Data-based agriculture in the V4 countries – sustainability, efficiency and safety

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Abstract

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. The aim of this paper is to investigate the data required for agricultural practices, as well as to identify risks that the agricultural data handling is facing.

Keywords: agricultural data, sustainability, data strategy, efficiency, security

Adatalapú mezőgazdaság a V4 országokban – fenntarthatóság, hatékonyság, biztonság

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Összefoglaló

Az agrárium adatainak szerepe felértékelődött, az agráradatra jelenleg hasonló súlyú inputként tekintenek, mint a termőföld, a vetőmag, vagy a kijuttatott tápanyag. Az agráradatok sajátossága abban rejlik, hogy az adatok több szinten is megjelennek, hiszen egyrészt számottevő mennyiségű közadat áll rendelkezésre, ilyenek például a meteorológiai adatok, a műholdas adatok, vagy a táblahatárokat nyilvántartó téradatstruktúrában nyilvántartott agrár-térinformatikai adatok, másrészt az agrárium digitalizációjának fejlődésével egyre több helyen keletkezik olyan magánadat, amely a döntéshozatali folyamatba kerülve segíti a gazdálkodók munkáját. A 2004-ben EU tagságot nyert kelet-közép-európai országok – közöttük a Visegrádi 4-ekhez tartozó Magyarország, Szlovákia és Csehország – a történelmi fejlődés eltérő útjain érkeztek az Európai Unióba, így agráradat rendszereik is eltérő módon alakultak. Annak azonban, hogy az agrárium számára oly fontos adatintegráció megszülessen, mindhárom országban az egyik sajátos akadálya, hogy az adatokat – amelyek komplex felhasználása a modern agrárium kulcsa – eltérő szervezetek eltérő struktúrában kezelik.

Az adatstruktúra rendszerezése, az adatok gyűjtésének helyszínei, az adatfeldolgozás és az adathasználat nemcsak versenyképességi tényező a magyar agráriumban, hanem egyben biztonsági kérdéseket is felvető vagyontárgy is. Az agráradatok kockázati tényezőit a szerzők három csoportba sorolják: 1. Az eszköz- és technológiai kockázatok, ame-

lyek hálózatokhoz köthető kockázatok, a távoli vezérlés és a blokkolás lehetőségével, de ebben az esetben a hagyományos, mindennapi eszközeinkhez hasonló a kockázati szint. 2. Az adat- és felhőszolgáltatási kockázatok, amelyek nem megfelelő szakmai felügyelet hiányában jelentős befolyással bírhatnak a mezőgazdasági döntéshozatali folyamatokra. 3. Az erőfölényből adódó kockázatok, amelyek a multinacionális szereplők számára átadott adatok révén nemcsak az egyes gazdálkodók, de akár a nemzeti kormányok számára is hátrányokat jelenthetnek.

Az adatok védelme, illetve az adattulajdonosok védelme tehát fontos szempont, azonban ahhoz, hogy az adatok alapján információ keletkezzen, további kockázatot jelent, ha az adatok szétszórtan, egymástól független szervezetek tulajdonában, nem összevethető és nem integrálható módon érhetőek el. Jelen tanulmány az agráradatok kezelőinek feldolgozásával ezekre a biztonsági problémákra hívja fel a figyelmet.

Kulcsszavak: agráradat, fenntarthatóság, adatstratégia, hatékonyság, biztonság

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 data recorded in spatial data structures that register field borders, and on the other hand, 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 *(Magyar–Varga, 2021)*. The Central and Eastern European countries that joined the EU in 2004, including Hungary, Slovakia and the Czech Republic, which are members of the Visegrad 4, came to the European Union after going through different paths of historical development; therefore, their agricultural data systems have also evolved in different ways. However, one of the specific obstacles to the data integration that is so important for agriculture in all three countries is that data, whose complex use is key for modern agriculture, 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 environment, globalisation: 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 optimised 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.

