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The place of data in precision agricultural data asset management

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Abstract: Data and information are both key players of the 21st century. Technology is rapidly changing, and the industrial revolution is represented in the field of agriculture as well. Precision farming helps farmers to maximise annual yields and use available data. Due to technological developments and data management, more and more information is available. Precision agriculture manages the variability in production agriculture in a more economic and environmentally efficient manner. It encompasses a suite of farm-level information technologies, monitors the major field crops and annual yields. Precision agriculture can survive only by using the data and information gained.

Keywords: precision agriculture, data asset management, technology

Agriculture is the art and science of cultivating the soil, growing crops and raising livestock. Centuries ago, the growth of agriculture contributed to the rise of civilisations. Agriculture kept formerly nomadic people near their fields and led to the development of permanent villages. Farmers used their knowledge and perceptions to cultivate the land. As time passed and people became wiser, they started to share "data" about their fields, what, how and when to sow to get higher yield. The 21st century brought the real industrial revolution in agriculture, since precision farming makes agriculture as digital as possible to save time, to combat climate change and to maximise the annual yield. The fourth industrial revolution has arrived. The revolution has sparked new technological innovations in artificial intelligence, robotics, Internet of Things, unmanned vehicles or nanotechnology. National policies related to the fourth industrial revolution based on global trends are being implemented across the planet. Over 200 years ago, more than 90% of the Earth's population was engaged in agriculture, but now more than 80% of the populations of major OECD countries are engaged in the service industry. The population engaged in agriculture, at present, is merely 2-3%. The age of individuals in farming households is increasing as well. In the current world economy, only 5% of the world's population works in agriculture, yet it accounts for more than 60% of the world's business.[1]

The farmer and the land remain at the heart of agriculture, but the rules are constantly changing. Farmers play a subordinate role to technology companies, which have the platforms to collect and manage data. The ultimate goal is to ensure that the data assets are not only available for global players

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to use, but also to farmers to produce effective and usable data.[2] In order for precision agriculture to be more profitable, the focus must be on data generated during production, collection and usage.

This article aims to present the use of data and data asset management possibilities in precision agriculture by stating the main milestone and technologies until the present day.

DATA ASSET MANAGEMENT

Data is the new driver of the economy and society. It is essential for economic growth, competitiveness, innovation, job creation and social development. Sharing information has become a necessity and it matters how much and what quality of information is available to whom. One of the key factors for business success (including agricultural success) is based on the quality of the company's data assets and information. For organisations, the effective management and analysis of the data takes paramount importance. To achieve this, the data available to the company must be taken into account in the organisation's operations. Data mapping creates a data dictionary (called a metadata catalogue) that allows data sources to be registered, expanded, explored, analysed and used, contributing to data consistency and further exploitation. The aim of data asset management is to facilitate the exploitation of data assets and the provision of data at the same time. The process of data management goes beyond the concepts of data management and data processing. It is about managing data as a resource in a comprehensive, efficient and effective way. Effective data management is not a simple technical issue, it requires a multi-faceted approach to data management. Data management brings together a number of areas and can therefore be seen as a framework.[3]

PRECISION AGRICULTURE

Future agriculture is expected to evolve into high-tech industries where systems are coupled with artificial intelligence and big data. Big data challenges include capturing data, data storage, data analysis, search, sharing, transferring, visualisation, querying and updating. The data tends to refer to the use of predictive analytics, user behaviour analytics, or certain other advanced data analytics methods that extract value from data, and seldom to a particular size of data set. Precise optimisation will solve many current problems in agriculture. Precision agriculture reflects on current environmental problems on Earth, yet the production of safe agricultural products is emerging. Interest in precision agriculture is increasing to minimise environmental pollution and maximise the production of agricultural products. Precision agriculture has emerged as a solution to this need, as it can increase the production of agricultural products while reducing the amount of harmful chemicals applied to the environment.[4]

Precision agriculture is a whole-farm management approach with the objective of optimising returns on inputs, while improving agriculture's environmental footprint. It has come about through the development of information technology and remote sensing. The most widely adopted precision farming technologies are knowledge-intensive. Data on farmers' use of precision-agriculture technology are sparse as countries do not usually collect such data. The adoption of precision-agriculture technologies is limited to only a few countries and sectors. The most widely adopted precision farming technologies are GPS guidance. Precision agriculture has a substantial role to play in fostering green growth in agriculture in OECD countries, but the prevalence of small-size farms in several countries makes widespread adoption problematic.[5]

