

Artificial Intelligence and Food Sovereignty: The Limits of the Food and Agriculture Organization's International Mandate in Governing Agricultural Technology

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Introduction

The agricultural sector is undergoing a profound technological transformation as artificial intelligence increasingly becomes integrated into the processes through which food is produced, managed, distributed, and consumed. Technologies based on machine learning, predictive analytics, satellite imagery, remote sensing, automated machinery, agricultural robotics, and intelligent decision-support systems are progressively changing conventional methods of agricultural management. Artificial intelligence can analyse extensive quantities of information concerning soil conditions, weather patterns, crop development, water availability, pests, diseases, market conditions, and agricultural productivity, allowing farmers, enterprises, and public authorities to make decisions based on increasingly sophisticated digital information. This transformation has created new opportunities for improving agricultural productivity and responding to climate change and resource scarcity, but it has simultaneously introduced new legal, economic, institutional, and sovereignty-related challenges.

The increasing digitalisation of agriculture is particularly significant because contemporary food systems are becoming increasingly dependent not only on land, water, seeds, machinery, and human labour, but also on data and technological infrastructure. Agricultural data constitute an increasingly valuable resource because they can reveal information concerning soil characteristics, production levels, crop patterns, irrigation requirements, land use, market behaviour, and the activities of farmers. When such information is processed through artificial intelligence systems, it can generate predictions and recommendations capable of influencing agricultural decision-making. Consequently, control over agricultural data and the technologies used to process them may become an important component of economic and strategic power within contemporary food systems.

This development raises a fundamental question concerning the relationship between technological innovation and food sovereignty. Food sovereignty traditionally concerns the ability of States, communities, and populations to determine their agricultural and food policies and to protect their food systems, agricultural resources, and livelihoods. However, the digital transformation of agriculture suggests that the concept of sovereignty must increasingly take account of technological and informational dimensions. A State may formally retain control over its agricultural land and natural resources while becoming heavily dependent on foreign companies for the algorithms, digital platforms, cloud infrastructure, agricultural machinery, satellite services, and data-processing systems required to manage those resources. Such

dependence may create a new form of structural vulnerability in which technological control becomes closely connected to control over agricultural production.

The problem becomes particularly important in developing countries, where limited digital infrastructure, insufficient technological expertise, restricted research capacity, and financial constraints may increase dependence on foreign technology providers. Large multinational corporations and technologically advanced States possess significant advantages in the development of artificial intelligence systems, data-processing infrastructure, digital platforms, and agricultural technologies. If developing countries become primarily consumers rather than producers and regulators of these technologies, the digital transformation of agriculture may reproduce existing inequalities within the international food system. The issue is therefore not simply whether developing countries should adopt artificial intelligence, but under what legal and institutional conditions such technologies can be adopted without compromising their capacity to control their agricultural systems and resources.

Artificial intelligence nevertheless offers considerable potential for strengthening food security. Predictive systems can assist in anticipating droughts, floods, pests, and crop diseases; precision agriculture can improve the allocation of water, fertilisers, and other agricultural inputs; remote sensing can facilitate crop monitoring; and intelligent supply-chain systems can contribute to reducing losses and improving the distribution of agricultural products. These applications demonstrate that artificial intelligence can become an important instrument for addressing some of the structural challenges affecting global food systems. However, technological efficiency cannot by itself guarantee food sovereignty. The benefits generated by AI depend upon who owns the technology, who controls the underlying data, who determines the algorithms, who has access to the resulting knowledge, and who ultimately benefits economically from its application.

The governance of agricultural data therefore constitutes one of the central dimensions of this debate. Questions concerning the collection, ownership, storage, processing, sharing, transfer, and commercial exploitation of agricultural data have become increasingly important. Data generated by farmers and agricultural activities may be processed through platforms controlled by private companies located outside the territory in which the data are produced. This may create difficulties concerning jurisdiction, transparency, accountability, privacy, data security, and the ability of States and farmers to exercise effective control over their agricultural information. The absence of sufficiently developed national and international rules may consequently allow technological and economic asymmetries to influence the distribution of benefits generated by digital agriculture.

Within this context, the Food and Agriculture Organization of the United Nations occupies an important institutional position. The FAO has a broad mandate relating to food and agriculture and contributes to international cooperation concerning food security, sustainable agricultural development, natural resources, rural development, and the improvement of agricultural productivity. The emergence of digital agriculture and artificial intelligence has consequently expanded the relevance of the Organization's activities. Through technical cooperation, knowledge production, policy guidance, capacity building, international dialogue, and the

development of principles and voluntary frameworks, the FAO can contribute to establishing responsible approaches to the use of emerging technologies in agriculture.