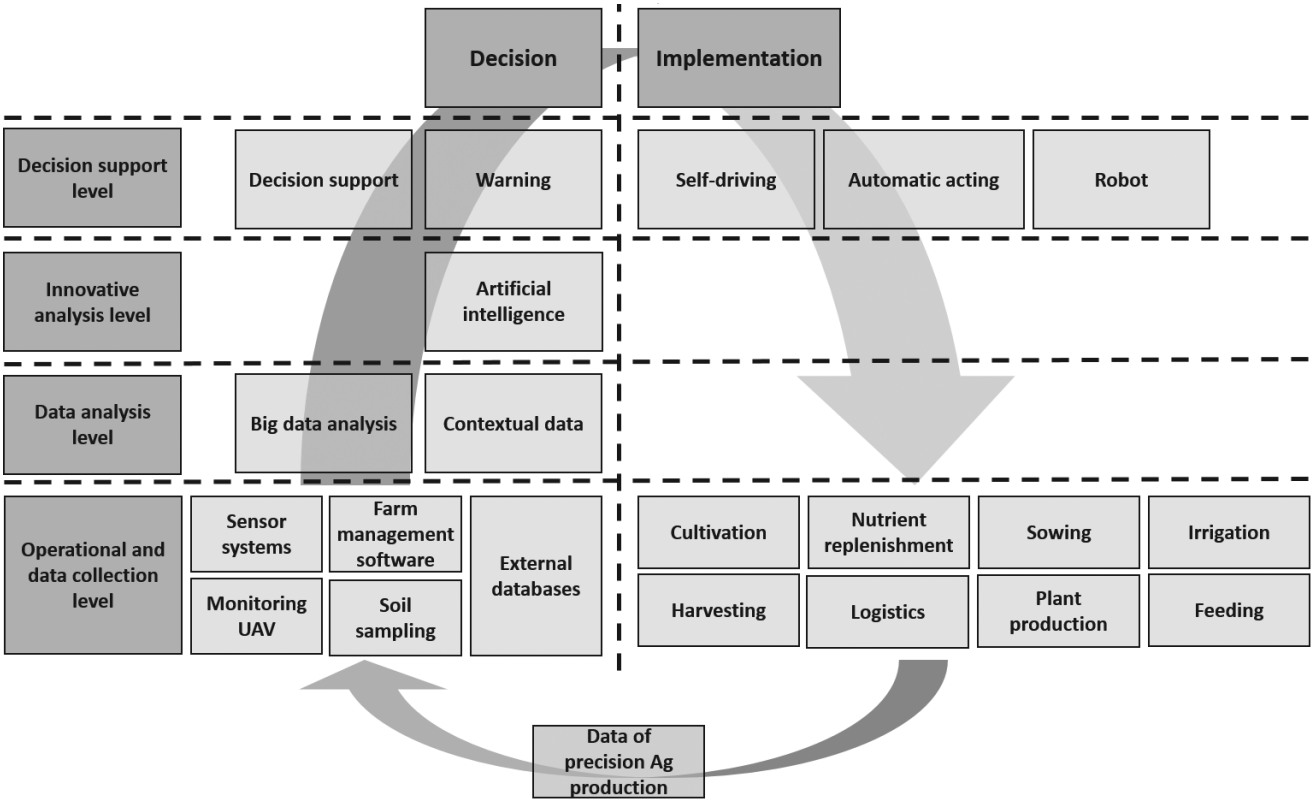

Figure 1 Schematic structure of data space and data flow of the up-to-date digital farms

Source: own work, based on information provided by Deloitte Hungary: A Nemzeti Ménesbirtok és Tangazdaság digitális fejlesztéseinek kiválasztása, [Selection of digital developments for the National Stud Farm and Experimental Farm (15 Feb 2021)]

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 all over 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 customised 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

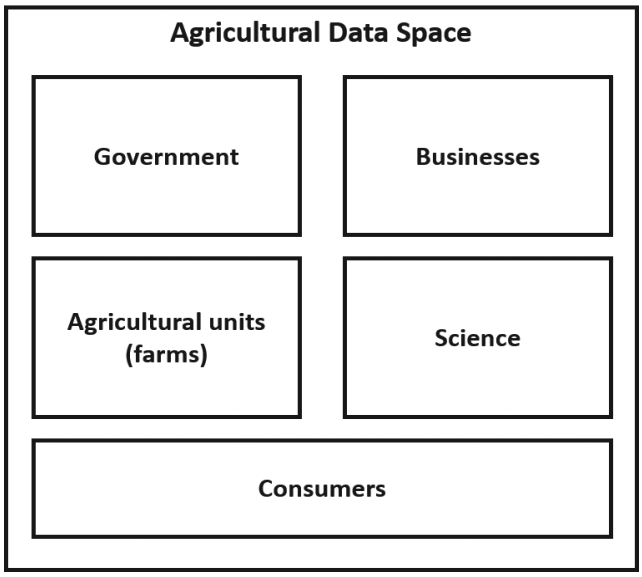

Figure 2 | Schematic structure of agricultural data space
Source: *Magyar–Varga, 2021*

accurate and customised 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):*

– **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 behaviour and health. It is important to create standardised 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 depend 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 digitalisation. The level of digitalisation 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.

