REGULATORY FRAMEWORK FOR
AGRICULTURAL DATA
IN THE NEAR EAST AND NORTH AFRICA REGION

Food and Agriculture Organization of the United Nations

SUSTAINABLE DEVELOPMENT GOALS

REGULATORY FRAMEWORK FOR
AGRICULTURAL DATA
IN THE NEAR EAST AND NORTH AFRICA REGION

Cover photo: ©FAO

CONTENTS

ACKNOWLEDGEMENTS

ABBREVIATIONS

ADFCA	Abu Dhabi Food Control Authority
AOAD	Arab Organization for Agricultural Development
CCPA	California Consumer Privacy Act
FAO	Food and Agriculture Organization of The United Nations
GDPR	General Data Protection Regulation (Europe)
GPS	Global Positioning System
GSARS	Global Strategy for the Improvement of Agricultural and Rural Statistics
ICARDA	International Center for Agricultural Research in the Dry Areas in Lebanon
ICBA	International Center for Biosaline Agriculture
ICT	information communication technologies
IFAD	International Fund for Agricultural Development
ISPM	International Standards for Phytosanitary Measures
JFDA	Jordan Food and Drug Administration
LARI	Lebanese Agricultural Research Institute
NADGF	National Agricultural Data Governance Framework (Canada)
NAIS	National Agricultural Information System (Jordan)
NENA	Near East and North Africa
NENA-RIAFS	Regional Initiative on Agrifood Systems Transformation in the Near East and North Africa
SDG	Sustainable Development Goals
UNICEF	United Nations Children's Fund
WFP	World Food Programme
WHO	World Health Organization

© FAO

1. INTRODUCTION

Two in three children between the ages of 6 months and 2 years are not getting the nutrients and food they need for healthy growth and development (UNICEF, 2023). Our food systems are major drivers of this problem. Current food systems processes, such as production, farming, processing and global supply chains, are affecting the health of people and further driving the climate crisis. The world's population is projected to reach nearly 10 billion by 2050, and the current food production system will not be able to meet the increased demand for food without significant improvements in efficiency and productivity. Updated projections of the number of undernourished people suggest that nearly 670 million people will still be undernourished in 2030. This projection has increased by 78 million more people because of the COVID-19 pandemic (FAO *et al.*, 2022). Resources such as water and land are becoming increasingly scarce, and traditional methods of food production are causing environmental degradation and resource depletion. Furthermore, up to one-third of all food produced in the world is lost or wasted. Global warming and its impacts such as more frequent extreme weather events, like drought, flooding and storms, pose a serious threat to food security and are making it necessary to improve the climate resilience, efficiency and productivity of the food system.

The Near East and North Africa (NENA) region[1] is also struggling with challenges to food security. Many countries of the NENA region are heavily dependent on imported foodstuffs and fertilizers from the Russian Federation and Ukraine. The current war in Ukraine puts the region at risk of a reduced food supply from the Russian Federation and Ukraine as well at the same time that food prices are increasing as a result of the disturbances caused by the COVID-19 pandemic. According to the *Near East and North Africa Regional Overview of Food Security and Nutrition 2022*, nearly one-third of the NENA region's population, accounting for 154 million people, experienced moderate or severe food insecurity in 2021, which is an increase of more than 12 million people from the previous year. The region will need a set of integrated interventions on the supply and demand side of the food system.

A food system is sustainable when it provides sufficient nutritious food for all without compromising the health of the planet or the ability of future generations to meet their own food and nutritional needs. To achieve such sustainability and meet the Sustainable Development Goals (SDGs), we need to transform our current food systems. The goal of food system transformation is to create a future where all people

---

[1] This report captures the countries of the Near East and North Africa (NENA) region: Algeria, Bahrain, the Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, the Sudan, the Syrian Arab Republic, Tunisia, the United Arab Emirates and Yemen.

have access to healthy diets, to produce food in sustainable and resilient ways, to restore nature and to provide equitable livelihoods (FAO, 2021). A digital transformation of the agrifood systems can help to address these challenges by improving the efficiency, productivity and sustainability of food production. By using digital technologies, we can also improve traceability and food safety.

Digital technologies are multifaceted and can transform agrifood systems by improving efficiency, reducing waste and increasing sustainable food production. A very good example is precision agriculture, which uses Global Positioning System (GPS) sensors and drones to collect data on soil conditions, weather patterns and crop growth. Data is then analysed to optimize planting, fertilizing and irrigating, which can lead to increased yields and reduced input costs. Livestock monitoring is another example where such digital technologies as sensors and cameras can be used to track the health and behavior of livestock. This information can be used to improve animal welfare and reduce the spread of disease. Even in supply chain management, digital technologies can be used to improve traceability and transparency in the food supply chain. For example, blockchain technology can be used to create a digital record of the journey of a food product from farm to table, allowing for more efficient tracking of food safety incidents. Robotics and automation can be used to automate repetitive tasks such as planting and harvesting, which can reduce labour costs and improve efficiency. Digital technologies can be used to improve our understanding of the impacts of climate change on agriculture and develop strategies for mitigating and adapting to these impacts.

Overall, digital technologies can potentially improve the efficiency, sustainability and resilience of agrifood systems. However, it is important to ensure that these technologies are accessible and affordable for farmers, especially smallholder farmers, and that they are used in a way that respects the rights and livelihoods of rural communities.

© FAO

2. IMPACT OF BIG DATA IN AGRICULTURE – CREATING VALUE

Advanced technologies are shifting agriculture towards the digital economy (precision agriculture). The integration of these technologies in farming is generating large amounts of data, known as big data, during production. Although enhanced data can be an asset for farmers, it can also provide high volumes of raw data that is not helpful. However, as data science and data interfaces evolve, we can see agriculture becoming more data driven. Agrifood systems generate data about the objects, events, or phenomena that have a location on the surface of the farm, when and how much pesticides, herbicides and fertilizers are applied, varieties of crops planted, seed quality, etc. Raw data becomes a fourth production factor along with land, labour and capital.

Big data technology facilitates better farm-level decisions in terms of production, procurement, human and financial management, etc., because real-time data can provide information on soil characteristics, climatic conditions, crop data, livestock data and market data. These data allow farmers to make efficient, real-time decisions. A survey of 81 international experts in plant breeding identified the importance of different enabling analytics for data-driven agriculture (Lassoued, 2023). Ranked among the top cross-cutting technologies were software-based decision support systems (that gather and analyse data to address system dynamics and optimization issues), sensors (that collect information on the functioning of equipment and farm resources), and digital communications tools as well as field-based technologies like geographic information and geo-locating systems that enable identifying and tracking the location of objects or people in real time.