Nevertheless, the international mandate of the FAO has important boundaries. Artificial intelligence is not exclusively an agricultural issue. Its governance intersects with international trade, investment, intellectual property, cybersecurity, personal and non-personal data governance, digital infrastructure, competition, technology transfer, and international human rights. These areas are governed by different national, regional, and international institutions and legal instruments. The FAO therefore operates within a fragmented international regulatory environment in which it cannot independently establish comprehensive and binding rules governing every dimension of artificial intelligence and agricultural data.

The predominantly cooperative and normative character of many international agricultural instruments also raises questions concerning their effectiveness. International guidelines and principles may provide valuable standards for States and other stakeholders, but their implementation frequently depends upon national legislation, institutional capacity, political commitment, and cooperation from private actors. In the context of AI, this limitation becomes particularly relevant because some of the most important technologies and datasets are controlled by private corporations whose activities may extend across several jurisdictions. The capacity of an international agricultural organisation to influence such actors is consequently different from the capacity of a State to regulate activities within its own territory.

The central issue of this study is therefore the extent to which the FAO can contribute to the establishment of an international framework for governing artificial intelligence and agricultural data in a manner that promotes food security without allowing technological and data concentration to undermine the food sovereignty of developing countries. The study proceeds from the assumption that technological innovation and food sovereignty are not necessarily contradictory. Rather, the relationship between them depends on the institutional arrangements through which technology is developed, transferred, regulated, and accessed. Artificial intelligence can contribute to food security and sustainable agriculture when it is accompanied by equitable access, appropriate regulation, technological capacity, transparent data governance, and meaningful participation by developing countries.

Accordingly, this study examines two interconnected dimensions. The first concerns the transformation of agricultural governance brought about by artificial intelligence and the implications of technological and data dependence for food sovereignty. The second concerns the role and institutional limits of the FAO in developing international approaches to AI and agricultural data governance. By analysing these dimensions together, the study seeks to determine whether the existing international agricultural governance framework is capable of responding adequately to the challenges created by digital transformation or whether broader international cooperation and complementary legal mechanisms are required.

The central argument advanced in this study is that artificial intelligence can strengthen food security and agricultural sustainability, but technological innovation alone cannot guarantee food sovereignty. Unless developing countries acquire meaningful capacities to govern agricultural data, access essential technologies, develop digital infrastructure, participate in international standard-setting, and negotiate equitable technological cooperation, digital

agriculture may reproduce existing patterns of dependency in a new technological form. The FAO can play a significant role in addressing this challenge, but its contribution must be understood within the limits of its international mandate and alongside the broader international legal and institutional framework governing technology, data, investment, trade, and intellectual property.

Section One: Artificial Intelligence and the Transformation of Agricultural Governance

Artificial intelligence represents one of the most significant technological developments affecting contemporary agriculture. Its application extends from precision agriculture and automated irrigation to crop monitoring, pest and disease detection, yield forecasting, livestock management, weather analysis, and agricultural supply-chain optimisation. By processing large quantities of information and identifying patterns that may not be immediately visible through conventional methods, AI systems can assist farmers and agricultural authorities in improving production decisions and allocating resources more efficiently. These applications can contribute to reducing agricultural losses, increasing productivity, improving water management, and strengthening resilience to environmental pressures. However, the increasing technological sophistication of agriculture also means that agricultural production is becoming more dependent on digital systems, technical expertise, and data infrastructure.

The digitalisation of agriculture has consequently transformed data into a strategic agricultural resource. Modern agricultural activities generate extensive information concerning soil quality, weather conditions, crop development, irrigation, machinery, land use, production volumes, prices, consumption patterns, and farmer behaviour. When this information is collected and analysed through artificial intelligence systems, it acquires additional economic and strategic value. Agricultural data can be used to predict production patterns, identify market opportunities, optimise resource allocation, and develop commercial products and services. The question of who controls such data is therefore increasingly connected to the question of who possesses decision-making power within agricultural systems. Where data generated within developing countries are collected and processed through foreign technological platforms, the economic value created from domestic agricultural activity may increasingly be captured outside the national economy.

This development makes agricultural data governance an essential component of contemporary agricultural governance. Governance concerns not only the technical protection of information but also questions relating to who is entitled to collect, access, process, transfer, store, and commercially exploit agricultural data. It also concerns the rights and interests of farmers and agricultural communities whose activities generate much of the underlying information. Without adequate regulatory frameworks, data generated by agricultural activities may be transformed into commercially valuable resources without sufficient transparency concerning their subsequent use. For developing countries, this creates a particularly important challenge because weak regulatory and technological capacities may reduce their ability to negotiate equitable arrangements with powerful technology providers.

