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Horizon Cloud – The Forum for Strategy Focused Cloud Stakeholders

Appendix 7:
Agriculture

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1 KEY PLAYERS IN AGRICULTURAL SECTOR

The agriculture sector is a multi-disciplinary sector that includes farmers, producers and representative associations, suppliers (seed, fertilizer, feed, supplements, etc.), specialized contractors (e.g., harvesting labour and machines), downstream supply chains, machinery, vehicles and systems (e.g., irrigation), weather forecasting, land use monitoring, and other environmental monitoring systems (nutrient management, water pollution), as well as biology, nutrition and climate scientists.

Processing and analysing agricultural production data, especially in combination with other data on the supply chain and other types of data, such as earth observation or meteorological data, allows for precise and tailored application of production approaches at farm level, and enables farmers to optimize their operations and improve the performance of their own farm business. These activities represent the "digital transformation" of agriculture and have sometimes been termed "precision agriculture" or "Agriculture 4.0", paralleling the broader "Industry 4.0" concept.

Agriculture 4.0 can be understood better by considering a number of categories of upstream agrifood innovation technologies[1]:

1. Ag Biotechnology: On-farm inputs for crop & animal ag including genetics, microbiome, breeding, animal health.
2. Agribusiness Marketplaces: Commodities trading platforms, online input procurement, equipment leasing.
3. Farm Management Software, Sensing & IoT: Ag data capturing devices, decision support software, big data analytics.
4. Farm Robotics, Mechanization & Equipment: On-farm machinery, automation, drone manufacturers, grow equipment.
5. Novel Farming Systems: Indoor farms, aquaculture, insect, & algae production.
6. Midstream Technologies: Food safety & traceability tech, logistics & transport, processing tech.
7. Bioenergy & Biomaterials: Non-food extraction & processing, feedstock technology, cannabis pharmaceuticals.
8. Innovative Food: Cultured meat, novel ingredients, plant-based proteins.

The digital transformation of agriculture primarily focuses on categories 2, 3 and 6, and partially 4 from this list.

The European Strategy for Data[2] (EUSD) has proposed a cross-border pan-European data space focussed on agriculture, intended to enable the digital transformation of the sector. Challenges specifically associated with realizing this common agricultural data space are identified along with more general challenges facing the digital transformation of agriculture.

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[1] AgFunder is one of the most active foodtech and agtech venture capital investors globally. In addition to investing, they track global agrifood innovation investments and provide annual reports on the sector: https://research.agfunder.com/2019/AgFunder-Agrifood-Tech-Investing-Report-2019.pdf. For this assessment we do not include "downstream" investment categories, which focus on distribution and food waste topics such as restaurant management, cloud kitchens and eGroceries.

[2] EC. Communication: A European strategy for data. 2020

1.1 Primary Producers

The agricultural sector centres around farms and farmers themselves, the vast majority of which in Europe are either subsistence farms or have extremely small economic output. The COPA-COGECA associations[3] represent a total of 23 million farmers and 22,000 agricultural cooperative associations across the EU. The total number of farms in the EU was 10.5 million in 2016[4], but only 304,000 (2.9%) of these farms had annual output of more than €250,000. (The minimum asset size typically defined for a small- or medium-sized enterprise (SME) is €2 million.) Just 3.3% of all EU farms (347,000) accounted for 52.7% of utilized agricultural area and 55.6% of Europe's total agricultural output.

Compared with the other sectors considered in the Green Paper[5] and related sector briefing papers, "cloud adoption" by the vast majority of farmers and other agricultural producers should probably be interpreted as "digitally enabled", just as individual citizens might be "digitally enabled" through broadband access to the Internet, availability of modern computers at home or mobile devices, and skills in using those technologies to improve their own lives and well-being. This perspective becomes more significant given that 55.7% of farmers are over 55 years old, and 68.7% have no formal training in farming, only practical experience. When farmers are thinking about digital tools, few are thinking about public cloud, private cloud, multi-cloud, etc. but rather looking for the right application(s) for their personal computers or mobile phones that can help them manage their farms efficiently and take advantage of new services that improve their profitability. Even the largest 3% of farms mostly fall into the "SME" category and face the same constraints on resources and skills faced by SMEs.

