ecological, economic and social perspectives.⁵⁶

6.2 International climate financing

Private international climate finance urgently needs to be scaled up. The nation-state logic of the Paris Agreement means that the climate mitigation measures of the industrialized countries are very largely nationally oriented. The main understanding is that the money should stay in one's own country.

There are considerable funding gaps amounting to trillions of dollars for both international climate mitigation and adaptation.⁵⁷ According to the recent *Adaptation Gap Report*, adaptation costs are estimated at \$215 billion per year in this decade. Considering that agriculture is one of the largest fields of action for climate adaptation measures, it quickly becomes clear how fundamental the changes in the areas of financing and governance will have to be in both areas.

One reason for these large gaps is that it is currently difficult for the private sector to get engaged internationally in this field. In many high-income countries, companies that voluntarily engage internationally are often accused of greenwashing or of neglecting local climate mitigation activities. Standards and certifications of projects are questioned and there is often a lack of trust in the carbon markets. Another criticism is neglecting local climate mitigation activities.

In this generally challenging situation, certified soil carbon projects are still underrepresented. The need for scaling up is enormous. In November, 2023, Climate Focus reported that smallholder farmers received in 2021 just two per cent of international public climate finance – \$2 billion.⁵⁸ This amounts to 0.3% of total international climate finance from both public and private sources. Yet just in sub-Saharan Africa, smallholders' finance needs are estimated at around \$170 billion per year.

Agricultural soils offer great potential as a carbon sink. The 4 per 1000 Initiative considers soil as a relevant CO₂ sink. It assumes that an annual, 0.4 per cent worldwide increase in soil carbon stock would significantly reduce the annual increase of CO₂ in the atmosphere.⁵⁹ The carbon in soil partially comes from atmospheric carbon dioxide, which plants extract through photosynthesis and store in the soil through plant roots and microorganisms. The more humus soil has, the more carbon it can store. Soil-preserving and humus-accumulating measures increase soil organic carbon, making fertile agricultural soil significant carbon sinks, and increase productivity. Humus-rich soils store more water and are therefore more resistant to extreme weather conditions such as droughts and heavy rainfall. This makes the soil more resilient to climate change, contributing to food security

55 Cf. WBCSD (2021).

56 Cf. Smith et al. (2019); ILO/UNEP/IUCN (2022).

57 Cf. UNEP (2023).

58 Cf. Climate Focus (2023).

59 Cf. 4 per 1000 Initiative (2023).

and to the creation of negative emissions or even permanent carbon removals urgently needed to limit climate change to a manageable level.⁶⁰

6.3 Paid ecosystem services

The preservation of nature and natural resources is another area in which an increase in funding is urgently needed.⁶¹ Nothing less than the basis of humanity's existence is at stake. Nevertheless, nature and ecosystems continue to be destroyed.⁶²

Soil regulates many ecosystem services and plays an important role in sustainable development in all its dimensions. The benefits received from soil are key to hunger and poverty alleviation as well as climate change mitigation. In addition, they are directly or indirectly linked to clean air and water.

Paid ecosystem services (PES) provide another important funding lever that can massively improve the hunger situation if implemented and successfully scaled. For some years now, the compelling need to pay more attention to soil for climate, food and development reasons and to channel funding to those whose livelihoods are based on soils, namely farmers worldwide, has been discussed. Many participants of the recent International Vienna Energy and Climate Forum have emphasized the need for financing and putting in place the required enabling measures.

6.4 Summary

A focus on nature and climate can lead to an optimistic outlook on the issue of overcoming hunger. While climate change and land degradation can have extremely negative effects on the agricultural supply and might increase hunger enormously, there is a small chance for the opposite to happen.

This requires a holistic approach with extensive international climate financing, as described in a recent publication on overcoming the energy and climate crisis.⁶³ Nature-based solutions are a central element.

Intense cooperation between North and South is required, since no country in the world can save the climate by focusing on its own territory. By providing the necessary financial support for social and ecosystem services in low- and middle-income countries, people living there may be able to restore their vast soil reserves and protect diversity, improving food security and reducing the impact of climate change beyond their borders.

Important instruments are the conservation of rainforests, the reforestation of a billion hectares of degraded land, and the improvement of agricultural soil on another billion hectares of land, particularly humus formation. There are countries where soil improvement has led to huge productivity increases and contributions to climate mitigation. Brazil is an impressive example. Over 10 years, the build-up of about 40 tons of carbon (which equals 150 tons of CO₂) per hectare seems possible.