Artificial intelligence also changes the relationship between farmers and agricultural decision-making. Traditional agricultural knowledge has historically been based on accumulated local experience concerning soil, climate, crops, water, seasons, and ecological conditions. AI

systems introduce another form of knowledge based on algorithms and large datasets. Although algorithmic recommendations can provide valuable information, they may not always reflect local ecological, social, or economic realities. An algorithm developed using datasets from one geographical region may produce recommendations that are less appropriate when applied to another agricultural environment. Consequently, the introduction of AI should not automatically replace local knowledge. A more sustainable approach requires interaction between technological knowledge and the knowledge possessed by farmers and local communities.

Technological dependence represents another major challenge. The effective use of sophisticated AI systems requires digital infrastructure, high-quality datasets, computing capacity, specialised human resources, maintenance, and continuous technological development. Many developing countries remain dependent on external suppliers for some of these requirements. Where agricultural institutions and farmers become dependent on foreign platforms, proprietary software, imported machinery, cloud services, or externally controlled data systems, the technological relationship may extend beyond the initial acquisition of a product or service. Long-term dependence can develop when users are unable to modify systems, transfer data freely, change providers, or develop equivalent domestic alternatives. Technological dependence may therefore become an important dimension of contemporary food sovereignty.

The distributional dimension of agricultural AI is equally important. The benefits of digital agriculture may not be equally accessible to all agricultural producers. Large commercial farms with substantial financial resources may be better positioned to acquire intelligent machinery, sensors, satellite services, automated systems, and advanced analytical tools, whereas smallholders may face financial, technical, or infrastructural barriers. If AI-driven agricultural development primarily benefits technologically advanced producers, digitalisation may intensify existing inequalities within rural areas. Food sovereignty therefore requires not only access to food but also equitable participation in the technological transformation of food production.

Artificial intelligence also has an environmental dimension. AI can contribute to more efficient use of water, fertilisers, pesticides, energy, and agricultural land by allowing resources to be allocated more precisely. This may support sustainable agriculture and reduce certain forms of environmental pressure. At the same time, digital agriculture depends on data centres, electronic equipment, communication networks, sensors, automated machinery, and other forms of digital infrastructure that themselves consume energy and generate material and environmental costs. Consequently, the sustainability of AI-based agriculture should be assessed across the entire technological lifecycle rather than solely according to the immediate efficiency gains achieved on farms.

The expansion of digital agricultural systems also raises questions concerning national regulatory autonomy. Agricultural data may cross national borders when they are transmitted to foreign servers, processed through international platforms, or incorporated into global technological systems. Such cross-border flows can create complex questions concerning jurisdiction, accountability, data security, and the applicability of domestic regulation. A State

may have authority over agricultural activities occurring within its territory while possessing limited practical control over the subsequent processing of data generated by those activities. The digitalisation of agriculture therefore requires national regulatory frameworks capable of addressing data governance while also requiring international cooperation concerning cross-border technological activities.

Artificial intelligence is also increasingly relevant to international agricultural investment. Foreign investors may introduce automated machinery, satellite monitoring, predictive analytics, smart irrigation systems, digital supply chains, and data-driven production models into host countries. Such investments may increase productivity and contribute to technological modernisation, but they can also create new forms of dependence if host States lack sufficient capacity to regulate data ownership, technological access, technology transfer, and the long-term use of digital infrastructure. Investment frameworks should therefore increasingly consider not only land, capital, and physical assets but also the ownership and governance of the data and technologies associated with agricultural investment.

The transformation of agriculture through artificial intelligence ultimately requires a broader understanding of food sovereignty. In a highly digitalised food system, sovereignty cannot be reduced to formal control over agricultural land and natural resources. It increasingly includes the capacity to influence the technologies, algorithms, data infrastructures, and knowledge systems through which agricultural resources are managed. A State that controls its land but lacks meaningful control over the digital systems governing agricultural production may possess formal territorial sovereignty while experiencing significant technological dependence. Food sovereignty in the digital era must therefore incorporate technological autonomy, data governance, capacity building, and equitable access to innovation.

The transformation of agricultural governance by artificial intelligence consequently presents both an opportunity and a structural challenge. AI can improve agricultural productivity, strengthen climate resilience, reduce resource waste, and contribute to food security. Yet these benefits cannot be separated from questions concerning ownership, access, control, accountability, and technological dependence. The central challenge for developing countries is therefore to participate actively in the digital transformation of agriculture rather than becoming passive recipients of externally controlled technologies. This requires domestic regulation, investment safeguards, agricultural data governance, technological capacity building, and international cooperation. Within this broader framework, the FAO can provide an important international platform for cooperation and standard-setting, but its role must be examined in light of the specific limits of its international mandate.