Precision farming is better described as data-based farming, as it is the key in the collection of data, the quality of the data and the accuracy of the information. Data can no longer come solely from self-collection, as there are a wide variety of data sources, such as meteorological data or satellite remote sensing data. By 2021 the Hungarian government has now created a domestic agricultural data market by linking private and public data. Hungary adopted the Artificial Intelligence Strategy[6] last autumn, and one of the pillars of the strategy was to launch agricultural data. Both data collec-

tion and data use need to be taken into account, as huge amounts of data are needed to kick-start data asset management in agriculture. Data from production can be collected and stored in a structured form, suitable for processing by technology providers and public administrations. Once the data has been processed, the information extracted can be used by producers in an appropriate way. The National Agency for Data Assets is responsible for getting the data asset off the ground at national level. In the field of agriculture, new solutions based on Hungary's Digital Agricultural Strategy will develop and ensure data collection in the public sector, which is one of the pillars of agricultural data production. The strategy launches programs to train and increase the capacity of the sector at producer level to create and interpret quality data and use it in decision-making. The primary goal of the data economy is to give producers control over their own data and the ability to transfer their data to whomsoever they want. The Artificial Intelligence Strategy includes the Agri-Data Framework, which is not a new data collector platform, but an interface that receives data firstly from public administrations and secondly from private data sets. The next stage of development is to build services on top of these data sets, such as expert advice. A common platform or data management platform, the advisory services will have complete, nationwide coverage of certain areas. The current function of agricultural data is not necessarily to give advice to the producer. In the future, data-driven extension will have the added advantage of being able to provide information on what is happening within the crop, at what price the buyer can find it on the market, and whether it meets their demand.

By managing and learning from the data, farmers can learn from each other's data. Farm management systems have access to even more data, companies offering business management software and systems can develop much better quality and more effective services. In the Netherlands, Syngenta provides data to Akkerweb[7], which is based at Wageningen University, where such large data warehouses have been operating for more than 15 years. The development of data warehousing is bringing a culture change, as agricultural operators accept and understand that their own data will not be less valuable when it is put on the data market, because they will keep it, manage it and use other data at the same time. The higher the quality of data in the dataset, the more it can be used for.

The Green Deal is the European Union's plan to move towards sustainable agriculture and food in practice. In order to make Europe climate neutral by 2050, major reforms in agriculture are needed, which can be achieved through data management. Data is essential for farmers' businesses, and it is up to them to collect it. The producer takes the data from the data storage system and uses it. Using the data extracted, the history of the farm can be traced and trends can be observed, from which analyses can be made and, ultimately, decisions can be taken.[8]

A Hungarian example for agricultural data collection and management is "Agriculture 4.0". This is a decision-supporting tool based on collecting and processing large amounts of digital agribusiness data, including "smart farming" and cloud services that enable the processing of large amounts of data. In agricultural production, the primary objective is to achieve precision farming in arable crops, livestock, horticulture, viticulture, fisheries and forestry. The profitability of precision farming is ensured by the data generated during production. The collection, processing and access to public data in this sector is a direct factor of competitiveness on the international market. Data generated in production and on the production trajectories are of strategic importance and national value. The aim is to collect and process data, to reduce the cost of access to data, and to make the necessary changes to the regulatory environment. The Digital Agricultural Reduction will reduce the administrative and other costs of the digital transformation of the agricultural economy that can be influenced by the state by significantly reducing the costs of digital access to data produced and collected by public organisations. The free availability of data from the National Meteorological Service can significantly help farmers prepare for weather anomalies and save huge amounts of money every year. Regionally speaking, Hungary's Digital Agricultural Strategy is not

a sectoral strategy in its own right, but a strategic document aligned with the sectoral objectives already set, analysing and building on them from a digitalisation perspective, which has placed Hungary among the leading countries in the European Union in terms of agricultural digitalisation objectives. The introduction of digitalisation in agriculture plays a significant role in data management, data production and processing. Digital technologies produce a significant amount of data in all areas. Data is generated from the production level through processing to trade in the context of technological operations, activities and interventions. The actors at different levels collect data and build databases, and the multiannual data series provide an opportunity to optimise activities.