Having high-income countries adequately pay for these volumes would provide a completely new approach to the area of financing agriculture – investing in these principal changes must be the goal. This would improve the situation for affected smallholder farmers considerably. This improvement is not linked to a loss of anything. To the contrary, it is a huge opportunity to be seized upon and into which to invest. A major motive to do so can be insightful selfishness.

⁶⁰ Cf. Lorenz & Lal (2018).

⁶¹ Cf. UNEP (2022b).

⁶² Cf. IPBES (2019).

⁶³ Cf. GES (2023).

7 UNIDO CONTRIBUTIONS TO FOOD SECURITY AND CLIMATE CHANGE

There are four dimensions of food and nutrition security:

1. Physical availability of food
2. Economic and physical access to food
3. Food utilization
4. Stability of the other three dimensions

Various United Nations agencies contribute to the global food security agenda by dealing with the transformation of food systems in line with the various goals of the 2030 Agenda, addressing different dimensions of food security stipulated above. The Food and Agriculture Organization (FAO) of the United Nations and the World Food Programme are two agencies with special focus on food security; the former addressing multiple dimensions of food security and the latter eradicating hunger and malnutrition through humanitarian aid. On the other hand, the International Fund for Agricultural Development (IFAD) aims to improve food security through better food production systems. Finally, UNIDO addresses the dimension of economic access to food by creating new jobs and higher income, very often with a special attention on rural communities and agribusinesses.

As described in the previous chapter, food systems have a complex relationship with the global climate crisis by contributing to and at the same suffering from it. Moreover, there are multiple intertwined and related impacts, like deforestation, biodiversity loss, freshwater withdrawal and degradation of resources, and marine pollution, negatively impacting public health, livelihoods, and biosphere integrity. A growing global population with changing demographics and consumer behaviours creates additional demand and associated risks, making it difficult to achieve food and nutrition security in the upcoming years without decided action.

The study has demonstrated that addressing the vital topics of food security and climate change can only be achieved through the structural transformation of socio-economic systems, incentivizing improved practices among stakeholders. Agriculture and food systems have the potential for readily available, scalable solutions with the inherent potential to be GHG-negative.

Smallholder farmers and small- and medium-sized enterprises are the most exposed and vulnerable to the negative consequences of climate change and paradoxically often food-insecure themselves. They therefore require particular attention and are central to the solution.

Simultaneously, there is a collective understanding of the need for shifting from linear to circular and more sustainable production and manufacturing practices. This can be achieved by enabling policy and legal frameworks, widespread use of greener and other new technological solutions, development of skills, and financing mechanisms.

The matrix in Annex 1 summarizes different levers that UNIDO suggests prioritizing in collaboration with partners. These support medium- and long-term objectives to end hunger and mitigate or adapt to climate change, with direct or indirect support. Overall, UNIDO's ability to deliver on these needs would be linked to mobilizing resources and building successful partnerships for investments.

Some interventions listed, particularly at the food production level, are aspirational and levers for future interventions.

Feeding humanity well under many major threats is a Herculean task. Significant investments in the agricultural sector are needed for equipment, crop protection, distribution systems and cold chains, as well as in other value-added structures.

Climate change has a particular impact on the stability of food and nutrition security, since the trend is currently unpredictable.

This chapter elaborates on UNIDO contributions from the dimension of stability, given the special focus on climate change. UNIDO interventions typically support improved resilience of households by improving income and job creation in downstream activities.

7.1 UNIDO contributions to improve production

Increasing food production through regenerative intensification is of the uttermost importance. UNIDO work in sustainable industrialization contributes to the creation of an enabling environment framework throughout supply chains. This allows increasing production in a manner that mitigates negative environmental consequences. Developing industrial support services for mechanization, value addition and cleaner production should be part of the solution.

Rural transformation centers (RTCs): The establishment of RTCs ensures the delivery of required services, agricultural inputs and equipment, and of machinery rental to enhance the likelihood of applying best practices. Modes for sharing and more efficient use of capital-intensive machines have been applied in different geographies and market contexts, such as cooperatives, machinery rings and contracting. Digitalization, including digital payment systems, provides new levels of access, convenience, and inclusion even for small scale farmers. Similar services can be provided for irrigation/fertigation, soil fertility management, crop protection, harvest, storage, and processing.

Placing RTCs close to integrated agro-industrial food parks provides collection points for smallholders to deliver produce, conduct sorting and grading, and access cold storage to maintain quality and value, allowing them to intensify production. The centres also address challenges of product compliance to traceability, and aggregate volume by clustering producer groups together, increasing market access and broader trade opportunities. Overall, RTCs contribute to better income and stability by mitigating the negative consequences of climate change and adapting to existing challenges.