Section Two: The Role of the Food and Agriculture Organization in the Governance of Artificial Intelligence and Agricultural Data

The Food and Agriculture Organization occupies a distinctive position within the international institutional framework governing food and agriculture. Its mandate is directly connected to improving nutrition, increasing agricultural productivity, contributing to the development of rural populations, and supporting the sustainable management of agricultural and natural resources. The emergence of artificial intelligence in agriculture therefore falls within an area of international concern that is closely connected to the Organization's traditional functions.

Although the FAO was not established specifically to regulate artificial intelligence, the digital transformation of agriculture has created new technological dimensions within the fields of food security and agricultural development in which the Organization possesses significant expertise and institutional relevance.

One of the principal contributions that the FAO can make is the development and dissemination of knowledge concerning responsible digital agriculture. Artificial intelligence requires reliable data, appropriate technological infrastructure, institutional expertise, and clear governance principles. Through research, technical guidance, international dialogue, and cooperation with Member States, the FAO can help identify the opportunities and risks associated with AI applications in agriculture. Its role is particularly important for developing countries that may lack the institutional resources necessary to independently assess complex technological systems. By providing technical knowledge and facilitating the exchange of experiences, the Organization can contribute to narrowing the knowledge gap between technologically advanced and less technologically advanced agricultural systems.

The governance of agricultural data constitutes another important area in which the FAO can contribute. The expansion of digital agriculture requires greater attention to questions of data access, control, interoperability, security, privacy, sharing, and commercial use. Agricultural data should not be considered merely as technical information because they can have direct implications for the economic interests of farmers, agricultural enterprises, and States. The FAO can contribute to developing principles that encourage transparent and responsible data governance while promoting the use of agricultural data for public-interest objectives such as food security, climate adaptation, agricultural research, and sustainable resource management. The Organization can also play an important role in addressing the technological divide affecting developing countries. Access to AI-based agricultural technologies depends on infrastructure, connectivity, technical expertise, financial resources, research institutions, and appropriate regulatory capacities. Developing countries may possess significant agricultural potential while lacking the technological systems necessary to exploit digital tools effectively. International technical cooperation, training, knowledge exchange, and institutional capacity building can therefore form an important part of the FAO's contribution to agricultural digitalisation. The objective should not merely be to transfer technologies but also to develop the capacity of national institutions and agricultural communities to understand, regulate, adapt, and eventually produce technological solutions.

The issue of inclusiveness is equally important. Smallholders and rural communities constitute an essential part of food systems in many developing countries, yet they may face significant barriers to accessing sophisticated digital technologies. Artificial intelligence governance that focuses exclusively on large commercial agricultural enterprises could reinforce existing economic inequalities. The FAO can contribute to ensuring that digital agricultural policies consider the needs of small-scale producers, rural communities, women, young farmers, and other groups that may be disadvantaged by unequal access to technology. An inclusive approach would seek to ensure that AI contributes to broad-based agricultural development rather than concentrating technological benefits among a limited number of actors.

Artificial intelligence also offers important possibilities for strengthening food security, which constitutes one of the central areas of the FAO's institutional concern. AI-based systems can assist in forecasting agricultural production, identifying crop diseases, monitoring environmental conditions, anticipating climate-related risks, reducing post-harvest losses, and improving supply-chain management. These applications can provide governments and agricultural actors with information that supports more timely decision-making. Nevertheless, AI should not be presented as a complete solution to food insecurity. Food insecurity is influenced by economic inequality, conflict, poverty, climate change, market instability, infrastructure deficiencies, and unequal access to agricultural resources. Technological tools can support responses to these challenges, but they cannot eliminate their underlying structural causes.

The FAO's contribution is also relevant to the environmental sustainability of digital agriculture. Intelligent irrigation systems, precision farming, and predictive technologies may contribute to more efficient use of water and agricultural inputs. Such applications can support the sustainable management of scarce resources and strengthen the resilience of agricultural systems. However, the environmental costs associated with digital infrastructure must also be taken into consideration. Responsible agricultural technology governance should therefore evaluate both the environmental benefits and the material and energy requirements of AI systems. The FAO can facilitate such an integrated approach by connecting technological innovation with its broader objectives concerning sustainable agriculture and natural-resource management.

Another important function of the FAO is its capacity to serve as a platform for dialogue among States and other stakeholders. The governance of agricultural AI cannot be effectively addressed by governments alone. Researchers, farmers, civil society organisations, international institutions, technology companies, agricultural enterprises, and development organisations all possess relevant knowledge and interests. A multistakeholder approach can facilitate the identification of common principles and encourage greater transparency in the development and application of agricultural technologies. The FAO's international character gives it the potential to facilitate dialogue between countries with significantly different technological capacities and agricultural conditions.

