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Data sources and risk management in precision agriculture

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Abstract.
The digitalisation of the agricultural economy provides more data about the biological processes and technological solutions used for producing agricultural products than ever before. Parallel to the data collection – aiming to provide information for agricultural decision-making and operations – the data informs the farmers, public administration officers and other players in agriculture about the state of the environment. The strategic planning on operation of farms and data handling technologies for the public administration, research, and business services and the agricultural data space created from consumer data, the regulation of data collection, data processing and access to the original or stored data have become a competitive factor for national agricultural sectors, however, it also raises security issues.

Authors have identified three types of risks that the agricultural data handling is facing, namely risk of dropout of services, risk of false/fraud data integration or stealing of the data, high level of concentration of the data in one service provider and presence of outsider (foreigner) data handlers especially due to cloud-based data providers.

In this paper required data and its availability is investigated in the national and local level for precision agriculture and decision making used for plant production.

Keywords.
Data in agriculture, risk management, data/cyber security in agriculture

Introduction

The role of agricultural data has significantly increased, and agricultural data is now seen as an input with a similar weight as land, seed or applied nutrients. The specificity of agricultural data lies in the fact that data appear on several levels, since on the one hand, there is a considerable amount of public data available, such as meteorological data, satellite data, or agricultural geographic information system (AgGIS) data recorded in spatial data structures that register field borders, and on the other hand, with the development of the digitalization of agriculture, more and more private data are being generated that help agricultural holding owners' work when integrated into the decision-making process (Magyar–Varga, 2021). One of the specific obstacles to the data integration in Hungary is that it complex use is key for modern agriculture, however public data are managed by different organisations and in different structures.

Data-based farming

At the beginning of the 21st century, agricultural production has to face several new and significant challenges. The most significant ones include:

– significant changes in the consumer market: increase in expected quantity, awareness of the nutritional content of foods, increased demand for 'free' foods, and the need for traceability and quality assurance,

– regulation and monitoring of environmental impact: regulation and continuous monitoring of environmental impacts related to agricultural production, regulation of impact levels,

– continuous changes in the regulatory environment: changes in the European Union's Common Agricultural Policy, strengthening of national and regional targeting systems, changes in the support system,

– changes in the management envir onment, globalization: globalisation of input and output markets, logistics exposure, reduced weight and voice of producers in the food value chain.

Technological decisions based on agricultural holding resources are not sufficient to maintain and increase agricultural holding efficiency and to generate the income needed to operate and improve agricultural holdings, main challenges shall also be taken into consideration. The natural, economic, market and regulatory environment of agricultural holdings also need to be constantly monitored by decision-makers to be able to make the right decisions.

The digitalisation of agriculture can be of significant help to decision-makers. With the help of precision tools, digitalisation generates large amounts of data on the holding's environmental resources, technological processes and products manufactured. Technological decisions can be optimized using precision – site-specific – technology based on the data available. Agricultural holdings' data can be analysed both from a decision and implementation perspective. These establish a unified data space from the agricultural holding's point of view, and a data flow that takes place within that space (Figure 1).

Data is primarily generated at the operational level from the operation of precision technology, sensors, analysis of images made by monitoring drones, soil sampling, processing of existing data , and external data sources (e.g. agro-meteorology, environmental data, plant protection, soil data). Available data is analysed using big data technology, filtering out contextual data. Organized data is suitable for the application of artificial intelligence at an innovative analysis level. The decision support level provides managers with the data, information and decision options needed to make substantiated decisions. As part of the decision support, the 'dashboard' helps managers to have constant overview of operations and monitor possible alerts.

Decisions and interventions are taken by the managers. There may be levels of technology where decisions are made based on data considering pre-defined parameters, and the result of the decision is implemented.