1.2 Farm Management Software (FMSs)

Farm management software (FMS) is the primary digital enabler for farmers. The FMS category generated $1.5 billion in global revenues in 2017, dominated by many US and Canadian software vendors, as well as offerings from companies in France, UK, Germany, and Italy, and revenues are projected to grow to $1.8 billion by 2023[6]. Many, but not all, FMS offerings are packaged in software-as-a-service (SaaS) formats with both desktop and mobile interfaces, as well as monthly pricing plans. FMS products fall into several categories:

- Packages that started life as farm-focussed accounting and "enterprise resource planning" (ERP) software, expanding with interfaces to suppliers and customers, as well as data services that integrate data collected from farm machinery, earth observation services as well as IoT devices such as wetness indicators installed at key points on the farm. While a few FMS vendors of this type are significant in size (such as France's ISAGRI, with 2,200 employees and roughly €200 million in annual revenues[7]), most are SMEs, with limited resources to support broad development activities related to data sharing, security, privacy, and integration.
- FMS packages integrated with data collected from farm equipment, e.g., John Deere Operations Center, Case IH's AFS Software, CLAAS' 365FarmNet, CNH Industrial. Current models of farm equipment collect real-time data not only on the

[3] https://copa-cogeca.eu/
[4] https://ec.europa.eu/eurostat/documents/3217494/9455154/KS-FK-18-001-EN-N.pdf/a9ddd7db-c40c-48c9-8ed5-a8a90f4faa3f
[5] Add reference
[6] https://cropom.com/articles/the-farm-management-software-market
[7] https://www.truffle100.fr/

operation of the equipment (e.g., fuel consumption and condition monitoring), but also on the actual operations being performed by the equipment (e.g., cultivating, seeding, harvesting, etc.) and where those operations are being conducted (drawn from integrated GPS systems). Manufacturers originally added these data collection and software tools to their offerings to create competitive advantage as well as some "stickiness" around purchasing decisions, but manufacturers have increasingly recognized that closed platforms cannot achieve market dominance and that customers expect interoperability among these platforms[8]. In late 2019, four of these equipment manufacturers agreed to the "DataConnect" initiative, allowing viewing and manipulation of basic machine data from multiple manufacturers and fleets[9].

- FMS packages linked to downstream suppliers, such as Bayer CropScience's Climate FieldView and Corteva's Encirca[10]. Here the focus is to use agronomy (the science of soil management and crop production) to generate insights on planting, irrigation, fertilization, etc. in pursuit of optimal crop yield and quality.

Each of these FMSs promises improvements in productivity and performance through expanded technology and data integration. At the same time, these FMSs are marked by limited integration or interoperability of either services or data[11], making it difficult for farmers even to make confident choices about which FMS(s) to use, much less using them seamlessly to manage their farm activities effectively.

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[8] https://www.cema-agri.org/images/publications/position-papers/2020-09-08-CEMA-Common_European_Agricultural_Data_Space.pdf

[9] https://www.deere.ca/en/our-company/news-and-announcements/news-releases/2019/agriculture/2019nov05-dataconnect/

[10] Corteva was formed from the merger of DowAgroSciences, DuPont Crop Protection and Pioneer.

[11] Tummers, J., Kassahun, A., and Tekinerdogan, B. (2019). "Obstacles and features of Farm Management Information Systems: A systematic literature review". In: Computers and Electronics in Agriculture 157, pp. 189–204. issn: 0168-1699. https://doi.org/10.1016/j.compag.2018.12.044. http://www.sciencedirect.com/science/article/pii/S0168169918307944. Munz, Jana, Gindele, Nicola, and Doluschitz, Reiner (2020). "Exploring the characteristics and utilization of Farm Management Information Systems (FMIS) in Germany". In: Computers and Electronics in Agriculture 170, p. 105246. issn: 0168-1699. https://doi.org/10.1016/j.compag.2020.105246. http://www.sciencedirect.com/science/article/pii/S0168169919316126.

2 AGRICULTURE 4.0

McKinsey & Company projects that the digital transformation of agriculture could trigger an 8.8% increase in agricultural output in Europe[12] . Based on the EU's €432.6 billion of output in 2017, this represents roughly €38 billion in potentially increased output. McKinsey identifies several key use cases that would contribute to this increase:

- Smart crop monitoring,
- Livestock monitoring,
- Building and equipment management,
- Farming by drone,
- Autonomous farming machinery.

Additional indirect benefits could be seen through the automation or elimination of time-consuming tasks for farmers, giving them the resources to take on additional productive activities (for example having time to cultivate fallow fields).