Vocational training for mechanization services: Operating and servicing ever more complex farm machinery requires dedicated training. Renewable energy, digitalization and electrification demand specific skills, which can be provided in partnership with machinery suppliers. UNIDO has set up public-private development partnerships through the Learning and Knowledge Development Facility (LKDF).⁶⁴ Within the agricultural sector, access to farm machinery for cultivation and processing is increasingly provided as a service, which opens opportunities for entrepreneurial engagement for graduates of vocational training, if financing is available to them.

Triggering a massive scale-up of international climate financing and paid ecosystem services for soil restoration would open up a significant new source of income for farmers. This developing area requires new instruments with the support of the international community.

⁶⁴ <https://www.lkdfacility.org/about>

7.2 UNIDO contributions on the downstream supply chain level

UNIDO plays an active role and a mandate to improve post-harvest practices, contributing to the wider agro-industrialization agenda of low- and middle-income countries. Although value addition generated by agro-industrialization contributes to the different dimensions of food and nutrition security, its impact on the socio-economic access to food is the most essential.

Improved local production of fortified food: Fortified food is crucial to address humanitarian situations. UNIDO has launched a unique collaboration with WFP to support local agribusinesses to comply with the highest quality and safety requirements required for people suffering from hunger. This would allow improved local sourcing of fortified food, creating jobs while reducing the environmental footprint of long-range transportation. As part of the technical support, UNIDO also assists micro-, small- and medium-sized enterprises (MSMEs) to improve their entrepreneurial and soft skills essential for the operation of agribusinesses.

Facilitating the establishment of agro-industrial food parks (IAFPs) supports local value addition to food commodities. As part of this, UNIDO assists countries and enterprises with feasibility studies, environmental and social assessments, and business models to mitigate any environmental and socio-economic risks related to the construction and operation of the park. UNIDO engages a wider investment community, including international financing institutions, to ensure the possibility of utilizing development finance.

The development of strategic storage capacities, including cold chain, requires detailed planning and engagement of development partners, particularly international financing institutions. UNIDO assists in conducting feasibility studies, developing protocols and training personnel on the proper handling, cleaning, and maintenance of food processing units and cold storage facilities. This ensures compliance with regulatory requirements, and optimizes the operation along the supply chain.

Sustainable food packaging involves the use of biodegradable alternative packing material that can have a significant impact on mitigating plastic pollution along the value chains. UNIDO has been collaborating with the World Packaging Organization to promote sustainable packaging and reduce food loss and plastic waste by having better packaging solutions.

Access to a reliable energy supply is a prerequisite to any industrializing activities. Therefore, a broad and technology-open approach to energy supply should be pursued in the whole agricultural sector, particularly in agro-industrialization. UNIDO will continue to contribute to make reliable, clean and affordable energy available for all.

Circular food production practices, including more resource-efficient food processing technologies, will play a key role in the upcoming year to allow companies to comply with new regulatory requirements in high-income countries. UNIDO provides support to its Member States in applying the more resource-efficient cold chain and refrigeration technologies. These solutions could also require a lower level of maintenance as well as saving resources, including electricity.

Developing conformity assessment services, particularly those related to food safety, is paramount for food security. UNIDO has developed its food safety approach to improve food safety management practices and create local enabling environments. Improved food safety practices can also reduce post-harvest losses and lower GHG emissions. UNIDO has been involved in building competencies of laboratory technicians, inspectors, auditors, and assessors that are fundamental for international recognition and create local jobs.

Innovative financing solutions are required for MSMEs to invest in the latest technologies for food processing and packaging. UNIDO collaborates with hosting governments and international financial institutions to ensure larger investment needs in low- and middle-income countries.

7.3 UNIDO wider economic transformation related work

To sustainably tackle food security and climate change, many low- and middle-income countries must undergo a wider economic transformation that incorporates food systems and agro-industrialization.

National action plans and roadmaps address challenges in food security and climate change and UNIDO has supported these endeavors through technical inputs. It also supports Member States in developing, negotiating, and adopting standards in the areas of food safety and quality, environmental and social compliance. UNIDO collaborates with international standard-setting bodies (Codex Alimentarius, World Organization for Animal Health, International Plant Protection Convention, and International Organization for Standardization). The Organization is also engaged with regional standard-setting bodies to ensure harmonized structures and protocols related to standard setting and where required for the industry, it also engages with voluntary sustainability standards.