In the next section, we will examine the agricultural public data sets of Hungary, Slovakia and the Czech Republic in detail, mainly from an interoperability point of view.

Public data sources for agricultural data in Hungary

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, pro-

ducers 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.

Public data sources for domestic agricultural data will be presented in detail in the next section.

Databases managed by the National Food Chain Safety Office (NFCSO)

- **Soil Protection Information and Monitoring System (SPIMS)** – Continuous monitoring of changes in soil quality and environmental status, and recording the results in a database based on samples gathered at 1,236 sampling points.
- **DataPlant** – Organizes data from the plant, soil and agricultural environmental domains into a unified IT database.
- **DataVet** – A professional master data system, an authentic public database providing IT support for the food chain concerning activities related to stock farming, transport and slaughtering, and to animals as products, based on data from the following specific systems:
  - Pig Tracking System,
  - EPIDEMIR epidemiological system,
  - MR animal by-products declaration system,
  - OLIR Equidae identification and registration system,
  - HALas system
  - Master datasets of species subject to the Integrated Identification and Registration System (ENAR) and the Poultry Information System (BIR) and new species are integrated into the DataVet system
- **Fruit cadastre** – Database on the fruit sector, whose main components include fruit field and fruit plantation coverage. The showcase project has already been implemented, and data has been digitised for one county.
- **Food Chain Monitoring Information System (FCMIS)** – The lawful operation of all food chain and agricultural business operators requires holding a FELIR ID in addition to the decision on authorization/registration issued by the competent authority. An FCMIS data query can be run by entering the first eight digits of the 'VAT number' for companies and sole proprietors, and the 'name' and 'date of birth' for agricultural producers and natural persons.
- **Pesticide database** – Database of prevailing authorisation documents for all pesticides.
- **Crop enhancing material database** – According to Section 8(3) of Decree No. 36/2006 (V. 18.) of the Ministry of Agriculture and Rural Development on the authorisation, storage, distribution and use of crop enhancing materials.
- **Seed label database** – Bovine unique identification number (ENAR) – A database that contains several years of data for certain livestock species, and more than two decades of data for bovine. In addition to the subsidy objectives, this also serves to meet breeding, veterinary and agricultural regulatory needs.

National Meteorological Service (OMSZ)

- **National Meteorological Service surveillance network database** – agrometeorological data collected by OMSZ stored in a single IT system, the national meteorological database.

Lechner Knowledge Centre Non-profit Ltd.

- **TakarNet** – TakarNet creates a computer network for land-related offices and provides external users (registered users with paying accounts) such as banks, public administrations, municipalities, notaries, law firms, etc. with remote access to land registry office databases.
- **Geoshop.hu** – The geoshop.hu website was created eight years ago following the EU INSPIRE directives, which require EU countries to ensure that spatial data is available, can be browsed and downloaded in electronic format. Geoshop offers access to map data produced using basic national cadastral and cartographic data and value-added products produced by the Lechner Knowledge Centre to everyone in a simple and easy-to-interpret format; however, this platform also needed a makeover.
- **Fentrol.hu** – The website provides public access to some of the recordings contained in the aerial film library of Lechner Nonprofit Kft. The film library contains almost half a million recordings made between 1959 and 2007. Around 63,000 archive recordings (i.e. more than 20 years of material) were digitised as part of the project, which was completed in the summer of 2014 with the help of European Union funding. As a result of continuous digitization, more than 185,000 scanned aerial photographs are now available online.
- **gnssnet.hu, farmrtk.hu** – national infrastructure and network-based RTK service to support real-time, precise (to the centimetre), satellite-based field positioning.
- **Aerial images and orthophotographs** – Data collection of aerial images and orthophotographs covering the whole country since 1959. An aerial and orthophotograph dataset covering the country's territory is available for every 4 years between 2007 and 2014 and for every 3 years starting from 2016, which constitutes the basis for LPIS.
- **Topographic maps** – Digitisation and georeferencing of paper-based maps from previous field recordings. The database contains maps of Hungary at scales of 1:10,000, 1:25,000, 1:100,000, 1:200,000.

