FAO

STUDY GUIDE

Agenda Item:

Agenda Item I:

Collaborative governance for coordinated policy responses to emerging global food crises towards sustainable agriculture and food system transformation

Agenda Item II:

Harnessing artificial intelligence, digitalization, and data governance for food security and nutrition

Model United Nations Bilkent University 2026

I. Letter From the Secretary-General

Esteemed Participants and Honored Guests,

It is a profound honor to extend my most formal welcome to you as we convene for the 13th edition of the Bilkent University Model United Nations Conference, MUNBU'26. My name is Zehra Yıldırım, and I'm a senior year law student at İhsan Doğramacı Bilkent University. As the Secretary-General of MUNBU 2026, I welcome you not only to a forum of debate but to a tradition of academic and diplomatic excellence that has defined our institution for over a decade.

The art of diplomacy is one of patience, precision, and profound responsibility. My own commitment to this discipline has been forged over nine years of active engagement within the international circuit—a journey that has evolved alongside my formal education in the Faculty of Law. These years have instilled in me a steadfast belief that the resolution of global conflict lies in the mastery of legal frameworks and the cultivation of refined statesmanship. It is this standard of rigor and intellectual integrity that I am committed to upholding throughout our deliberations.

Bilkent University stands as a bastion of higher learning, dedicated to the pursuit of truth and the development of future leaders. It is our distinct privilege to host you within an environment that reflects the visionary principles of the founder of our Republic, Mustafa Kemal Atatürk, who declared: *"Peace at Home, Peace in the World."* Guided by this transcendent ideal, we are committed to providing you with the highest level of hospitality, ensuring that your experience is marked by the grace, professionalism, and mutual respect that our University and the Republic of Türkiye represent on the international stage.

MUNBU Conferences remain a premier platform where the complexities of the global order are met with the sharpest minds of our generation. As we embark on this 13th session, I invite you to embrace the gravity of your roles. Let us ensure that our discourse remains as sophisticated as the challenges we face, and that our hospitality remains as enduring as our commitment to justice.

I wish you all fruitful debates and a joyful conference. Should you have any inquiries, please do not hesitate to contact me via my email, zehray@ug.bilkent.edu.tr

Best Regards,

Zehra YILDIRIM

Secretary General of MUNBU'26

II. Letter From the Co-Under Secretary-General

The most esteemed participants,

It is a great honour for me to welcome you to the Bilkent University Model United Nations Conference 2026 as the Co-Under Secretary-General of the Food and Agriculture Organization of the United Nations, or FAO. To briefly introduce myself, I am Alp Arifoğlu, a sophomore student at Ankara University studying political science and public administration.

In this year's MUNBU, the Food and Agriculture Organization of the United Nations will be featured. Considering all the tragedies the world has witnessed, one of the largest issues countries all around the world are facing today is a food crisis. The measures implemented up until this point were insufficiently effective in stopping the crisis. Food crises and digital adaptation need to be a priority for the younger generation, who are more aware of global concerns. All the information required for you, the delegates, to discuss and learn about the topic is contained in the study guide. We have a responsibility to begin debating and coming up with solutions to problems.

Finally, but just as importantly, I want to thank Zehra Yıldırım, the Secretary-General, for this amazing opportunity and for being a Secretary-General that an under secretary-general should serve under. I cannot put into words how I feel about her; she is a wonderful friend and one of the cutest people I know. In addition, I would like to express my gratitude to Ebrar Korkmaz, whom I will serve with on this committee. She is one of the most academically capable people, and I am sure that one day she will lead to a lot of great things.

All the delegates are expected to read the study guide, and for further enquiries, you can contact me at alparifoglu@icloud.com . I hope to see you all at the conference.

Sincerely,

Alp Arifoğlu, Co-Under Secretary-General of FAO

III. Letter from the Co-Under Secretary-General

Distinguished delegates,

My name is Ebrar Korkmaz, and I am the Under Secretary-General of the FAO committee in MUNBU’26. I am very proud to be a part of the MUNBU’26 family, and I am very excited to be presenting this guide to you, esteemed delegates.

MUN has a very special place in my heart, as I met lots of people in conferences. I guarantee that you will feel much better with attending MUNs. Furthermore, I hope you will have a good time discussing this topic. We tried our best to prepare this guide with my Co-Under Secretary-General and my best friend, Alp Arifoğlu. I wish for you all to have a great time during the conference, and I hope you will enjoy reading this study guide.

I would like to thank MUNBU’26’s Deputy Secretary-General, Oğuz Efe Arı, for his efforts. Lastly, I want to present my gratitude to MUNBU’26’s honourable Secretary-General, Zehra Yıldırım, for giving me a chance to make this committee and for being my first Under Secretary-General in my MUN career.

Should you have any inquiries, please do not hesitate to contact me via my email, ebrarkorkmaz494@gmail.com

Kindest Regards,

Ebrar Nazife Korkmaz, Co-Under Secretary-General of FAO

1. Introduction To The Agenda Item: Collaborative governance for coordinated policy responses to emerging global food crises towards sustainable agriculture and food system transformation

1.1. History of Administration

In recent years, lots of crises have happened around the world, such as climate change, armed conflict, economic instability, and pandemics, and these events exposed structural issues in food systems. According to the international organisations, food crises are not temporary issues anymore; due to this, they require long-term solutions. Traditional policy focuses on short-term emergency assistance. In many cases, lack of coordination between governments and international organisations causes inefficient resource allocation and policy incoherence for local communities and private sectors. In order to address these shortcomings, there is an urgent need for collaborative governance frameworks. [1]

Collaborative governance is a process of institutionalised interaction between public or private entities that aims at achieving collective goals, particularly in the context of sustainability challenges that require the involvement of diverse stakeholders. Collaborative governance is wanted when the management of a sector requires more technical, analytical, and financial power than is possessed by one party. Collaborative governance is often chased as a solution to the principal-agent difficulty. The principal-agent problem occurs when one person is responsible for making decisions on behalf of another; this can result in conflicts of interest and legitimacy problems. By including a full range of stakeholders, collaborative arrangements may mitigate this. [2]

---

[1] "High Level Panel of Experts on Food Security and Nutrition Conflict-Induced Acute Food Crises: Potential Policy Responses in Light of Current Emergencies," 2024. https://www.fao.org/fileadmin/templates/cfs/Docs2324/BurAg/240729/CFS_BurAG_2024_07_04_HLPE-FSN_Issues_Paper.pdf.

[2] Collaborative Governance – Participedia. "Collaborative Governance – Participedia." Participedia.net, 2021. https://participedia.net/method/collaborative-governance.

Within the CFS's work on collaborative governance for coordinated policy responses to emerging global food crises towards sustainable agriculture and food system transformation, the CFS holds biannual sessions between 2024 and 2027 to take stock of the evolving global food and nutrition security situation. These Collaborative Governance Dialogues aim to share experiences, data and information between countries on existing initiatives and to identify key actions that need to be taken towards enhanced policy coordination and collaborative governance. The workstream supports the convening power of the CFS, its focus on the facts of the right to adequate food, and its ability to mobilise. It pays particular attention to the voices of the most affected countries and constituencies.

1.2. Understanding Global Food Crisis

1.2.1. Introduction

Food security is mainly occurring when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Acute food insecurity arises when one, or all, of the perspectives of food security – food availability, access, and stability – is disrupted by other factors. It can be diligent over time, largely due to structural causes, or occur at a specific point in time. Acute food insecurity can be temporary or persistent. The GRFC (Global Report on Food Crises) defines a food crisis as a situation where acute food insecurity requires important action to protect and save lives and livelihoods at local or national levels. Food crises are more likely among populations already suffering from kept-up food insecurity and malnutrition. Food crises can be localised, affect an entire country/territory or spread across borders to become regional. They can also affect only specific population groups, such as refugees or migrant populations. Food crises can occur regardless of a country's wealth status and level of domestic food production, underscoring their complexity. However, more affluent nations are expected to have greater capacity to respond to shocks and mitigate their impacts on food insecurity. [3]

1.2.2. Climate Change and Environmental Degradation

The climate will continue to evolve even if all emissions from human activities were to cease abruptly. However, without prompt and significant mitigation efforts, greenhouse gas emissions are poised to significantly intensify global warming and alter climate patterns, leading to extreme weather events such as heatwaves, storms, floods, and fires. Pollution, overconsumption, resource depletion, and environmental degradation are expected to result in serious, extensive, and potentially irreversible impacts on ecosystems, communities, infrastructure, and economies worldwide. This underscores the urgent need for environmental action aimed at minimising damage and circumventing the most severe consequences of climate change and ecological deterioration. Moreover, adapting to climate change is essential for decreasing susceptibility to unavoidable adverse effects. Living within 'planetary boundaries', the ecological limits that allow humanity to thrive safely, will necessitate fundamental lifestyle changes, particularly in affluent nations. A consequence of heightened environmental awareness is the increasing challenge and transformation of established beliefs and behaviours among individuals and businesses. [4]

Climate change driven by human activities persists unabated. Anthropogenic greenhouse gas emissions continue to rise primarily due to economic expansion and population growth. These emissions elevate the concentration of greenhouse gases in the atmosphere, which subsequently influences the pace of global warming. Since the onset of the industrial revolution, human activities have led to escalating greenhouse gas emissions that drive an unprecedented increase in average global surface temperatures. The resultant

---

[3] "FSIN Joint Analysis for Better Decisions Food Security Information Network," n.d. https://www.fsinplatform.org/sites/default/files/resources/files/GRFC2025-no-countries.pdf.
[4] Knowledge for policy. "Climate Change and Environmental Degradation - Knowledge for Policy - European Commission," 2025. https://knowledge4policy.ec.europa.eu/climate-change-environmental-degradation_en.

climate change will have long-lasting effects on Earth since carbon dioxide can linger in the atmosphere for 300-1000 years. We are already witnessing signs of climate change through diminishing Arctic sea ice and rising sea levels. [5]

Various outcomes of climate change affect human health significantly. Extreme heat events, poor air quality, inadequate food and water safety, shifts in infectious agents (emerging threats), natural disasters, and undernutrition contribute to physical health problems and higher mortality rates. Moreover, both climate change and environmental degradation can lead (both directly and indirectly) to stressors that impact mental health. Issues like eco-anxiety and climate anxiety are becoming increasingly relevant areas of research concerning the effects wrought by climate change and environmental decline. [6]

1.2.3. Economic Shocks and Market Volatility

Food price volatility is historically driven by economic shocks. After 20 years of relative equilibrium in global prices, 2007–08 and 2010–11 featured large price shocks to both the global food market and broader global economic crises that exposed serious short-term weaknesses of the international food system when faced with the surprise shocks to macroeconomic circumstances. The FAO characterises these times as being highly volatile times when world food prices sharply rise and can bring great threats to the food security of consumers and producers, in particular low-income countries. Economic shocks, particularly the 2008 global financial crisis, raised food prices and aggravated their instability via changes in demand, investment flows, and exchange rates that all impact the food market. In Asia but elsewhere, this shock has contributed to vulnerabilities that have already existed and meant governments used trade and fiscal policy levers to attempt to stabilise the domestic markets.

FAO analysis shows that highly volatile food costs are especially damaging during times of overall economic crisis: Households and governments with relatively limited

[5] Knowledge for policy. "Climate Change Continues - Knowledge for Policy - European Commission," 2023. https://knowledge4policy.ec.europa.eu/foresight/climate-change-continues_en.
[6] Knowledge for policy. "Climate Change Continues - Knowledge for Policy - European Commission," 2023.

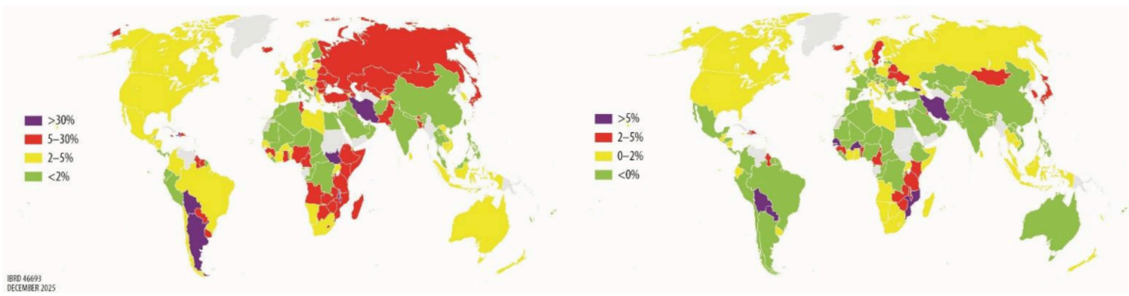
liquidity have less ability to handle inflation and to anticipate price fluctuations. Economic considerations affect the volatility in various ways through shifts in global demand in terms of both income and consumption (a key element in a number of sectors, including agriculture), differences in input prices (fuel and fertiliser) (associated with fluctuations in the world economy), and linkages between agricultural markets, financial and commodity markets. These characteristics can also deepen swings in prices around the world as the economy is rattled. FAO's examination as a regional entity also emphasises the fact that price volatility can quickly travel from international markets to domestic ones, leaving poor, import-dependent countries particularly vulnerable. In addition, economic shocks should not occur in isolation. They are often exacerbated by or alongside other sources of volatility, including rising energy prices, trade policy shifts or drops in commodity stocks. FAO and other previous papers have observed that price volatility is typically higher in high-price and economic instability contexts because a system that is too tight becomes less able to respond to more external disturbances. Generally speaking, the FAO's report points out that macroeconomic shocks work to both lead and widen volatility in the price of food, undermining global food security, decreasing consumers' purchasing power, driving away investment by farmers and complicating responses at a national level. Economic instability and food market stability are interdependent, emphasising the need for coherent policy responses that can address, in the short term, spikes in food prices as well as facilitate economic stability and transparency and help make the economy and markets able to be responsive to future shocks of food insecurity to address the problems ahead of it. [7]

Domestic food price inflation, indicated by the annual change in the food segment of a country's Consumer Price Index (CPI), continues to be moderately elevated.

[7] Jayasuriya, Sisira, Purushottam Mudbhary, and Sumiter Singh Broca. "Food Price Spikes, Increasing Volatility and Global Economic Shocks: Coping with Challenges to Food Security in Asia a Comparative Regional Study of the Experiences of Ten Asian Economies FOOD and AGRICULTURE ORGANIZATION of the UNITED NATIONS REGIONAL OFFICE for ASIA and the PACIFIC BANGKOK, 2012," n.d. https://www.fao.org/4/i3031e/i3031e00.pdf.

Data from August and November 2025, where food price inflation figures are accessible, reveals significant inflation levels in numerous low- and middle-income nations (see Figure 2a). Specifically, inflation surpassed 5 percent in 45.0 percent of low-income countries (a decrease of 10.6 percentage points compared to the previous update on October 31, 2025), in 43.5 percent of lower-middle-income countries (down by 7.6 percentage points), in 41.9 percent of upper-middle-income countries (a reduction of 13.1 percentage points), and in just 9.1 percent of high-income countries (which is down by 10.9 percentage points). In real terms, food price inflation outpaced overall inflation, defined as the year-on-year change in the overall CPI, in 54 percent of the 166 countries for which both food CPI and overall CPI data are available (Figure 2b). [8]

Figure 2a: Food Inflation Heat Map **Figure 2b: Real Food Inflation Heat Map**



Source: International Monetary Fund, Haver Analytics, Trading Economics, and World Bank Real Time Price estimates.
Note: Food inflation for each country is based on the latest month from August to November2025 for which the food component of the Consumer Price Index (CPI) and overall CPI data are available. Real food inflation is defined as food inflation minus overall inflation.

(Food Price Inflation Dashboard) [9]

Economic shocks are also one of the leading causes of food price volatility because food markets are tightly integrated into world economic and financial systems, according to the Global Panel on Agriculture and Food Systems for Nutrition (GloPAN). Immediate

---

[8] "AT a GLANCE GLOBAL MARKET OUTLOOK (as of DECEMBER 15, 2025) Trends in Global Agricultural Commodity Prices," n.d. https://thedocs.worldbank.org/en/doc/40ebbf38f5a6b68bfc11e5273e1405d4-0090012022/related/Food-Security-Update-120-December-19-2025.pdf.