© FAO

3. DIGITAL AGRICULTURE – A CONTINUOUS TRANSFORMATION OF AGRICULTURE

There has been a dramatic increase over the last few years in the amount of data collected on farms. Specifically, new players from the private sector, such as agricultural technology providers, high-tech corporations and data companies, have begun to play an increasingly important role in the processes of collecting, storing, processing and analyzing agricultural data. It is estimated that the amount of data generated per day by average farm exceeded 250 000 data points in 2015 (Kosior, 2019). Further increases in agricultural data generation is forecasted – from about 500 000 data points per day in 2020 to more than 2 million data points per day in 2030. This unprecedented surge in agricultural data volumes has been enabled by the combination of general-purpose technologies and new digital tools and devices designed specifically for agricultural production and farms. With advances in information and communication technologies and the emergence of the internet of things, it has turned out that agricultural data may be collected through sensors and other measurement devices almost continuously and in real time. In addition, in contrast to time-consuming surveys used in agricultural data statistics, digital data collected thorough the internet of things devices have proved efficient in providing very detailed and granular information on on-farm processes related to production, environment, animals, plant health, etc.

3.1 Big data and issues of food security

Big data can be a real game changer for the agriculture sector. The collection and analysis process of big data not only plays a vital role in boosting the productivity of individual farms but also proves helpful in relieving some risks of a global food crisis.

The United Nations estimates that the global population will reach 9.8 billion by 2050, a 2.2 billion increase from today. This means that we must increase crop production significantly to provide for so many more people (Talend, 2023).

Today, there is already a need to produce more food on less land to feed the growing population. However, governments are confronted with challenges due to changing climate and environmental issues that have a direct impact on food production. To reach increased food production targets, policymakers and industry leaders are looking at technological innovations such as big data, cloud computing, the internet of things, etc. These technological advances could prove to be highly beneficial in improving operations and boosting productivity. Using analytics in agriculture has become increasingly more common. The analytics market size is expected to grow from USD 585 million in 2018 to USD 1.236 billion by the end of 2023, at a compound annual growth rate of 16.2 percent (Talend, 2023).

© FAO

4. USE OF BIG DATA IN AGRICULTURE IN NENA REGION

The use of big data in agriculture in the NENA region has been growing rapidly in recent years, as the region faces several challenges related to water scarcity, climate change and food security. Governments, research institutions and private companies have been exploring the potential of big data to address these challenges and improve agricultural productivity, sustainability and resilience.

Some examples of big data initiatives in the NENA region include:

→ In Egypt, the Agricultural Research Center has developed a mobile app that allows farmers to access information on weather, pests and diseases, and crop management practices based on big data analysis.

→ In Jordan, the Ministry of Agriculture and the Jordanian Research and Education Network have launched a project to create a national agricultural data platform that will collect and analyze data from various sources to improve decision-making in the agriculture sector.

→ In Lebanon, the International Center for Agricultural Research in the Dry Areas (ICARDA) has developed a digital agriculture platform that integrates data on weather, soil moisture and crop growth to provide real-time recommendations to farmers on irrigation, fertilization and pest control. The platform also includes a mobile app that allows farmers to access these recommendations from their smartphones.

→ In Morocco, ICARDA has developed a big data platform that uses satellite imagery, weather data and machine learning algorithms to improve irrigation management and crop yield prediction.

→ In Qatar, the Ministry of Municipality and Environment has established a geospatial database of agricultural land that includes information on soil quality, water resources and land use. The database is being used to inform policy decisions on land use planning and agricultural development.

→ In Saudi Arabia, the Ministry of Environment, Water and Agriculture has launched a project to collect and analyze data on crop yields, water usage and soil health using drones, satellite imagery and other sensors. The project aims to improve water efficiency and increase crop yields in the country's arid regions.

→ In Tunisia, the National Institute of Agricultural Research has established a data observatory to collect and analyze data on agricultural production, water resources and climate change to inform policymaking.

→ In the United Arab Emirates, the Abu Dhabi Food Control Authority (ADFCA) has developed a smart farming system that uses sensors and machine learning algorithms to optimize irrigation, fertilization and pest control in greenhouses. The system can also track the growth of crops in real-time and alert farmers to any issues.

These and many more initiatives have led to many success stories in the agriculture sector of the NENA region.

→ **Enhancing irrigation efficiency in Egypt:** In 2020, ICARDA implemented a project in Egypt that used big data to improve the efficiency of irrigation and reduce the amount of water wasted. The project used satellite imagery, weather data and soil moisture sensors to develop a real-time irrigation scheduling tool that provided farmers with recommendations on when and how much to irrigate. As a result, farmers were able to reduce their water usage by up to 40 percent while maintaining or improving crop yields.

→ **Reducing food waste in Jordan:** In 2021, the Jordan Food and Drug Administration (JFDA) launched a project that used big data to reduce food waste and improve food safety in the country. The project collected data on food production, distribution and consumption from various sources and used predictive analytics to identify potential food safety risks and reduce food waste. As a result, JFDA was able to reduce food waste by up to 20 percent and improve food safety standards across the country.

→ **Improving wheat production in Lebanon:** In 2019, the Lebanese Agricultural Research Institute (LARI) launched a project that used big data to improve wheat production in the country. The project collected data on weather, soil and crop growth from various sources and used machine learning algorithms to develop predictive models for wheat yield. The models were then used to provide farmers with customized recommendations on planting, fertilization and irrigation, resulting in a 15 percent increase in wheat yields.

Despite these promising initiatives, there are still several challenges to the widespread adoption of big data in agriculture in the NENA region, including limited access to data, inadequate infrastructure and a lack of technical expertise. There is growing recognition of the potential benefits of big data for agriculture, and efforts need to be made to address the challenges relating to its use in agriculture and to promote further innovation in the sector.

© FAO

5. CHALLENGES AND GOVERNANCE OF DATA IN AGRICULTURE

Agricultural data and their use for better decision making and innovation are at the center of the digital transformation of agriculture. But fragmented and unclear data governance arrangements may make farmers less willing to adopt digital solutions. This, in turn, may reduce the availability and accessibility of agricultural data for policymaking, for the agricultural innovation system and for developing services for farmers. A key challenge for policymakers lies in finding a balance between protecting the privacy and confidentiality of agricultural data, and the economic interests of farmers in those data, while making it possible to leverage their potential for the sector's growth and innovation. Some of the challenges and governance issues relating to agri data are discussed in the following.