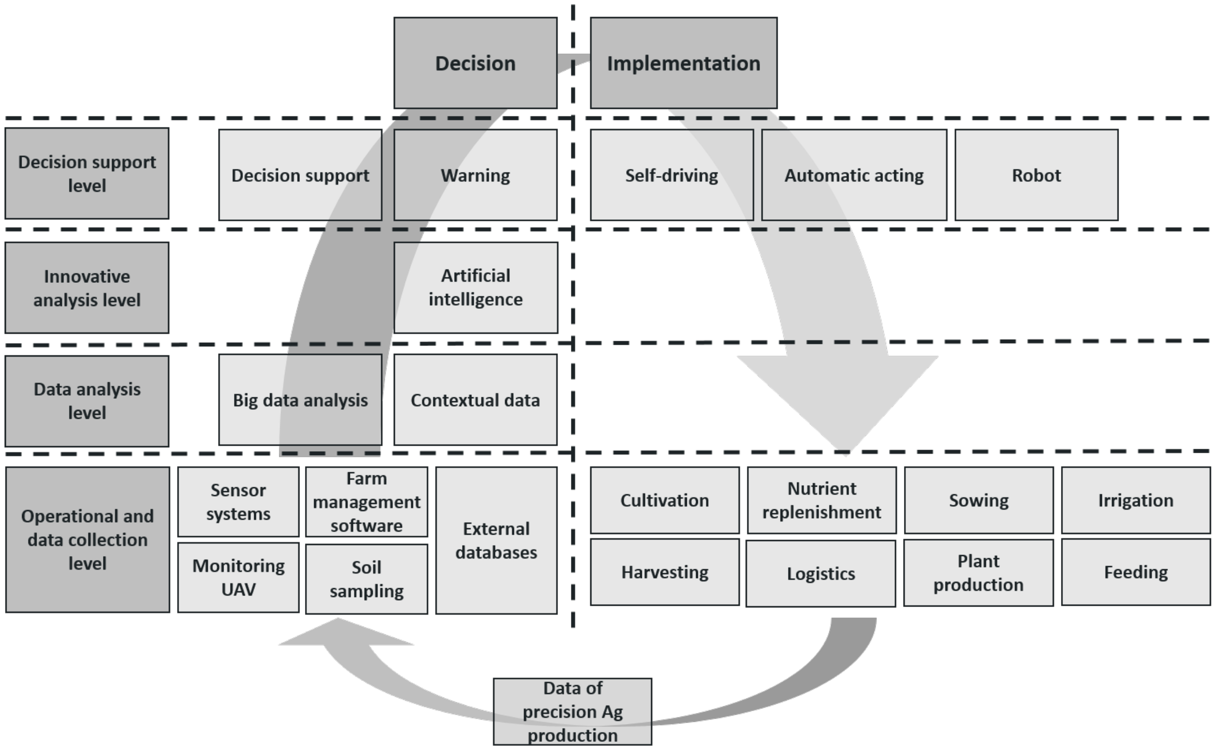

Fig 1. Schematic structure of data space and data flow of the up-to-date digital farms. Source: Selection of digital developments for the National Stud Farm and Experimental Farm, 15.02.2021, based on information provided by Deloitte Hungary, own work

On the implementation side, after the decision is made, automatic and robotic interventions take place, which can be triggered by the decision. Other operations are carried out by collecting data using precision and conventional tools. Such data is also transferred to the decision side. Holding-level data space is connected to the agricultural sector data space that contains environmental data through external data sources.

Agricultural data space

The European Data Strategy adopted in 2020 (COM/2020/66 final) considers the establishment of single European data spaces a top priority. The Single European Data Space is intended to create a single market for data. According to the definition of the EU, the Single Data Space is open to data originating from allover the world. The data space is a medium where both personal and non-personal data, including sensitive business data, is safe, and businesses have easy access to an almost infinite amount of reliable, high-quality data. This stimulates growth and creates value while minimising the human carbon and environmental footprint. The European data space will enable European enterprises to take advantage of the opportunities offered by the size of the single market. Common European rules and effective implementation mechanisms shall ensure that:

– data can flow within the EU and among sectors;

– European rules and values are fully respected, in particular in the areas of protection of personal data, consumer protection, and competition law;

– rules on access to and use of data are balanced, practical and clear, and clear and reliable data governance mechanisms are in place; and an open but firm approach is taken to international data flows, based on strong European values.

Based on the European Data Strategy, the Commission supports the creation of nine common European data spaces, including the Common European Agricultural Data Space, which aims to improve the sustainability performance and competitiveness of the agricultural sector through the processing and analysis of production and other data, enabling accurate and customized production approaches at agricultural holding level. The Commission believes that data is a key factor in improving the sustainability performance and competitiveness of the agricultural sector. The management and analysis of production data, in particular in combination with other supply chain data and other types of data such as land monitoring or meteorological data, allows for accurate and customized production approaches at the agricultural holding level. The agricultural data space is a neutral platform that allows for the sharing and aggregation of agricultural data (private and public). It supports the establishment of a data-driven ecosystem based on fair contractual relations, helps to strengthen capacities aimed at monitoring and implementing common policies, and reduces administrative burdens on governments and beneficiaries. Several EU working groups are working on the definition of the agricultural data space. The following data sets of the agricultural data space have been identified based on the data sets needed for effective decision making by producers (Figure 2.)