The relationship between AI governance and food sovereignty further increases the importance of developing-country participation in international discussions. If technological standards and data governance principles are developed primarily by technologically advanced countries or private corporations, developing countries may have limited influence over the rules that subsequently shape their agricultural systems. The FAO can provide an institutional space in which developing countries articulate their concerns and participate in discussions concerning agricultural technology. Such participation is essential because food sovereignty in the digital era depends not only on access to technology but also on the ability to participate in determining the rules under which technology is developed and used.

However, the FAO's institutional capacity has clear boundaries. Artificial intelligence is a cross-sectoral technological phenomenon extending beyond agriculture. Issues concerning intellectual property rights, international trade, foreign investment, cross-border data transfers,

cybersecurity, competition, digital infrastructure, and technology markets are governed through multiple national, regional, and international frameworks. The FAO cannot independently establish a comprehensive global legal regime covering all these dimensions. Its agricultural mandate provides an important foundation for addressing AI in food systems, but it must operate alongside other international institutions and legal regimes.

A further limitation concerns the predominantly normative and cooperative nature of international agricultural governance. Principles, guidelines, technical standards, and voluntary frameworks can influence State behaviour and provide useful benchmarks for national policy, but their effectiveness depends substantially on domestic implementation and institutional capacity. The FAO cannot automatically transform international guidance into binding obligations applicable to all States or private technology companies. The effectiveness of its contribution therefore depends on the willingness of Member States to incorporate relevant principles into national legislation and agricultural policies and to cooperate with other international institutions.

The FAO also has limited direct authority over private corporations that control important AI technologies and digital platforms. Major technology companies may own proprietary algorithms, software, datasets, cloud infrastructure, and intellectual property that are essential to modern digital agriculture. An international agricultural organisation cannot simply compel private companies to transfer proprietary technologies or surrender commercially valuable data. Addressing this issue requires complementary legal mechanisms concerning competition, intellectual property, investment, data governance, technology transfer, and corporate accountability.

Consequently, the FAO should be understood as an important pillar rather than the sole regulator of agricultural artificial intelligence. Its contribution can include knowledge production, technical assistance, capacity building, international cooperation, policy guidance, and the development of responsible principles for digital agriculture. Nevertheless, the protection of food sovereignty requires a broader institutional framework capable of addressing the economic and legal power associated with technology and data. The next stage of the analysis must therefore examine the limits of the FAO's international competence and the prospects for strengthening international governance mechanisms capable of preventing technological and data concentration from undermining the food sovereignty of developing countries.

Section Three: The Limits of the FAO's International Mandate and Prospects for Protecting Food Sovereignty in the Age of Agricultural AI

The increasing integration of artificial intelligence into agricultural systems demonstrates that the governance of agricultural technology cannot be separated from broader questions concerning international authority and regulatory competence. Although the Food and Agriculture Organization possesses an important mandate in the fields of agriculture, food security, rural development, and sustainable management of natural resources, its institutional competence does not extend to all dimensions of artificial intelligence governance. The technological transformation of agriculture intersects with areas traditionally regulated through different legal and institutional frameworks, including international trade, foreign investment,

intellectual property, data protection, competition, cybersecurity, and digital infrastructure. The fragmented nature of these regulatory domains constitutes one of the principal limitations affecting the capacity of the FAO to establish a comprehensive international governance framework for agricultural AI.

A first limitation arises from the absence of a universally comprehensive and binding international legal regime specifically governing artificial intelligence in agriculture. Existing international approaches to digital technologies generally consist of different principles, guidelines, policy frameworks, ethical recommendations, and sector-specific instruments. Although these mechanisms can contribute to establishing common expectations concerning responsible technological development, they do not necessarily create uniform legal obligations for States and private actors. In the agricultural context, this situation may produce significant regulatory disparities between countries. States with strong technological and institutional capacities may establish sophisticated domestic frameworks, while developing countries may lack the resources necessary to regulate complex AI systems effectively. The resulting asymmetry may increase the dependence of developing countries on foreign technological providers and reduce their ability to determine independently the conditions under which agricultural AI is introduced.

A second limitation concerns the predominantly cooperative character of the FAO's international activities. International cooperation constitutes an essential element of the Organization's functioning, but cooperation does not automatically produce enforceable obligations. International principles and guidelines may influence national agricultural policies and provide valuable standards for responsible technology governance, yet their effectiveness ultimately depends on national implementation. Where States lack appropriate legislation, institutional capacity, financial resources, or technical expertise, international recommendations may have limited practical effect. This creates a particular challenge for developing countries because the existence of international guidance does not necessarily guarantee that they possess the capacity to negotiate equitable technological arrangements with powerful foreign companies or technologically advanced States.