[9] AT a GLANCE GLOBAL MARKET OUTLOOK (as of DECEMBER 15, 2025) Trends in Global Agricultural Commodity Prices," n.d.

macroeconomic events such as global financial crises, economic recessions, high inflation, currency devaluations, and dramatic oil and energy price volatilities. They can quickly dislocate prices of food at the national and international level. For instance, rises in fuel and energy prices increase the cost of growing food by increasing the cost of fertilisers, irrigation, mechanisation, processing, and transportation. Such higher costs are usually transferred to consumers, for example, as food prices, even though food availability has not changed much. But economic shocks decrease income for households and purchasing power, especially for lower-income groups, who already use a large percentage of their income on food. This phenomenon would see even modest price increases severely cut into access to proper nutrition. GloPAN illustrates food price volatility and price increases but adds that sudden decreases in price are not only detrimental, especially for smallholders and producers from small-scale farms, but also cut farm incomes and discourage further investment in future output. This establishes a vicious cycle of underinvestment that could potentially weaken the food supply resilience in time. It is the unpredictable nature of food price variability due to economic shocks that is especially hurtful. And uncertainty hampers farmers', traders' and governments' ability to plan, manage risks or stabilise markets. GloPAN adds that economic shocks are often entangled with other stresses, from climate-related crop failures and conflict to trade constraints, amplifying risk and further exacerbating food insecurity. At times of high volatility, households shift consumption toward lower-cost but, on the whole, calorie-dense but nutrient-poor foods, leading to malnutrition, which in turn leads to worse long-term health. Overall, GloPAN shows that food price volatility and economic shocks weaken every aspect of food security – availability, access, utilisation, and stability. That's why the panel emphasises integrated policy responses, such as increasing the transparency of the market, early warning systems, social protection mechanisms or macroeconomic stabilising measures. Without an economic explanation for the price volatility of food, food systems are still incredibly susceptible to shocks and to the achievement of sustainable food security and nutrition results. [10]

1.2.4. Impacts on Food Security and Consumption

Recent worldwide assessments and projections confirm an escalation of rising food insecurity, a product of a confluence of fragility, conflict, and climate changes. A World Food Programme (WFP) report on hunger hotspots also shows 16 countries are projected to experience worsening food security over the next 12 months, including Afghanistan, Somalia, and Syria, another item on this frightening list. In the WFP's 2026 Global Outlook, there is a 20% increase in the number of people who are experiencing acute food insecurity compared with previous years, according to the report. Conflict is cited in the Global Hunger Index as the highest cause of hunger worldwide, exacerbated by climate change, which has transformed from an intermittent threat to a persistent one. The agricultural and cereal price indices have increased by 1 and 3 percent, respectively, since the last update on October 31, while the export price index has been unchanged. Wheat, maize and rice prices have increased by 1, 4 and 5 percent respectively. Year on year, maize prices increased by 2 percent; wheat was down by 3 percent and rice was down by 29 percent. The December 2025 AMIS report on global markets shows that global markets are adequately supplied: wheat and rice are falling, while maize is stable; soybean prices are up slightly, and fertiliser costs are modestly lower. However, persistent high input costs remain a limiting factor in demand among lower-margin agricultural systems. The FAO State of Food and Agriculture report for 2025 highlighted the impacts of land degradation on agricultural productivity in both the short- and long-term, alongside those of food security and ecosystem resilience. Besides, by 2025 the State of the World's Children report stated that more than 417 million children worldwide are severely deprived of at least two basic needs—education, health care, housing,

[10] daveg. "Food Price Volatility – Global Panel." Global Panel, March 16, 2016. https://www.glopan.org/food-price-volatility/.

nutrition, sanitation, or clean water, based on their geographic location. These negative situations greatly impair families' capacity to supply adequate diets to children during lean economic episodes. This is especially serious in sub-Saharan Africa and South Asia, where many children suffer extreme poverty and nutritional insufficiencies. [11]

1.3. Keywords

1.3.1. Acute Food Insecurity

The GRFC characterises a food crisis as a scenario in which severe food insecurity necessitates immediate intervention to safeguard lives and means of subsistence, either locally or nationally, surpassing the available resources and capabilities for response. Severe food insecurity is described as a condition where communities encounter hunger that endangers their survival or economic well-being, irrespective of the underlying reasons, circumstances, or time frame involved. [12]

1.3.2. Malnutrition

Malnutrition encompasses various forms, including undernutrition (characterised by wasting, stunting, and being underweight), deficiencies in essential vitamins or minerals, and conditions like overweight and obesity, which can lead to diet-related noncommunicable diseases. It signifies an imbalance, whether a deficiency or excess, in an individual's energy or nutrient intake. [13]

1.3.3. World Food Programme

The World Food Programme stands as the largest humanitarian entity globally, dedicated to preserving lives during crises and employing food aid as a means to foster peace.

---

[11] AT a GLANCE GLOBAL MARKET OUTLOOK (as of DECEMBER 15, 2025) Trends in Global Agricultural Commodity Prices," n.d.

[12] FSIN. "Global Report on Food Crises (GRFC) 2024." Fightfoodcrises.net, April 24, 2024. https://www.fightfoodcrises.net/report/global-report-food-crises-2024/.

[13] World. "Malnutrition." Who.int. World Health Organization: WHO, March 2024. https://www.who.int/news-room/fact-sheets/detail/malnutrition#:~:text=There%20are%204%20broad%20sub,height%20is%20known%20as%20wasting.

stability, and prosperity for individuals overcoming the challenges posed by conflict, disasters, and climate change.

1.3.4. International Development Association

The International Development Association (IDA) was created in 1960 as a subsidiary of the International Bank for Reconstruction and Development (World Bank) to extend support for similar objectives as the Bank, with a particular focus on aiding poorer developing nations under more favourable conditions. Although it operates as a separate legal and financial entity from the Bank, IDA utilises the same personnel. Functioning as a development finance institution, IDA provides concessional loans and grants specifically to the poorest developing countries worldwide. As part of the World Bank Group, IDA is based in Washington, D.C., United States. Its inception aimed to supplement the existing International Bank for Reconstruction and Development by offering financial assistance to nations experiencing the lowest gross national income, poor credit ratings, or minimal per capita income. [14]

1.3.5. Food Security

According to the 1996 World Food Summit, food security refers to a situation where every individual, at all times, has both physical and economic access to an adequate supply of safe and nutritious food. This food should fulfil their dietary requirements and personal preferences to support an active and healthy lifestyle. There are four main aims of food security: [15]

- *Physical Availability of Food:* The concept of food availability pertains to the "supply side" aspect of food security, which is influenced by

[14] "International Development Association (IDA)." Yearbook of the United Nations, December 31, 1992, 1135–39. https://doi.org/10.18356/d4f7446a-en.
[15] Group, World Bank. "What Is Food Security." World Bank. World Bank Group, December 16, 2024. https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security#:~:text=Based%20on%20the%201996%20World,an%20active%20and%20healthy%20life.

factors such as the volume of food production, existing stock levels, and net trade activities.

- *Economic and physical access to food:* The mere availability of food on a national or international scale does not automatically ensure food security at the household level. As a result of worries regarding inadequate access to food, there has been an increased emphasis in policy on factors such as income, spending, market dynamics, and pricing in order to meet food security goals.
- *Food Utilisation:* Utilisation refers to how effectively the body capitalises on the various nutrients found in food. Adequate energy and nutrient consumption among individuals stems from proper care, effective feeding practices, appropriate food preparation, a varied diet, and equitable distribution of food within households. When coupled with efficient biological utilisation of ingested food, these factors play a critical role in determining an individual's nutritional well-being.
- *Stability of Other Dimensions Over Time:* Even if your current food intake meets adequate levels, you may still face food insecurity if access to food is inconsistent over time, which could jeopardise your nutritional health. Factors such as unfavourable weather conditions, political turmoil, or economic influences can significantly affect your overall food security status.

1.3.6. Nutrition

Nutrition encompasses the act of consuming and assimilating food necessary for bodily sustenance. This process includes the breakdown of food into various nutrients, which are chemical compounds essential for the body's operation. However, this vital process extends beyond merely providing nutrition. [16]

2. Governance Challenges in Current Food Systems

2.1. Fragmentation of Global and National Food Governance

Food system governance and governance itself are marred by chronic and structural fragmentation at global and national levels, restricting the ability to respond to food insecurity and related nutrition issues. As the IDDRI working paper has put it, the global governance of food and nutrition security was not an "emergent" integrated single system but emerged from a collection of different policy domains of specific issue areas, and particularly, agricultural production, international trade, humanitarian food aid, nutrition, rural development, environmental sustainability, and the right to food. Each part of these sectors developed their own institutional forms, policy instruments, expert communities, and decision-making frameworks, which might sometimes be adopted as responses to specific crises or political agendas. This institutionalisation may be described as part of the process in which countries managed their responses to crises and to strategic challenges. Over time, this has manifested in a muddled, crowded approach to UN governance with overlapping mandates and limited coordination among multiple UN agencies, international financial institutions, donor-led initiatives, regional entities, and multi-stakeholder platforms.

Internationally, this fragmentation has generated institutional competition instead of policy coherence, with organisations motivated by divergent aspirations and accountability modalities. Coordination efforts did follow the 2007–08 global food price crisis (especially via the reform of the Committee on World Food Security (CFS) and the establishment of the UN High-Level Task Force on Food Security and Nutrition), but these became little more than a meta-governance arrangement with little power. Even as they excel in dialogue and

[16] Clinic, Cleveland. "What Is Nutrition & the Essential Nutrients Your Body Needs." Cleveland Clinic, March 18, 2025. https://my.clevelandclinic.org/health/articles/nutrition.

inclusion, those platforms are powerless politically and structurally to reorient long-term institutional need or to foster cross-sectoral policy convergence. Governance, thus, is fragmented, and no single institution can reconcile agriculture, trade, nutrition, climate change and development approaches and results.

The fragmentation is also apparent at the national level, where governance functions are widely shared among and within ministries and agencies associated with food systems, such as agriculture, health, trade, finance, social protection and environment. These institutions often operate in sectoralised administrative silos determined by sectors' and budget constraints, which inhibit effective collaboration and coordination.

Accordingly, agricultural productivity-optimising policies may conflict with nutrition goals or environmental sustainability goals or social protection plans. The disjointed character of policy renders national food strategies ineffective and precludes the appropriation of multidimensional and multifactorial interventions towards food security in the context of determinants of food security such as availability, access, utilisation, and stability.

Furthermore, fragmented governance systems tend to reproduce existing power asymmetries and benefit powerful actors and mainstream policy narratives over smaller states, local communities and vulnerable populations. In this context, the result is related to issues of legitimacy, accountability, and equity in food governance. There is, as articulated by IDDRI, a deficit of joined-up and inclusive governance processes that constrain collective action, curtail learning at institutions and reduce flexibility to address fresh issues, from climate change, economic shocks and lingering global food crises. Until coordination and governance mechanisms are improved, food systems will remain ill-prepared to support sustainable, equitable and resilient transformation. [17]

[17] "François Lerin (CIHEAM-IAMM), Selim Louafi (CIrAd)." Accessed January 6, 2026. https://www.iddri.org/sites/default/files/import/publications/wp1014_fl-sl_fns-governance.pdf.

2.2. Policy Incoherence Across Agriculture, Trade and Climate

The myriad of fragmented and contradictory policies that have plagued the current food systems have created fragmented and conflicting solutions that keep us moving slower than needed towards tackling common problems like hunger, malnutrition, poverty, and environmental degradation.

The absence of coherence undermines the efficient realisation of the numerous objectives of the food system and creates a gap between the different actors, causing tension among the stakeholders within the food system, indicating the need for policy coherence. It shows policy coherence by making the coordinated actions and decisions in the whole food system. The degree of connection ensures that if one result matters, another will get better – something which is pertinent when the Sustainable Development Goals (SDGs) are so deeply intertwined. By driving mutually reinforcing policy initiatives across departments and institutions of government, synergies can be developed to achieve objectives.

For example, a policy framework addressing the development of sustainable aquaculture to encourage greater seafood production without compromising marine ecosystems may be buttressed by other sectors supporting the same effort. Policies for trade could feature the importation of sustainably sourced seafood, which could motivate compliance with global standards of sustainability.

Moreover, training and skills development programmes on sustainable aquaculture for the youth could be integrated. The National Biodiversity Strategy and Action Plan can prioritise marine ecosystem protection while integrating multiple benefits like increased and sustainable aquaculture, food security and nutrition, as well as job creation and social protection. Food systems are also to be actively included in climate strategies, not least through nationally determined contributions (NDCs) under the Paris Agreement.

Understanding such linkages also allows policymakers to better contend with trade-offs and synergies in multiple outcomes. This approach methodically reduces internal inefficiencies and disputes. It allows for an all-level understanding of all the possible solutions of complex challenges from policies. The focus of comprehensive and effective policies, which should recognise the complexities and interdependencies of food systems, should be on establishing collaboration and strong relationships between diverse stakeholders.

At the international level, in conjunction with your diplomatic ties, you can advocate for the assimilation of environmental factors, and in particular the NDCs and the National Biodiversity Strategies and Action Plans (NBSAPs), into larger food policy frameworks, and food into a set of environment-related policies and processes where they can align with wider sustainability goals. This builds on a broader approach to delivering the 2030 Agenda through an integrated approach to both food systems and climate change, biodiversity loss, and pollution and thus on supporting two of the six UN key transitions (1) and (6) to create pathways to investment in such transitions. One new entry point toward policy coherence on the transformation of food systems is water. Water scarcity is acute in many countries, having major consequences at the socioeconomic level. Food is inextricably connected to water, and water policy can focus at the moment on food security and future solutions to reduce water scarcity in the long term.

Nowadays, both food and environmental agendas, when used side by side into alignment, are ripe for future efforts such as integration in some of the following aspects within the arena of politicisation: Interconnecting food systems transformation and climate action: in the context of the United Nations Framework Convention on Climate Change (UNFCCC) conference architecture, we have framed the integration of transformation in food systems and the urgent need for climate action.

Bringing together the transformation of food systems and biodiversity protection: As we get closer to COP29, with an explicit mention of the Kunming-Montreal Global Biodiversity Framework, emphasising the urgent necessity of an interlinked transformation to sustainability and, in turn, the food system change with biodiversity preservation as well.

Mobilising support for national pathway implementation: Under the auspices of the UN Food Systems Summit (UNFSS) Stocktaking Moments, mobilising support for the implementation of national pathways and promoting tangible progress on sustainable transformation. [18]

3. Collaborative governance mechanisms for financing food security and nutrition

3.1. Introduction

Food system governance refers to the mechanisms by which decision-making and activities on food production, classification and consumption are based. Such institutions can be both formal and informal systems, rules, practices and processes for changes in food systems. In recent years, there has been a noticeable decline in the role of governments around food system governance, accompanied by an increased input from civil society actors. From the perspective of civil society activities, Multi-Stakeholder Partnerships (MSPs) are gradually emerging because they help tackle systemic challenges in food systems by overcoming resistance to change and building up state capacities. It increases the participation of stakeholders engaged in various aspects of the food system. This evolution brings the question of how MSPs can effectively complement traditional governance roles. FAO proposed a framework that outlines principles of effective governance arrangements in the food sector. This framework helps to analyse the governance structures that mix formal and informal arrangements, as well as the actors required in food system governance. [19]

---

[18] "Food Systems Thinking Guide for UN Resident Coordinators and UN Country Teams," January 8, 2025. https://doi.org/10.4060/cd0497en.

[19] Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." Global Food Security 32 (November 25, 2021): 100592–92. https://doi.org/10.1016/j.gfs.2021.100592.

3.2. System-based problem framing

The essence of problem framing is to transform ambiguous situations into task work. At the heart of this process is defining a problem's edges, its limits, and making the meaning of matters known; context is critical. The essential aspect of problem framing is that it works to turn ambiguous cases into action items at a level the same as preparing for a performance where each player would have in fact understood their tasks – the roles, conversations and activities. For instance, by means of using the concept that the problems in a healthcare system that a detailed solution can be inefficiencies, a specific problem, or an improved-enough problem definition for healthcare organisations can bring out patient flows such that the 'system issues' are clearly detailed rather than "system issues". This clarity enables stakeholders to align their activities as well as resource planning towards a single solution when working together. A key element of the problem is to correctly define the issue that is the focus of what is at stake. Incorrect identification can throw a wrench into the problem-solving path, just as a medical error can knock a car over a sidewalk. You need techniques such as root cause analysis or the "Five Whys" method to uncover deeper layers of a problem and find its essence. For example, in the beginning, a slump in sales may seem to be due to marketing pain points; however, underneath is a problem with design that does not meet the needs of the users. At best, even combining many perspectives is not only beneficial but also absolutely essential for problem framing. In this manner, embracing different perspectives can prevent the lack of diversity in thinking across viewpoints, which can be typical in organisations as a result of a monolithic point of view. Such diversity can be further nurtured by forming cross-functional teams, running workshops and running inclusion efforts to bring together a full complement of experiences and expertise into one group.