Farmers' willingness to pay is constrained by their expectations of the benefits of digital transformation:

- A recent survey[13] of farmers in the US estimated the value of digital transformation at roughly $2.50 per acre per year (approximately €4 per hectare). Even for the 300,000 most productive farms in Europe, with an average of 300 hectares of land under cultivation, this provides a limited incentive to invest in digital transformation. For most smaller farms, benefits at this scale would have minimal impact, and government support would certainly be needed for these farms to make this investment.
- Based on McKinsey's estimates, digital transformation in Europe promises more than €400 per hectare of aggregate increased output. Although this is significant for a 300-hectare farm, this assumes the farm benefits from all possible improvement scenarios. Implementing the first scenario with positive payback could be more challenging.

Despite these macroeconomic estimates, many agricultural enterprises are seeing benefits from their investments in "Agriculture 4.0". For example,

- GAIA[14], a unit of Consilium Technologies in Australia, has developed machine-learning tools to analyze multi-spectral satellite images to produce detailed, row level analyses of crop health, delivered to customers via the web. They provide a subscription-based information service priced at AU$40/hectare-year and present a case study where over AU$2,000 in financial benefits resulted from interventions prompted by GAIA-generated insights. This represents a 50X payback, before accounting for the direct costs of recommended tree removal and compost application.
- Idroplan[15], an Italian agtech startup, monitors irrigation and crop protection for wineries, charges approximately €30/ha-year for wireless data collection and analysis and decision support. Paybacks range from just €100/ha/year in water savings, to €300-500/ha from improved quality (e.g. increasing alcohol content of grapes by

[12] https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth
[13] https://www.precisionag.com/digital-farming/data-management/what-is-the-value-of-sharing-farm-data/
[14] https://gaia.ag/
[15] https://www.idroplan.org/, and interviews with the company

50%), to more through improved crop yields. Farmers typically need to invest about €100 euro in sensors per hectare, which is often paid back within the first year. (Note that Idroplan often spends as much as €12/year for wireless data collection per customer.)

Clearly there are scenarios where precision agriculture offers a return on investment to farmers.

3 CHALLENGES FOR A COMMON EUROPEAN AGRICULTURAL DATA SPACE

3.1 Organizational Challenges to Agriculture 4.0 and a European Agricultural Data Space

Generating the benefits described above requires a number of challenges to be addressed:

- Uncertain payback from investments,
- Lack of appropriate, affordable connectivity on the farm,
- Lack of a trusted, much less secure and comprehensive, data sharing/data exchange regime,
- Complexity of integrating both technology (e.g., remote sensors on the farm) and data (e.g., satellite imagery, data collected by farm machinery),
- Difficulty for farmers analysing and interpreting the integrated data themselves, and lack of trust in insights and recommendations that might be offered by vendors.

As noted above, it is unclear if the benefits of precision agriculture will outweigh their costs. Selected case studies highlight successful scenarios, but it is difficult for farmers to know *a priori* whether specific investments will pay off.

Connectivity on farms has been a long-standing challenge to transformation in agriculture. For some farmers, appropriate connectivity is simply not available. Unlike higher density urban areas, where individual communications investments can generate a rapid payback through use by many customers, each investment in rural communications (for example a mobile base station at a rural crossroads) sees a much slower payback because there are fewer nearby users with a lower willingness to pay. For those farmers that do have adequate on farm connectivity, the cost of this service (including the cost of any required on-premise networking equipment) is an additional factor in the concerns over the cost and likely payback of precision agriculture. The EU agriculture community has recognized this challenge and has consistently advocated for improved connectivity in rural areas. [16]

Farmers' "sovereignty" over their own data was described as a principle of the 2018 "EU Code of conduct on agricultural data sharing by contractual agreement" [17].. This code of conduct goes some way to address farmers' concerns that data were being collected on their farms (e.g., by farm equipment) without respecting this principle. Nevertheless, this code of conduct embodies a self-regulatory approach, through a non-binding agreement among stakeholders in the EU agricultural community, rather than being adopted by the EU itself, and relies strongly on another component of the code of conduct, namely the need for explicit contractual agreements, which in turn can sometimes be difficult to understand and biased against farmers. Even if the EU legislates the principle of a farmer's ownership of the data produced on his/her farm, work is still needed to implement technical solutions that will facilitate trust in agricultural data sharing solutions, and separate regulatory oversight (rather than self-regulation) may be needed to build trust by the farming community in these solutions[18]. Realizing the benefits of a pan-European data space will require action to address these challenges.