– **Digital topographic maps** – Data was collected by digitising topographic maps and processed by vectorising topographic maps contained in the Integrated National Projection at M=1:10,000.
– **National Land Registry Map Database** – Archived copies of the so-called royal cadastral maps were produced during the national survey between 1855 and 1930.
– **Elevation and Horizontal Reference Points Database** – The elevation database contains the data of the first-, second- and third-order Integrated National Elevation Network and Bendefy elevation reference points and the points of the Bendefy third-order supplementary network.
– **Earth surface monitoring databases** – Data is collected using a variety of sources, including Earth surveillance satellites (space segment) and so-called in situ data (ground segment). In the course of data processing, the user segment (services) provides information using the aforementioned data in six thematic areas, such as land, seas, atmosphere, climate change, disaster management and security.
– **Terrain model database** – Data was processed by vectorising scanned and transformed files of topographic coverages of 1:10,000 scale topographic maps.
– **Satellite images database** – The space images archive contains about 40,000 space images of the territory of Hungary, including images taken by the SPOT, IRS, IKONOS and LANDSAT satellites and satellite families.
– **Topographic database** – Data collection was carried out by updating the topographic maps (1979 and 2000) and incorporating major changes in topography since 2000 (e.g. highway construction or the opening of opencast mines) using stereophotogrammetry. Data were processed to produce a topographic model of the terrain, enhanced by stereo photogrammetric evaluation, using the terrain model of the 1:10,000 scale topographic maps.
– **Digital surface model** – Data collection and processing were carried out using informed, overlapped stereo aerial imaging models, and resulted in an unedited digital surface model (point cloud) obtained by an automated method.

National Land Centre

– **Land Parcel Identification System (LPIS)** – The exclusive reference, identification and spatial information system for agricultural and rural development support financed by EU and national funds. The tasks related to the operation and development of LPIS and the updating of data contained therein are carried out by the National Land Centre – NLC, as the state administration body responsible for land surveys and geographic information system, in cooperation with the Hungarian State Treasury. Data used to build LPIS means orthophotographs, which provide a cartographic base and a renewable background, topographic maps help to identify boundary features that are stable over time (M = 1:5,000), multi-year space image time series help to identify different land uses, and cadastral maps can be used as coverages to help with orientation. Data processing involves the integration of input data into a geographic information system. The LPIS database constitutes the basis for the exclusive geographic information system for area-based subsidies, owned by the Hungarian State and controlled by the Hungarian State Treasury as the agricultural and rural development support body.
– **VINGIS** – A comprehensive database at the vineyard level. VINGIS is a nationwide system that includes the production field cadastral coverage, the vineyard coverage, the subsidy coverage, the mountain community boundary coverage, the cadastral coverage, the orthophotograph, the topographic coverage, the county boundary coverage, the soil coverage and the block boundary coverage.

Hungarian State Treasury (HST)

– **Integrated Administration and Control System (IACS)** – An integrated IT system responsible for the management and control of support data relating to measures and for the unified submission of applications.
– **Unified Agricultural Customer Registration System** – The system responsible for the identification and registration of master customer data who are involved in procedures monitored by the agricultural and rural development support body and the food chain control body, and the Land Parcel Identification System (LPIS), which is the national land identification system used for measures covered by the Act.
– **Complex Agricultural Risk Management System (CARMS)** – An IT system built around mitigation activities using advanced technology and procedures (remote sensing, geographic information system, meteorology, GPS technology). Reduces the administrative burden on producers, shortens procedural deadlines.
– **MobileGAZDA app** – The app aims to inform agricultural holding owners in real time and through a more direct communication channel about the opportunities and obligations of their subsidies. Using the app will increase information exchange and make applications more accurate, which will facilitate smoother application handling, faster decisions on and payments of subsidies. In addition to a more dynamic administration, the proper use of the app can also mean fewer on-site inspections for agricultural holding owners.

– **Agricultural and Environmental Information System (AEIS)** – The database ensures the interoperability and query ability of the main databases on agricultural lands, objects and assets in a single reference system, integrating them as an interoperable system. With the creation of AEIS, the following aims have been fulfilled:
  • sharing of relevant data among the organisations involved in the project, in the form of data provision and receipt, using AEIS as an electronic tool;
  • the creation of a unified reference system, the ability to display available data and geographic information in a single place and in a unified structure, which also means the comparison and consolidation of data from different registers through the dataspace created.