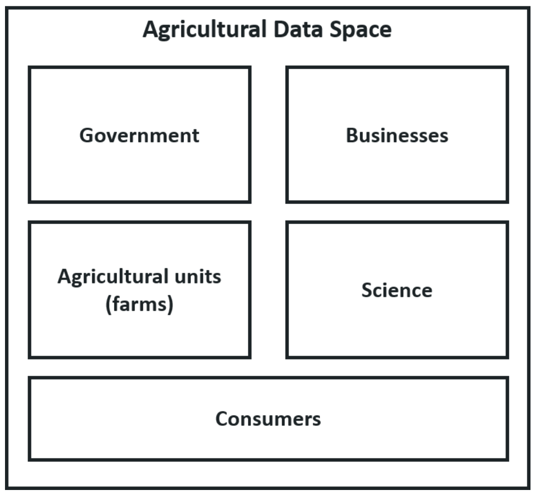

Fig 2. Schematic structure of agricultural data space Source: MAGYAR F. – VARGA P. M., 2021

Government data

Data collected by government operators from producers, on the sector, the environment, and the holding. Data is mainly recorded for some kind of administration, official tasks, control, and monitoring activities. However, public data are of considerable value as external data, which can be used by agricultural holdings and producers at the agricultural holding level for the purposes of decision-making. Government data will be discussed in more detail in the next chapter; however, it is worth listing them here. Main government datasets include:

• agrometeorological forecasts,

• pest, weed, nutrient deficiency detection forecasts,

• plant protection forecast and information,

• soil information,

• veterinary information,

• market information,

• production statistics,

• water data,

• subsidy-related data,

• official records.

Agricultural data collected by business operators

Operational and environmental data collected by input and output suppliers, technology suppliers, IT service providers, consultants, retailers, wholesalers, integrators and food processors in the sector.

Agricultural holding and producer data

Precision technology, sensors, monitoring devices, management and production data.

Agricultural data collected by scientific operators

Data derived from research and development activities. Scientific databases contain data on agriculture, environmental areas, holding, consumer behavior and health. It is important to create standardized data spaces to facilitate the analysis of data interaction in the field of science and individual institutions.

Consumer data

Like producers, consumers also create a significant amount of data through their consumption activities. Retail networks mainly collect data on consumption habits. Among retailers, mainly multinational chains and online retailers see value in detailed, article-level consumer data. Independent operators and retailers often do not use such data.

Business and government operators and retail chains are the ones that currently hold the most data in the data space (consumer data). Agricultural holdings' data collection and agricultural holding-level data space depends on the preparedness of agricultural holding management and the availability of precision tools for data collection. According to surveys carried out in the context of Hungary's Digital Agricultural Strategy (Hungarian Chamber of Agriculture [HCA], 2019), there is a strong correlation between agricultural holding size (based on standard production value) and the level of digitalization. The level of digitalization of smaller agricultural holdings is much lower than that of larger agricultural holdings. Smaller agricultural holdings, although often equipped with precision tools, do not use data to make management decisions, do not collect, process and evaluate such data. Larger holdings use a higher percentage of the data set generated in the holding for their management decisions. Although science has large datasets, they are collected on a project or institutional basis, and there is no interoperability of data within science.

Public agricultural data in Hungary is collected by 13 institutions, stored, and processed in 48 databases in the public administration. Interoperability between databases can be observed in several places, and in general, producers only have personal access to domestic public data for agricultural holding-level decisions. Plant-level decision support applications do not directly access the systems' databases. For data-based precision agriculture decision support this structure and handling of data is not usable. The data bases and their names are visible in Table 1, complete description of the data bases and institutions are available at Milics et al., 2022.

1. Table: Public agricultural databases in Hungary, 2021

	Database	Organisation	Soil, land affairs	Plant production	Stock farming	Weather, environment	Economic data
1	Soil Protection Information and Monitoring System (SPIMS)	NFCSO	x				
2	DataPlant	NFCSO	x	x			