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[16] Copa-Cogeca perspective on long term vision for rural areas_EN

[17] https://copa-cogeca.eu/img/user/files/EU%20CODE/EU_Code_2018_web_version.pdf

[18] Sanderson, J., L. Wiseman, S. Poncini (2018), "What's Behind the Ag-Data Logo? An Examination of Voluntary Agricultural Data Codes of Practice", International Journal of Rural Law and Policy (https://doi.org/10.5130/ijrlp.1.2018.6043). See aso Tatge, J. (2016), "The land grab for farm data", TechCrunch, (https://techcrunch.com/2016/07/06/the-land-grab-for-farm-data/).

The community has recognized the need for greater interoperability across systems, platforms and ecosystems. Over the last few years, several platforms focussing on data sharing have been created to improve interoperability, such as Djust Connect[19], API-Agro[20], DKE Agrirouter[21], JoinData[22], Agrimetrics[23] and Aladin.farm[24], as well as the DataConnect initiative mentioned above. In addition, several large EU-funded projects (ATLAS[25], DEMETER[26], SmartAgriHubs[27], IoF2020[28]) have focussed on the digital transformation of European agriculture. The ATLAS project specifically targets the "interoperability of agricultural machines, sensors and data services and enable[s] farmers to have full control over their data and decide which data is shared with whom and where".

The EUSD's proposal to create a common European agricultural data space contemplates building on the progress of these initiatives and projects. However, it is unclear how such a common data space would relate to existing initiatives or to existing FMS ecosystems. Potential data space participants in an Expert Workshop on a Common European Agricultural Data Space[29], convened on September 8, 2020, raised a number of concerns about the new initiative:

- The new data space might be competitive or threatening to their existing business, rather than complementary.
- How will the business investments, intellectual property and other assets that have been built up over time be protected?
- How will the new data space add value to existing FMS and data sharing offerings?
- How would a new federated approach operate, and specifically how would existing business arrangements (contracts) between participants, or even broader commercial platforms, be accommodated in any transition to a new federated model?

During the workshop, ILVO[30] highlighted a number of specific concerns and recommendations about federated data sharing structures:

- A clear business model is needed, identifying common objectives, synergies among partners, and resources that can be usefully shared. This point mirrors best practices for the organization of federations described in Appendix 15: The Potential of Cloud Federation. The IoF2020 project also notes the importance of focussing on specific sectors, rather than attempting to meet all needs simultaneously, as well as keep the purpose of the federation clearly in focus[31].
- Services to customers (farmers), not data sharing *per se*, should be the focus of any platform or federated business model.

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19 https://djustconnect.be/nl/
20 https://api-agro.eu/
21 https://my-agrirouter.com/
22 https://join-data.nl/
23 https://agrimetrics.co.uk/
24 https://www.aladin.farm/
25 https://www.atlas-h2020.eu/
26 https://h2020-demeter.eu/
27 https://www.smartagrihubs.eu/
28 https://www.iof2020.eu/
29 Summarizing position papers submitted to https://ec.europa.eu/digital-single-market/en/news/expert-workshop-common-european-agricultural-data-space-0
30 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=69562
31 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=69551

- Inclusion of the complete value chain ("farm to fork") is important to enable synergistic value creation. This could expand the scope of data involved to include food quality, safety and traceability.
- Multiple stakeholders along the value chain participate in creating value, have valuable data to contribute to the platform, and should be included in the business planning and governance process. These include agricultural cooperatives, farmer professional associations and downstream processors and distributors. This point highlights the importance of identifying relevant and important stakeholders and including them both in organizing and governing any federated data sharing initiatives. This is mirrored by the work of the Global Forum on Agricultural Research and Innovation. [32]

3.2 Technical Challenges to a Common European Agricultural Data Space

In addition to the organizational challenges identified at the Expert Workshop, a number of technical issues were raised:

3.2.1 Semantic Interoperability

If data is to be "joined up" in a data space, the meaning of each piece of data must be well defined. This "semantic interoperability" is critical to a well-functioning data space in any domain. Participants in the Expert Workshop acknowledged the importance of semantic interoperability, as well as the challenges involved in achieving it. Some participants recommended that there should be respect for existing efforts around interoperability, rather than any imposition of new schemes.