5.1 Including many stakeholders creates issues of data ownership

In agriculture, data is generated by a range of actors including farmers, agribusinesses, government agencies and researchers. Each of these stakeholders may have different interests and priorities when it comes to data ownership and control. For example, farmers may be reluctant to share their data with others, particularly if they perceive it as valuable and proprietary information that gives them a competitive advantage. Yet, researchers and policymakers may see the value in aggregating and analyzing data from multiple sources to identify trends, develop insights and inform policy decisions. Property rights to different types of agricultural data are not yet clearly defined. Generally, farmers are considered to be the owners of the raw agricultural data collected on their farms, but aggregated datasets, which, in fact, allow for extracting new knowledge and insights important to farmers, are considered to be owned by the companies and organizations engaged in collecting and aggregating the data.

Ownership as a legal concept is rather complex, and farming data is not traditionally recognized as a type of property that is subject to ownership. The currently available ownership-like rights of data are limited to intellectual property rights (copyright, patents, database rights, trade secrets and plant breeders' rights). However, none of these provide adequate protection for data ownership. Copyright is one way in which data can be owned, but data is not always or even normally copyright protected by default (Zampati, 2023).

Ultimately, addressing data ownership issues in agriculture requires a collaborative and multi-stakeholder approach that recognizes the value of data as a public good while also respecting the rights and interests of individual stakeholders. It is more appropriate to determine who should have control and access to farm data, rather than who should have ownership of data. In many cases, farmers own the data that comes from their farms, but they have little control over who or how their data is used.

5.2 Determining rights over the value generated from the data

The question of who has the right to the value generated by big data in agriculture is complex and often depends on a range of factors such as the data ownership rights, data sharing agreements and the context in which the data is generated and used.

In general, when data is generated by a single entity, such as a farmer or agribusiness, that entity typically has the primary right over the value generated by that data. However, when data is generated through collaboration or is shared between multiple entities, the question of ownership and value can become more complicated.

In some cases, agreements may be put in place to determine how the value generated by big data is shared among different stakeholders. For example, a farmer may share their data with a technology company in exchange for access to advanced analytics tools or other benefits. In this case, the farmer may retain ownership of the data, but the technology company may have a right to some of the value generated by that data.

Similarly, in cases where data is generated through publicly funded research or data sharing initiatives, there may be policies in place that govern how the value generated by that data is distributed. For example, some research institutions require that data generated through publicly funded research be made freely available to the public or to other researchers.

Ultimately, the question of who has the right over the value generated by big data in agriculture is still being debated and may depend on a range of legal, ethical and social considerations. As the use of big data in agriculture continues to grow, it will be important to develop clear and transparent policies that govern data ownership and sharing to ensure that the value generated by that data is fairly distributed among all stakeholders.

5.3 Accessing and sharing data

The important question is who has access to which data and in what context. These data sharing issues arise in other sectors too, but there are scientific hurdles that are specific to agriculture. The data is heterogeneous. It comes from satellites, ground-based sensors, markets, etc. It comes in the form of texts, images and measurements. There must be a way for these data to communicate with each other (and the next challenge is to make sure that all the stakeholders in the industry can benefit from it) by accessing a level of data aggregation that does not exceed what the other stakeholders want to make available.

If big data is to facilitate sustainable farming and agriculture, the role of farmers must be better understood. Modern farm machines can be equipped with sensors and cameras, which capture field-level data. Hence, farmers are becoming significant data holders. Given the geoclimatic-specific nature of agricultural production, data aggregation across a large number of farms is essential in order to develop accurate forecasting models and production management recommendations using big data analytics. Data at the individual farm level has finite value to the given farm, but aggregated data pooled across many farms has the potential to reveal undiscovered patterns and insights that are impossible to determine if only

examining individual farm data. Therefore, the realization of the revolutionary value promised by big data technologies may depend upon the willingness of farmers to pool their agricultural production data.

If farmers do not know who is collecting their data, how it will be used, or whether it is being used ethically and in compliance with regulations, it will be difficult for farmers to trust third-party providers of data and technology services. For example, farmers may be concerned that a provider of precision agriculture technology is collecting data in a way that is not transparent or not aligned with the farmer's interests or needs.

5.4 Data privacy and related rights of farmers to data

Processed data becomes information capable of generating tangible monetary and non-monetary benefits. Secrecy and privacy of data goes to the very roots of fairness and trust. Data privacy is a major concern of agricultural data sharing, and private agricultural data owners may be reluctant to share their data. Security is another concern. Many private agricultural datasets are stored locally rather than on cloud computing platforms due to security concerns, and these concerns must be addressed before many data owners will be willing to share their data.

5.5 Insufficient legal frameworks concerning agricultural data

While laws and regulations governing personal data (such as the European General Data Protection Regulation [GDPR]) are becoming increasingly common, there is a lack of legislation covering the collection, sharing and use of data in agriculture.

The lack of a regulatory framework with big data in agriculture can lead to many challenges. One major issue is that it can be difficult for farmers and other stakeholders in the agriculture sector to understand their rights and responsibilities when it comes to data collection, storage and use. The absence of a regulatory framework can make it difficult for government agencies and other organizations to monitor the use of big data in the agriculture sector. Without clear regulations in place, it can be challenging for these organizations to identify and address any potential issues with data privacy, security or misuse.

Without regulation, it can also be hard for farmers to ensure that data-driven technologies are used ethically and sustainably, as there is no mechanism in place to enforce environmental, labour or social standards. Regulation of big data in agriculture is important for protecting farmers' rights, ensuring transparency and trust, and promoting the sustainable and ethical use of data-driven technologies. It is essential for government and industry stakeholders to work together to develop and implement effective regulations that balance the benefits of big data in agriculture with the need to protect farmers' rights and promote sustainable and ethical practices.

5.6 Risks of unauthorized access and use of such data and uncompetitive practices

From an economic perspective, the integration of big data and technology can improve the efficiency and productivity of agriculture by enabling farmers to make more informed decisions. However, the collection and processing of data may be subject to unfair market practices. Once data is collected, it is prone to misuse, like imbalances in price negotiations, manipulation of research outcomes, cumbersome contractual clauses, exclusivity clauses (where a farmer may not be allowed to share the data with others), etc. Intervention by public authorities may be required to empower the farmers to fight against any such unfair market practices.