A third limitation results from the concentration of agricultural technologies in the hands of a relatively limited number of technologically powerful private actors. Contemporary agricultural AI increasingly depends on sophisticated algorithms, cloud computing, satellite services, sensors, automated machinery, digital platforms, and proprietary software. Many of these technologies are developed and controlled by companies operating across national borders. The FAO may encourage responsible technological practices and facilitate dialogue among stakeholders, but it does not possess direct regulatory authority over all private corporations involved in the digital transformation of agriculture. Consequently, the protection of food sovereignty cannot depend exclusively on agricultural institutions. It also requires effective national and international rules concerning corporate responsibility, competition, intellectual property, technology transfer, and data governance.

The concentration of agricultural data presents an even more complex challenge. Data generated through agricultural activities may be collected through digital platforms and subsequently processed outside the territory where they were originally produced. When

farmers or national agricultural institutions rely on foreign technological systems, questions may arise concerning who owns the data, who has access to them, where they are stored, how long they are retained, and for what purposes they may be commercially exploited. Large-scale agricultural datasets can provide significant economic and strategic advantages because they allow companies to improve algorithms, develop new technological products, predict agricultural markets, and optimise commercial operations. If developing countries have little control over these data, digital agriculture may generate a new form of dependency based not on physical ownership of agricultural resources but on control over information concerning those resources.

The protection of food sovereignty therefore requires a broader conception of agricultural data governance. Developing countries should be capable of establishing clear rules concerning the collection and use of agricultural data while ensuring that farmers and agricultural communities are not deprived of meaningful rights and interests in information generated through their activities. Data governance should also promote transparency concerning algorithmic systems and the purposes for which agricultural information is processed. Where technologically advanced companies control both the data and the algorithms used to analyse them, significant informational asymmetries may emerge between technology providers, governments, and farmers. Strengthening institutional capacity to understand and regulate these systems is therefore essential for maintaining meaningful national and agricultural autonomy.

Intellectual property constitutes another significant limitation on the ability of developing countries to obtain technological autonomy. Many AI systems, software platforms, agricultural technologies, and digital tools are protected by intellectual property rights. Such protection can encourage innovation and investment, but it may simultaneously restrict access to essential technologies, particularly where developing countries lack sufficient domestic research and development capacities. The challenge is therefore to achieve an appropriate balance between protecting technological innovation and ensuring that agricultural technologies capable of contributing to food security are accessible to countries that need them. The FAO can promote dialogue and cooperation concerning technology access, but addressing the underlying legal structure of intellectual property requires coordination with other international institutions and national authorities.

Technology transfer represents another essential dimension of this problem. Merely importing sophisticated agricultural technologies does not necessarily produce technological independence. If developing countries remain dependent on foreign suppliers for software updates, technical maintenance, data processing, equipment, and specialised expertise, technological dependence may persist even after substantial investments have been made in digital agriculture. Meaningful technology transfer should therefore include not only the delivery of technological products but also the development of local skills, research capabilities, infrastructure, institutional knowledge, and opportunities for domestic innovation. International agricultural cooperation should consequently move from a model based primarily on technology consumption toward one that supports technological adaptation and production within developing countries.

The question of technological infrastructure is also closely connected to food sovereignty. AI-based agricultural systems require reliable internet connectivity, data centres, cloud services, electricity, digital devices, sensors, satellite technologies, and secure communication networks. Countries lacking these infrastructures may face significant barriers to adopting AI effectively. Moreover, dependence on foreign digital infrastructure can create vulnerabilities concerning the continuity of agricultural services and the location and control of agricultural data. Building domestic and regional digital infrastructure is therefore an essential component of technological sovereignty. International cooperation should support developing countries not only through access to AI applications but also through investment in the infrastructure necessary to operate, maintain, and govern these technologies independently.

Another important limitation concerns the participation of developing countries in international technological standard-setting. International rules and technical standards can have long-term effects on the structure of agricultural markets and the accessibility of digital technologies. If developing countries have limited participation in the development of these standards, they may ultimately be required to implement rules designed primarily according to the technological and economic interests of more powerful actors. The FAO can contribute to correcting this imbalance by providing a platform for broader participation and by ensuring that agricultural technology discussions reflect the realities of smallholders, rural communities, and developing-country agricultural systems. Meaningful participation should extend beyond formal representation and include genuine influence over the development of principles and policy frameworks.

Food sovereignty also requires attention to the relationship between agricultural AI and international investment. Foreign investment can provide capital, infrastructure, technical expertise, and access to advanced technologies, but investment agreements may also restrict the regulatory space available to host States in certain circumstances. Where foreign agricultural investors introduce AI systems and retain control over the associated data and technologies, the host State may face difficulties in ensuring that the benefits of digital transformation remain within the national agricultural economy. Future investment frameworks should therefore increasingly consider provisions concerning agricultural data, technology transfer, interoperability, transparency, local capacity building, and responsible technological practices. Such provisions can help reconcile the objectives of attracting investment with the need to preserve national regulatory autonomy.