One of the most common errors in problem framing is the tendency to rush through the process. The pressure to identify solutions can often eclipse the necessity for a thoughtfully constructed problem frame. Hasty framing may result in misguided efforts, squandered resources, and ultimately ineffective outcomes. Thus, it is vital to allocate sufficient time to gain a thorough understanding of the issue at hand. No person or group is devoid of biases and prejudices, and their impact on problem framing can be particularly subtle. These subjective inclinations can distort problem identification, goal formulation, and even the choice of decision-making tools. It is therefore important to utilise methods such as blind data analysis or peer reviews to reduce bias influence and achieve a more objective approach to problem framing. Effective problem framing serves as an essential resource for decision-makers, enabling them to impose order on chaos and pursue solutions systematically. [20]

3.3. Boundary-spanning structures

Boundary-spanning structures refer to institutional arrangements, mechanisms, or platforms that link and coordinate actors across various sectors, levels of governance, and organisational boundaries. They are originally designed to bridge the divide which leads to fragmentation when policy areas like agriculture, trade, climate change, health, finance, and social protection operate independently. Many multi-stakeholder partnerships (MSPs) often function within the confines of their specific mandates and priorities, primarily focusing on objectives and activities defined internally instead of pursuing collaboration with other MSPs. Consequently, connections between similar partnerships are generally weak, hindering information sharing, collective learning, and coordinated efforts. This inward orientation diminishes the ability of MSPs to self-organize, formulate joint strategies, or participate in cohesive advocacy, ultimately limiting their effectiveness in tackling complex and interconnected challenges related to food security and nutrition. Decision-making in many systems of food security and nutrition is embedded within separate "silos" in which

[20] Branch, Eryk. "Problem Framing: A Strategic Approach to Decision Making." IIENSTITU, November 22, 2023. https://www.iienstitu.com/en/blog/problem-framing-a-strategic-approach-to-decision-making.

ministries, international organisations, private sector actors, and civil society pursue relatively narrow mandates, resulting in little effective communication or cooperation. Such fragmentation leads to both duplication of responsibilities and inconsistent policy implementation as well as an inefficient allocation of resources.

Boundary-spanning structures allow horizontal coordination across sectors as well as vertical coordination among local, national, regional, and global levels by spanning these disparate subsystems. They open dialogues and data-sharing, as well as joint planning, for different players to coordinate aims and harmonize policies. A boundary-spanning platform, for example, could integrate ministries of agriculture, finance, and environment with humanitarian agencies, development banks, farmers' organizations, and private companies to act on a combined basis to tackle food crises and long-term transformation of food systems. These structures also, of great importance, serve to translate knowledge across boundaries. Scientific knowledge, early warning information, and local knowledge may originate in distinct institutional contexts and are not always easily apprehended or implemented by policymakers. Boundary-spanning mechanisms are the intermediaries that link technical knowledge with practice and the policy process, which is required in order that evidence-based decisions may lead to coordinated responses. This is especially important on a global scale of emergency food security in the context of new types of food crises, where timely coordination and integration of effort are essential to reduce risk and enhance resilience. Boundary-spanning structures contribute to collaborative governance in total through the resolution of fragmented and siloed organisational structures. They build trust among stakeholders, increase accountability, and promote greater coherence and inclusiveness. policy responses to food security and nutrition challenges that ultimately lead to resilient and sustainable food systems. [21]

[21] Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." Global Food Security 32 (November 25, 2021): 100592–92. https://doi.org/10.1016/j.gfs.2021.100592.

3.4. Adaptability addresses

The complexities of food systems, viewed as intricate socio-ecological frameworks, pose challenges due to their inherent uncertainties and volatility. To effectively govern these adaptive food systems, it is essential to foster increased flexibility, engage in reflexive learning through practical experiences, and promote relational learning by exchanging information across various scales and communities. [22]

3.5. Inclusiveness

It also stresses that food systems governance is of course, always political and that governance processes are not neutral but are influenced by decisions on who is included, who is excluded, and whose interests are placed ahead of others. These preferences influence priorities, resource allocation, and policies, frequently reflecting power asymmetries that exist in food systems. If a small and privileged group of actors (governments, large corporations, or technical experts) exercises control over governing, then other interests (smallholder farmers, indigenous peoples, local communities, and consumers) may be disregarded or excluded from the decision process. Limited citizen involvement is a perennial challenge to food system governance and can undermine the effectiveness and legitimacy of policy outcomes. The absence of affected communities can diminish the relevance of policies on the ground and erode trust of the public in institutions. This inclusive participation is also key to improving the soundness of policy design and ensuring that governance arrangements are thought to be legitimate and accountable. Large-scale stakeholder engagement helps ensure justice, fairness, and equity with an emphasis on enabling the most marginalised in society and vulnerable with the most pressing needs related to food insecurity and nutrition challenges. The involvement of citizens and civil society actors to an extent will support the ground for governance mechanisms being embedded into the diversity of knowledge systems,

[22] Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." Global Food Security 32 (November 25, 2021): 100592–92.

the experience of living on the ground, and the diversity of social as well as local interests. This diversity also contributes to greater transparency and responsibility and is one of the foundational aspects of sustainable development. The political aspects of inclusion and exclusion are necessary for food system governance systems that are resilient, equitable, and socially sustainable. [23]

3.6. Transformative capacity

It tackles a key problem: resistance baked into existing food systems governance that is usually influenced by long-standing institutions, policy traditions, and economic interests that promote the status quo and incremental change. It is this kind of pushback that can either slow or weaken efforts to introduce more sustainable, resilient, and inclusive approaches. Such approaches facilitate space for innovation and coordinated reform by challenging these structural and institutional barriers. They simultaneously help support transitions toward fundamentally different food systems that prioritise long-term food security, environmental sustainability, resilience, and social equity rather than short-term productivity and efficiency alone. [24]

4. Coordinated Policy Responses to Emerging Food Crises

4.1. Abstract

Emerging food crises are growing increasingly complex, rapid, and interconnected – with climate-related shocks, armed conflict, economic instability, pandemics, and global supply-chain disruption contributing, too. Unlike earlier food crises that were local or ephemeral, these modern crises are frequently interlinked and mutually reinforcing, making them an ongoing stressor on a national and global scale. These forces highlight the

[23] Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." Global Food Security 32 (November 25, 2021): 100592–92.

[24] Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." Global Food Security 32 (November 25, 2021): 100592–92.

weaknesses of fragmented, reactive, sectoral policy responses and the necessity for aligned policy environments that can cross sectors, governance, and institutional boundaries. Conducting coordinated policy responses through prioritising short-term humanitarian actions with longer-term development and resilience objectives. Ensuring good coordination between governments, international organisations, humanitarian actors, financial institutions, and the private sector. Responses are at risk of duplication, delays and contradictory policies without coordination — such as emergency food aid under severe trade restrictions or austerity policy. Coordination provides more predictability and confidence among relevant actors, and thus it is easier for them to respond quickly and better understand the level of hazard. Through linking early warning, emergency relief, trade policy, and crisis financing in a unified governance arrangement, the potential impact of food crises can be attenuated and a more resilient food system can be enabled. This section reviews the four elements of coordinated response: early warning and crisis anticipation; emergency food assistance and social protection; trade policy coordination; and the financing of crisis response.

4.2. Early Warning Systems and Crisis Anticipation

Early warning systems are crucial to predicting the kinds of food crises we face now. Such are systems that monitor many indicators, from climate patterns to agricultural production to market prices to the intensity of conflict, the level of population displacement, and nutritional outcomes. Interconnected, these indicators guide decision-makers in tracking threats and halting emergencies before they translate into large-scale humanitarian crises. The success of early warning systems relies not only on the availability of data but also on how adequately institutions coordinate and communicate in a timely fashion. Data is collected in silos, leading to fragmented data collection across many contexts and slow response times. These integrated early warning frameworks are intended to harmonise and integrate information at the sectoral and governance levels to ensure that risk signals lead to policy action. That could mean linking early warning reports to a menu of a range of available response strategies, such as deploying contingency financing, expanding social protection programmes or pre-positioning food stocks. Political will to act on early warnings is also needed for crisis anticipation. The insights that can help to inform actions toward future crises at the food system level highlight that while warnings may be issued well in advance, the prompt action could be hindered by uncertainty and the conflicting priorities of policy and expense. So the issue is to deepen the institutional connection from the early warning systems to the decision-making processes. This might involve setting clear thresholding for actions, setting out mechanisms for accountability, and coordinating humanitarian and development stakeholders. Early warning systems also are enabling resilience over the longer term in times of climate change and growing uncertainty. Identifying such recurring patterns of risk enables policymakers to design adaptive responses, including climate-resilient agriculture, risk-informed land use planning, and disaster preparedness. For these reasons, early warning systems are not limited in their scope to crisis detection and risk management but also provide a strategic mechanism to mitigate vulnerability and optimise food system stability.

4.3. Emergency Food Assistance and Social Protection Policies

Emergency food assistance continues to be an essential part of the response in contexts of acute food insecurity as a result of conflict, natural disasters, or sudden economic shocks. That kind of assistance is meant to guarantee rapid access to food and prevent severe malnutrition, hunger, and loss of life. The methods comprise in-kind food aid, cash transfers, and vouchers that are customised to suit prevailing market conditions and population requirements. Yet food aid in an emergency is not adequate to counteract the structural drivers of food insecurity and should be reinforced by broader social protection policies. Social protection systems – including cash-based safety nets, public works programmes, school feeding schemes, and nutrition-sensitive transfers – are fundamental to stabilising household consumption in times of emergency. If thoughtfully designed, such systems can be quickly scaled up during shocks, offering predictable support for the most vulnerable.

Integrated emergency assistance and social protection frameworks can drive efficiency, prevent duplication, and improve national ownership of crisis responses. The integration of humanitarian and social protection systems also moves us from short-term relief to longer-term resilience. Instead of responding to crises repeatedly through ad hoc interventions, coordinated efforts allow governments to establish lasting mechanisms that safeguard livelihoods and diminish vulnerability over the long term. In protracted crises, populations face repeated shocks and prolonged food insecurity. This is especially important.

4.4. Trade Policy Coordination and Export Restriction Management

Food trade policy is a key factor for determining the availability, provision, affordability and stability of food during a time of crisis. In a globally networked food economy, international trade helps the world move food from surplus to deficit, thereby stabilising supply and counteracting localised production shocks. However, in emergent food crises, fragmented trade policy at the world level is likely to do more harm than good to food insecurity. Such measures, while often designed to protect domestic consumers, historically have had the counterproductive effect of exacerbating global price volatility and undermining collective food security. Export restrictions are generally introduced when food prices (and supply) are increasing, and in attempts to maintain domestic availability and contain inflationary pressures. But when major food-exporting countries set limits at the same time, supply falls sharply in the global market, raising prices violently. Thereby uncoordinated trade actions can turn local shocks into global crises. The goal of trade policy coordination is to avoid the risk of these negative spillover effects through increased transparency, predictability and cooperation between countries. Such information-sharing mechanisms, early notification of policy changes, and regional consultation platforms serve to reduce uncertainty and help prevent panic-based responses. Unified governance models also incentivise governments to examine the more general systemic consequences of trade policies, regardless of short-run concerns for those countries. International trade guidelines, rules of the road and voluntary trade agreements act as stabilising references in such an environment, promoting norms against too many or lengthy export restrictions. In addition to export controls, trade policy coordination covers the standardisation of sanitary and phytosanitary provisions, customs policies and logistics rules, which in turn affect, and can affect in concert with trade policies in terms of logistics, the functionality of food chains in times of crisis. Disruptions in transportation, border delays, and regulatory barriers can compound shortcomings, whether food is found on the shelves or not. Trade facilitation measures, therefore, integrated with other measures of trade facilitation, help keep the food moving from one side of the border to the other as well, in times of crises. Effective export restriction management necessitates an appropriate domestic response. Targeted social protection measures, strategic food reserves and price stabilisation measures could help to reduce pressure on governments to resort to trade distortions. When it's in a broader context of a coordinated emergency approach, governments can make the case that trade policy safeguards sensitive communities while ensuring a stable global market. For example, greater trade policy coordination ultimately heightens resilience, mitigates volatility, and promotes equitable access to food amidst systemic stress.

4.5. Financing Mechanisms for Crisis Response

Mechanisms for financing are a critical pillar of the response to emergent food crises, and the timing, scale, and effectiveness of responses largely depend on the availability of sufficient money. Food crises need near-term assistance (in the form of emergency food assistance, nutrition support, and market stabilisation) and sustained investment in recovery and resilience. Yet, conventional funding mechanisms often experience fragmentation, are reactive, and are short-term; therefore, they are unable to effectively counter and respond to crises that are escalating in complexity and duration. Crisis financing is also a time-sensitive issue. This situation can magnify human misery and raise the cost of the response, leading to significant delays in mobilising resources. There are cases of early action, and those early responses are much more cost-effective than late humanitarian responses. Coordinated financing mechanisms attempt to do this by connecting funding disbursement to early warning triggers, allowing funds to be released before crises fester into full-scale emergencies.

An additional challenge involves financial streams being fragmented. Humanitarian aid, development finance, climate finance, and agricultural investments are often implemented under separate institutional frameworks that have a limited degree of coordination. Such fragmentation leads, among other things, to overlapping interventions, funding deficiencies, and misaligned priorities. Integrated financing solutions seek to close these gaps, balancing short-term emergency funding with medium- and long-term development goals. When they align, they enable the continuity of crisis response, recovery, and structural transformation of food systems. Government, multilateral development bank, and international organization coordination is required in order to allocate resources efficiently. When there is no coordination, it is easy for funding to focus on visible emergencies while ignoring more delayed or long-lasting ones. Harmonised financing arrangements improve transparency, cut down on duplication, and enhance accountability, while fostering ownership of response strategies at the national level.

Also, these financing mechanisms are strategically supportive of investing in resilience, climate-resilient agriculture, infrastructure development, risk management tools, and improving institutional capacity. Integration of crisis financing and long-term food system transformation facilitates coordinated financial responses that reduce the reliance on repeated emergency interventions. Thus, financing mechanisms cannot be viewed simply as mechanisms for crisis management but also for transformative systems change that helps to ensure that food systems are able to withstand future shocks from economic, climatic, and geopolitical contexts.

5. Transforming Food Systems Towards Sustainability

5.1. Promoting Climate-Resilient and Sustainable Agriculture

To make food systems sustainable, this would require that agriculture become resilient and sustainable in terms of climate change and national policies that include climate adaptation, mitigation, and long-term food security. FAO insists that the impact of climate change on agricultural productivity is growing in severity owing to increasing frequency of droughts, floods, heat stress, soil degradation, and the spread of pests and diseases. Agriculture is, however, a substantial source of greenhouse gas emissions; thus, a response to it by countries on how to improve resilience and minimise environmental consequences is needed. Different countries have pursued different routes to climate-resilient agriculture, reflecting their ecological conditions, priorities for development, and institutional capacities.

In Ethiopia, climate-resilient agriculture is encouraged by using massive soil and water conservation interventions and sustainable land management programs to decrease land degradation and strengthen resilience to drought. FAO-supported interventions focus on watershed management, agroforestry, and climate-smart farming techniques as systems to stabilise yields and protect rural livelihoods. These strategies show how integrating ecosystem restoration with agricultural production can strengthen resilience in climate-vulnerable contexts.

Bangladesh is a good example for adapting to climate-induced flooding and salinity intrusion in coastal and delta regions. Flood-tolerant (and salt-resistant) crops and new technologies such as floating agriculture and improved drainage systems have become important in agricultural strategies. FAO points to Bangladesh as an example of how localised technical innovation, enhanced by locally available knowledge, can sustain food production and nutrition in times of extreme climatic stress.

In Brazil, strategies for sustainable agriculture are developing to link productivity increase with climate mitigation and environmental protection. National programmes encourage integrated crop-livestock-forestry systems, conservation tillage, and the restoration of degraded pastureland. These combined systems drive food security and contribute to better overall sustainability through increased productivity per unit of land and a reduction in deforestation and agricultural emissions, according to FAO, demonstrating the integration of climate-resilient agriculture into food security and broader sustainability goals.

In the Netherlands, the main task of sustainable agriculture is to reduce environmental costs of heavily industrialised farming. Some policies support precision agriculture, nutrient-use efficiency, circular nutrient management, and low-emission livestock production. FAO says that although the methods are based on high-tech solutions, the core principles, such as efficiency, innovation, and resource conservation, apply to differing socioeconomic settings.

That is why, from these country experiences, we can see that climate-resilient and sustainable agriculture is facilitated by coherent policies, collaborative governance, and sustained investment. FAO emphasises that scaling up successful practices across regions depends on strengthened international cooperation, knowledge sharing, and access to climate finance. Using these as a building block, there is the potential to transform the national structure of food systems to become resilient, protect ecosystems, and ensure long-term food security and nutrition.

5.2. Reducing Food Waste

Food loss and waste pose tremendous challenges to a sustainable food system where challenges, including food insecurity, environmental degradation, and resource depletion, are growing more significant. The United Nations Food and Agriculture Organization (FAO) reported that about a third of the food considered in the food supply chain (production, harvesting, processing, retail, and household consumption) is lost or wasted, making it 1.3 billion tonnes annually for the purpose of human consumption. The phenomenon of food loss and waste (FLW) mirrors larger structural challenges such as insufficient storage and transportation infrastructure in many low- and middle-income countries, production and market demand discrepancy with the respective resources, lack of cold-chain logistics (particularly in many retailers), and consumer waste at home and in stores. Food waste effects have multi-faceted environmental and economic dimensions. Food loss or wastage does not only mean its loss in economic value for producers, retailers and consumers, but it is also a waste of resources — water, land, energy and labour spent on their production and distribution.