Further, if the technology and data access is not evenly distributed and accessible, it will give bigger farmers a competitive advantage over smaller ones. Additionally, the high cost of the technology may not allow small-scale farmers to purchase the necessary infrastructure.

Therefore, the use of big data and technology in the agriculture sector also has the potential to bring about new economic and social inequalities. For example, large agribusinesses may have easier access to, and be more easily able to use, data-driven technologies such as precision agriculture compared to smaller farmers. This could lead to larger farms becoming more efficient and profitable, while smaller farms struggle to compete. Smaller and family run farms may not have the same level of digital literacy and technological know-how as larger operations, making it more difficult for them to use data-driven technologies effectively. There may also be a lack of access to the internet and other digital infrastructure in rural communities, which could further exacerbate these inequalities.

©FAO

6. REGULATORY POLICIES AND LANDSCAPE OF NENA COUNTRIES ON THE USE AND STORAGE OF DATA

6.1 Data protection laws and policies in NENA countries

The countries in the NENA region have a diverse set of data protection laws and policies. Some countries, such as the United Arab Emirates, have relatively strong data protection laws in place, while others have less robust protections. In general, the NENA region has yet to fully adopt ambitious data protection laws, such as the European Union's GDPR; however, many countries are in the process of updating their data protection laws to align with international standards. While some countries still lack any data protection laws, e.g. Iraq, Somalia, the Sudan, the Syrian Arab Republic and Yemen.

6.2 Deficiencies in current data regulations with respect to agricultural data

In the NENA region, there are some initiatives that focus on agricultural data governance. For example:

→ The Arab Organization for Agricultural Development (AOAD) has developed a regional strategy for the digital transformation of agriculture that includes agricultural data collection and analysis, but it lacks any regulatory framework concerning data governance.

→ In Morocco, the National Agriculture Competitiveness and Sustainable Development Program includes improving access to data and information for farmers, as well as establishing a framework for managing and sharing agricultural data.

→ Similarly, the Regional Initiative on Agrifood Systems Transformation in the Near East and North Africa (NENA-RIAFS) has identified the need for governance frameworks and policies to manage agricultural data in the region.

→ The Ministry of Agriculture in Tunisia has established a national database of agricultural holdings that includes information on crop yields, livestock production, and land use. The database is used to inform policies and programmes aimed at supporting the agricultural sector in the country.

→ The Government of Egypt has launched a digital platform called Farms of the Future that promotes precision agriculture by providing farmers with access to real-time data on weather conditions, soil moisture and other relevant information.

→ The International Center for Biosaline Agriculture (ICBA) has developed a framework for managing agricultural data in the NENA region that includes guidelines for data collection, sharing, and use, as well as recommendations for developing policies and regulations to govern the management of agricultural data.

→ The Food and Agriculture Organization of the United Nations (FAO) has developed a programme called the Global Strategy for the Improvement of Agricultural and Rural Statistics (GSARS) that includes a focus on improving the collection and management of agricultural data in the NENA region.

→ In the United Arab Emirates, the Food Security and Agriculture Strategy 2051 promotes sustainable agricultural practices and increasing food self-sufficiency in the United Arab Emirates. As part of this strategy, the Government established a National Food Security Data Bank to collect and manage data on food production and consumption.

→ In Jordan, the National Agricultural Information System (NAIS) provides a centralized platform for collecting and sharing data on agriculture in the country.

The focus in the NENA region is on the use of big data in agriculture for informed decision making. However, there may not be any specific regulations or guidelines concerning the use, collection or storage of agricultural data. AOAD has recognized the importance of developing a legal and regulatory framework for the use of big data in agriculture in the NENA region.

AOAD launched a project to develop a regional framework for the governance of big data in agriculture that includes conducting a review of existing laws and policies related to big data in agriculture in the NENA region. The project aims to identify gaps and challenges in the legal and regulatory framework, and it develops recommendations for a regional legal framework for the use of big data in agriculture.

In addition, some individual countries in the NENA region, such as Saudi Arabia and the United Arab Emirates, have launched initiatives and strategies to promote the use of big data in agriculture. While these initiatives may not include specific laws or regulations related to the governance of big data in agriculture, they provide a regulatory framework and direction for developing and implementing policies and technologies in the agricultural sector.

Current frameworks for agricultural data governance and existing regulations are incomplete and cannot be adapted to deal with the challenges and needs of responsible, smart farming. Moreover, some elements in the existing framework seem to increase tensions in the emerging digital-agriculture ecosystems. The lack of specific legal provisions concerning the ownership and protection of raw agricultural data enhances the position of agricultural technology providers and third-party aggregators in the smart farming data value chain.

The laws protecting personal data include a set of provisions aimed at enhancing the protection, privacy and security of personal data. The relevant regulation defines personal data as any information relating to an identified or identifiable natural person (data subject). Individuals have the right to have access to their

personal data collected and processed by data controllers and data processors to correct inaccuracies in their personal data, to give consent to the processing of their personal data for one or more specific purposes, to withdraw such consent, or to have their data deleted. Personal data is to be processed lawfully, fairly and in a transparent manner. Data controllers have also been obliged to notify data subjects about any breaches of their personal data. Undoubtedly, the regulation provides important legal standards and guidelines for the ethical use of personal data in a digital economy, but at the same time it may be barely applicable to agricultural data.

Most smart farming data is machine-generated and concerns soil, plants and animals. Although it may be linked with data on profitability of specific production types or the GPS location to reveal important personal information such as farmers' incomes or farm locations, its primary character is still non-personal. For example, a farmer may face difficulties when using personal data protection laws to withdraw their consent to processing farm data collected on their farms with the use of machines and other devices as specified in the contractual agreement with an agricultural technology provider. This would be particularly true for data items subject to aggregation and anonymous procedures and presented in databases independently from datasets including personal data.

Therefore, the agricultural data needs to have separate regulations that may smooth the transformation of agrifood systems from traditional to digital. Some key deficiencies of the current regulations include a lack of data ownership. Current data regulations may not clearly define who owns agricultural data, and this can make it difficult for farmers and other stakeholders to control access to and use of their data.