The FAO can nevertheless contribute significantly to addressing these challenges by promoting a coordinated international approach to agricultural AI. Its role could include the development of international principles concerning responsible agricultural data governance, the promotion of equitable access to digital technologies, support for national capacity building, and the facilitation of cooperation between developing and technologically advanced countries. The Organization can also encourage the integration of food sovereignty considerations into discussions concerning digital agriculture. Such an approach would recognise that agricultural technology should not be evaluated solely according to productivity or profitability but also according to its effects on farmers, communities, natural resources, national autonomy, and the equitable distribution of technological benefits.

A particularly important prospect concerns the development of stronger coordination between the FAO and other international institutions. Because AI governance extends beyond agriculture, no single international organisation can adequately address all its dimensions. Cooperation among institutions responsible for agriculture, trade, investment, intellectual property, development, digital governance, and human rights can contribute to reducing regulatory fragmentation. Such coordination could help ensure that international rules governing technology and data do not inadvertently undermine food security or food sovereignty. The FAO's agricultural expertise could therefore complement the legal and institutional expertise of other international bodies, creating a more coherent framework for governing agricultural AI.

National legislation remains equally important. International cooperation cannot substitute for effective domestic regulation. Developing countries should establish legal frameworks addressing agricultural data governance, algorithmic transparency, cybersecurity, digital infrastructure, technology transfer, and the responsibilities of private technology providers. National authorities should also strengthen their capacity to evaluate AI systems before they are introduced into strategic agricultural sectors. Regulatory frameworks should ensure that technological innovation does not occur at the expense of farmers' interests, environmental sustainability, or national control over critical agricultural information. Strong domestic institutions are therefore necessary to transform international principles into effective protection mechanisms.

Finally, protecting food sovereignty in the age of artificial intelligence requires a shift from a purely technological understanding of agricultural modernisation toward a governance-based approach. The central question should not simply be whether developing countries have access to AI, but whether they possess the institutional, legal, technological, and economic capacity to govern its use. Artificial intelligence should contribute to strengthening agricultural systems rather than creating new structures of dependence. This requires combining technological innovation with data sovereignty, capacity building, equitable technology transfer, inclusive participation, sustainable infrastructure, and appropriate regulatory safeguards. The FAO can make an important contribution to this process by using its international agricultural mandate to promote cooperation and responsible governance. However, its effectiveness will ultimately depend on broader international coordination and the willingness of States to strengthen the legal and institutional mechanisms necessary to ensure that the digital transformation of agriculture contributes to food security without undermining food sovereignty.

General Conclusion

The integration of artificial intelligence into agriculture represents a profound transformation of contemporary food systems. AI technologies are increasingly capable of analysing agricultural data, predicting climatic and production risks, monitoring crops, detecting diseases, optimising irrigation, improving supply chains, and supporting agricultural decision-making. These developments create significant opportunities for increasing productivity, reducing resource waste, strengthening climate resilience, and improving food security. Nevertheless, the digital transformation of agriculture also introduces new forms of dependency that require careful consideration, particularly in developing countries whose technological, financial, and

institutional capacities remain unequal in comparison with those of technologically advanced States and multinational corporations.

The central finding of this study is that artificial intelligence can contribute substantially to food security, but technological innovation cannot automatically guarantee food sovereignty. The ability to use AI technologies effectively increasingly depends on access to agricultural data, digital infrastructure, computing capacity, specialised expertise, algorithms, and technological platforms. Where these essential elements are controlled externally, States may remain formally sovereign over their agricultural land and natural resources while becoming increasingly dependent on foreign actors for the digital systems through which those resources are managed. Food sovereignty must therefore be understood in a broader contemporary sense that incorporates technological capacity, agricultural data governance, digital infrastructure, and meaningful participation in the development of technological standards.

Agricultural data constitute one of the most important dimensions of this transformation. Data generated through agricultural activities can reveal information concerning land use, soil conditions, crop production, water consumption, agricultural productivity, farmer behaviour, and market conditions. When such information is accumulated and processed through AI systems, it becomes a strategic economic resource. The concentration of agricultural data in the hands of a limited number of technologically powerful actors may therefore generate significant asymmetries between data producers, technology providers, and public authorities. For developing countries, ensuring effective governance of agricultural data is consequently essential to preventing digitalisation from becoming a new mechanism of economic and technological dependency.