Moreover, food that is thrown in the garbage provides methane, a potent greenhouse gas that is a major contributor to climate change. Addressing FLW is essential for tackling FLW, which is important for controlling GHG emissions on top of climate change effects to reduce greenhouse gas intensity and protect ecosystems. Due to the substantial share of food systems in terms of global greenhouse gas emissions as well as ecological impact, they are already an issue of environmental factors contributing to many problems, and problems are given food systems account for a sizeable portion of global emissions and environmental issues. Food systems face many challenges worldwide, and everywhere food systems face many challenges in the world, and all of them have different targets for each of them, as they all are trying to meet different kinds of goals that are working to solve this.[25]

Food waste reduction in these systems with a specific target is one of the key objectives, which is the reduction of food waste, and it has been linked to Sustainable Development Goal 12. This goal emphasises the need for “sustainable consumption and production patterns”. In particular, by 2030, target 12.3 seeks to halve per capita global food waste—at both retail levels and among consumers—and reduce losses through production and supply chains, particularly post-harvest losses. Boosting resilience towards fewer food waste attempts, more usually, is aimed at strengthening the environmental sustainability of the agricultural practices. Due to the enormous scale and resource implications of this issue, food waste has become a major concern in food security. A rapidly growing human population raises the need for food products, thus placing further stress on agricultural systems and producing more food waste. Most of the food waste comprises proteins, carbohydrates and lipids that provide favourable conditions for different microorganisms.

Moreover, the burning of food waste in organic compounds rich in nutrients and highly moisturised with energy can also generate dioxins in the food incinerate process, posing threats to both the environment and human health. Food waste can occur at any stage of the supply chain: production, distribution, sales and user. [26]

UN ESCWA emphasises that effective reduction of food waste should have a holistic system perspective and be attained through systemic measures by everyone involved, not the use of a single intervention. From a production and post-harvest perspective, more could be done to invest in storage infrastructure, cold chains and better harvesting techniques to

---

[25] “Inclusive Healthy Resilient Sustainable Regional Policy Brief TRANSFORMING FOOD SYSTEMS Introduction on Food Systems,” n.d. https://www.unescwa.org/sites/default/files/pubs/pdf/transforming-food-systems-english_0.pdf.
[26] Kilemile, Warren, Kelvin E. Vulla, Fabian Mihafu, and Vidhya Chandrasekaran. “Transforming Food Systems: A Review of Sustainable Approaches to Minimize Food Loss and Waste.” Food Science & Nutrition 13, no. 11 (November 2025). https://doi.org/10.1002/fsn3.71167.

minimise the waste before foods reach the markets. Giving farmers access to technology, extension services, and climate-resilient practices equates to greater efficacy and lower crop spoilage for farmers. The policies based on logistics improvements, food processing capacity development, and market transparency can align the supply with the demand at the supply chain and market level.

But you can also incentivise the private sector to innovate across packaging, preservation, and digital supply chain management. These forms of regulation incentivise businesses to reduce waste by providing tax benefits and mandates for reporting and the possibility of redistributing surplus food. Retail and consumer behaviour change is crucial. UN ESCWA emphasises the need for public education campaigns, educating consumers, and clearer labelling of food products for reduced food-expired-date confusion. Food donation programmes, food recovery policies, and partnerships with food banks help to funnel surplus food to the most vulnerable among us, cutting waste and improving access to food. Governance and coordination are also key.

UN ESCWA stresses that reducing food waste should be enshrined within national food system strategies, climate policies and sustainable development planning. Dialogue and communication between governments, private sector organizations, civil society and international organizations will bring this stage where the action will fall in line across sectors, through multi-stakeholder dialogue and communication. Monitoring systems and data collection methodologies will also need to be established if monitoring is to be carried out so that the information on progress can guide the development of evidence-based policies. Tackling food waste is a new approach to the future, sustainable reorganisation of food systems. Working the entire food value chain not only can help to reduce waste, but it will help to make certain that the whole food value chain is more resilient and fair to all countries and that it contributes to longer-term sustainable development objectives both by addressing problems and inefficiencies in the entire food value chain and by taking a coordinated policy process.

6. Introduction to the Agenda Item: Harnessing Artificial Intelligence, Digitalization and Data Governance for Food Security and Nutrition

The reality of the current age of digitalisation has a significant impact on the social, political and economic spheres. Under the light of developments in technology and artificial intelligence, global and local actors that take place in the mentioned spheres are forced to adapt to these developments. Agriculture, although it does not hold a large place in the global economy, continues to take a crucial part in global trades and has to be changed in accordance with the developments. The Food and Agriculture Organisation considers this fact as one of their agenda items to set global standards and missions for this change. *The Multi-Year Programme of Work (MYPoW) identifies that "innovations such as artificial intelligence (AI), digital platforms and big data analytics have the potential to enhance productivity, improve early warning systems, support climate adaptation and strengthen value chains. At the same time, these technologies also bring new challenges, including concerns around data privacy, equity, algorithmic bias, digital exclusion and lack of governance mechanisms".* [27]

7. The 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs)

7.1. The 2030 Agenda

The 2030 Agenda for Sustainable Development is a global plan adopted by all United Nations member states in 2015 to promote peace, prosperity, and environmental protection. It is built around 17 Sustainable Development Goals (SDGs) and 169 specific targets, ranging from ending poverty and hunger to ensuring quality education, gender equality, and climate action. [28] The 2030 Agenda underlines that development must be inclusive and universal,

---

[27] FAO CFS, "HIGH-LEVEL FORUM 'HARNESSING ARTIFICIAL INTELLIGENCE, DIGITALIZATION and DATA GOVERNANCE for FOOD SECURITY and NUTRITION,'" August 12, 2025.
[28] Un.org. "Transforming Our World: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs," 2015. https://sdgs.un.org/2030agenda?utm_source=copilot.com.

meaning all member states should be able to implement developments while balancing economic growth, social inclusion, and environmental sustainability. The Agenda also highlights the importance of global partnerships, encouraging cooperation between governments, civil society, and the private sector in the context of accessibility of resources and knowledge. [29]

7.2. 2030 Agenda and Digitalisation

Digitalisation plays a central role in adapting the United Nations' 2030 Agenda for Sustainable Development since improvement in technology makes progress faster across most of the 17 Sustainable Development Goals. Technologies such as artificial intelligence, mobile connectivity, and big data analytics are used to expand access to education, improve healthcare delivery, and strengthen climate monitoring. At the same time, global initiatives like the SDG Digital Acceleration Agenda and the Global Digital Compact highlight the need for responsible governance, cybersecurity, and ethical use of technology. [30] In this way, digitalisation is both a driver of innovation and a safeguard for equity, making it a vital actor for achieving the 2030 Agenda's vision of a sustainable and fair future.

7.3. Related Sustainable Development Goals

7.3.1. Goal 1: End poverty in all its forms everywhere

"Goal 1: End poverty in all its forms everywhere" aims to minimise the extreme poverty in all member states by 2030, ensuring that all people have equal access to basic resources, services, and social protection systems. It emphasizes reducing the proportion of people living on less than $1.90 a day, addressing vulnerabilities caused by disasters, and creating sustainable economic opportunities. The goal recognises poverty as

[29] Un.org. "Transforming Our World: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs," 2015.
[30] Un.org. "Global Digital Compact | Office for Digital and Emerging Technologies," 2025. https://www.un.org/digital-emerging-technologies/global-digital-compact?utm_source=copilot.com.

multidimensional, not only about income but also about access to education, healthcare, housing, and dignity. [31]

7.3.2. Goal 2 : End hunger, achieve food security and improved nutrition and promote sustainable agriculture

"Goal 2 : End hunger, achieve food security and improved nutrition, and promote sustainable agriculture" focuses on ending hunger, achieving food security, and promoting sustainable agriculture. It aims for universal access to safe, nutritious, and sufficient food all year round, while also improving agricultural productivity and ensuring resilient food systems. This goal highlights the importance of supporting small-scale farmers, protecting ecosystems, and adapting to climate change to secure long-term food supplies. It also links hunger eradication with better nutrition and sustainable rural development. [32]

7.3.3. Goal 10 : Reduce inequality within and among countries

"Goal 10 : Reduce inequality within and among countries" seeks to reduce inequality within and among countries by promoting social, economic, and political inclusion. It emphasises eliminating discriminatory laws, policies, and practices while ensuring equal opportunities for marginalised groups. The goal also addresses global inequality by calling for fairer trade, financial flows, and migration policies, recognising that inequality undermines social cohesion and sustainable development. [33]

8. Key Elements of the Agenda Item

8.1. Artificial Intelligence (AI)

'Artificial intelligence' is the term to explain the ability of computers or digital devices to complete and perform actions which are done by intelligent beings. [34] The term 'AI' was first introduced in the 1950s as an idea of simple actions. 1980s was the time that the term

[31] Un.org. "Goal 1 | Department of Economic and Social Affairs," 2025. https://sdgs.un.org/goals/goal1.
[32] Un.org. "Goal 2 | Department of Economic and Social Affairs," 2022. https://sdgs.un.org/goals/goal2.
[33] Un.org. "Goal 10 | Department of Economic and Social Affairs," 2025. https://sdgs.un.org/goals/goal10.
[34] Copeland, B.J. "Artificial Intelligence (AI) | Definition, Examples, Types, Applications, Companies, & Facts." Encyclopedia Britannica, July 20, 1998. https://www.britannica.com/technology/artificial-intelligence.

'machine learning' started to be used to describe *"the process which involves creating models by training an algorithm to make predictions or decisions based on data. It encompasses a broad range of techniques that enable computers to learn from and make inferences based on data without being explicitly programmed for specific tasks."* Machine learning is the backbone of the AI that is popular today. [35] For almost 30 years the system continued to be developed in different places and for different purposes. This development concluded with a new version called 'Deep Learning' in the 2010s. 'Deep Learning' refers to the ability of a machine to use multilayered networks, collect information and use it to simulate human decision-making power. The example for this version of AI is the early times of OpenAI applications. Lastly, by the 2020s, the AI transformed into generative AI, which contains much more developed deep learning systems combined with the ability to generate images, videos or audio.

AI is beneficial for society and organisations in lots of spaces, like medical, political, psychological or educational. The most outstanding benefits of AI are *"enhanced decision-making, automation and efficiency, continuous learning and self-development."* [36] As much as it is beneficial, AI comes with a set of risks which are mostly the reasons for current debates. The risks can be cited as *" data privacy, environmental issues, job losses, lack of transparency, misinformation and manipulation"*. [37]

8.2. Age of Digitalization

The age of digitalisation is the transformative era where the digital aspects have started to shape economic, social and cultural spheres starting from the mid-20th century. The history of digitalisation began in the mid-twentieth century with the invention of the first

---

[35] Stryker, Cole, and Eda Kavlakoglu. "Artificial Intelligence." Ibm.com, August 9, 2024. https://www.ibm.com/think/topics/artificial-intelligence.

[36] @thomsonreuters. "Benefits of AI," April 14, 2025. https://www.thomsonreuters.com/en/insights/articles/benefits-of-artificial-intelligence-ai.

[37] Caballar, Rina Diane. "10 AI Dangers and Risks and How to Manage Them." Ibm.com, September 3, 2024. https://www.ibm.com/think/insights/10-ai-dangers-and-risks-and-how-to-manage-them.

computers, such as ENIAC in 1945, which were massive machines capable of basic calculations but laid the groundwork for the digital revolution.[38] The following decades saw the development of personal computers in the 1980s and the rise of the World Wide Web in the 1990s, which brought digital tools into homes and workplaces. By the early 2000s, mobile phones and broadband internet had accelerated connectivity, and smartphones had quickly made digital access consistent and global. Today, digitalisation has progressed to advanced technologies such as artificial intelligence, blockchain, and cloud computing, marking the most recent stage of this evolution. [39]

Digitalisation has shown its advantages in several functions, mostly in the human-based activities. The core of digitalisation is turning analogue information into digital information or data, which makes the action that the device is responsible for faster and more efficient.[40] In economic terms, it streamlines production processes, increases efficiency, and generates entirely new business models such as e-commerce, digital banking, and platform economies. In governance, digitalisation promotes transparency and accessibility through e-government services, while in social life, it connects people across borders, reshaping communication and cultural consumption through digital technology. Digitalisation in education and healthcare enables online learning, telemedicine, and advanced simulations, while in scientific research it allows for complex data analysis and modelling. [41]

8.3. Data Governance

Data governance is the discipline concerned with managing data as a strategic asset, ensuring its accuracy, security, accessibility, and ethical use. At its core, it establishes policies and processes that define the accessibility of data, the usage of data, and the quality of

[38] CCNet. "Historical Development of Digitalization: How It All Began." CCNet - Blog, June 24, 2024. https://www.ccnet.de/en/blog/dav4-historical-development-of-digitalization-how-it-all-began/?utm_source=copilot.com.
[39] CCNet. "Historical Development of Digitalization: How It All Began."
[40] Derici, Serkan. "Digitalization Concept and the Historical Evolution of Digitalization." Advances in Computer and Electrical Engineering, July 12, 2024, 90–106. https://doi.org/10.4018/979-8-3693-4111-7.ch006.
[41] Zaagsma, Gerben. "Digital History and the Politics of Digitization." Digital Scholarship in the Humanities 38, no. 2 (September 16, 2022): 830–51. https://doi.org/10.1093/llc/fqac050.

maintenance. The idea emerged in the late 20th century as organisations began to recognise that data was not just a byproduct of operations but a valuable resource that could drive decision-making and innovation. [42]

In the 2010s, data governance expanded quickly due to the explosion of big data, cloud computing, and analytics, which complicated the management of data across multiple platforms and jurisdictions. The introduction of the General Data Protection Regulation (GDPR) in 2018 in the European Union further elevated data governance by making data privacy and protection legally enforceable. Today, data governance is not only about compliance but also about enabling innovation and supporting artificial intelligence, machine learning, and digital transformation by ensuring that data is trustworthy and responsibly managed. [43]

Different models have been adopted at the national level by nations based on their institutional structures and priorities. Argentina, for example, has established centralised data stewardship through its National Statistical Office, guaranteeing uniform data governance and collection. A Chief Data Officer has been appointed in Australia to supervise government-wide data strategies with an emphasis on citizen trust and transparency. Belgium uses a federated hybrid model, which strikes a balance between centralised supervision and dispersed duties among agencies.

9. Scope of the Problem

9.1. Issues in Agriculture Sphere

9.1.1. Yield Gap

The difference between a crop's potential maximum yield under ideal circumstances and the actual yield that farmers achieve in practical situations is known as the yield gap.

[42] Holdsworth, Jim, and Matthew Kosinski. “Data Governance.” Ibm.com, September 20, 2024. https://www.ibm.com/think/topics/data-governance?
[43] European Commission. “Data Protection,” 2024. https://commission.europa.eu/law/law-topic/data-protection_en.

While biological factors like crop genetics, soil fertility, and water availability determine potential yield, pests, diseases, nutrient deficiencies, and management techniques limit actual yields. This disparity exposes agricultural production inefficiencies and shows that current technologies and knowledge are not being fully utilised to achieve maximum productivity.

The yield gap is further widened by climate pressures, which introduce unpredictable variables that restrict production. Rising temperatures, shifting rainfall patterns, and increased frequency of droughts or floods reduce the stability of growing seasons and push yields closer to their biological limits. For example, crops like maize and wheat are highly sensitive to heat stress during flowering, which can drastically reduce yields even when other conditions are favourable. These climate-induced risks make it harder for farmers to close the yield gap, as they must adapt to changing environments while maintaining productivity. [44]

9.1.2. Production Limits

Production limits are the natural and ecological boundaries that limit how much agricultural output can be increased, even when farmers use improved practices and technologies. In contrast to the yield gap, which highlights inefficiencies between potential and actual yields, production limits represent crops and livestock's biological ceiling. Plant physiology, soil fertility, water availability, and ecosystems' finite capacity to support intensive farming all influence these limits. For example, a wheat plant has a maximum genetic potential for grain production that no amount of fertiliser or irrigation can exceed without causing environmental stress. [45]

9.1.3. Climate Volatility and Environmental Degradation

[44] "GENETIC RESOURCES for FOOD SECURITY and NUTRITION OVERALL GOAL Conserving Genetic Resources for Food and Agriculture and Promoting Their Use in Support of Global Food Security and Sustainable Development for Present and Future Generations," n.d. https://openknowledge.fao.org/server/api/core/bitstreams/e90eaed4-3759-48d7-a956-0534298d80bb/content.

[45] SDGIndicators. "Analytical Reports | SDG Indicators Data Portal | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/sustainable-development-goals-data-portal/resources/analytical-reports/?

Climate volatility refers to the increasing unpredictability and intensity of weather patterns caused primarily by global warming. Rising temperatures are making natural climate oscillations like the El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and North Atlantic Oscillation (NAO) more disruptive, resulting in crop failures across regions. [46] ENSO events, for example, can cause droughts in Sub-Saharan Africa while also triggering floods in South Asia, causing global food supply chains to become unstable.