Some of the most important information datasets outlined in AEIS include:
  • LPIS data (e.g. physical block data);
  • land use data (agricultural and environmental management data, Natura 2000 data, other thematic layers);
  • state-owned land data;
  • data on nature conservation and environmental land and special protection areas;
  • data on forest areas;
  • data on bovine, pig, sheep, goat, poultry, and horse holdings.

Hungarian Central Statistical Office (HCSO)

– The HCSO uses either the LAKOS or the GÉSA systems for organising the data collection, depending on the subject thereof. The LAKOS system is used for collecting residential data, while GÉSA is used to manage business associations and their data. In addition to organising the data collection, the evaluation of the data collection is also performed. The collected data is prepared using two HCSO frameworks (ADEL, BLUMEN) and other applications. After data preparation, the data is processed in the HCSO Unified Data Processing System (UDPS). The aim here is to produce final data.
– The HCSO receives data from several data owner organisations through its own secure data interchange system (KARÁT), based on Act CLV of 2016 on Official Statistics and cooperation agreements concluded with data host organisations. This tool allows the HCSO to receive data relevant for agricultural producers from the Research Institute of Agricultural Economics, the Ministry of Agriculture, the Hungarian State Treasury and the National Food Chain Safety Office.

Institute of Agricultural Economics Non-profit Ltd.

– **Farm Accountancy Data Network (FADN)** – Farm Accountancy Data Network (FADN) was set up by the European Commission to support the CAP, to monitor the development of agricultural holding incomes and agricultural holding management. The Hungarian subsystem of the FADN, the Farm Accountancy Data Network, serves both domestic information needs and the connection to the FADN system of the EU.

The main topics covered by data collection performed in the test sites include:
  • holding identification and basic data,
  • land area data,
  • employee data,
  • enterprise's balance sheet data,
  • profit and loss statement data,
  • variation in fixed assets,
  • statement on the value of livestock and inventories,
  • a statement on the due date of receivables and maturity of accounts payable,
  • variation in livestock and inventories,
  • a statement on the subsidies applied for in the current year,
  • the area is sown, average yields, average prices, internal holding use,
  • sectoral cost declaration and accrual accounting.

– **Market Price Information System (MPIS)** – The institute operates a Market Price Information System (MPIS) for the management and operation of the agricultural sector and to fulfill its obligations to the European Union. The aim of MPIS is to provide the European Commission with mandatory price information on EU market regulation and to provide objective and up-to-date information to domestic professional and market organisations.

Monitored product lines include grains, oilseeds, sugar, vegetables, fruits, wine, milk and dairy products, poultry and eggs, meat (pig, bovine, sheep). The system collects information on a daily, weekly and monthly basis. Along the product path, the system collects three prices that are well distinguishable in terms of content: the producer price, the selling price of processed products and the consumer price.
– **Pig Information System (PIS)** – The service monitors and collects, among other things, domestic and international pig prices, key indicators of foreign trade, legislative changes, and documents generated at professional conferences, and thereby supports the preparation of sector-related decisions.

– **Agricultural Statistical Information System (ASIS)** – The Agricultural Statistical Information System (ASIS) performs statistical data collection tasks under the framework of the National Statistical Data Collection Programme (NSDCP). These data collections are partly mandatory under EU regulations and partly serve the needs of public institutions and professional researchers. ASIS is closely linked to the information systems of the HCSO. Among the tasks carried out in cooperation, the most important is the Economic Accounts for Agriculture (EAA), which shall be developed upon the European Commission's request by the Member States based on a common methodology.
– **Fisheries Information System (FIS)** – FIS is a public geoportal that displays fish production data collected by AKI under the framework of the National Statistical Data Collection Programme. The input data of the FIS web app consists of map layers, which can be Esri base maps, Natura 2000 sites, Ramsar wetlands, and county and region (OSM), either of which can be selected as a background map. Specific basic FIS data is retrieved from the existing Agricultural Statistical Information System (ASIS) and aggregated while respecting requirements on statistical data.
– **Fish Prices Data Query Interface (Halár)** – The AKI website provides consumer price data for the past 10 years regarding certain major fish products at major retail chains and rural fish markets.