Conformity assessment services are essential to implement and monitor food safety and environmental standards. This includes testing, inspection, certification, and accreditation, as well as the establishment and capacity building of institutions in national and regional quality infrastructure systems. As part of this work, UNIDO develops national quality policies that stipulate the envisaged structure and services and assists in creating a roadmap with the acceptance of various stakeholders. Where certain services are lacking, UNIDO assists in the creation of those, taking into consideration the future sustainability and feasibility of their operations.

The Innovation Hub for Agribusiness Transformation aims to accelerate and scale innovative solution systems among countries by developing local support services. UNIDO facilitates partnerships through innovation hubs, coordinating required services for businesses and identifying potential scaling opportunities. This collaborative approach also supports technology and service providers to ensure that agribusiness has access to internationally accepted solutions. In coordination with education partners, agricultural technical and educational training plays a key role in knowledge transfer. Both soft and technical skills are equally important due to the needed behavior changes.

The overall economic transformation contributing to sustainable food system requires intensive investment. The differential cost of transformation compared to remaining in the status quo should be borne by the high-income countries – in the logic of the Montreal Protocol. The UNIDO Montreal Protocol Division has expanded its range of activities far beyond ozone depleting substances, engaging a broad coalition of institutions, associations and development partners, in support of wider sustainable development goals.⁶⁵

⁶⁵ Cf. UNIDO (2023).

8 SUMMARY AND OUTLOOK

At first glance, the status quo of SDG 2 Zero Hunger provides little hope of finally achieving food security and providing healthy, nutritious, and sufficient food for all. The global population continues to grow rapidly while soil degradation continues, the water supply deteriorates and the international willingness of states to cooperate is declining. The worsening climate change, which is having a negative impact on food production in many areas, is an additional major challenge. No other sector of the economy is as dependent on climatic conditions as agriculture. There is an overwhelming consensus among academia, the UN and industry that the current situation is not sustainable, and above all, the problem of hunger will remain unresolved until 2030.

Despite these many obvious difficulties, this study revealed opportunities to significantly improve the situation over the coming decades. The considerable deficits and inefficiencies of the *status quo* can be turned into advantages – if the right strategies are pursued internationally and the **required co-financing** by industrialized countries and the private sector is activated. This increased financial aid should not be seen as charity, but as valuable investments that stabilize the climate system and ecosystems.

A first and central point of intervention should be focused on the 500 million smallholder farmers who currently feed half of humanity – and often face hunger or calorie deficits themselves. The productivity per hectare of these farmers is up to six times lower than in high-income countries. If that productivity (only) doubles, global food security will increase considerably. At the same time, smallholder farmers will grow out of hunger and poverty.

These productivity increases require more agricultural knowledge, better crop varieties and irrigation, optimized use of fertilizers as well as measures to close carbon and nitrogen cycles through agricultural inputs like compost and biochar.

Improving the soil quality through more careful handling and increasing the humus content is key. This helps soils absorb and hold more carbon – these negative emissions could add up to at least five tons of CO₂ per hectare per year over decades, and if broadly adopted easily reaching 5 to 10 billion tons of CO₂ over the next 10 years.

All this adds up to a positive vision – and the implementation of many SDGs: more food, more income, soil protection, and permanently removing and storing high levels of CO₂ emissions.

The second major intervention is reducing food loss and waste, with special attention on the post-harvest stage. In the first case, the food produced does not reach the people. This often happens in low- and middle-income countries due to a lack of cold chains, inadequate distribution system, and scarcity of processing and storage options. The lack of or limited access to the processing, packaging and cold chain technologies also often result in product safety and quality issues. These are also direct contributors to greenhouse gas emissions. In addition, underdeveloped food control systems limit the economic development of countries, including access to export markets, causing an estimated 600 million cases of foodborne diseases and 420 000 deaths.

Within downstream side of supply chains, access to finance remains a major challenge for SMEs. On the other hand, clean water and energy resources are also scarce which remain a major factor for processing and storing food products. Although progress has been made in recent years, those most in need are still facing the some challenges today.

On the other hand, high-income countries have food waste as the predominant issue. Reducing post-harvest loss and waste from 20 per cent loss to 10 per cent will make at least 10 per cent more food available for people. This increase does not lead to any further negative climate effects because the corresponding value creation (the food produced) also took place in the past.

Today's situation can be seen as "fortune in misfortune". The high inefficiencies of the status quo open up great opportunities. Technical progress plays a major role through micro-dosing of herbicides and pesticides as a form of precision farming, which will be strongly driven by information technology and artificial intelligence in the future. Brazil is making excellent progress and may serve as a role model.