The DEMETER project conducted a detailed analysis[33] of relevant data models, taxonomies and ontologies, identified points of both commonality/ overlap and disagreement, and proposed a comprehensive (draft) Agriculture Information Model (AIM) to enable semantic interoperability. This partially incorporates the Next Generation Services Interface (NGSI) standard that has been notably employed by FIWARE and now incorporated into an ETSI standard (NGSI-LD). The AIM also partially aligns with the IDS Information Model of the International Data Space Association (IDSA).

DEMETER's AIM explicitly acknowledges the "nested" nature of data models, where greater detail is needed for specific subdomains, without requiring that level of detail to be reflected in other subdomains[34]. Workshop participants made similar points.

DEMETER's AIM also notes the need for translators, also mentioned by several Workshop participants. One participant suggested the concept of "Naming Authorities" as a role that will be needed in any architecture to accomplish this translation.

Finally, several Workshop participants highlighted the need to work toward global standards -- not just European standards -- since products and services need to work globally.

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[32] https://cgspace.cgiar.org/bitstream/handle/10568/92477/GFAR-GODAN-CTA-white-paper-final.pdf?sequence=3&isAllowed=y

[33] D2.1 Common Data Models and Semantic Interoperability Mechanisms (May 2020) https://h2020-demeter.eu/wp-content/uploads/2020/10/DEMETER_D21_final.pdf

[34] The IEC presents a best practice approach to creating interoperable data models. See https://webstore.iec.ch/publication/65942

3.2.2 Technical Interoperability: Need for a Common Architecture

Workshop participants identified the need for an agreed architecture of the data space, allowing participants to map their activities and technical functions onto a larger framework and work together more effectively. This problem actually requires alignment and harmonization of several high-level architectures that have already been proposed over the last 2 years:

- D3.2 ATLAS Service Architecture (April 2020)[35]. (This has many similarities to a federated data architecture.)
- D3.1 DEMETER Reference Architecture (Release 1) (February 2020)[36]
- Agricultural Data Space (ADS), of the Fraunhofer Project COGNitive AgriCulture (COGNAC) (2019)[37]
- IDSA Reference Architecture Model v3 (April 2019)[38]
- AIOTI's High Level Architecture for an IoT Data Marketplace (February 2019)[39]
- Smart farming IoT platform based on edge and cloud computing (January 2019)[40]
- IoF2020's IoT Reference Architecture (May 2018)[41].

CEMA (the European Agricultural Machinery Association), without proposing any architecture, does identify a number of features any useful architecture would need to support including:

- Robust identity management (for individuals, farms, equipment, farm fields, etc.)[42]
- Data governance tools such as distributed ledger technologies and "sticky policies"
- Common Data Models (described above), as well as translation services to bridge between specialized data domains
- Tools to accept and process streaming data, such as generated by farm implements operating in the field
- Flexible support for new communications technologies, such as 5G wireless, and adaptive edge technologies.

In addition to these formal specifications, the architectures of operational data exchanges (such as DKE's AgriRouter) should be examined for practical ideas that should be incorporated.

3.3 Data Required for a Common European Agricultural Data Space

A number of data sources have been identified as important for the functioning and utility of a Common European Agricultural Data Space. In contrast to farm-related data and data

[35] https://www.atlas-h2020.eu/wp-content/uploads/2020/06/ATLAS-D3.2-Service-Architecture-Specification.pdf
[36] https://h2020-demeter.eu/wp-content/uploads/2020/10/D3.1-DEMETER-reference-architecture_v1.0.pdf
[37] https://www.iese.fraunhofer.de/content/dam/iese/en/dokumente/Innovition-Themes/COGNAC_Whitepaper_ADS2019_eng.pdf
[38] https://www.internationaldataspaces.org/wp-content/uploads/2019/03/IDS-Reference-Architecture-Model-3.0.pdf
[39] https://aioti.eu/wp-content/uploads/2019/02/IoT-data-market-places-drivers-and-architechtures-white-paper-Elloumi-De_Block-Samovicz.pdf
[40] Zamora-Izquierdo, Miguel & Santa, José & Martinez, Juan & Martínez, Vicente & Skarmeta, Antonio. (2019). Smart farming IoT platform based on edge and cloud computing. Biosystems Engineering. 2019. 4-17. https://doi.org/10.1016/j.biosystemseng.2018.10.014
[41] Presented in https://www.iof2020.eu/deliverables/d3.3-opportunities-and-barriers-in-the-present-regulatory-situation-for-system-development-v1.2.pdf
[42] ILVO notes the need for distributed identifiers and identity management, recognizing the fact that specific entities (farmers, farms, etc.) are frequently identified differently in different systems and databases.

collected on farms, where data sovereignty and control over data sharing are important concerns (discussed above), the challenge with these common data sources is one of accessibility -- essentially ensuring that these data comply with FAIR principles (findable, accessible, interoperable, reusable).