© FAO

7. INTERNATIONAL BEST PRACTICES FOR REGULATIONS IN DIGITAL AGRICULTURE

There are few examples of specific agricultural data governance frameworks that have been developed to manage the collection, storage and use of agricultural data in a way that is fair, transparent, and respects the rights of farmers and other data providers. Here are a few examples:

→ The National Agricultural Data Governance Framework (NADGF), developed by the Government of Canada, establishes guidelines and standards for collecting, storing and use of agricultural data, and it is intended to ensure that data is used in a fair and transparent way and that farmers and other data providers are fairly compensated for the value they create.

→ The Data Governance Framework for Agriculture, developed by the Government of Australia, establishes guidelines and standards for data management within the agricultural sector and helps ensure the fair and responsible use of agricultural data, as well as protecting the rights of farmers and other data providers.

→ The Agricultural Data Management Framework, developed by the Government of the United Kingdom of Great Britain and Northern Ireland, focuses on the collection and management of data and establishes guidelines and standards for protecting the rights of farmers and other data providers and managing data in a way that promotes transparency and fairness.

→ The European Union Data Governance Act, which is in force from 24 September 2023, aims to provide a legal framework for collecting, using and sharing data to support fair and transparent data governance for the European Union agrifood system.

→ The Agrifood Data Governance Code, developed by the European Forum for Agrifood Research for Development, promotes the responsible use of agricultural data to support sustainable development and the reduction of poverty in the agrifood sector.

→ The Agricultural Data Management and Utilization Policy, developed by the Government of India, focuses on the collection, storage and use of agricultural data, and aims to ensure that data is used in a way that is fair and transparent and that farmers and other data providers are compensated for the value they create.

→ The Data Governance Framework for Agriculture and Agrifood, developed by the Government of New Zealand, establishes guidelines and standards for data management within the agricultural sector and focuses on protecting the rights of farmers and other data providers and ensuring that data is used in a way that is safe, secure and respects the privacy of data providers.

→ The Agricultural Data Management Standards, developed by the Agricultural Data Coalition, an organization based in the United States of America, focuses on data management practices and protocols that help to ensure the security, privacy and accuracy of agricultural data.

→ The International Standards for Phytosanitary Measures (ISPM) is set of international standards developed by FAO, which lays out guidelines for collecting and managing data related to plant health and biodiversity. It also addresses trade-related aspects of plant health.

In addition to these examples, many organizations, such as research institutions, companies and cooperatives, have their own agricultural data governance frameworks that are intended to set standards and protocols for data governance, provide guidance and education on best practices, as well as promoting transparency and trust in the use of agricultural data.

These frameworks typically include guidelines and standards for data collection, storage and use, as well as measures to ensure that data is used in a fair and transparent way and that farmers and other data providers are compensated for the value they create. Additionally, they often include measures to protect the rights of farmers and other data providers and to ensure that data is used in a way that is safe and secure. But these are still insufficient considering the various aspects of agricultural data requiring the attention of decision makers for a regulatory framework.

© FAO

8. AREAS THAT REQUIRE POLICIES OR REGULATIONS TO ENSURE THE SUSTAINABLE TRANSFORMATION OF AGRIFOOD SYSTEMS

8.1 Ability to trace back anonymous, manipulated or misused data

There are several regulation requirements that are important to consider to prevent the manipulation or misuse of anonymous agricultural data. Regulations should require data controllers to keep records of the origin and movement of data, so that it can be traced back to its source in case of misuse or manipulation.

Data accuracy and integrity: Regulations should require data controllers to ensure the accuracy and integrity of the data they collect and use, and to provide mechanisms for correcting errors or inaccuracies.

Data deletion and retention: Regulations should require data controllers to delete or destroy data that is no longer needed or when the purpose for which it was collected has been fulfilled. They should also set a retention period for data, after which the data would be destroyed, archived or made anonymous.

Data quality and standardization: Regulations should require data controllers to ensure the quality and reliability of agricultural data and provide mechanisms for feedback, quality control and standardization.

Data security: Regulations should require data controllers to implement technical and organizational measures to protect data from unauthorized access, alteration, or disclosure, including encryption and regular security assessments.

Data protection by design and default: Regulations should require data controllers to adopt data protection measures at the earliest stage of data processing, and these measures should be built into the design of systems and processes.

Data audits: Regulations should require data controllers to be subject to regular audits to verify compliance with data protection regulations, and to have a plan for dealing with data breaches or unauthorized access to data.

Data governance: Regulations should require data controllers to establish clear governance structures for data management, including roles and responsibilities, data sharing agreements and dispute resolution mechanisms.

Data ethics: Regulations should require data controllers to consider the ethical implications of their data collection and use, such as privacy, bias, transparency, accountability and inclusivity.

8.2 Variety of data formats and interfaces

Regulations need to address the issue of a variety of data formats and interfaces in agriculture through data standardization and data mapping. Regulations can require data controllers to use specific data formats and interfaces that are widely adopted and accepted in the agricultural industry. This can ensure that data is consistent and easily shareable among different stakeholders. Regulations can also require data controllers to provide mapping guidelines and tools to help stakeholders understand and use the data in different formats and interfaces.

8.3 Network effects, digital and tech giant monopolies

The problem of network effects in the digital and technology industries can lead to monopolies, which can negatively affect competition and innovation. In the context of the agrifood system transformation, these monopolies have the potential to limit access and control of small and medium-sized farmers to new technologies and information, hindering their ability to participate in and benefit from the transformation. Therefore, regulations may be needed to ensure fair competition and equitable access to these technologies for all stakeholders in the agricultural industry. Regulations can address the problem of network effects and monopolies in the agrifood system transformation through:

Antitrust laws: These laws can be used to prevent companies from engaging in monopolistic practices, such as price fixing, exclusive dealing and predatory pricing.

Net neutrality regulations: These regulations can ensure that all internet traffic is treated equally, preventing companies from prioritizing their own services over those of competitors.

Data sharing and interoperability requirements: Regulations can be put in place to ensure that data is shared and made available to all stakeholders, rather than being controlled by a single company.

Open-access policies: Governments can require companies to make their technology and intellectual property available to others on fair and reasonable terms.

8.4 Potentially constraining effects of new ownership rights or limited residual ownership to agricultural data

New ownership rights or limited residual ownership of agricultural data can constrain the agrifood system by limiting access to data, taking away control over data, and by reducing innovation and competition, etc., which can impede the growth and development of the agricultural industry and limit the ability of farmers and other stakeholders to participate in and benefit from the agrifood systems transformation.

A regulatory framework can address these potentially constraining effects by framing data sharing and interoperability requirements, data access and control regulations, data portability and data ownership and control regulations.