	Database	Organisation	Soil, land affairs	Plant production	Stock farming	Weather, environment	Economic data
3	DataVet	NFCSO			x		
4	Fruit cadastre	NFCSO		x			
5	Food Chain Monitoring Information System (FCMIS)	NFCSO					x
6	Pesticide database	NFCSO		x			
7	Crop enhancing material database	NFCSO		x			
8	Seed label database	NFCSO		x			
9	OMSZ surveillance network database	OMSZ				x	
10	TakarNet	Lechner	x				x
11	Geoshop.hu	Lechner	x				x
12	Fentrol.hu	Lechner	x				x
13	gnssnet.hu, farmrtk.hu	Lechner	x	x			
14	Aerial images and orthophotographs	Lechner	x				
15	Topographic maps	Lechner	x				
16	Digital topographic maps	Lechner	x				
17	National Land Registry Map Database	Lechner	x				x
18	Elevation and Horizontal Reference Points Database	Lechner	x				
19	Earth surface monitoring databases	Lechner	x				
20	Terrain model database	Lechner	x				
21	Satellite images database	Lechner	x				
22	Topographic database	Lechner					
23	Digital surface model	Lechner	x				
24	Land Parcel Identification System (LPIS)	NLC	x	x			x
25	VINGIS	NLC	x	x			x
26	Integrated Administration and Control System (IACS)	HST		x	x		x
27	Unified Agricultural Customer Registration System	HST					x
28	Complex Agricultural Risk Management System (CARMS)	HST	x	x			x
29	MobilGAZDA application	HST					x
30	Agricultural and Environmental Information System (AEIS)	HST	x	x	x		x
31	HCSO	HCSO					x

	Database	Organisation	Soil, land affairs	Plant production	Stock farming	Weather, environment	Economic data
32	Farm Accountancy Data Network (FADN)	AKI	x	x	x		x
33	Market Price Information System (MPIS)	AKI					x
34	Pig Information System (PIS)	AKI			x		x
35	Agricultural Statistical Information System (ASIS)	AKI	x	x	x		x
36	Fisheries Information System (FIS)	AKI			x		x
37	Fish Prices Data Query Interface (Halár)	AKI			x		x
38	DoSoReMi.hu Digital, Optimized, Soil Related Maps and Information in Hungary	MTA ATK TAKI	x				
39	EU-SoilHydroGrids 3D Soil Hydraulic Database of Europe	MTA ATK TAKI	x				
40	Digital Kreybig Soil Information System (DKSIR)	MTA ATK TAKI	x				
41	AGROTOPO	MTA ATK TAKI	x				
42	OKIR Soil Degradation System (SDS)	MTA ATK TAKI	x				
43	Land Monitoring Information System (LMIS)	Government IT Development Agency	x	x			
44	HCA membership register	HCA					x
45	Electronic Trade and Transport Control System (ETTCS)	NTCA					x
46	Online cash register	NTCA					x
47	Water Consumption Information, Control and Integrated Regulatory Framework (WCICIRF)	MoI	x			x	
48	ePincekönyv	National Council of Mountain Communities (NCMC)		x			x

Source: Own edition

Identification of data-based risks

The current situation of agricultural digitalization poses several significant risks related to the management, processing, use and possession of data. The following classification system was used to review data security challenges of agricultural digitalization (Babos et al., 2020):

- **physical data collection and operation execution layer** – this is where sensory data is collected and responses based on this data are executed by machines (precision operation);

- **network layer** – this layer is responsible for transmitting the data system;

- **consumer layer** – this is where primary data processing takes place, where sensor and other data is entered, where decision support takes place and where cloud services are connected;

- **cloud layer** – the place where holding-level data is aggregated and processed at the macro level using deep learning and artificial intelligence, and where the algorithms used by decision support applications in the user layer are developed.

The most precise identification of risks requires the segmentation of the production level. Based on the DAS survey, the analysis was carried out based on the standard production value (SPV). Holdings have been divided into four size groups: miniature, small, middle-sized and large holdings. The number of holdings and producers per group is shown in Table 2.

2. Table: Number of agricultural holdings by standard production value and size categories, 2016 [pcs] (Source: HCSO, 2016)

Standard production value size category, Euro	(pcs)
miniature holdings (< 1,999 SPV)	265,459
smallholdings (2,000-7,999 SPV)	93,777
middle-sized holdings (8,000-499,999 SPV)	70,305
large holdings (500,000 < SPV)	1,716
Total	**431,257**

With the progress of the digitalisation of agriculture, in parallel with international processes, service chains have started to develop, which take data from the physical layer through the network layer and not only reach the machines of the user layer, but also the cloud service of the service provider, utilise the possibilities of deep learning and artificial intelligence, and return them to the producers. In the following, only these fully established **service chains, spanning all four layers, will be analysed** from a safety perspective. We look at safety issues from three perspectives:

- from a device, network and technology risk perspective,

- the risks associated with data and cloud services,

- the dominant position of service providers and its derived reasons.

In arable crop production, a total of six cases were investigated: meteorological, soil service, remote sensor image analysis, navigation, machine optimization and management zone-based substance application. For stock farming, we examine agricultural holding management systems for bovine, pigs and poultry. For greenhouse horticulture, we focus on control systems, and we examine agricultural holding management and ERP systems among general systems at the agricultural holding level.