Hungarian Academy of Sciences, Centre for Agricultural Research (MTA ATK), Research Institute for Soil Science and Agricultural Chemistry (TAKI)

– **DoSoReMi.hu Digital, Optimized, Soil Related Maps and Information in Hungary** – The DoSoReMi database aims to renew the Hungarian soil space data infrastructure, to produce digital, thematic soil maps on a national scale. The data collection involved the analysis and integration of spatial and thematic properties of existing soil maps and databases (soil information, digital topographic parameters, remotely sensed data, other environmental information, soil information). The spatial extension of the soil sample information was carried out using spatial variables related to environmental factors associated with soil formation processes and their consequences, providing full coverage of the area to be mapped.
– **EU-SoilHydroGrids 3D Soil Hydraulic Database of Europe** – The purpose of EU-SoilHydroGrids is to provide information on the most common soil hydraulic characteristics, with full European coverage down to 2 m depth, in 250 m or 1 km resolution. Data were derived using the European pedotransfer functions (EU–PTF), which are based on simple soil parameters.
– **Digital Kreybig Soil Information System (DKSIR)** – DKSIR is a series of segmented maps that provide information on soil characteristics that reveal the physiological conditions of the organisms that live and the plants that are grown in the soil. The map series is based on the 1:25,000 scale Kreybig Soil Survey Map Series, whose field survey was conducted between 1935 and 1950. The database was made based on a geographic information system adaptation and reanalysis of the map series.
– **AGROTOPO** – The purpose of the AGROTOPO database is to provide a series of soil maps that define the field conditions in Hungary. The map series is based on the Soil Survey Map Series, which was generalised and processed by an analogue method to produce the 1:100,000 scale soil map.
– **OKIR Soil Degradation System (SDS)** – The OKIR Soil Degradation System aims to monitor the environmental impact that results from agricultural activities based on the data in the agricultural holding owners' Logbooks (AHL) and to classify the environmental impact by defining the pressure indicators that characterise the main soil degradation processes.

Governmental Agency for IT Development (KIFÜ)

– **Land Monitoring Information System (LMIS)** – Provides the public administration, specialised administrative systems, the private sector and the entire Hungarian society with relevant, detailed, easy to access and up-to-date land monitoring data, including the following datasets and services:
  • creates an electronic Land (eFöld) surface from visual data derived from Copernicus
  • establishes of a Land Monitoring Data Centre
  • provides process and service developments to improve the efficiency of satellite data acquisition
  • establishes a remote space sensory data processing interface for domestic SMEs
  • ensures access to Copernicus data for Hungary

Hungarian Chamber of Agriculture

– **Membership register** – A database to register all members of the HCA-based compulsory chamber membership and to record-holding management data required for the assessment of membership fees.

National Tax and Customs Administration of Hungary

– **Electronic Trade and Transport Control System (ETTCS)** – Only taxpayers who have an ETTCS number may carry out road transport activities. The system only issues a number for the consignment of

customers with an FCMIS ID for products that fall under the responsibility of the NFCSO.
– **Online cash register** – Data provided by enterprises that use a cash register.

Ministry of Interior

– **Water Consumption Information, Control and Integrated Regulatory Framework (WCICIRF)** – The system supports the water licensing process, related water management, maintenance, authority, taxation, research and statistical tasks. It provides support for water rights-related tasks and the application of a customer-friendly solution that aims to simplify user administration.

National Council of the Wine Communities (NCWC)

– **ePincekönyv** – In addition to the digitisation of the excise and professional records (winery register or small-scale wine producer register) (providing an alternative to electronic management), it also includes the integration of different IT systems (e.g. specific systems like HEGYIR, NÉBIH BOR).

Table 1 analyses each database according to the currently available main data domains: soil, land; plant production; stock farming; weather, environment; economic data.

Data collection and handling institutions in Slovakia

In Slovakia agricultural data are available in National State Institutions, which are similar to Hungary divided into smaller data holding units. In data publicity, Slovakia is much more open than Hungary, as personal data are available in an open form for the users on designated websites.