The study has also demonstrated that the Food and Agriculture Organization possesses an important role in responding to these challenges. Its international mandate concerning food security, agricultural development, rural livelihoods, and sustainable natural-resource management provides a significant institutional basis for addressing the agricultural dimensions of artificial intelligence. Through technical cooperation, knowledge production, capacity building, international dialogue, policy guidance, and the promotion of responsible digital agriculture, the FAO can assist States in developing approaches to AI that are consistent with food security and sustainable agricultural development. Its international character also enables it to provide a platform through which developing countries can participate in discussions concerning agricultural technology and data governance.

However, the analysis confirms that the FAO's capacity is subject to significant institutional and legal limitations. Artificial intelligence is inherently cross-sectoral and extends beyond agriculture into areas such as international trade, investment, intellectual property, cybersecurity, competition, digital infrastructure, and cross-border data governance. These fields are governed by multiple national, regional, and international institutions. The FAO therefore cannot independently establish a comprehensive and universally binding legal framework governing all dimensions of AI. Its agricultural expertise and institutional legitimacy are important, but they must operate within a fragmented international regulatory environment.

The predominantly cooperative and normative nature of international agricultural governance constitutes another important limitation. International principles, guidelines, technical standards, and policy recommendations can influence State behaviour and provide valuable frameworks for responsible technological development. Nevertheless, their practical effectiveness frequently depends on national implementation, institutional capacity, financial resources, and political commitment. In developing countries, the existence of international guidance may therefore be insufficient where domestic institutions lack the technical capacity to regulate complex AI systems or negotiate equitable arrangements with multinational technology companies. International standards must consequently be accompanied by concrete mechanisms for capacity building, technology transfer, and institutional strengthening.

The protection of food sovereignty also requires greater attention to the concentration of technological power. Agricultural AI increasingly depends on proprietary algorithms, cloud computing, satellite technologies, automated machinery, digital platforms, and specialised software. Where these systems are controlled by a limited number of private actors, developing countries may face difficulties in accessing technologies on equitable terms or maintaining control over agricultural information. The challenge is therefore not to prevent technological innovation or foreign investment but to establish governance mechanisms that ensure that technological innovation contributes to national agricultural development rather than creating long-term structural dependence.

Technology transfer represents a particularly important component of this process. Genuine technological cooperation should extend beyond the simple importation of agricultural equipment or software. It should include the development of local technical expertise, research and development capacities, digital infrastructure, institutional knowledge, and the ability to adapt technologies to local agricultural and environmental conditions. Developing countries should progressively move from being passive consumers of imported agricultural technologies toward becoming active participants in technological development and governance. Such an approach would strengthen both technological autonomy and food sovereignty.

The study further demonstrates that food sovereignty in the digital era requires inclusive governance. The benefits of AI should not be concentrated exclusively among large agricultural enterprises and technologically advanced actors. Smallholders, rural communities, women, young farmers, researchers, and local agricultural institutions must have meaningful opportunities to access and influence digital agricultural technologies. AI systems should also be adapted to local ecological, economic, and social conditions rather than being introduced as universally applicable solutions. Combining algorithmic knowledge with local and traditional agricultural knowledge can contribute to more context-sensitive and sustainable forms of digital agriculture.

A further conclusion concerns the need for greater coordination between the FAO and other international institutions. Because the governance of agricultural AI extends across multiple legal fields, fragmented institutional action may produce regulatory gaps and inconsistencies. Cooperation among international bodies concerned with agriculture, trade, investment, intellectual property, development, digital governance, and human rights could contribute to the creation of a more coherent international framework. Within such a framework, the FAO

could provide its specialised agricultural expertise while other institutions address the technological, commercial, legal, and economic dimensions that fall outside its direct mandate. Ultimately, the study concludes that the protection of food sovereignty in the age of artificial intelligence requires a transition from a purely technology-centred approach toward a comprehensive governance model. The fundamental question is not whether developing countries should adopt AI, but whether they possess sufficient legal, institutional, technological, and economic capacity to govern its adoption in accordance with their national agricultural priorities. Artificial intelligence should serve as a means of strengthening food systems rather than becoming a new source of dependency. This requires responsible agricultural data governance, equitable access to technology, effective technology transfer, investment safeguards, domestic capacity building, inclusive participation, sustainable digital infrastructure, and stronger international cooperation.

The FAO can play a significant role in this transformation, but it cannot accomplish it alone. Its international mandate gives it an important normative, technical, and coordinating function, yet the broader protection of food sovereignty requires complementary action by States, international organisations, research institutions, farmers, civil society, and private technology actors. The future of agricultural AI governance should therefore be based on cooperation rather than technological concentration, capacity building rather than technological dependence, and shared benefits rather than unequal control. Only through such an integrated approach can artificial intelligence contribute simultaneously to technological progress, sustainable agricultural development, food security, and the preservation of food sovereignty, particularly in developing countries.

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