Regulations can be put in place to ensure that data is shared and made available to all stakeholders, rather than being controlled by a single company. Governments can require companies to provide farmers with access to their own data and control over how it is used. Regulations can also be put in place to ensure that farmers are able to take their data with them if they switch to a different provider or platform. Governments can set up legal frameworks for data ownership and control, such as through data trusts, to ensure that farmers and other stakeholders have a say in how their data is used.

As with any regulation, it is essential to strike the right balance between protecting the interests of farmers and other stakeholders without stifling innovation and progress.

8.5 Incomplete or missing small farm data markets

Incomplete or missing data markets can impede the growth and development of small farmers and limit their ability to participate in and benefit from the agrifood systems transformation. It is important that governments, the private sector and other organizations invest in data collection, analysis, and dissemination in order to improve data availability and quality for small farms. Through regulations, governments can require companies and organizations to collect and report data on small farms, and make it available to researchers, policymakers and other stakeholders. Governments can fund research and development projects that focus on collecting and analysing data on small farms. This can help to fill the gap of missing data and make it more accessible. Financial incentives or subsidies should be provided to encourage small farmers who share their data with researchers, policymakers and other stakeholders.

8.6 Economies of scale favouring the data assets of larger farms

Larger farms typically have more resources to invest in data collection and analysis, such as advanced sensors and software. This can give them an advantage over smaller farms in terms of the amount and quality of data they can collect. Larger farms may have more bargaining power when it comes to negotiating data sharing agreements with technology providers and other organizations, which can give them an advantage over smaller farms in terms of access to data. These economies of scale can result in larger farms having a greater ability to collect, analyse, and utilize, resulting in a competitive advantage in the market. This can make it more difficult for small farmers to compete and innovate. To address this, governments and private organizations can invest in programmes and initiatives to provide small farmers with access to data collection and analysis tools, as well as training and support to use them effectively.

© FAO

9. RECOMMENDATIONS ON HARMONIZING THE REGULATORY FRAMEWORKS AND SYSTEMS ON AGRICULTURAL DATA IN THE NENA REGION

Harmonization of regulatory framework within the NENA region can foster fair data market that so that also smallholder farmers benefit from these opportunities of digital agriculture. Harmonizing regulatory frameworks and systems on agricultural data in the NENA region can be a complex and multifaceted process that requires engaging a wide range of stakeholders. Here are a few strategies that could be used to harmonize regulatory frameworks and systems on agricultural data in the NENA region:

Multistakeholder engagement: Harmonization efforts should involve a wide range of stakeholders, including farmers, researchers, policymakers, data managers and private sector representatives, to ensure that all their needs and perspectives are taken into account.

Technical assistance: Technical assistance and capacity building should be provided to help countries in the NENA region develop and implement regulations and systems related to agricultural data, which will help to ensure that these regulations and systems are appropriate for the specific context of the region.

Develop common standards: Establishing common standards and guidelines for data collection, management, sharing and use can help to ensure that data is consistent and comparable across different countries in the NENA region, which can facilitate data sharing and collaboration.

Regional cooperation and coordination: Harmonization efforts should be coordinated regionally, such as through regional organizations, to ensure that regulations and systems are aligned and consistent across different countries in the NENA region.

International best practices: Harmonization efforts could draw on international best practices and standards in the area of agricultural data governance, to ensure that regulations and systems in the NENA region are up-to-date and consistent with the global standards. International organizations such as FAO have an important role to play in this regard as it can help countries to develop policies and regulations for the use of big data in agriculture on the basis of the same set of pre-defined standards.

Monitoring and evaluation: Regular monitoring and evaluation of the harmonization efforts are necessary to ensure that the objectives are met and the approaches adjusted accordingly, if necessary.

The harmonization process of regulations and systems on agricultural data in the NENA region may take a long time, as it requires the long-term commitment and coordination of all the parties involved. It is also important to consider cultural, economic and political differences across the region.

© FAO

10. RECOMMENDATIONS ON HOW TO USE THE AGRICULTURAL DATA TO SUPPORT THE TRANSFORMATION OF THE AGRIFOOD SYSTEMS IN THE NENA REGION

10.1 Protecting ownership of farm data and the underlying rights to the derived data

The most important aspect of regulations is the protection of the ownership of farm data and the underlying rights to derived data. This can be achieved either through separate legislation for farm data or by making amendments to the existing legislation relating to intellectual property, data protection or those relating to antitrust and competition. Here are a few examples of how the ownership of farm data may be protected with regulations:

Intellectual property laws: Many countries have intellectual property laws that protect the rights of data owners, such as farmers, over their data. This can include laws related to patents, trademarks, and copyrights that provide legal protection for certain types of data, such as agricultural innovations or proprietary software.

Data privacy and security laws: Some countries have laws and regulations that govern data privacy and security, such as the GDPR in the European Union and the California Consumer Privacy Act (CCPA) in the United States of America, which can protect the rights of data owners to their personal data. Similar laws can also be framed for farm data with different features.

Competition laws: Competition laws help ensure fair competition in the market by preventing companies from engaging in monopolistic or anticompetitive practices. This can include regulations that prevent companies from using proprietary data to gain an unfair advantage in the market.

Farmers' rights: Few countries have specific laws that protect the rights of farmers to their data, such as the farmers' rights laws in India, which protects the rights farmers have to their traditional knowledge and practices, including access to and control over the genetic resources of the plants that they use to develop their agricultural practices.

Data governance frameworks: Data governance frameworks may be framed to establish clear guidelines and standards for data management, such as in Canada and Australia where national data governance frameworks for the agricultural sectors are being established to ensure that data is used in a fair and transparent way, and that farmers and other data providers are fairly compensated for the value they create.

Industry self-regulation: Some countries rely on industry self-regulation, such as codes of conduct, to ensure that companies treat farm data with respect and do not misuse or mishandle data in ways that harm farmers and other data providers.

10.2 Fair distribution of value created through data

Ensuring fair distribution of value created through agricultural data can be a difficult process. However, clear policies and regulations that establish the rights of data owners, such as farmers, and limit the use of their data without their consent can help to ensure fair distribution. Data sharing agreements that establish the terms and conditions under which data can be shared and used can help to ensure that the value created through agricultural data is distributed fairly among all stakeholders.

Establishing effective data governance structures, such as data trusts or data cooperatives, fair pricing and compensation mechanisms, such as data royalties or data sharing fees, regulations that protect against anticompetitive practices, such as price fixing and monopolies, ensuring transparency in the collection, use and sharing of data, and ensuring that data users, such as agribusinesses and researchers, disclose information about their data collection, storage and use practices can help to ensure that the value created through agricultural data is distributed fairly to data providers, such as farmers.