The growing demand for food from a growing population, the shrinking agricultural land and water scarcity are driving the need for more efficient farming methods, which could facilitate the rapid spread of precision farming. Precision irrigation is also growing in importance due to the limited water resources available. As precision technologies evolve, further automation and linking of applications is expected. Data management will have implications for the whole agricultural value chain and will provide new business opportunities in the fields of extension, analysis and modelling. Free data from the Copernicus program is also being used to build the EU-funded APOLLO Project, involving Greece, Spain, Austria, Belgium and Serbia.[9]

Government organisations which collect or store agricultural data could work together with data providers and data users to establish clear frameworks governing data access and use. It is essential that such frameworks should be coherent with broader policies governing such issues, as well as with underlying legislation authorising government agencies to collect agricultural data. In seeking to improve publicly-held agricultural datasets, data-collection agencies can explore how the burden of existing data collection by government organisations can be lessened while maintaining or strengthening data collection through the use of digital technologies, including considering how digital tools could be used to gather data via alternative pathways. The data management framework could also support the evaluation of data quality for data from alternative sources and planning. Developing a data infrastructure might require different types of actions and roles for the government, as a coordinator, as a regulator setting interoperability standards, or to directly develop the data infrastructure and create markets for usage rights. Providing physical infrastructure such as connectivity, sensor networks and physical elements of a tracking and traceability system faces traditional issues for infrastructure in network industries. The sharing of data according to the definition and value provided to the different use of data produced by private systems remains an issue.

Good quality data is indispensable for data management, since even the most refined algorithm will not be able to provide good information. New digital technologies such as blockchain or artificial intelligence are sophisticated programs, the value of which also depends on the quality of the data they use. If bad quality data is used in automation, it can potentially have negative consequences.[10]

At the international level, the Food and Agriculture Organization of the United Nations created FAOSTAT to provide free access to food and agriculture data for over 245 countries and territories and covering all FAO regional groupings. The Agricultural Market Information System (hereinafter: AMIS) is an inter-agency platform to enhance food market transparency and policy response for food security. It provides market information on four grains that are particularly important in international food markets: wheat, maize, rice and soybeans.

The Food and Agriculture Microdata (FAM) catalogue provides an inventory of datasets collected through farm and household surveys, which contain information related to agriculture, food security and nutrition. The FAM catalogue is based on datasets which are collected directly by the FAO. The microdata contains information on individuals, households, business and geographic areas, and provides rich input into policy analysis, research, and highly disaggregated statistics.[11]

The data revolution in agriculture, information and communications technology for agricultural services can support smallholder farmers in addressing their challenges and increasing their incomes and yields. Smallholder farmers represent the biggest employment sector in rural areas of the developing world, and they are also the most important contributors to global food production. More than 90% of the farms in the world are family farms. They produce 80% of the food and operate 75% of the farmland.[12] Farm-level data is essential in delivering actionable and tailored farmer-centric services and information to individual farmers.

Many individuals and organisations collect a broad range of different types of data to perform their tasks. Government is particularly significant in this respect, both because of the quantity and centrality of the data it collects, but also because most of that government data is public, and therefore can be made open and available for others to use.[13]

The use of digital technologies and related innovation is another step in the history of offering new opportunities. Information communication technologies, including the internet, mobile technologies and devices as well as data analytics are used to improve the generation, collection, exchange, aggregation, combination, analysis, access, searchability and presentation of digital content, including for the development of services and apps. Advances in massive data acquisition, storage, communication and processing technologies have enabled the rapid transfer of vast quantities of data that would not have been possible even a decade ago, and have greatly magnified the ability to process large datasets and to automate analytical processes with machine learning. In the past, many types of agricultural data were previously held in paper-based filing systems. Digitalisation does not create new data, but rather, by converting existing data into a digital format, it allows data to be used and transferred in new ways. Having more data is not enough, but combined with progress in communication and processing capacity, this data is progressively used to create knowledge and provide advice about production processes, and even to automate some activities on farms.

Access to farm data can also improve efficiency in the management of trade regulation, particularly when trade systems are administered through the adoption of paperless trade and electronic documents. The data infrastructure is the system enabling and governing the collection, access and transfer of data (data governance) and the analysis of farm data to produce knowledge and advice and feedback loops to stakeholders in the agriculture sector, including farmers as well as policy makers.[14]

Investing in data services to provide linked datasets to increase the usefulness of government data collections for policy-making and related research. One important aspect of this to consider is how, and when, to link farm financial datasets with physical data such as soils, precipitation, and other climate variables. It is essential to increase use of secure remote access mechanisms to reduce transaction costs of allowing trusted actors such as policy researchers to access agricultural micro data held by governments, and in the near future, to explore how new data sharing technologies such as confidential computing could avoid the traditional confidentiality-accessibility dilemma.[15]

DATA MANAGEMENT

Agriculture has signalled a proliferation of connected sensors across farms and throughout value chains whose streams of data offer the allure of value to those who possess the requisite skills or acumen. The devices used in agriculture digitalise farms and create new opportunities for agricultural production systems, value chains and food systems. Data produced by Smart Farming is the core resource that enables value, is often the good exchanged, and even the currency that finances interactions throughout agricultural value webs,[16] while agricultural data is at least an asset and must be managed like any other asset. Stakeholder participation in data sharing platforms is more than transactional, value can be created from Smart Farming data as stakeholders collab-

orate around data, conduct arbitrage with data or compete for data. A data sharing platform is a community of stakeholders who share a common, data-related goal, data collected from, and for, the community, and a system that uses the data to enable and incentivise stakeholders to make valuable interactions. The operation of a data-sharing platform describes a process that takes data as one of a number of inputs and produces value as an output. Stakeholders in a data-sharing platform act like individual firms in supply chains for whom collective benefit must be achieved, not by managing individual functions but by adopting an integrated approach to their separate activities. This creation of value from data and accompanying assets is enabled by the system through the use and exchange of data.