National level – Slovakia – state institutions:

Ministry of Agriculture and Rural Development

Agricultural Paying Agency
National Agricultural and Food Center (www.npcc.sk) – consists of
o Research Institute of Soil Science and Soil Protection (www.podnemapy.sk)
o Research Institute of Plant Production
o Research Institute of Grasslands and Mountain Agriculture
o Research Institute of Agroecology
o Research Institute of Animal Production Nitra
o Food Research Institute
o Research Institute of Agricultural and Food Economics
o Technical and Testing Institute of Agriculture

Other significant institutions:

- Central Agricultural Inspection and Testing Institute (www.uksup.sk)
- Breeding services of the Slovak Republic – Central Register of Livestock
- National Forestry Center (NLC) (www.forestportal.sk)
- Hydromelioration s.e.
- State Veterinary and Food Administration
- Slovak Land Fund

Office of Geodesy, Cartography and Cadastre of the Slovak Republic

Cadastral maps, topographic maps, aerial images, satellite images, LIDAR data

Digital terrain model, national GPS network (www.gku.sk, www.geoportal.sk)

Ministry of the Environment of the Slovak Republic

Water Management Research Institute (wwww.vuvh.sk)
Slovak Hydrometeorological Institute (www.shmu.sk)
State Nature Protection (www.soprs.sk)
(www.enviroportal.sk)
Dionýz Štúr State Geological Institute

These institutions give free of charge data to 2 integrated systems, which are used by agricultural enterprises for their activities.

The basic source of information for farmers is the portal www.podnemapy.sk.

It was built by the Research Institute of Soil Science and Soil Protection for the needs of the Paying Agency. It integrates data from LPIS (Land Parcel Information System) as a basis for EU subsidies, as well as information on soil, erosion, environmental restrictions, fertilisation limits, the Nitrates Directive, NATURA 2000 areas – i.e. all layers that the farmer needs to know in order to apply for subsidies, both in terms of Direct Area Payment and the Rural Development Program. The portal therefore also integrates data from the Ministry of the Environment, which are necessary for farmers.

The portal www.geoportal.sk solves the connection of cadastral maps, topographic maps, satellite and aerial images with selected layers of LPIS – the boundaries of production blocks, users in the land within the blocks as well as the rental prices of agricultural land. All this data are public and free. In Slovakia, data on cadastral parcels

Table 1 | Public agricultural databases, 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			
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
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

and owners are public. Concerning fragmented land ownership – i.e., the inheritance under Hungarian law – it was necessary to integrate LPIS blocks with cadastral maps and to allow direct identification of landowners under large land blocks used to identify land ownership and leases.

Data collection and handling institutions in Czech Republic

Ministry of Agriculture of the Czech Republic
The **State Agricultural Intervention Fund (SZIF)** is an accredited **paying agency** that acts as an intermediary responsible for the administration of financial subsidies.

Public research institutions:
- o Research Institute of Hydromelioration and Soil Protection
- o Food Research Institute
- o Research Institute of Plant Production
- o Research Institute of Animal Production
- o Research Institute of Forestry and Hunting
- o Research Institute of Veterinary Medicine

An organizational unit that is a state administration body:
- o Czech Breeding Inspection
- o State Agricultural and Food Inspection Authority
- o Institute for the Control of Veterinary Biopreparations and Drugs
- o Central Agricultural Inspection and Testing Institute
- o State Veterinary Administration
- o State Land Office

An organizational unit that is not a state administration body:
Institute for Forest Management

Czech Geodetic and Cadastral Office

Cadastral maps, topographic maps, aerial images, digital terrain model
(geoportal.cuzk.cz)

Ministry of the Environment of the Czech Republic
- o Czech Hydrometeorological Institute (www.chmi.cz)
- o Water Management Research Institute T.G.Masaryka
- o Nature and Landscape Protection Agency of the Czech Republic (www.ochranaprirody.cz)
- o Czech Geological Survey (www.geology.cz)
- o Czech Environmental Information Agency (CENIA) (www.cenia.cz)

CENIA's mission is to collect, evaluate and interpret environmental information and provide it to the professional and lay public. CENIA cooperates with all providers of data sources in the Ministry of the Environment as well as with numerous research projects, scientific and university workplaces. It participates in the development and provision of selected data and map services and is the operator of many information systems.

It is visible that in all three countries, data collection, storage, and disclosure involve many completely separate institutions, making data integration difficult to achieve.

Identification of data-based risks

The current situation of agricultural digitalisation 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 digitalisation *(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.*

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 learn-

Table 2 | Number of agricultural holdings by standard production value and size categories, 2016 [pcs]

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**

Source: HCSO, 2016

ing 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 optimisation 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 summarised in *Table 3*. Basic risks include:

– **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 the market concentration is.

Table 3 | 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 system								For	Serv	Data	Market	For	Serv	Data	Market	For
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

– **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.

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