Achieving fair distribution of value created through agricultural data is not a one-size-fits-all solution, and it can be challenging to reach. It requires collaborative efforts and coordination among all stakeholders, and it is important to be flexible and adaptable to the context, and to cultural, economic and political differences.

10.3 Fair and transparent contracts

Ensuring fair and transparent contracts in the agrifood system is important for protecting the interests of all stakeholders and promoting the sustainable development of the agricultural sector. Here are a few strategies that can be used to ensure fair and transparent contracts:

Clearly defined terms and conditions: Contracts should clearly define the terms and conditions of the agreement, including the rights and responsibilities of all parties, and any potential liabilities or disputes.

Standardized contract templates: Using standardized contract templates can help to ensure that contracts are fair and transparent, by providing clear and consistent terms and conditions across different agreements.

Dispute resolution mechanisms: Contracts should include dispute resolution mechanisms, such as mediation or arbitration, to resolve any disputes that may arise between the parties.

Fair pricing and compensation mechanisms: Contracts should include fair pricing and compensation mechanisms to ensure that all parties are compensated fairly for the value they create.

Data privacy and security: Contracts should include data privacy and security provisions that protect the rights of data owners, and govern how data can be collected, stored and used.

Compliance with laws and regulations: Contracts should comply with all relevant laws and regulations, such as those related to data privacy, intellectual property, and competition law, to avoid conflicting or inconsistent agreements.

Transparency: Contracts should be transparent, meaning that all the relevant parties have access to the information required to understand and agree to the terms of the contract.

Review and feedback: Contracts should be reviewed and evaluated periodically to ensure that they are still fair, transparent and adapted to the changes in market, technology and the legal environment.

Fair and transparent contracts require the collaboration and coordination of all stakeholders, and engagement with legal experts to ensure they are legally binding and enforceable. Contracts should also be adapted to the specific context of the agrifood system, and to the cultural, economic and political differences.

10.4 Liability mechanism

Liability mechanisms are an important aspect of agricultural data governance, as they help to ensure that data is used responsibly and ethically and that any harm caused by the misuse of data is addressed. In the context of the NENA region, a few key liability mechanisms that could be implemented in support of transforming agrifood systems include:

Legal liability: Legal liability mechanisms establish the legal responsibility of data providers, users and processors for any harm caused by the misuse of data. This could include criminal or civil liability for breaches of data privacy, intellectual property or competition laws.

Data sharing agreements: Data sharing agreements can include liability clauses that establish the liability of data providers and users in the event of a data breach, misuse or unauthorized use of data.

Data privacy and security policies: Policies that clearly define the rights and responsibilities of data providers and users with regard to data privacy and security can help to ensure that data is used responsibly, and any harms caused by data breaches or misuse can be mitigated.

Insurance: Agricultural data providers and users can purchase insurance policies to protect themselves against possible financial liabilities arising from misused data.

Auditing and monitoring: Regular auditing and monitoring of data usage can help to ensure that it is being used responsibly and any harms caused by misuse can be identified and addressed quickly.

Data governance structure: Data governance structures, such as data trusts or data cooperatives, can include liability mechanisms that ensure that data providers and users are held accountable for any harm caused by the misuse of data.

Liability mechanisms may vary depending on the specific context of the NENA region, and laws and regulations may not yet exist or be developed yet. Liability mechanisms should be tailored to the specific circumstances and conditions of the agrifood systems.

10.5 Simple and coherent policies for data that promote the digital transformation of the agrifood system

Simple and coherent policies for data can play a critical role in promoting the digital transformation of the agrifood system by fostering innovation, collaboration and sustainable development. Here are a few key elements of simple and coherent data policies:

Data privacy and security: Policies should ensure that data privacy and security are protected, and that an individual's personal data is handled ethically and responsibly.

Data sharing and interoperability: Policies should promote data sharing and interoperability among stakeholders, such as public sector, farmers, researchers and private sector companies, to foster innovation and collaboration.

Data standardization and quality: Policies should promote the use of common data standards and formats to ensure that data is consistent and comparable across different systems and organizations.

Data governance and management: Policies should establish clear guidelines for data governance and management, including policies for data collection, storage, sharing and use.

Data ownership and control: Policies should protect the rights of data owners and ensure that data is not used without their consent, and that it is used in a fair and transparent way.

Data pricing and compensation: Policies should establish fair pricing and compensation mechanisms for data, to ensure that data providers, such as farmers, are compensated for the value they create.

Capacity building: Policies should provide for capacity building and training programmes to help stakeholders, particularly farmers, to effectively manage and use agricultural data.

Regular evaluation: Policies should include regular monitoring and evaluation to ensure that they are still relevant and effective in promoting the digital transformation of the agrifood system.

The process of implementing simple and coherent policies for data should take into account the specific context of the agrifood systems, such as cultural, economic and political differences, and should be adaptable to the changing market, technology and legal environment.

10.6 Regulations – ensuring the right balance between adapting to the changing nature of technological advancements and creating a level playing field

Finding the right balance between adapting to the changing nature of technological advancements and creating a level playing field is important for the sustainable and equitable development of the agricultural sector. Adapting to technological advancements is important because it can lead to improved efficiency and productivity in the agricultural sector, and it can also help to improve the quality of agricultural products. This can support agrifood systems in meeting the increasing global demand for food. Creating a level playing field is important because it ensures that small-scale farmers and other marginalized groups are not left behind and that they will have opportunities to benefit from technological advancements. This is important for promoting sustainable and equitable development in the agricultural sector. Balancing the two goals is important because rapid technological changes can cause disruption and inequalities,

particularly for small-scale farmers who may not have the resources to access new technologies. Therefore, it is essential to ensure that policies and regulations are in place to balance the benefits of technological advancements with the need to promote fairness and inclusivity in the agricultural sector.

Encouraging the adoption of new technologies by providing incentives, such as subsidies, tax breaks or training programmes, can help to balance the needs of farmers with the need to keep up with technological advancements. Investing in education and training programmes to help farmers and other stakeholders in the agricultural sector to better understand and make use of new technologies can be a powerful way to balance the needs of farmers with the need to keep up with technological advancements.

Regular monitoring and evaluation of the impact of technological advancements on the agricultural sector can help to ensure that the right balance is being maintained and that any negative effects are identified and addressed in a timely manner.