Global warming amplifies these oscillations, increasing the frequency and severity of extreme events. Heat stress during critical crop growth stages, such as flowering in maize or rice, has been shown in studies to reduce yields in affected regions by up to 50%. [47]Volatility also undermines farmers' ability to plan by making traditional knowledge of seasonal cycles unreliable. This unpredictability raises production risks, lowers resilience, and makes smallholder farmers more vulnerable because they lack access to insurance or adaptive technologies.

Environmental degradation refers to the long-term decline of ecosystems due to human activity and climate change. Deforestation, soil erosion, nutrient depletion, salinisation, and desertification are all processes that reduce land's ability to sustain agriculture.[48] For example, soil erosion removes fertile topsoil, reducing crop productivity, and salinisation from irrigation mismanagement renders land unsuitable for cultivation.

Deforestation not only reduces biodiversity, but it also disrupts the carbon and water cycles, increasing climate volatility. Land degradation is estimated to affect more than 3.2 billion people worldwide, with serious consequences for rural livelihoods and food security. In Sub-Saharan Africa and South Asia, degradation interacts with climate variability to form

[46] Li, Linchao, Bin Wang, Puyu Feng, Chaoqun Lu, Jonas Jägermeyr, Senthold Asseng, Jing-Jia Luo, et al. "Global Warming Increases the Risk of Crop Yield Failures Driven by Climate Oscillations." One Earth 8, no. 6 (June 2025): 101318. https://doi.org/10.1016/j.oneear.2025.101318.

[47] Li, Linchao, Bin Wang, Puyu Feng, Chaoqun Lu, Jonas Jägermeyr, Senthold Asseng, Jing-Jia Luo, et al. "Global Warming Increases the Risk of Crop Yield Failures Driven by Climate Oscillations."

[48] Dubey, Aastha, Prasun Kumar Singh, Shalini Singh, Uzma Manzoor, Chinmaya Sahoo, and Ankit Saini. "Impact of Climate Change and Land Degradation on Agriculture." Sustainability Solutions, 2025, 49–95. https://doi.org/10.1007/978-3-032-00708-7_3.

a vicious cycle: degraded soils are more vulnerable to droughts and floods, which accelerates further degradation. [49]

The interaction of climate volatility and environmental degradation creates additional risks to agriculture. According to the FAO, climate extremes, combined with degraded soils and ecosystems, increase the likelihood of simultaneous yield failures across major breadbasket regions, endangering global food security. Long-term droughts, for example, in degraded lands can cause crop failure, livestock mortality, and forced migration. [50]

Furthermore, degradation reduces ecosystems' adaptive capacity, making them less resilient to climate shocks. This means that even moderate climate variability can have disastrous consequences when combined with degraded soils, deforested landscapes, or polluted water systems. The end result is a feedback loop in which climate volatility accelerates degradation and degradation amplifies the effects of climate volatility.

9.1.4. Pest, Disease and Biosecurity Threats

Pest, disease, and biosecurity Threats pose systemic risks to agriculture, food security, and ecosystem health, resulting from the spread of harmful organisms and pathogens that disrupt production and stability. These threats are exacerbated by globalisation, climate change, and environmental degradation, necessitating integrated governance frameworks to manage risks to plant, animal, and human health.

Pests are organisms that harm crops, livestock, or stored products, lowering yields and jeopardising food supply chains. Insects, weeds, and invasive species compete for or destroy agricultural resources. Pest persistence is associated with ecological imbalances, monoculture farming, and climate variability, all of which increase their geographic range and resilience. [51]

[49] Dubey, Aastha, Prasun Kumar Singh, Shalini Singh, Uzma Manzoor, Chinmaya Sahoo, and Ankit Saini. “Impact of Climate Change and Land Degradation on Agriculture.”
[50] Fao.org. “FAO Knowledge Repository,” 2025. https://openknowledge.fao.org/items/ed331aea-c65e-4770-a096-d449cc50fcdf?.
[51] Fao.org. “FAO Knowledge Repository,” 2025. https://openknowledge.fao.org/items/c9304805-d858-433c-a137-a553b0846517?.

Agricultural diseases affect both plants and animals and are caused by fungi, bacteria, viruses, and parasites. Plant diseases like rusts, blights, and wilts lower productivity, whereas livestock diseases like foot-and-mouth disease or avian influenza disrupt trade and food systems. Pathogen spread is accelerated by global trade, intensive farming, and weakened ecosystems. Disease management involves surveillance, resistant breeding, and biosecurity measures to prevent outbreaks from escalating into regional or global crises.

Biosecurity refers to the policies and practices used to prevent, control, and eradicate pests and diseases. It is a comprehensive approach that incorporates plant, animal, and human health within the One Health framework, recognising ecosystem interdependence. Quarantine regulations, border inspections, sanitary standards, and international cooperation all help to reduce risks. The FAO emphasises biosecurity as essential to protect food production, biodiversity, and human health, ensuring resilience against invasive species and emerging pathogens. [52]

Globalisation facilitates the movement of goods and organisms, increasing the risk of transboundary pest and disease transmission. Climate change exacerbates these threats by altering habitats, allowing pests and pathogens to thrive in new areas, and stressing agricultural systems. Environmental degradation, such as soil erosion and biodiversity loss, weakens natural defences, leaving ecosystems vulnerable. These pressures create a feedback loop in which weakened environments amplify pest and disease risks, and outbreaks further degrade ecosystems.

9.2. Issues in Efficiency Sphere

9.2.1. Definition of Efficiency in Context of Political Science

In political science literature, agricultural efficiency refers to the optimal use of resources (land, labour, capital, and technology, among others) within governance and

[52] OneHealth. “Biosecurity,” 2024. https://www.fao.org/one-health/areas-of-work/biosecurity/en?

institutional frameworks to maximise agricultural output while minimising waste, inequality, and environmental harm. It is more than just a technical measure of productivity; it also reflects how political institutions, policies, and governance structures influence the distribution and effectiveness of agricultural resources.

To elaborate, efficiency in agriculture has traditionally been defined as the relationship between inputs (such as land, water, seeds, fertiliser, and labour) and outputs (crop yields, livestock production, or value added). In political science, however, efficiency is more broadly defined as the ability of governance systems to allocate resources fairly and effectively in order to achieve agricultural productivity and sustainability. It entails both technical efficiency (maximising output from given inputs) and allocative efficiency (ensuring that resources are allocated to the most socially beneficial uses).

In terms of political science, agricultural efficiency is inextricably linked to governance quality, institutional arrangements, and policy frameworks. Studies show that indicators such as the rule of law, government effectiveness, regulatory quality, and corruption control have a significant impact on agricultural efficiency. [53] Efficient agricultural systems require not only technology but also political stability, equitable land distribution, and open decision-making. Countries with strong governance structures, for example, are more likely to close yield gaps and manage production risks effectively than those with weak institutions.

9.2.2. The Paradox of Input Efficiency in Agriculture

The paradox of input efficiency describes the situation in which increases in agricultural input efficiency do not always result in lower overall resource use or environmental impact. Instead, efficiency gains frequently encourage increased production and intensification, which can offset or even outweigh the anticipated benefits. This

[53] Bayyurt, Nizamettin, and Fatma Eban ArÄ±kan. “Good Governance and Agricultural Efficiency.” Journal of Social and Development Sciences 6, no. 1 (March 30, 2015): 14–23. https://doi.org/10.22610/jsds.v6i1.831.

phenomenon is closely related to the Jevons Paradox, which was first formulated in the nineteenth century and explains how technological improvements that increase resource efficiency can paradoxically result in higher aggregate consumption. [54]

In agriculture, efficiency is pursued through innovations such as precision farming, drip irrigation, and improved fertiliser formulations. These technologies enable farmers to produce more with fewer resources, potentially reducing waste and environmental damage. However, lower costs per unit of output frequently encourage farmers to expand cultivation, increase yields, or intensify production. [55]As a result, total input consumption may increase, and environmental pressures such as soil degradation, water scarcity, and greenhouse gas emissions may worsen. This rebound effect shows that efficiency alone cannot ensure sustainability.

This paradox has important implications for agricultural governance and sustainability. From a political science perspective, efficiency must be embedded in institutional frameworks that align technological advancements with broader social and environmental goals. Without regulatory oversight, efficiency gains risk fuelling unsustainable intensification. Policies such as resource-use caps, incentives for circular economy practices, and sustainability standards are required to ensure that efficiency leads to genuine reductions in environmental impact. The paradox of input efficiency highlights the tension between technological progress and systemic sustainability, emphasising the need for integrated approaches that combine innovation with governance, equity, and ecological limits. [56]

9.2.3. Supply Chain Fragility and Food Loss

[54] Ceddia, M.G, S Sedlacek, N.O Bardsley, and S. Gomez-y-Paloma. "Sustainable Agricultural Intensification or Jevons Paradox? The Role of Public Governance in Tropical South America." Global Environmental Change 23, no. 5 (August 20, 2013): 1052–63. https://doi.org/10.1016/j.gloenvcha.2013.07.005.
[55] OECD. "Resource Efficiency and Circular Economy," 2025. https://www.oecd.org/en/topics/policy-issues/resource-efficiency-and-circular-economy.html.
[56] World Bank. "Overview," 2025. https://www.worldbank.org/en/topic/agriculture/overview.

Agriculture supply chain fragility refers to the susceptibility of food systems to disruptions at all stages of production, processing, distribution, and consumption. Modern agricultural supply chains are highly globalised and complex, with multiple actors and cross-border trade. This interconnectedness improves efficiency while also creating systemic risks, as shocks in one part of the chain can cascade globally. Climate volatility, geopolitical tensions, trade restrictions, infrastructure vulnerabilities, and reliance on limited logistical actors all contribute to fragility. [57]

Food loss is closely related to supply chain fragility, as it represents a decrease in quantity or quality of food before it reaches consumers. Losses occur at various stages, including harvesting, storage, transportation, processing, and retailing. Approximately 14% of food produced globally is lost between harvest and retail, with an additional 17% wasted by consumers. [58] Structural inefficiencies, inadequate cold chains, and poor governance all contribute to these losses. In terms of political economy, food loss reflects not only technical inefficiencies but also institutional failures to ensure equitable resource distribution and effective policy frameworks. [59]

The interaction of supply chain fragility and food loss generates systemic risks to food security and sustainability. Fragile supply chains exacerbate losses during crises because disruptions in logistics or trade can prevent food from reaching markets, resulting in waste even when production levels are high. Persistent food loss, on the other hand, weakens supply chain resilience by reducing efficiency and increasing demand for natural resources. Addressing these issues necessitates integrated governance approaches that incorporate technological innovation, infrastructure investment, and institutional reform. [60]

---

[57] "AGRICULTURAL TRADE, CLIMATE CHANGE and FOOD SECURITY AGRICULTURAL COMMODITY MARKETS 2018 the STATE OF," n.d. https://openknowledge.fao.org/server/api/core/bitstreams/2263cf55-1ad8-4121-929d-bd9d34f786e0/content.

[58] FoodLossWaste. "Technical Platform on the Measurement and Reduction of Food Loss and Waste | Food and Agriculture Organization of the United Nations," 2015. https://www.fao.org/platform-food-loss-waste/en.

[59] Worldbank.org. "Development Topics | World Bank Group," 2025. https://www.worldbank.org/ext/en/development-topics.

[60] OECD. "Agriculture and Fisheries," 2025. https://www.oecd.org/en/topics/agriculture-and-fisheries.html.

9.2.4. System interoperability and fragmentation in agriculture and food systems

System interoperability refers to the ability of various technological, institutional, and organisational systems in agriculture and food supply chains to communicate, exchange data, and work together seamlessly. It ensures that diverse actors, like farmers, governments, private companies, and international organisations, can efficiently coordinate through shared standards, platforms, and governance mechanisms. [61] Interoperability is critical for resource optimization, policy coherence, and resilience, as it allows integration of information across domains such as production, logistics, trade, and environmental monitoring. [62]

In contrast, fragmentation occurs when systems are isolated, incompatible, or poorly coordinated. This can manifest itself in technological silos, where digital platforms and databases cannot exchange information, or in institutional fragmentation, where policies and regulations differ across jurisdictions without harmonisation. Fragmentation reduces efficiency, duplicates efforts, and reduces the capacity to respond to systemic challenges such as climate volatility, food insecurity, and biosecurity threats. [63]

The tension between interoperability and fragmentation is especially noticeable in global food governance. While interoperability encourages transparency, traceability, and coordinated crisis responses, fragmentation reflects national sovereignty, competing standards, and uneven technological adoption. In a policial perspective, fragmentation is frequently caused by power imbalances, in which stronger actors impose standards that weaker actors cannot meet, resulting in exclusion and inefficiency. [64] Interoperability, on the

[61] AgroInformatics. “Home | Agro-Informatics | Food and Agriculture Organization of the United Nations,” September 15, 2022. https://www.fao.org/agroinformatics/en.
[62] OECD. “Agriculture and Fisheries,” 2025
[63] “AGRICULTURAL TRADE, CLIMATE CHANGE and FOOD SECURITY AGRICULTURAL COMMODITY MARKETS 2018 the STATE OF,” n.d.,
[64] OECD. “Agriculture and Fisheries,” 2025

other hand, necessitates collaborative action, shared governance frameworks, and investment in common infrastructures to ensure inclusiveness and resilience. [65]

9.3. Issues in Economic Sphere

9.3.1. The Digital Divide and Economic Inequality

The digital divide is defined as the unequal distribution of access to information and communication technologies, which has been identified as a structural barrier to inclusive development and a source of inequality, particularly in rural and agricultural settings. The FAO has emphasised the importance of bridging this divide in order to achieve the Sustainable Development Goals (SDGs) and ensure that rural populations do not miss out on the benefits of digitalisation.

The digital divide is defined as a multidimensional phenomenon that includes disparities in infrastructure, affordability, digital literacy, and institutional capacity. It has been observed that limited access to digital technologies disproportionately affects rural areas, smallholder farmers, women, and youth, limiting their ability to participate in modern agricultural systems, markets, and governance structures. According to FAO, digitalisation has the potential to transform agriculture and food systems; however, without deliberate efforts to address the divide, these benefits risk being captured only by those with existing resources and capacities. [66]

The perpetuation of the digital divide has been linked to structural inequalities in infrastructure investment, particularly rural connectivity. Gaps in broadband coverage, electricity supply, and access to affordable devices have been identified as primary barriers preventing rural communities from leveraging digital tools. It has been noted that these

[65] “Technical Platform on the Measurement and Reduction of Food Loss and Waste | Food and Agriculture Organization of the United Nations,” FoodLossWaste, 2015

[66] Newsroom. “Digitalization: It Is Time to Bridge the Gap between Urban and Rural Areas.” FAO, May 27, 2024. https://www.fao.org/newsroom/detail/digitalization--it-is-time-to-bridge-the-gap-between-urban-and-rural-areas/?

infrastructural deficits are compounded by affordability challenges, as the cost of smart farming equipment, precision agriculture solutions, and digital services remains prohibitive for many small-scale producers. [67]

Another critical aspect of the divide is digital literacy. Even when infrastructure and devices are available, vulnerable populations' ability to benefit from digital technologies is limited by a lack of skills in using them effectively. FAO has emphasised that digital inclusion necessitates not only physical access but also the development of human capital, such as training and education, to ensure that rural communities can fully participate in digital economies. This has been framed as necessary to avoid reinforcing cycles of exclusion and inequality. [68]

The digital divide has also been framed within the larger context of sustainable development. The FAO has stated that digital inclusion is a prerequisite for achieving multiple SDGs, including those related to poverty reduction, decent work, and long-term economic growth. The divide has been described as both a cause and a consequence of inequality; exclusion from digital opportunities perpetuates economic and social disparities, whereas existing inequalities limit marginalised groups' access to digital tools. This interdependence has been identified as a systemic challenge that requires coordinated global governance responses. [69]

9.3.2. Economic Inequality

[67] SDGHelpdesk. "FAO at the UNECE Regional Forum on Sustainable Development 2025: SDG 8 Roundtable," 2025. https://www.fao.org/sustainable-development-goals-helpdesk/transform/article-detail/fao-at-the-unece-regional-forum-on-sustainable-development-2025--sdg-8-roundtable/en?utm_source=copilot.com.

[68] FAODirectorGeneral. "Director-General Highlights the Transformational Potential of Digitalization and Calls for Tackling the Digital Divide in a Speech to the World Summit on the Information Society Forum." FAO, March 14, 2023. https://www.fao.org/director-general/news/details/Director-General-highlights-the-transformational-potential-of-digitalization-and-calls-for-tackling-the-digital-divide-in-a-speech-to-the-World-Summit-on-the-Information-Society-Forum/en?

[69] Newsroom. "Digitalization: It Is Time to Bridge the Gap between Urban and Rural Areas." FAO, May 27, 2024.