Data sources referenced in connection with a Common European Agricultural Data Space fall into four categories.

3.3.1 Geospatial Data

The EUSD proposes, in connection with the Open Data Directive, to support Member States in making their geospatial, earth observation and environment, and meteorological data accessible and available as part of a common European data space. This effort also aligns with the proposal in the EUSD to create "Destination Earth": a high precision digital model, or "twin", of the Earth that will enable visualization, monitoring and forecasting of natural and human activity on the planet in support of sustainable development. This can be expected to extend, quite extensively, the geospatial data management tools created by the INSPIRE project[43].

Specific data sources of value to a Common European Agricultural Data Space include:

- Satellite-based Earth Observation data (Copernicus, Digital Globe)
- topological information
- field objects (like pylons)
- road information
- Soil maps (types and properties)[44] (of special relevance for initiatives around carbon sequestration)
- Geological data about minerals, heavy metals, ground water.

Note that geospatial data presents challenges for potential users and when considering incorporation into a data space, related both to data discoverability and data ownership and to the ability to create proprietary products derived from that data:

1. The platform: To facilitate and standardise access to earth observation data, the European Commission funded the deployment of five separate cloud-based platforms that provide access to distinct sets of Copernicus data and related processing tools (DIAS). These platforms are not federated, so it is difficult to bring these data sets together for analysis and interpretation. The EUSD refers to "interconnection" of both DIAS (as a single entity) and the European Open Science Cloud with the proposed cloud federation, in order to encompass Copernicus data within a broader common data space, but more work will be needed to achieve seamless access and integration, both from a data perspective and from a data processing perspective.
2. Integrated data-centric services: Earth data, including the open data from the Copernicus programme, are often too big to download and store locally, therefore, co-locating data access services and the related data processing facilities is urgently needed. Examples include services to process Satellite images for biodiversity and surface water quality. By contrast, Google Earth Engine[45] is an example of a commercial PaaS cloud service, providing an integrated data, storage, computing, and software environment. The EUSD's reference to "enhancing the Copernicus

[43] https://inspire.ec.europa.eu/
[44] https://data.isric.org/
[45] https://earthengine.google.com/

ecosystem through the application of European digital technological solutions"[46] may signal action to address this challenge.

3.3.2 Meteorological Data

Historical, real time and forecasted climate and weather data (on microclimate scale) -- at national and regional scales and from various service providers. Like geospatial data, relevant data needs to be filtered to the farm level and may benefit from the data management tools of INSPIRE.

This data might be complemented by "local" weather data collection, e.g., from IoT devices and drones. Some commercial weather forecast services and pollution monitoring services rely heavily on IoT-like solutions and small embedded systems to tackle "micro" aspects not covered by usual services for weather and pollution. Some are specialised on agrifood, combining satellite with drones and other technologies[47].

3.3.3 Agricultural Reference Data

Several categories of reference data, specific to the agricultural domain, will be important:

- crop databases, including yields and other agronomic data
- registries of agrochemicals
- data regarding farm animals, or agricultural machinery
- databases of plants and seeds
- prices of agricultural products
- costs of various consumables/resources, such as fertilizers, pesticides, water costs, energy costs, fuel prices, etc. are useful for determining the operating costs and to gauge the efficiency of agricultural operations
- Data about plant (variety), animal, insects and disease with images and possibly DNA
- Historical and real-time public data on pest and diseases infestations[48].

3.3.4 Agricultural Administrative Data

In contrast to the reference data above (much of which might fall into the domain of research), relevant administrative data is held by the European Commission or public administrations of Member States and falls into one of the categories of "high value datasets" to be made available as proposed by the EUSD.