Data-sharing platforms consist of three assets together with three management tasks that span each pair of assets to enable valuable interactions across the platform. The three core assets that data-sharing platforms rely on are: a community of stakeholders, a facilitatory system, and data on and for that community.[17]

When smart farming and precision agriculture are discussed, agri-based Internet-of-Things (IoT) devices can help farmers with real-time information about lands and crop parameters. The agri-based IoT devices are extensively utilised to collect real-time field-based and/or farmer-level data. Agri-based sensor devices allow farmers to obtain real-time information about soil, water and crop quality and help them integrate it with blockchain technology to obtain digital information assets. IoT devices can communicate with each other for the extensive farmland to broadcast transactions between IoT devices and share the results into the blockchain. When data are shared with external agencies, blockchain utilises a Resource Description Framework (RDF) linked to a graph database. Data are essential components that provide complete detail about a specific instance. In the blockchain-based agriculture value chain ecosystem, data are collected from different silos and processes. In precision farming, agriculture data and information flow comprise four stages: planning, application, result and evaluation. These stages contribute to data collection and analysis for real-time decision-making.[18]

The blockchain-based solution to store data would be easier to find and access for any other system. It should be interoperable with the existing agriculture system and easy to reuse data stored in blockchain by replacing different silos of data. Electronic agriculture data, human beings and machines should be able to find it. Once agri-data is found in blockchain, it should be accessible to various stakeholders at the protocol layer with predefined data access controls. In e-agriculture, data are generated from the different systems which are accustomed to other protocols. Agri-data consists of multiple stakeholders. Front-end applications and agri-IoT sensor devices such as GPS tracking during transportation, soil condition, and water quality data and digital machines generate data with varying degrees of layer collaboration and minimal human intervention required.[19]

LEGAL PROVISIONS

In the European Union, certain Member States enacted actions to improve digitalisation in their agricultural sectors and policy implementation in 2020. The Belgian region of Wallonia verified the validation of all farm payments using data from Copernicus Sentinel Satellites[20] in 2020, and completely replacing on-farm controls throughout the entire Wallonian territory.

In 2020, the European Commission launched a new EU Soil Observatory (EUSO). The EUSO aims to support policymaking in the European Union by providing the Commission and the broader soil user community with the soil knowledge and data flows needed to safeguard soils. The EUSO aims to collect high-resolution, harmonised and quality-assured soil information to track and assess progress by the European Union in the sustainable management of soils and the restoration of degraded soils.[21]

Besides the fact that precision agriculture equipment can reveal details about farming conditions

and techniques and other potentially sensitive business data, there is also data collected by other actors, especially the government. There is no legal protection yet for this type of sensitive non-personal data, unless they are classified as trade secrets, in which case they should not be shared. Ownership is a legal assertion and data ownership is not addressed by legislation except for copyright for datasets as intellectual products. The concept of ownership is not strictly applicable to farm data. Given the lack of legal applicability of the concept to raw data in general, machine-generated farm data presents additional complexities. It is generated on the farm and is about the farm, but it is generated by machines without the intervention of the farmers, so the farmer is not considered the generator or collector. In the beginning it is raw data, so not an intellectual product, but it is then transmitted and processed and combined with other data in aggregated datasets, which are intellectual products and can therefore be owned. The right to control assigns the right to decide on the sharing and further reuse of the data. For the further reuse of data, under personal data protection laws it is very common to apply the principle of purpose limitation, and this principle is sometimes recognised for non-personal data too. The right to access and control the data is the right to exchange the same data again with other actors. A farmer using precision agriculture equipment that collects data on soil properties, irrigation, weather and crop health may want to share this data with an insurance company to negotiate better premiums, or with a bank to demonstrate the viability of his/her business. The data probability is also linked to the issue of interoperability between farm instruments and tractors and the data they generate, which is often only compatible with other machinery of the same brand.