Economic inequality has been defined as a broad term that includes income inequality, wealth inequality, and consumption inequality. Income inequality refers to differences in the distribution of earnings among individuals or households, whereas wealth inequality refers to differences in asset ownership, such as real estate, savings, and investments. Consumption inequality has been defined as unequal access to goods and services, resulting in disparities in living standards. [70]

Economic inequality has structural and multifaceted causes. Education and skill gaps have been identified as primary drivers, as unequal access to high-quality education perpetuates disparities in labour market outcomes. Globalisation and technological change have also contributed to inequality, with high-skilled workers and capital owners benefiting disproportionately from new opportunities, while low-skilled workers have experienced wage stagnation or job displacement. Also, institutional factors such as tax regimes, labour market regulations, and social protection systems have influenced the distribution of income and wealth. Inequality of opportunity, defined as disparities arising from circumstances outside individual control such as family background, gender, or ethnicity, has been emphasised as a critical determinant of long-term inequality. [71]

Economic inequality has had a wide-ranging impact on the economy, society, and politics. Economically, high levels of inequality have been linked to lower aggregate demand, less investment in human capital, and slower long-term growth. Social inequality has been linked to lower social mobility, higher poverty rates, and greater disparities in health and education outcomes. Politically, persistent inequality has been linked to weakened democratic institutions, lower trust in governance, and a higher risk of social unrest. These impacts have

[70] IMF. "Introduction to Inequality," June 5, 2024.
https://www.imf.org/en/topics/inequality/introduction-to-inequality?utm_source=copilot.com.
[71] Duignan, Brian. "Economic Inequality." Encyclopedia Britannica, June 13, 2025.
https://www.britannica.com/story/economic-inequality.

been identified as systemic, reinforcing cycles of exclusion and limiting societies' capacity to achieve inclusive development. [72]

9.3.3. Data Economics and Sovereignty

Data economics and sovereignty in agriculture are defined by the governance of non-personal data, valuation mechanisms, and institutional frameworks that govern ownership, access, and utilisation. These dimensions are increasingly being recognised as critical to food system equity, sustainability, and innovation.

The concept of data sovereignty has been defined as stakeholders' right to control the collection, storage, and use of data generated within agricultural value chains. Data sovereignty has been emphasised as not only a legal construct but also an economic and institutional principle, as data ownership and governance have a direct impact on the distribution of value among actors. In agricultural contexts, sovereignty has been linked to the ability of farmers and cooperatives to negotiate data-sharing agreements, ensure transparency in contractual arrangements, and prevent power imbalances between technology providers and producers. [73]

The economic dimension of data has been examined using valuation models that consider both direct and indirect benefits. Direct benefits include commercial applications like precision input management and market intelligence, whereas indirect benefits include ecosystem services, knowledge generation, and long-term sustainability outcomes. A valuation framework has been proposed that takes into account investment costs, potential commercial usage, and data's broader social and ecological value, allowing it to be included in agricultural accounting practices. [74]

---

[72] Dheyaa Khalaf and Ahmed Dildar, "Income Inequality: A Microeconomic Analysis of Its Causes and Consequences," Tuijin Jishu/Journal of Propulsion Technology 44, no. 5 (2023): 1001–4055.
[73] "Data Sovereignty in Agricultural Value Chains Study and Recommendations." Accessed December 29, 2025. https://www.foodfortransformation.org/files/upload/4%20Digitalisierung%20und%20Innovation/20230111_Study%20Datensouver%C3%A4nit%C3%A4t/Study_Data_Sovereignty_200922_final.pdf?
[74] Gans Combe, Caroline, and Stéphanie Camaréna. "Data Sovereignty and Valuation Model for Sustainable Agriculture Innovation and Equity." Npj Sustainable Agriculture 3, no. 1 (November 18, 2025). https://doi.org/10.1038/s44264-025-00102-z.

Legal and institutional mechanisms have been investigated as important sources of sovereignty. Because much of the data generated in agriculture is non-personal, it is not subject to personal data protection regimes like the General Data Protection Regulation (GDPR). This has resulted in governance gaps that necessitate alternative instruments such as voluntary codes of conduct, contractual standards, and cooperative data trusts. These mechanisms have been identified as necessary to balance the dual path of shared access and individual ownership, ensuring that innovation is not impeded while rights are preserved. [75]

Educational and technological barriers have also been identified. Limited digital literacy among producers, insufficient infrastructure for secure data storage, and a lack of interoperability between platforms have all hampered the realisation of sovereignty. Addressing these barriers has been deemed critical for equitable participation in data-driven economies. Gender equity has also been emphasised as a dimension of sovereignty, because unequal access to digital tools and decision-making processes can reinforce existing disparities. [76]

Data sovereignty has systemic implications for governance at both the national and international levels. Sovereignty has been framed as a prerequisite for long-term innovation, because without clear ownership and valuation, data risks being monopolised by a few actors, reducing collective benefits. Policy frameworks have thus been urged to integrate sovereignty principles into agricultural strategies, ensuring that data flows are managed in ways that respect local rights while facilitating global cooperation. [77]

9.3.4. Labor Market Disruption

---

[75] Berisha, Fjolla, Peter Mooney, Zohreh Pourzolfaghar, and Markus Helfert. "Shared yet Owned: The Dual Path of Data Ownership in Agriculture: A Systematic Review." Data & Policy 8 (December 29, 2025). https://doi.org/10.1017/dap.2025.10050.

[76] Gans Combe, Caroline, and Stéphanie Camaréna. "Data Sovereignty and Valuation Model for Sustainable Agriculture Innovation and Equity."

[77] Data Sovereignty in Agricultural Value Chains Study and Recommendations."

Automation and digital technologies have changed occupational structures by reducing the demand for manual labour in repetitive tasks like harvesting, sorting, and monitoring. According to research, mechanisation and algorithmic systems have resulted in significant reductions in low-skilled employment while increasing demand for workers with expertise in data management, system maintenance, and analytical functions. [78] This shift has been interpreted as a transfer of labour from the physical to the cognitive domains, necessitating new forms of training and education.

The economic implications of this disruption have been examined through the lenses of productivity and wage dynamics. While automation has increased efficiency and reduced costs, it has also led to wage polarisation, with high-skilled workers benefiting from increased demand and low-skilled workers facing fewer opportunities. This polarisation has been linked to larger structural disparities in rural areas, where access to education and digital infrastructure is still uneven. [79]

The social dimension of disruption has been observed in rural areas, where changes in labour demand have altered demographic patterns and migration flows. Younger people have been drawn to new opportunities in technologically advanced industries, while older workers have been excluded due to their limited adaptability. This has raised concerns about generational gaps and the sustainability of rural livelihoods.

From a systemic standpoint, labour market disruption has been portrayed as both a challenge and an opportunity. On the one hand, it risks exacerbating inequalities and undermining traditional employment structures; on the other, it allows for the development of resilient, knowledge-based economies capable of supporting long-term agricultural

[78] Apicella, Andrea. “Automation in Agriculture: Occupational Trends, Worker Outcomes, and Labor Market Implications.” International Journal of Academic Research in Business and Social Sciences 15, no. 8 (August 7, 2025). https://doi.org/10.6007/ijarbss/v15-i8/26128.
[79] Ndhlovu, Emmanuel. “Digital Agriculture: Implications for the Agricultural Labour Market.” International Journal of Research in Business and Social Science (2147- 4478) 14, no. 4 (July 15, 2025): 335–46. https://doi.org/10.20525/ijrbs.v14i4.3997.

transformation. The path of disruption has thus been understood as dependent on governance choices, institutional capacity, and the ability to integrate social safeguards into economic modernisation.

10. Risks and Possible Outcomes of Adaptation

10.1. The Inequality of Adaptation

10.1.1. The Matthew Effect

The Matthew Effect is a sociological principle in which "the rich get richer and the poor get poorer," which applies to situations in which early adopters of technological innovations reap disproportionate benefits. In agricultural systems, this has resulted in the concentration of data, capital, and market access among larger or better-connected producers, while smaller farmers continue to be excluded from the benefits of digital transformation. The effect has been linked to systemic inequalities, as access to digital tools, infrastructure, and knowledge varies across regions and social groups.

According to research, the Matthew Effect in farming networks manifests itself through power asymmetries. Farmer producer companies and cooperatives, while intended to democratise access, frequently reproduce legacy hierarchies, with certain actors wielding significant power over market connections and digital resources. This concentration of power has been shown to undermine resilience. Networks dominated by a few actors are less adaptable to shocks and less inclusive in distributing benefits. [80]

The economic consequences of the Matthew Effect have been examined in terms of cumulative advantage. Larger producers who can invest in digital technologies gain efficiency, market intelligence, and bargaining power, bolstering their competitive position. Smaller producers, who lack the resources to implement such technologies, face lower relative productivity and market participation. This divergence has been considered a driver

[80] Jayaraman, Aishwarya, Sudhir Chella Rajan, and Palaniappan Ramu. "Food System Resilience: Unraveling Power Relations and the Matthew Effect in Farmers Networks." Technological Forecasting and Social Change 200 (March 2024): 123144. https://doi.org/10.1016/j.techfore.2023.123144.

of structural inequality in rural economies, reinforcing the existing divides between capital-rich and resource-poor actors. [81]

10.1.2. The "Hollowing Out" of Rural Economies

The hollowing out of rural economies is defined as the gradual deterioration of local productive structures, employment bases, and community resilience as a result of technological change, demographic shifts, and structural inequalities. This process has been identified as a critical challenge for long-term inclusive agricultural transformation. The phenomenon has been described as the decline of traditional economic activities in rural areas, with automation and digitalisation reducing demand for manual labour while failing to provide equivalent opportunities for displaced workers. As repetitive tasks are increasingly replaced by automated and data-driven systems, the economic foundation of many rural communities deteriorates, resulting in declining employment, reduced income diversity, and weakened local markets. This hollowing out has been reinforced by migration patterns, as younger populations move to urban areas in search of better opportunities, leaving behind ageing demographics with limited adaptability to new technologies. [82]

The hollowing out process has far-reaching implications for social cohesion and resilience. As economic opportunities decrease, so does trust in local institutions, reducing collective capacity to respond to shocks. This erosion of resilience has been viewed as particularly problematic in contexts where rural economies play a critical role in food security and environmental stewardship. Without deliberate interventions, the weakening of rural structures has the potential to undermine broader sustainability goals.

10.2. Systemic Vulnerabilities

---

[81] Ammar, Esraa E., Samah Abdel Aziz, Xiaobo Zou, Sohaila A. Elmasry, Soumya Ghosh, Basma M. Khalaf, Nouran A. EL-Shershaby, et al. “An In-Depth Review on the Concept of Digital Farming.” Environment, Development and Sustainability, June 29, 2024. https://doi.org/10.1007/s10668-024-05161-9.

[82] Europa.eu. “Harnessing Digitalisation for Sustainable Agriculture and Resilient Rural Communities: New EESC Study | Rural Pact Community Platform,” 2025. https://ruralpact.rural-vision.europa.eu/news/harnessing-digitalisation-sustainable-agriculture-and-resilient-rural-communities-new-eesc_en?

10.2.1. The “Black Box” Problem

The "Black Box" problem in agriculture refers to the opacity of algorithmic systems and digital platforms, where decisions are made without transparent explanations, posing risks to accountability, sovereignty, and fair governance. The problem is defined by the reliance on artificial intelligence and machine learning models, which produce highly accurate results but lack interpretability. These systems frequently operate as opaque mechanisms, with users having difficulty understanding the logic behind predictions, classifications, or recommendations. In agricultural settings, this opacity has been linked to decisions about resource allocation, crop management, and market participation, all of which are increasingly mediated by algorithms. The lack of transparency has been deemed problematic because it undermines trust, limits stakeholders' ability to contest or validate outcomes, and concentrates power in the hands of technology providers. [83]

The “Black Box” nature of digital systems has been linked to the erosion of sovereignty, as farmers and institutions become reliant on proprietary platforms whose internal operations are inaccessible. This dependency has been described as a form of asymmetry, in which corporations centralise knowledge and control while producers are cut off from understanding how their data is processed and used. Such asymmetries have been demonstrated to weaken bargaining power, reduce autonomy, and create vulnerabilities in governance structures. [84]

When decisions are made by algorithms that lack transparency, errors or biases embedded within them may propagate across entire systems without detection. This is especially problematic when predictive systems fail to account for local conditions, as the resulting recommendations may be misaligned with real-world contexts and potentially

---

[83] Ngo, Quoc Hung, Tahar Kechadi, and Nhien-An Le-Khac. “OAK4XAI: Model towards Out-Of-Box EXplainable Artificial Intelligence for Digital Agriculture.” arXiv.org, 2022. https://arxiv.org/abs/2209.15104?

[84] Bioneers. “Farming in the Dark: The Black Box of AI and the Erosion of Food Sovereignty - Bioneers.” Bioneers, July 3, 2025. https://bioneers.org/farming-in-the-dark-the-black-box-of-ai-and-the-erosion-of-food-sovereignty-ztvz2507/?

harmful. Because such systems are difficult to examine or modify, stakeholders frequently fail to identify or correct errors, reducing the system's ability to adapt to changing real-world conditions. [85]

10.2.2. Cybersecurity and Biosecurity Threats

The expansion of digital infrastructures in agriculture has created new vulnerabilities, which are exploited by cyberattacks on farm management systems, sensor networks, and cloud-based platforms. The integration of Internet of Things devices, drones, and automated machinery has resulted in complex ecosystems that make intrusion detection difficult and allow malicious actors to manipulate data flows, disable equipment, or undermine decision-making processes. According to research, ransomware, denial-of-service attacks, and data breaches are becoming more common in smart agriculture, with consequences ranging from financial losses to systemic disruptions in supply chains. [86]

As biological data, such as genetic resources, soil microbiome information, and pathogen surveillance records, become digitised and stored in cloud systems, the risk of unauthorised access or manipulation rises. Such breaches may result in the misuse of sensitive biological information, the alteration of disease monitoring systems, or the disruption of biosecurity protocols. The digitisation of biosecurity infrastructures has created a dual vulnerability in which both cyber and biological risks converge, amplifying potential impacts on food safety and public health.

Governance frameworks have been identified as being inadequately prepared to address these converging threats. While cybersecurity policies exist in broader contexts, agriculture-specific standards remain underdeveloped, leaving critical infrastructures

[85] Ngo, Quoc Hung, Tahar Kechadi, and Nhien-An Le-Khac. “OAK4XAI: Model towards Out-Of-Box EXplainable Artificial Intelligence for Digital Agriculture
[86] Campoverde-Molina, Milton, and Sergio Luján-Mora. “Cybersecurity in Smart Agriculture: A Systematic Literature Review.” Computers & Security 150 (March 2025): 104284. https://doi.org/10.1016/j.cose.2024.104284.

exposed. Biosecurity regulations have traditionally focused on physical containment and monitoring but have not fully integrated digital safeguards, resulting in resilience gaps.

10.3. Biological Simplification

Biological simplification, also known as the emergence of algorithmic monocultures, has been defined as the loss of ecological and genetic diversity caused by the widespread use of uniform technological and data-driven practices in agriculture.

The phenomenon has been described as the result of digital systems that prioritise efficiency and standardisation. Algorithms trained on dominant datasets typically recommend the same crop varieties, input regimes, and management strategies, resulting in landscape homogeneity. When these outputs are widely used, ecosystems lose heterogeneity, and production systems' adaptive capacity decreases. This narrowing of biological bases has been considered dangerous because it makes crops more vulnerable to pests, diseases, and climate variability, while also limiting the potential for innovation in diverse farming practices. [87]

Algorithmic monocultures have also been associated with the concentration of knowledge and control. When predictive systems are developed and owned by a small number of corporations or institutions, the recommendations they generate reinforce pre-existing production patterns. Farmers who rely on these systems frequently have little flexibility to tailor outputs to local conditions, reducing autonomy and sovereignty. This dependency has been described as a structural imbalance, in which power is centralised in technological infrastructures and local communities are excluded from shaping their own strategies. [88]

10.4. Data Colonialism and Loss of Sovereignty

[87] Mohsen Yoosefzadeh Najafabadi, and Scott A Jackson. "Hybrid AI in Synthetic Biology: Next Era in Agriculture." Trends in Plant Science, September 1, 2025. https://doi.org/10.1016/j.tplants.2025.08.011.
[88] Chinese Academy of Sciences. "Scientists Outline Integrated AI-Biotech Approach to Advance Sustainable Crop Development." Phys.org, July 23, 2025. https://phys.org/news/2025-07-scientists-outline-ai-biotech-approach.html?

Data colonialism in agriculture has been defined as the extraction and control of information by third parties, in which data generated by local producers and institutions is collected, stored, and monetised without transparent redistribution mechanisms, resulting in a loss of autonomy and sovereignty. Farmers and rural communities generate large volumes of data through production, monitoring, and resource management; however, ownership and governance of this data are frequently concentrated in corporations or institutions that control digital infrastructures, creating structural imbalances that mirror earlier forms of colonial resource exploitation. [89]

This dynamic has been linked to reliance on proprietary platforms, in which agricultural decisions are mediated by external systems that determine resource allocation, market participation, and policy design, reducing local actors' bargaining power and reinforcing reliance on outside providers. In this context, sovereignty has been defined as the right to control data flows and ensure fair distribution of benefits; however, global corporations that dominate technological infrastructures frequently undermine this right.