The right balance between adapting to the changing nature of technological advancements and creating a level playing field varies depending on the specific context of the region or country, including factors such as the availability of resources, infrastructure, education and training levels, and the economic and social conditions of the population. It is important to consider these factors when developing policies and regulations related to technological advancements in the agricultural sector. Additionally, involving different stakeholders, such as farmers, researchers, private sector companies, and government agencies in the decision-making process helps to ensure that the policies and regulations are tailored to the specific needs and context of the region or country.

© FAO

11. CONCLUSION

Agricultural data and their use for better decision making and innovation are at the centre of the digital transformation of agriculture. The integration of big data and technology can improve the efficiency and productivity of agriculture by enabling farmers to make more informed decisions. The increase of agricultural productivity in the NENA region with scarce natural resources is crucial to meet sustainably the food demand of a growing population. Despite some promising initiatives, there are still several challenges to the widespread adoption of big data in agriculture in the NENA region, including limited access to data, inadequate infrastructure and regulatory framework, and a lack of technical expertise.

As the use of big data in agriculture continues to grow, it is important to develop clear and transparent policies that govern data ownership and sharing to ensure that the value generated by that data is fairly distributed among all stakeholders, including farmers and technology companies. The absence of a regulatory framework can make it difficult for government agencies and other organizations to monitor the use of big data in the agriculture sector. Without regulation, it can also be hard to ensure farmers that data-driven technologies are used ethically and sustainably, as there is no mechanism in place to enforce environmental, labour or social standards. Thus, farmers might be reluctant to share their data. Furthermore, if the technology and data access is not evenly distributed and accessible, it will give bigger farmers a competitive advantage over smaller ones. Additionally, the high cost of the technology may not allow small-scale farmers to purchase the necessary infrastructure. Therefore, the use of big data and technology in the agriculture sector also has the potential to bring about new economic and social inequalities. Intervention by public authorities may be required to fight against unfair market practices.

The analysis of current data protection laws in the region reveals that current frameworks for agricultural data governance and existing regulations are incomplete and cannot be adapted to deal with the challenges and needs of responsible, smart farming. Moreover, some elements in the existing framework seem to increase tensions in the emerging digital-agriculture ecosystems. The lack of specific legal provisions concerning the ownership and protection of raw agricultural data can make it difficult for farmers and other stakeholders to control access to and use of their data and enhances the position of agricultural technology providers and third-party aggregators in the smart farming data value chain.

Current existing international best practices in agriculture typically include guidelines and standards for data collection, storage and use, as well as measures to ensure that data is used in a fair and transparent

way and that farmers and other data providers are compensated for the value they create. Additionally, they often include measures to protect the rights of farmers and other data providers and to ensure that data is used in a way that is safe and secure. But these are still insufficient considering the various aspects of agricultural data requiring the attention of decision makers for a regulatory framework.

Harmonization of regulatory framework within the NENA region can foster fair data market in such a way that also smallholder farmers benefit from the value created by digital agriculture. Harmonizing regulatory frameworks and systems on agricultural data in the region can be a complex and multifaceted process that requires engaging a wide range of stakeholders, regional cooperation and technical assistance, developing common standards and building on international best practices.

In addition, non-regulatory measures such as public-private partnerships, education, training or technical assistance programmes can also be effective in promoting the agrifood systems transformation, especially when they are well designed and implemented. In practice, a combination of regulations, education and technical assistance programmes, as well as private sector investments, work together to encourage the sustainable and equitable development of agricultural systems.

Some recommendations emanate from this report on how to use the agricultural data to support the transformation of the agrifood systems in the NENA region:

→ Protection of the ownership of farm data and the underlying rights to derived data can ensure that farmers, including smallholders, benefit from the value generated by agricultural data.

→ Clear policies and regulations that establish the rights of data owners, such as farmers, and limit the use of their data without their consent can help to ensure a fair distribution of benefits.

→ Ensuring fair and transparent contracts in the agrifood system is important for protecting the interests of all stakeholders and promoting the sustainable development of the agricultural sector.

→ Liability mechanisms, such as legal liability or data sharing agreements, are an important aspect of agricultural data governance, as they help to ensure that data is used responsibly and ethically and that any harm caused by the misuse of data is addressed.

→ Simple and coherent policies for data can play a critical role in promoting the digital transformation of the agrifood system by fostering innovation, collaboration and sustainable development.

→ Finding the right balance between adapting to the changing nature of technological advancements and creating a level playing field to ensures that small-scale farmers and other marginalized groups benefit from the digital transformation of agriculture.

REFERENCES

FAO (Food and Agriculture Organization of the United Nations. 2021. Agri-food systems transformation: new, ambitious framework proposed to monitor progress. In: *FAO Newsroom.* Rome. Cited 10 April 2023. www.fao.org/newsroom/detail/new-framework-proposed-to-monitor-food-systems-progress/en

FAO, IFAD (International Fund for Agricultural Development), UNICEF (United Nations Children's Fund), WFP (World Food Programme) & WHO (World Health Organization). 2022. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable.* Rome, FAO. https://doi.org/10.4060/cc0639en

Kosior, K. 2019. *From Analogue to Digital Agriculture. Policy and Regulatory Framework for Agricultural Data Governance in the EU.* Conference Paper. www.researchgate.net/publication/333929761_From_Analogue_to_Digital_Agriculture_Policy_and_Regulatory_Framework_for_Agricultural_Data_Governance_in_the_EU

Lassoued, R. 2023. Big data transforms agriculture from traditional to digital. In: *CAST. Council for Agricultural Science and Technology.* Ames, Iowa. Cited 10 April 2023. www.cast-science.org/value-of-big-data-and-artificial-intelligence-in-agriculture/

Talend. 2023. Big Data and Agriculture: A Complete Guide. In: *Talend*. San Mateo, California. Cited 10 April 2023. www.talend.com/resources/big-data-agriculture/

UNICEF. 2023. Food Systems: What they are, why they matter. In: *UNICEF*. New York. Cited 10 April 2023. www.unicef.org/stories/food-systems

Zampati, F. 2023. Ethical and Legal Considerations in Smart Farming: A Farmer's Perspective. In: In: H.F., Williamson, H.F. & S. Leonelli, eds. *Towards Responsible Plant Data Linkage: Data Challenges for Agricultural Research and Development*, 257–272. Springer. doi.org/10.1007/978-3-031-13276-6_13