Based on the cases identified, we examine the key risks by holding size, which is summarized in Table 3. Basic risks include:

3. Table – Identified main risks

Risk layers	Miniature holdings (< 1,999 SPV)				Smallholdings (2,000-7,999 SPV)				Middle-sized holdings (8,000-499,999 SPV)				Large holdings (500,000 < SPV)			
Arable crop production and horticulture																
failure of meteorological services	SERV	DATA			SERV	DATA			SERV	DATA			SERV	DATA		
precision soil analysis service								FOR	SERV	DATA		FOR	SERV	DATA	MARKET	FOR
satellite/drone image analysis service				FOR	SERV		MARKET	FOR	SERV	DATA	MARKET	FOR	SERV	DATA	MARKET	FOR
precision navigation service							MARKET	FOR	SERV	DATA	MARKET	FOR	SERV	DATA	MARKET	FOR
precision machine optimisation service					SERV			FOR	SERV		MARKET	FOR	SERV	DATA	MARKET	FOR
precision management zone handling and substance application					SERV			FOR	SERV	DATA	MARKET	FOR	SERV	DATA	MARKET	FOR
STOCK FARMING																
pig rearing installation management system								FOR	SERV	DATA	MARKET	FOR	SERV	DATA	MARKET	FOR
poultry rearing installation management								FOR	SERV	DATA	MARKET	FOR	SERV	DATA	MARKET	FOR

system																
bovine rearing installation management system								For	Serv	Data	Market	For	Serv	Data	Market	For
Greenhouse horticulture																
greenhouse control systems								For	Serv	Data	Market	For	Serv	Data	Market	For
General systems																
Farm management systems					Serv		Market	For	Serv	Data	Market	For	Serv	Data	Market	For
ERP systems								For	Serv	Data		For	Serv	Data	Market	For

- **Service outage, risk arising out of bad/fake services** (see in the Table as **Serv**). In the detailed test, we consider the potential impact of the following events at the physical and network layers, as well as at the user layer which directly controls the physical layer:

- RTK radio signal interference
- virus infection of devices
- service outage/overload attack
- turning devices into a botnet (externally managed network)

- **Risk value arising out of data theft, data falsification, unlawful use of data** (see in the table as **Data**). In the detailed test, we consider the potential impact of the following events on the data and decision support system in the cloud layer and the user layer that is responsible for central management:

- theft of cloud data
- erasure of cloud data
- stopping cloud artificial intelligence and other computing mechanisms
- entering false data into the data system
- sending false data/notifications on behalf of the holding

- **Market concentration among operators** (see in the table as **Market**). As far as risks are concerned, we examine the asymmetry of the relationship between agricultural producers and precision service providers that supply them with digital services and how significant is the market concentration.

- **Foreign presence in products/cloud services** (see in the table as **For.**). Foreign ownership: since foreign, multinational enterprises find it much easier to impose their will, sometimes even be excluded from domestic jurisdiction.

Evaluation of the risk assessment

The analysis is based on an assessment of the three risk aspects considered:

- **Device- and technology-related risks** – devices are predominantly operated locally or are dependent on the local network; however, many devices may also be remotely controlled or blocked. Overall, the device-level risk is not higher for digital solutions than for 'traditional' devices.

- **Data and cloud service risks** are much more significant, as the entire service process and the decision and control instructions at the end of this process can fail, and as a result, several producers may be exposed to serious failures and downtime simultaneously. The control and configuration of precision machines is a major risk for cloud services. Control based on professional decisions through data collection and cloud-based processing provides an opportunity for malicious interventions, harmful levels of or incomplete interventions. Cloud services without professional control ultimately offer the possibility to take over the management of production, even regarding the external control of produced volume.

- **Dominance-based risks** are present across the entire data space, as many of the operators are global enterprises that monopolise technological developments to gain significant dominance, which can put considerable pressure not only on the producer but also on national governments.

Summary

The role of agricultural data has significantly increased, and is now seen as an input with a similar weight as land, seed or applied nutrients. The specificity of agricultural data lies in the fact that data appear on several levels, since there is a considerable amount of public data available, such as meteorological, satellite, or agricultural data recorded in spatial data structures that register field borders, and with the development of the digitalisation of agriculture, more and more private data are being generated that help agricultural holding owners' work when integrated into the decision-making process. In case public data is hardly available for small size precision farmers, this data is not going to be the driver of the developments. Moreover, farmers applying precision agriculture practice are at high risks for the IT sector. The paper identified three main types of risk: Device and technology related risks, data and cloud service risk and dominance based risks.

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