Data colonialism has far-reaching implications for governance and sustainability, as policies shaped by external ownership frequently fail to reflect local realities in favour of efficiency and profit. This has been described as a continuation of colonial patterns, in which knowledge and value are extracted from the Global South and concentrated in the Global North, reproducing inequalities and limiting local communities' ability to shape their own futures.

11. Current Challenges

11.1. The Triple Divide

In FAO's infrastructure work, the triple divide is defined as the combination of digital, rural, and gender barriers that limit equitable access to technologies and weaken rural

[89] Alam, Firoze. “Precision Agriculture and the Emergence of Data Colonialism.” The Palgrave Handbook on Decoloniality in Asia, 2025, 263–80. https://doi.org/10.1007/978-981-96-2336-5_13.

communities' ability to benefit from transformation. The digital divide reflects unequal access to connectivity, devices, and digital literacy, which excludes many rural populations from new opportunities. [90] Geographic isolation and poor infrastructure are examples of the rural divide, as they limit integration into markets and knowledge systems, lowering competitiveness and resilience. The gender divide manifests itself in unequal access to tools, training, and decision-making, with women being disproportionately excluded from technological benefits, exacerbating systemic inequality. [91]

The digital divide manifests itself when rural communities lack reliable internet access, preventing them from using modern tools and services. It also appears when farmers cannot afford the equipment or software required to participate in digital markets. Limited digital literacy exacerbates the gap, as many producers are unable to use available technologies effectively. [92]

The rural divide shows itself in geographic isolation, with communities cut off from infrastructure that promotes innovation and market integration. Rural populations find it more difficult to connect to larger economic networks due to inadequate transportation and energy infrastructure. These areas are less likely to benefit from national and global strategies due to a lack of institutional support.

The gender divide emerges when women have less access to digital tools than men, limiting their participation in FAO innovation. It also appears in training programmes, where women are frequently excluded or under-represented, limiting their ability to learn new skills. Women's perspectives are frequently overlooked during decision-making processes, which reinforces inequalities in governance and resource distribution.

---

[90] Fao.org. "FAO Knowledge Repository," 2025. https://openknowledge.fao.org/items/029121f1-a4f5-49c3-9e97-ec71e72867df.

[91] Fao.org. "Digital Public Goods for Digital Agriculture and Innovation: Key Takeaways from LLDC3 | E-Agriculture | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/e-agriculture/news/digital-public-goods-digital-agriculture-and-innovation-key-takeaways-lldc3

[92] Fao.org. "Digital Public Goods for Digital Agriculture and Innovation: Key Takeaways from LLDC3 | E-Agriculture | Food and Agriculture Organization of the United Nations," 2025

FAO has emphasised that overcoming the triple divide necessitates investment in digital public infrastructure, which provides interoperable, secure, and accessible platforms for transparent data flows and inclusive service delivery. Without such infrastructures, rural communities are excluded from innovation, and inequalities grow, undermining resilience and sustainability. As a result, the triple divide has been viewed as a structural challenge that undermines sovereignty, equity, and long-term sustainability, making it a key component of the FAO's inclusive transformation agenda. [93]

11.2. The "Data Silo" and Interoperability Crisis

The data silo and interoperability crisis in agriculture has been described as one of the most pressing challenges of digital transformation, with fragmented systems and isolated datasets impeding effective information sharing across platforms and institutions. Data silos occur when information is stored in separate infrastructures with no mechanisms for integration, resulting in duplication, inefficiency, and limited access. This fragmentation has been shown to limit the ability of farmers, policymakers, and researchers to make informed decisions, because valuable insights are locked within proprietary systems or institutional boundaries. [94]

The interoperability crisis occurs when different digital tools and platforms are unable to communicate with one another, causing barriers to data exchange and collaboration. In agriculture, there are no common standards for data formats, metadata, or governance protocols, making system integration difficult. The lack of interoperability limits the ability of digital infrastructures to deliver collective benefits because datasets remain fragmented and cannot be combined to generate comprehensive analyses. The FAO has emphasised the

---

[93] Fao.org. "Transforming Agrifood Systems with Digital Public Infrastructure, One of the Paths to Sustainable Development | E-Agriculture | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/e-agriculture/news/transforming-agrifood-systems-digital-public-infrastructure-one-paths-sustainable-development?

[94] Fao.org. "Digital Public Goods for Digital Agriculture and Innovation: Key Takeaways from LLDC3 | E-Agriculture | Food and Agriculture Organization of the United Nations," 2025.

importance of interoperability in creating inclusive and transparent digital ecosystems in which data can flow securely and equitably across actors. [95]

The persistence of silos and interoperability gaps has been linked to structural risks in governance and sovereignty, because when data infrastructures are controlled by external corporations or institutions, local actors lose the ability to manage and integrate their own information, reinforcing power dynamics as those who own interoperable systems gain control over knowledge flows and decision-making processes. This situation has been viewed not only as a technical issue but also as a systemic challenge that undermines autonomy and equity in agricultural transformation while also having implications for resilience and sustainability, because isolated datasets cannot provide the comprehensive insights required to address climate variability, market fluctuations, and resource constraints. Without interoperability, predictive models and monitoring systems are incomplete and less effective in supporting adaptive strategies, resulting in a proliferation of tools and platforms that increases data availability while decreasing usability due to fragmentation.

11.3. The Human Capital Gap Issue

The human capital gap is defined as the difference between the skills required in a digitalised environment and individuals' actual abilities to use and adapt to new technologies. In general, this gap occurs when populations lack sufficient digital literacy, which means they are unable to effectively access, interpret, and apply digital tools in education, employment, or governance. The lack of these skills reduces participation in modern economies, limits innovation, and reinforces inequalities, as those with higher digital competence gain disproportionate advantages while others are excluded. [96]

In agriculture, the human capital gap occurs when farmers, rural workers, and institutions lack the knowledge and training required to operate digital infrastructures that

[95] Fao.org. "FAO Knowledge Repository," 2025.
[96] Skills beyond School. OECD Reviews of Vocational Education and Training. OECD, 2014. https://doi.org/10.1787/9789264214682-en.

support production, resource management, and market integration. Limited digital literacy prevents the effective use of tools like data platforms, monitoring systems, and predictive models, lowering efficiency and resilience. This gap has been described as a barrier to inclusive transformation, because rural communities cannot fully benefit from technological progress without adequate skills, making them dependent on external actors and vulnerable to systemic inequalities. [97]

The human capital gap in agriculture has been reinforced by aging demographics and the trust deficit, since both factors reduce the ability of rural communities to adapt to digital transformation. Ageing demographics result in a situation in which a large proportion of farmers are older and less familiar with digital tools, limiting their ability to learn new skills and lowering the sector's overall digital literacy level. This demographic imbalance slows down the diffusion of innovation, as younger populations frequently migrate to urban areas, leaving behind communities with limited adaptability and fewer opportunities to close the human capital gap. [98]

The trust deficit exacerbates this gap, as many farmers and rural institutions are hesitant to adopt digital platforms due to concerns about data misuse, a lack of transparency, and reliance on external corporations. When trust in digital infrastructures is low, even those who have access to technology may avoid using them, reducing the effectiveness of training programmes and undermining human capital investment. This combination of ageing demographics and trust deficit is thus directly connected to the human capital gap, as limited digital literacy, reluctance to adopt innovations, and structural inequalities reinforce each other, leaving rural communities excluded from the benefits of digital transformation. [99]

11.4. Regulatory Issues and Governance Lag

[97] Fao.org. "FAO Knowledge Repository," 2025.
[98] "Transforming Agrifood Systems with Digital Public Infrastructure, One of the Paths to Sustainable Development | E-Agriculture | Food and Agriculture Organization of the United Nations," Fao.org, 2025,
[99] Fao.org. "FAO Knowledge Repository," 2025.

The regulatory and governance lag in agricultural digitalisation has been defined as the inability of institutional frameworks and policy instruments to keep up with the rapid pace of technological innovation. As advanced tools like artificial intelligence, precision farming systems, and integrated data platforms become more prevalent, regulatory structures are frequently outdated or fragmented, resulting in a misalignment between technological advancement and institutional oversight. This lag has been viewed as a systemic issue, in which governance mechanisms do not evolve in tandem with digital infrastructures, resulting in inconsistencies in data management, interoperability, and accountability. As a result, regulatory and governance lag has been acknowledged as a structural challenge in agricultural digitalisation, reflecting the gap between technological development and institutional adaptation. [100]

Data sovereignty laws and liability have been linked to a regulatory and governance lag in agriculture's digitalisation, as the rapid expansion of digital infrastructures has outpaced institutions' ability to establish clear and coherent frameworks. Data sovereignty laws define states' and communities' rights to control the collection, storage, and use of agricultural data within their jurisdiction; however, in many contexts, these laws are incomplete or inconsistently applied, reflecting the broader delay in governance adaptation.

This delay has been worsened by liability issues, as responsibility for errors, misuse, or security breaches in digital systems is often left unclear. As a result, farmers, businesses, and governments lack clear accountability. The lack of shared liability rules demonstrates that governance has not kept pace with technological advancement, resulting in gaps in oversight and coordination between institutions. When combined, data sovereignty laws and liability issues reveal the systemic nature of regulatory delay, in which legal and institutional systems

[100] Fao.org. “FAO Knowledge Repository,” 2025.

lag behind technological progress, resulting in inconsistent standards and poor alignment between digital transformation and governance adaptation.[101]

12. Global Applications

12.1. The "Hand-in-Hand" (HiH) Geospatial Platform

The HiH Geospatial Platform was created to provide advanced information by unlocking millions of data layers from a variety of domains and sources, including FAO's flagship databases like FAOSTAT, as well as datasets from UN agencies, NGOs, academia, private sector actors, and space organisations. This integration has enabled the platform to act as a primary enabling tool for FAO's Hand-in-Hand Initiative, helping governments, economists, and technical specialists analyse agricultural data and food security indicators across more than 245 nations and territories. [102]

The Hand-in-Hand Geospatial Platform was created to integrate geospatial information, such as satellite imagery and aerial data, with statistical time series, resulting in a comprehensive environment for monitoring natural resources, identifying risk areas, and supporting targeted interventions.

Remote-sensed data is increasingly being used to track phenomena such as pest outbreaks, land degradation, and climate variability, while statistical datasets provide the socioeconomic context required for policy alignment. This dual integration has been deemed essential for reducing poverty and hunger and strengthening economic development strategies. The platform has also been structured to allow both technical experts and non-specialist users to visualise and analyse data, with interactive features enabling the creation of customised maps by overlaying multiple datasets, comparing trends across time, and examining conditions at global, national, and subnational levels, thus enhancing

---

[101] Transforming Agrifood Systems with Digital Public Infrastructure, One of the Paths to Sustainable Development | E-Agriculture | Food and Agriculture Organization of the United Nations," Fao.org, 2025,
[102] HiHGP. "Home| Hand-In-Hand Geospatial Platform | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/hih-geospatial-platform/en/?utm_source=copilot.com.

transparency and accessibility so that diverse stakeholders can engage with complex data environments without requiring advanced technology.

Institutionally, the platform has been positioned within FAO's Digital FAO and Agro-informatics Division, reflecting its role as a digital public infrastructure that supports systemic coordination. By consolidating fragmented datasets into interoperable frameworks, the Hand-in-Hand Geospatial Platform has addressed challenges of data silos and governance lag, providing a foundation for coherent strategies in agricultural transformation, while its emphasis on open access. [103]

12.2. AMIS (Agricultural Market Information System)

The Agricultural Market Information System (AMIS) was established by the G20 in 2011 as a global platform coordinated by FAO to improve transparency in international food markets and strengthen policy coordination among major producing, consuming, and trading nations. It is intended to collect, analyse, and disseminate data on staple crops such as wheat, maize, rice, and soybeans, which together account for the majority of global caloric intake and trade flows. [104]

AMIS was designed to provide timely, reliable, and harmonised data on production, consumption, trade, and stocks, resulting in a consolidated environment for monitoring market conditions. The system has been positioned as a central mechanism for reducing uncertainty and improving the quality of market forecasts by integrating data from national governments, international organisations, and private sector actors. [105]

In addition, AMIS has been linked to the Rapid Response Forum, which brings together senior officials from participating countries to discuss emerging market challenges and coordinate policy responses. This forum is intended to prevent unilateral actions that

---

[103] HiHGP. “Home| Hand-In-Hand Geospatial Platform | Food and Agriculture Organization of the United Nations,” 2025.

[104] Amis-outlook.org. “AMIS Agricultural Market Information System,” 2025. https://www.amis-outlook.org/home.

[105] Amis-outlook.org. “AMIS Agricultural Market Information System,” 2025.

could exacerbate volatility, such as export restrictions or stockpiling, and to promote collaborative approaches to market stability. The combination of AMIS data and the Rapid Response Forum has been considered indispensable for strengthening global governance in food markets. [106]

12.3. GIEWS (Global Information and Early Warning System)

The FAO established the Global Information and Early Warning System (GIEWS) as the primary mechanism for monitoring food supply and demand conditions around the world and providing early warnings of impending food crises. It is intended to collect, analyse, and disseminate information on crop production, food availability, trade flows, and price developments, allowing for continuous surveillance of global and national food security situations. [107]

GIEWS has been designed to combine multiple sources of information, such as official government reports, field assessments, satellite imagery, and market data, to produce comprehensive analyses of food supply and demand balances. This integration has enabled the system to detect vulnerabilities in agricultural production and distribution, as well as track the impact of external shocks like climate variability, natural disasters, and conflicts. Through this approach, GIEWS has been recognised as a central instrument for anticipating disruptions in food systems and informing international and national responses.

The system has several outputs, including the Crop Prospects and Food Situation quarterly report, which provides global and regional assessments of food supply conditions, and the Special Alerts and Reports, which highlight emerging crises or unexpected changes in food security outlooks. These publications were created to ensure that policymakers, humanitarian agencies, and development institutions have timely and consistent information

[106] Amis-outlook.org. "AMIS Agricultural Market Information System," 2025.
[107] Fao.org. "GIEWS - Global Information and Early Warning System on Food and Agriculture | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/giews/en/

to guide their actions. Early warning has been considered essential in reducing the impact of crises by enabling preventive and coordinated measures. [108]

13. Questions to be Answered

- What international legal frameworks should be established to define ownership of smallholder farmer-generated agricultural data and prevent multinational technology corporations from exploiting it?
- How can member states strike a balance between the need for open data sharing (to combat global food insecurity) and the right to national security and privacy in domestic food supply data?
- To what extent should the FAO intervene to prevent a small number of private multinational corporations from monopolising digital agriculture platforms, and what antitrust mechanisms can be implemented globally?
- What specific, binding policies must member states implement to ensure that rural women, who face disproportionate barriers to technology access, receive priority in national digitisation strategies?"
- What social safety nets and reskilling programmes should be mandated for rural populations whose livelihoods are under threat from agricultural automation and robotization?
- How can the international community ensure that AI models used in developing countries are trained using local ecological data rather than biassed datasets from various climate zones?
- What steps can be taken to incorporate traditional and indigenous agricultural knowledge into AI decision-making systems while preventing the eradication of local farming practices?

[108] Fao.org. “GIEWS - Global Information and Early Warning System on Food and Agriculture | Food and Agriculture Organization of the United Nations,” 2025.

- How can member countries standardise their national data formats to form a unified, real-time Global Early Warning System for famine and market shocks, as proposed by the FAO?

14. Bibliography

"Benefits of AI," April 14, 2025. https://www.thomsonreuters.com/en/insights/articles/benefits-of-artificial-intelligence-ai.

"AGRICULTURAL TRADE, CLIMATE CHANGE and FOOD SECURITY AGRICULTURAL COMMODITY MARKETS 2018 the STATE OF," n.d. https://openknowledge.fao.org/server/api/core/bitstreams/2263cf55-1ad8-4121-929d-bd9d34f786e0/content.

AgroInformatics. "Home | Agro-Informatics | Food and Agriculture Organization of the United Nations," September 15, 2022. https://www.fao.org/agroinformatics/en.

Alam, Firoze. "Precision Agriculture and the Emergence of Data Colonialism." *The Palgrave Handbook on Decoloniality in Asia*, 2025, 263–80. https://doi.org/10.1007/978-981-96-2336-5_13.

Amis-outlook.org. "AMIS Agricultural Market Information System," 2025. https://www.amis-outlook.org/home.

Ammar, Esraa E, Samah Abdel Aziz, Xiaobo Zou, Sohaila A Elmasry, Soumya Ghosh, Basma M Khalaf, Nouran A EL-Shershaby, et al. "An In-Depth Review on the Concept of Digital Farming." *Environment Development and Sustainability*, June 29, 2024. https://doi.org/10.1007/s10668-024-05161-9.