In many countries there are legal provisions for agricultural data asset management and data sharing. There are policies prescribing that public sector data should be open and reusable. The objective of these policies is to provide free useful data for the development of innovative services. Types of data that are useful in agriculture and are traditionally prioritised in open data policies are geospatial data, soil data and soil maps, cadastre data, weather data and price data. Open data enables access to data for the less resourced actors, like small farmers who can only get data from expensive providers.

Responsible data sharing in agricultural value chains outlines the policy spaces and instruments to be considered when dealing with farmers' data sharing. The policy spaces that are relevant here are different from those relevant for the open data lifecycle. Data shared along the value chain is normally not open and not designed for public use but for mutual transactions for the provision of specific services. Many aspects of agricultural data sharing such as attribution, access, portability, interoperability, benefits and risk of lock-in are not covered by legislation. Responsible data sharing in agricultural value chains illustrates existing examples of such instruments, such as codes of conduct and guidelines agreed upon by different value chain actors, and their potential role in making data sharing fairer. The data platform in the ecosystem can be managed by different actors and with different purposes; in most cases, farm data is still managed on technology providers' platforms, but there are examples of farm data cooperatives and the potential role of Trust Centres with trusted governance.

Agricultural data sharing does not have a dedicated policy space but there are broader policy instruments to be used to ensure fairness of farm data sharing. Public policies do not address agricultural data sharing explicitly and do not offer solutions for most of the issues highlighted in the previous sections, it is useful to be aware of the existing policy spaces to understand where these issues might be addressed, and to be able to influence these policies and push for instance for a better coverage of the data dimension in agricultural policies and the value chain and data asymmetry dimension in digital strategies.

In many countries, there are policies that prescribe public data should be open and reusable. To assess the availability of free open data and therefore to be able to determine the feasibility of services which may need additional paid data, ser-

vice providers and farmers need to be aware of the open data policies and data publication status in their country. In policy briefs the European Union policy-makers issued the 2018 EC Communication "Towards a common European data space" and the Public Sector Information Directive, which focus on reusability and the impact of data, and encourage the identification and prioritisation of high-value datasets and the publication of real-time data. A significant proportion of the data that governments have already opened or are expected to open for the benefit of farmers is quite static or changes over longer periods, like soil maps and cadastre data.

A high amount of public interest data is held by the private sector. Data that have high value to farmers is collected or aggregated by private companies, such as reliable weather data, market data, precision-agriculture aggregated data on soil, water, use of fertilisers and pesticides. Many governments are trying to negotiate the publication of private-sector data of public interest and to explore grounds in which the private sector might be willing to share data, both with other businesses and with the government to boost innovation and public interest.

In order to build and maintain trust in data, it is necessary to have stable data management principles and practices in place. Good data management principles help to ensure that data produced or used are registered, stored, made accessible for use and reuse, managed over time and/or disposed of according to legal, ethical and funding requirements as well as good practice. A data management policy can be used to address strategic issues such as data access, relevant legal matters, data stewardship issues and custodial duties, data acquisition and other issues. Effective data sharing depends on a string network of trust between data providers and consumers.[22]

Under the EU PSI Directive, any information or content accessible to citizens under the laws of a country can be recycled and shared with others. Building a European data economy is part of the Digital Single Market strategy.[23] The initiative aims to make the most of the potential of digital data for the benefit of the economy and society, removing barriers to the free flow of data and supporting the realisation of the European Single Market.

The EU classifies high-value data sets into six broad categories, where the priority is to share public data without restrictions – earth observation and environmental data – energy consumption data and satellite imagery (weather, land, water quality, air monitoring, energy use, emission levels) and meteorological data.[24]

CONCLUSION

Big data and the Internet of Things enable numerous sources of information to be analysed by intelligent software to help farmers see crop and livestock performance. These kinds of technology can help farmers re-adjust practices based on real-time data produced via satellite imagery from drones to sensors that measure moisture levels in the soil. By using software based on data sets, it can identify the most precise tasks to be carried out. With the food crisis the planet is on the brink of entering, these new technological inventions to increase yields could be life-saving. The Internet of Things is used to improve the quality of data gathering. In the future, precision agriculture based on data will be more revolutionary than it is now. To improve decision-making efficiency it is important to collect data, create databases and share it with a wide range of farmers. In the future, farmers will not sit in machines; data and technology will be utilised to plant, irrigate or harvest. Data asset management in agriculture is not only useful for precision agriculture and to maximise yields, but it is essential to monitor the climate and take actions against climate change. Precision agriculture is an approach to farming that employs data sensors, connected devices, remote control tools and other advanced technologies to give farmers more control over the field and the team. Data management is able to adapt to and predict environmental changes as well as reduce risks when creating distribution strategies.

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