- Farm Accountancy Data Network (FADN) data
- Eurostat agri indicators
- CAP indicators
- Agricultural traceability systems, such as the EU TRACES database (Trade Control & Export System)[49], and Hi-Tier[50] in Germany
- Integrated Administration and Control System (IACS) data
    - National/regional Cadastral Systems (Land Parcel Information Systems)

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[46] EUSD, p. 17.

[47] Examples of commercial weather and pollution services using Edge technology include: https://www.aeroqual.com/, https://plumelabs.com/en/air, https://developer.awhere.com/, https://agromonitoring.com/api, https://www.weatherbit.io/

[48] https://usablight.org/; http://www.icar-crida.res.in:8080/naip/index.jsp; https://openupguideforag.info/

[49] https://ec.europa.eu/food/animals/traces_en

[50] https://www.hi-tier.de/

- Historical crop insurance data.

Particular effort would be needed to harmonize existing EU farm registry systems -- data from one national system is not interoperable with data from other national systems, limiting the utility of this type of data.

4 KEY CHALLENGES

Table 1 illustrates the cloud-adoption and "data-enablement" challenges faced by the agricultural sector, mapped to the deployment model used throughout the Horizon Cloud project's analysis. Individual challenges are itemized in greater detail below.

Table 1. Demand Side Challenges in the Agriculture Sector.

<table>
<tr><th rowspan="2">Organisational complexity</th><th colspan="3">Deployment sophistication</th></tr>
<tr><th>A: Relatively simple cloud deployments</th><th>B: High data protection and security needs</th><th>C: Sophisticated deployment of more advanced technology</th></tr>
<tr><td>Level 4: Cross sector coordination</td><td>"Farm to Fork" Value Propositions and Stakeholder Involvement (D-A Challenge 1)</td><td rowspan="4">Trusted mechanisms for data sovereignty and confidentiality (D-A Challenge 4)</td><td rowspan="4">Accessibility and Interoperability of data across the data space (D-A Challenge 5)

High performance access to large data sets through the co-location and coordinated provisioning of computing, applications and data spaces (D-A Challenge 6)</td></tr>
<tr><td>Level 3: Multiple orgs, same sector</td><td>Clear value proposition for data sharing and data spaces (D-A Challenge 1)</td></tr>
<tr><td>Level 2: Single larger org & supply chain</td><td>Enough flexibility for service providers to differentiate themselves and profit (D-A Challenge 3)

Affordable Connectivity and IoT devices (D-A Challenge 2)</td></tr>
<tr><td>Level 1: Single small/med size org.</td><td>Millions of farms are "micro-scale" businesses (<5 employees), with limited/no IT resources or skills (D-A Challenge 1)

Affordable Connectivity and IoT devices (D-A Challenge 2)</td></tr>
</table>

D-A Challenge 1: Value Proposition for Farmers in for Precision Agriculture and Data Sharing. Regardless of farm size, for the most part farmers remain sceptical of the return on investment in precision agriculture, and in data sharing in particular. For larger farms, and the broader value chain ("farm to fork"), work is still needed to develop compelling business models for complex new solutions. For the smallest farms, of which there are millions across Europe, embracing precision agriculture is difficult given limited resources for this kind of activity.

D-A Challenge 2: **Affordable Connectivity and IoT devices.** Precision Agriculture and Data Sharing depend on the availability and affordability of connectivity to each farm, as well as the affordability of the IoT devices that create the data that might be shared.

D-A Challenge 3: **Value Proposition for Service Providers/FMS Vendors in the context of a Common European Agricultural Data Space.** The EC is perceived by some ecosystem participants as creating a new platform that, if not "competitive", at least disrupts their current business plans.

D-A Challenge 4: Sovereignty and confidentiality for farm-based data. Limits on the current Code of Conduct, as a self-regulatory approach and one linked to the need for clear and balanced contractual arrangements. Lack of effective and trusted technologies that can be relied upon to protect confidential data while enabling the kind of data sharing that might be beneficial to data owners. Need for trusted oversight mechanisms that will help farmers protect sovereignty over their own data.

D-A Challenge 5: **Accessibility and Interoperability of data across the data space.** The "public" data proposed to be incorporated into the Common European Agricultural Data Space will require significant investment before it is easily accessible by average users, or before it will be interoperable with other data sources in the data space or with existing systems already operating in the market.

D-A Challenge 6: **High performance, *in situ,* analysis of distributed big data.** Today this requires local downloads which are undesirable for many reasons. No market solutions exist today, proven at the scales needed for the volume of data required.