Apicella, Andrea. "Automation in Agriculture: Occupational Trends, Worker Outcomes, and Labor Market Implications." *International Journal of Academic Research in Business and Social Sciences* 15, no. 8 (August 7, 2025). https://doi.org/10.6007/ijarbss/v15-i8/26128.

"AT a GLANCE GLOBAL MARKET OUTLOOK (as of DECEMBER 15, 2025) Trends in Global Agricultural Commodity Prices," n.d. https://thedocs.worldbank.org/en/doc/40ebbf38f5a6b68bfc11e5273e1405d4-0090012022/related/Food-Security-Update-120-December-19-2025.pdf.

Badman, Annie, and Matthew Kosinski. "Data Silos." Ibm.com, February 12, 2025. https://www.ibm.com/think/topics/data-silos#:~:text=Data%20silos%20are%20isolated%20collections,and%20make%20data%2Ddriven%20decisions..

Bayyurt, Nizamettin, and Fatma Eban ArÄ±kan. "Good Governance and Agricultural Efficiency." *Journal of Social and Development Sciences* 6, no. 1 (March 30, 2015): 14–23. https://doi.org/10.22610/jsds.v6i1.831.

Berisha, Fjolla, Peter Mooney, Zohreh Pourzolfaghar, and Markus Helfert. “Shared yet Owned: The Dual Path of Data Ownership in Agriculture: A Systematic Review.” *Data & Policy* 8 (December 29, 2025). https://doi.org/10.1017/dap.2025.10050.

Bioneers. “Farming in the Dark: The Black Box of AI and the Erosion of Food Sovereignty - Bioneers.” Bioneers, July 3, 2025. https://bioneers.org/farming-in-the-dark-the-black-box-of-ai-and-the-erosion-of-food-sovereignty-ztvz2507/.

Branch, Eryk. “Problem Framing: A Strategic Approach to Decision Making.” IIENSTITU, November 22, 2023. https://www.iienstitu.com/en/blog/problem-framing-a-strategic-approach-to-decision-making.

Caballar, Rina Diane. “10 AI Dangers and Risks and How to Manage Them.” Ibm.com, September 3, 2024. https://www.ibm.com/think/insights/10-ai-dangers-and-risks-and-how-to-manage-them.

Campoverde-Molina, Milton, and Sergio Luján-Mora. “Cybersecurity in Smart Agriculture: A Systematic Literature Review.” *Computers & Security* 150 (March 2025): 104284. https://doi.org/10.1016/j.cose.2024.104284.

CCNet. “Historical Development of Digitalization: How It All Began.” CCNet - Blog, June 24, 2024. https://www.ccnet.de/en/blog/dav4-historical-development-of-digitalization-how-it-all-began/.

Ceddia, M.G., S. Sedlacek, N.O. Bardsley, and S. Gomez-y-Paloma. “Sustainable Agricultural Intensification or Jevons Paradox? The Role of Public Governance in Tropical South America.” *Global Environmental Change* 23, no. 5 (October 2013): 1052–63. https://doi.org/10.1016/j.gloenvcha.2013.07.005.

CFS, FAO . “HIGH-LEVEL FORUM ‘HARNESSING ARTIFICIAL INTELLIGENCE, DIGITALIZATION and DATA GOVERNANCE for FOOD SECURITY and NUTRITION,’” August 12, 2025.

Chinese Academy of Sciences. “Scientists Outline Integrated AI-Biotech Approach to Advance Sustainable Crop Development.” Phys.org, July 23, 2025. https://phys.org/news/2025-07-scientists-outline-ai-biotech-approach.html.

Clinic, Cleveland. “What Is Nutrition & the Essential Nutrients Your Body Needs.” Cleveland Clinic, March 18, 2025. https://my.clevelandclinic.org/health/articles/nutrition.

Collaborative Governance – Participedia. “Collaborative Governance – Participedia.” Participedia.net, 2021. https://participedia.net/method/collaborative-governance.

Copeland, B.J. “Artificial Intelligence (AI) | Definition, Examples, Types, Applications, Companies, & Facts.” Encyclopedia Britannica, July 20, 1998. https://www.britannica.com/technology/artificial-intelligence.

“Data Sovereignty in Agricultural Value Chains Study and Recommendations.” Accessed December 29, 2025. https://www.foodfortransformation.org/files/upload/4%20Digitalisierung%20und%20Innovation/20230111_Study%20Datensouver%C3%A4nit%C3%A4t/Study_Data_Sovereignty_200922_final.pdf?.

daveg. “Food Price Volatility – Global Panel.” Global Panel, March 16, 2016. https://www.glopan.org/food-price-volatility/.

Derici, Serkan. “Digitalization Concept and the Historical Evolution of Digitalization.” *Advances in Computer and Electrical Engineering*, July 12, 2024, 90–106. https://doi.org/10.4018/979-8-3693-4111-7.ch006.

Dubey, Aastha, Prasun Kumar Singh, Shalini Singh, Uzma Manzoor, Chinmaya Sahoo, and Ankit Saini. “Impact of Climate Change and Land Degradation on Agriculture.” *Sustainability Solutions*, 2025, 49–95. https://doi.org/10.1007/978-3-032-00708-7_3.

Duignan, Brian. “Economic Inequality.” Encyclopedia Britannica, June 13, 2025. https://www.britannica.com/story/economic-inequality.

Europa.eu. “Harnessing Digitalisation for Sustainable Agriculture and Resilient Rural Communities: New EESC Study | Rural Pact Community Platform,” 2025. https://ruralpact.rural-vision.europa.eu/news/harnessing-digitalisation-sustainable-agriculture-and-resilient-rural-communities-new-eesc_en?.

European Commission. “Data Protection,” 2024. https://commission.europa.eu/law/law-topic/data-protection_en.

Fao.org. “Digital Public Goods for Digital Agriculture and Innovation: Key Takeaways from LLDC3 | E-Agriculture | Food and Agriculture Organization of the United Nations,” 2025.

https://www.fao.org/e-agriculture/news/digital-public-goods-digital-agriculture-and-innovation-key-takeaways-lldc3?.
Fao.org. "FAO Knowledge Repository," 2025. https://openknowledge.fao.org/items/ed331aea-c65e-4770-a096-d449cc50fcdf?.
Fao.org. "FAO Knowledge Repository," 2025. https://openknowledge.fao.org/items/c9304805-d858-433c-a137-a553b0846517?.
Fao.org. "FAO Knowledge Repository," 2025. https://openknowledge.fao.org/items/029121f1-a4f5-49c3-9e97-ec71e72867df.
Fao.org. "GIEWS - Global Information and Early Warning System on Food and Agriculture | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/giews/en/.
Fao.org. "Transforming Agrifood Systems with Digital Public Infrastructure, One of the Paths to Sustainable Development | E-Agriculture | Food and Agriculture Organization of the United Nations," 2025. https://www.fao.org/e-agriculture/news/transforming-agrifood-systems-digital-public-infrastructure-one-paths-sustainable-development?.
FAODirectorGeneral. "Director-General Highlights the Transformational Potential of Digitalization and Calls for Tackling the Digital Divide in a Speech to the World Summit on the Information Society Forum." FAO, March 14, 2023. https://www.fao.org/director-general/news/details/Director-General-highlights-the-transformational-potential-of-digitalization-and-calls-for-tackling-the-digital-divide-in-a-speech-to-the-World-Summit-on-the-Information-Society-Forum/en?.
"Food Systems Thinking Guide for UN Resident Coordinators and UN Country Teams," January 8, 2025. https://doi.org/10.4060/cd0497en.
FoodLossWaste. "Technical Platform on the Measurement and Reduction of Food Loss and Waste | Food and Agriculture Organization of the United Nations," 2015. https://www.fao.org/platform-food-loss-waste/en.
"François Lerin (CIHEAM-IAMM), Selim Louafi (CIrAd)." Accessed January 6, 2026.
https://www.iddri.org/sites/default/files/import/publications/wp1014_fl-sl_fns-governance.pdf.
FSIN. "Global Report on Food Crises (GRFC) 2024." Fightfoodcrises.net, April 24, 2024. https://www.fightfoodcrises.net/report/global-report-food-crises-2024/.

"FSIN Joint Analysis for Better Decisions Food Security Information Network," n.d. https://www.fsinplatform.org/sites/default/files/resources/files/GRFC2025-no-countries.pdf.

Gans Combe, Caroline, and Stéphanie Camaréna. "Data Sovereignty and Valuation Model for Sustainable Agriculture Innovation and Equity." *Npj Sustainable Agriculture* 3, no. 1 (November 18, 2025). https://doi.org/10.1038/s44264-025-00102-z.

"GENETIC RESOURCES for FOOD SECURITY and NUTRITION OVERALL GOAL Conserving Genetic Resources for Food and Agriculture and Promoting Their Use in Support of Global Food Security and Sustainable Development for Present and Future Generations," n.d. https://openknowledge.fao.org/server/api/core/bitstreams/e90eaed4-3759-48d7-a956-0534298d80bb/content.

Gerben Zaagsma. "Digital History and the Politics of Digitization." *Digital Scholarship in the Humanities* 38, no. 2 (September 16, 2022): 830–51. https://doi.org/10.1093/llc/fqac050.

Group, World Bank. "What Is Food Security." World Bank. World Bank Group, December 16, 2024. https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security#:~:text=Based%20on%20the%201996%20World,an%20active%20and%20healthy%20life.

Herens, Marion C, Katherine H Pittore, and Peter J.M Oosterveer. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." *Global Food Security* 32 (November 25, 2021): 100592–92. https://doi.org/10.1016/j.gfs.2021.100592.

———. "Transforming Food Systems: Multi-Stakeholder Platforms Driven by Consumer Concerns and Public Demands." *Global Food Security* 32 (November 25, 2021): 100592–92. https://doi.org/10.1016/j.gfs.2021.100592.

"High Level Panel of Experts on Food Security and Nutrition Conflict-Induced Acute Food Crises: Potential Policy Responses in Light of Current Emergencies," 2024. https://www.fao.org/fileadmin/templates/cfs/Docs2324/BurAg/240729/CFS_BurAG_2024_07_04_HLPE-FSN_Issues_Paper.pdf.

HiHGP. “Home| Hand-In-Hand Geospatial Platform | Food and Agriculture Organization of the United Nations,” 2025. https://www.fao.org/hih-geospatial-platform/en/.

Holdsworth, Jim, and Matthew Kosinski. “Data Governance.” Ibm.com, September 20, 2024. https://www.ibm.com/think/topics/data-governance?.

IMF. “Introduction to Inequality,” June 5, 2024. https://www.imf.org/en/topics/inequality/introduction-to-inequality.

“Inclusive Healthy Resilient Sustainable Regional Policy Brief TRANSFORMING FOOD SYSTEMS Introduction on Food Systems,” n.d. https://www.unescwa.org/sites/default/files/pubs/pdf/transforming-food-systems-english_0.pdf.

“International Development Association (IDA).” *Yearbook of the United Nations*, December 31, 1992, 1135–39. https://doi.org/10.18356/d4f7446a-en.

Jayaraman, Aishwarya, Sudhir Chella Rajan, and Palaniappan Ramu. “Food System Resilience: Unraveling Power Relations and the Matthew Effect in Farmers Networks.” *Technological Forecasting and Social Change* 200 (March 2024): 123144. https://doi.org/10.1016/j.techfore.2023.123144.

Jayasuriya, Sisira, Purushottam Mudbhary, and Sumiter Singh Broca. “Food Price Spikes, Increasing Volatility and Global Economic Shocks: Coping with Challenges to Food Security in Asia a Comparative Regional Study of the Experiences of Ten Asian Economies FOOD and AGRICULTURE ORGANIZATION of the UNITED NATIONS REGIONAL OFFICE for ASIA and the PACIFIC BANGKOK, 2012,” n.d. https://www.fao.org/4/i3031e/i3031e00.pdf.

Khalaf, Dheyaa, and Ahmed Dildar. “Income Inequality: A Microeconomic Analysis of Its Causes and Consequences.” *Tuijin Jishu/Journal of Propulsion Technology* 44, no. 5 (2023): 1001–4055.

Kilemile, Warren, Kelvin E Vulla, Fabian Mihafu, and Vidhya Chandrasekaran. “Transforming Food Systems: A Review of Sustainable Approaches to Minimize Food Loss and Waste.” *Food Science & Nutrition* 13, no. 11 (November 1, 2025): e71167–67. https://doi.org/10.1002/fsn3.71167.

Knowledge for policy. “Climate Change and Environmental Degradation - Knowledge for Policy - European Commission,” 2025. https://knowledge4policy.ec.europa.eu/climate-change-environmental-degradation_en.

Knowledge for policy. “Climate Change Continues - Knowledge for Policy - European Commission,” 2023. https://knowledge4policy.ec.europa.eu/foresight/climate-change-continues_en.

Li, Linchao, Bin Wang, Puyu Feng, Chaoqun Lu, Jonas Jägermeyr, Senthold Asseng, Jing-Jia Luo, et al. “Global Warming Increases the Risk of Crop Yield Failures Driven by Climate Oscillations.” *One Earth* 8, no. 6 (June 2025): 101318. https://doi.org/10.1016/j.oneear.2025.101318.

Najafabadi, Mohsen Yoosefzadeh, and Scott A. Jackson. “Hybrid AI in Synthetic Biology: Next Era in Agriculture.” *Trends in Plant Science*, September 2025. https://doi.org/10.1016/j.tplants.2025.08.011.

Ndhlovu, Emmanuel. “Digital Agriculture: Implications for the Agricultural Labour Market.” *International Journal of Research in Business and Social Science (2147-4478)* 14, no. 4 (July 15, 2025): 335–46. https://doi.org/10.20525/ijrbs.v14i4.3997.

Newsroom. “Digitalization: It Is Time to Bridge the Gap between Urban and Rural Areas.” FAO, May 27, 2024. https://www.fao.org/newsroom/detail/digitalization--it-is-time-to-bridge-the-gap-between-urban-and-rural-areas/.

Ngo, Quoc Hung, Tahar Kechadi, and Nhien-An Le-Khac. “OAK4XAI: Model towards Out-Of-Box EXplainable Artificial Intelligence for Digital Agriculture.” arXiv.org, 2022. https://arxiv.org/abs/2209.15104.

OECD. “Agriculture and Fisheries,” 2025. https://www.oecd.org/en/topics/agriculture-and-fisheries.html.

OECD. “Resource Efficiency and Circular Economy,” 2025. https://www.oecd.org/en/topics/policy-issues/resource-efficiency-and-circular-economy.html.

OECD. *Skills beyond School. OECD Reviews of Vocational Education and Training*. Organization for Economic Cooperation and Development, 2014. https://doi.org/10.1787/9789264214682-en.

OneHealth. “Biosecurity,” 2024. https://www.fao.org/one-health/areas-of-work/biosecurity/en.

SDGHelpdesk. “FAO at the UNECE Regional Forum on Sustainable Development 2025: SDG 8 Roundtable,” 2025. https://www.fao.org/sustainable-development-goals-helpdesk/transform/article-detail/

fao-at-the-unece-regional-forum-on-sustainable-development-2025--sdg-8-roundtable/en.
SDGIndicators. “Analytical Reports | SDG Indicators Data Portal | Food and Agriculture Organization of the United Nations,” 2025. https://www.fao.org/sustainable-development-goals-data-portal/resources/analytical-reports/.
Stryker, Cole, and Eda Kavlakoglu. “Artificial Intelligence.” Ibm.com, August 9, 2024. https://www.ibm.com/think/topics/artificial-intelligence.
Un.org. “Global Digital Compact | Office for Digital and Emerging Technologies,” 2025. https://www.un.org/digital-emerging-technologies/global-digital-compact.
Un.org. “Goal 1 | Department of Economic and Social Affairs,” 2025. https://sdgs.un.org/goals/goal1.
Un.org. “Goal 2 | Department of Economic and Social Affairs,” 2022. https://sdgs.un.org/goals/goal2.
Un.org. “Goal 10 | Department of Economic and Social Affairs,” 2025. https://sdgs.un.org/goals/goal10.
Un.org. “Transforming Our World: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs,” 2015. https://sdgs.un.org/2030agenda.
Wfp.org. “UN World Food Programme (WFP),” 2021. https://www.wfp.org/who-we-are#:~:text=The%20World%20Food%20Programme%20is,the%20impact%20of%20climate%20change.
World. “Malnutrition.” Who.int. World Health Organization: WHO, March 2024. https://www.who.int/news-room/fact-sheets/detail/malnutrition#:~:text=There%20are%204%20broad%20sub,height%20is%20known%20as%20wasting.
World Bank. “Overview,” 2025. https://www.worldbank.org/en/topic/agriculture/overview.
Worldbank.org. “Development Topics | World Bank Group,” 2025. https://www.worldbank.org/ext/en/development-topics.

Model United Nations Bilkent University 2026