These transformations require considerable investments, but will be financially self-sustaining in the medium to long term. This is due to the expected increase of hectare productivity, and the climate financing potential that can be tapped for the negative emissions generated. The public sector is urgently needed for pre-financing – estimated by Ceres and others at \$15 billion per year over the next 10 to 20 years.

This is relatively little money to not only solve the issue of hunger, but also to significantly contribute to addressing climate change. At the same time, great opportunities such as creating new value are foreseeable and should be seized.

As UNIDO has demonstrated, it has the technical expertise, innovation and technology hubs, networks and track record to provide critical support to these efforts. The plan is large but so is the need. With the required commitments outlined in this report, the opportunity exists to create new pathways that bring together the private, public and international sectors to meet many of the Sustainable Development Goals and make long-lasting improvements to climate and economic stability for people across the globe.

There is a widening global consensus on the understanding that a holistic approach for food system transformation can only address the challenge of food insecurity. In this regard, further collaborations among relevant UN agencies, namely IAEA, IFAD, FAO, UNIDO, WFP and WHO, can better leverage investments, reduce costs through information sharing and tackle complex development issues in a timely manner. New innovative initiatives, such as the Agrifood Systems Transformation Accelerator (ASTA) and UNIDO-WFP supplier development programme, already show the first promising results and therefore further investments in such partnerships will be essential from the development community.

Table 1. Recommended interventions for food security and climate change from agro-industrialization perspective

| | Policy & regulatory framework | Infrastructure | Technology & Innovation | Skills Development | Finance |
|--------------------------------------|--|---|---|---|--|
| Agri-food production / supply | <ul style="list-style-type: none"> 1. Rural transformation centres (RTCs) established and linked to Integrated Agro-industrial Food Parks (IAFPs) 2. Policy advise to improve quality of degraded land 3. Policy support for extension services | <ul style="list-style-type: none"> 1. Accessibility and hydrological infrastructure for RTCs and IAFP 2. Energy access for productive use and local value addition 3. Cooling chains, storage and logistics 4. Hybrid land use strategies | <ul style="list-style-type: none"> 1. Improved access to farming inputs and mechanization to reduce yield gaps 2. Precision agriculture and digitalization; 3. Resilient and regenerative agricultural practices, integrated pest management 4. Access to real-time farming advice, weather forecast, farming calendar, and market intelligence | <ul style="list-style-type: none"> 1. Climate-responsive circular livestock 2. Regenerative agriculture and good animal husbandry practices 3. Vocational training for mechanization services 4. Digital spatial skills 5. Extension services and research providing advisory support through good practice guides | <ul style="list-style-type: none"> 1. Investment in the conversion of degraded land 2. Agricultural inputs as a service 3. Commodity collateralized finance 4. Alternative marketing, direct value addition for export 5. Massive scale-up of international climate finance and paid ecosystem services |
| Post-harvest practices | <ul style="list-style-type: none"> 1. Industrial, climate, sectoral, and trade policies to support value-added manufacturing among MSMEs | <ul style="list-style-type: none"> 1. Agro-industrial food parks (IAFPs) development 2. Strategic storage capacities, including cold chain facilities 3. Reliable energy supply | <ul style="list-style-type: none"> 1. Climate-responsive agribusiness packing 2. Digital traceability 3. More resource-efficient food processing technologies and cold storage capacities | <ul style="list-style-type: none"> 1. Operation and maintenance of heavy-duty equipment required for infrastructure development and logistics 2. Proper handling, cleaning, and maintenance of food processing units and (cold) storage facilities 3. Competency development of conformity assessment service providers 4. Entrepreneurial skills development | <ul style="list-style-type: none"> 1. Innovative financing solutions for MSMEs and investment promotion 2. Partnerships with IFIs for loans to establish integrated agro-industrial parks 3. Feasibility planning and financing solutions for IAFPs |
| Economic transformation | <ul style="list-style-type: none"> 1. Contributions to national action plans for food systems transformation 2. Relevant standards adopted for the food supply chain through a control and quality system for food safety and sustainability 3. Conformity assessment services and quality infrastructures developed, including national quality policy | <ul style="list-style-type: none"> 1. Innovation Hubs, Research and Development Networks | <ul style="list-style-type: none"> 1. Agricultural TVET institutions and services | <ul style="list-style-type: none"> Differential cost of transformation financed by high-income countries, in the logic of the Montreal Protocol | |

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