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Data-Gold at the End of the Sustainable Food Production Rainbow?

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Abstract: An important way for the agrifood industry to continue to feed a growing world population as well as reduce its environmental impact is to extensively adopt Information Technologies that will "datafy" the industry. While the promises of datafication are high, the realization is lagging behind. We identify and discuss from an institutional economics point of view three related issues that help explain needs run behind realization: supply of data is separated from use of data; data quality, interoperability and standardization; and data completeness.

Keywords: agriculture, food production, information technology, data

JEL Classification Codes: M11, M15, O13, Q16, Q10

Particularly in primary stages of production of agrifood, data already is and could even more extensively be produced and used. It is believed that "datafying" through extensive and integrated use of Information Technology (IT) will make agrifood (even) more efficient, while meeting sustainability-inspired Strategic Development Goals. Agrifood is core to many sustainability challenges. Use of pesticides, fertilizers, and water must be reduced, yet at the same time output can increase in quantity and quality while also reducing food waste levels —extensive use of IT promises to allow for this.[1] Agrifood impacts climate change too: third of greenhouse gases emitted relates to food production and processing (Crippa et al. 2021), and at the same time is impacted by climate change (Camanzani et al. 2017). These high expectations (cf. Coble et al. 2018) suggest the *American question*: "If you're so smart, why aren't you rich?"; Why have digital data in agrifood not been used more extensively? We identify reasons why supply and demand of agrifood data may not match and datafication in agrifood is held back. Obviously, high quality data production is costly, in part because data must be processed into a format fit-for-purpose relevant for the needs of a diversity of players across the agrifood value chain. We identify and elaborate on three related issues relevant for understanding why extensive use of IT to datafy agrifood (i.e., to produce and use food-data

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[1] Food wasted and lost accounts for 30% of land-use for agriculture's primary production (FAO 2013).

in order to further improve food production while contributing to SDGs) is more limited so far than what could be expected: (1) datafication (supply) separated from data use (demand), (2) data quality, interoperability, and standardization, and (3) data completeness. Different players in agrifood value chains will have different positions for these issues.

Datafying Agrifood: Value, but for Whom?

Agri-food is already quite some years in transition from analogue to digital or smart systems. According to AgFunder's (2021, 2022) *AgriFoodTech Investment Report,* in 2020 about $26.1 billion and in 2021, $51.7 billion worldwide were invested on Ag-Biotech, Farm Management Systems, farm robotics and equipment, agribusiness market places and innovative food. At the same time, about 14.3 billion were invested in in-store restaurants and retail, online restaurants and meal kits, eGrocery, restaurant marketplaces, home, and cooking in 2021 (AgFunder 2022). Digital and smart systems generate data originated and collected on several levels of value chain, which has its own use and value for related actors. Table 1 provides insights into the types of technologies currently being developed for agritech.

At the beginning of the agri-food chain, data is or can be generated at individual unit level (e.g. per animal or per crop or even plant), making use of modern digital devices, such as sensors, harvesting robots, or self-driving tractors, thus generating an enormous amount of data. Individual unit data can be combined at production unit level, for example that of field, stable or single-location farm. Combined with data about the weather or soil condition in a smart farming management system, such data can provide insight for various support tools to farmers to enhance their decision making. Unit-level, location-specific data, beneficial for individual actors, we refer to as "small" data (Forney and Epiney 2022; Kitchin and Lauriault 2015). Small data can be used for, e.g., individual animal monitoring or crop-specific weeding and fertilization. Small data as input for farm management system is quite extensively used by farm advisory organizations and extension services (Eastwood, Edwards, and Turner 2021). Table 1 provides an overview from small to big data levels.

Small data, however, is of limited use when seeking to change an entire supply chain. Data contain more value and values when they are complete, accurate, continuous, collected in real-time and in particular integrated with other, higher-level data to form big data (Kamilaris Kartakoullis, and Prenafeta-Boldú 2017).[2] Pooling or integrating small data, if available (publicly), can be at regional, supply chain, national and global levels. Big data allows for better policy interventions and strategic advice for the agricultural macroeconomy. Integrating small data into bigger data in such a manner promises to add economic value, but other values as well, yet poses challenges too (Wolfert 2021). A first challenge is that a farmer is no longer just managing a farm with support of digital technologies, but needs to navigate the increasingly complex ecosystem of agricultural and digital technology providers, high-tech corporations, software developers, digital platforms, and data engineers (McCampbell et al. 2022; Wolfert et al. 2023). At the same time new actors in agrifood, posing a second challenge: e.g. new technology providers, high-tech corporations, and data companies, or existing actors from adjacent industries who have adapted their business towards a digital future (Rijswijk et al. 2019). These parties have their own interested in agri-food data to improve their business models and market position, which may be ill-understood by

[2] Big data is data in large volumes that comes in at velocity and is varied. Therefore, in terms of the argument here, it is very likely to originate from different sources; integration of data may thus face challenges.

incumbent agrifood organizations. Furthermore, much of the big data produced on farm are in the hands of private actors and often not publicly available.

Data receives even higher value when integrated from various sources, such as public data, machine and sensor data, private data, market data, weather data. Social media and other online platforms contain valuable, albeit unstructured data on market prices, food demands, and other developments in agri-food systems.

Table 1. Levels of Agri-Food Data and Interested Users

	Data levels	Categories of Inter-ested users	Examples of related data sources
Big Data	Global	Global organizations, multi-nationals, digital tech giants	Statistical systems of individual countries Research
	Supra National (e.g., European)	EU policy making organizations, multi-nationals	Databases, such as Information system for Agricultural Market Management, Auditing systems, Systems for Fund Management Statistical and admin data sources AGRIVIEW system Research
	National	National government, policy making, digital tech giants	Statistical databases on e.g. market prices, environmen-tal data. Administrative data sources Research
	Regional	Regional policy mak-ing, digital tech giants	Survey on farm economic performance Land use and land availability Meteorological measurements Satellite Research
↕	Market	Tech organizations, seed and chemical fertilizer producers, investors	Digital processing technologies In-store self-stacking robots E-grocery Online stores ag food marketplaces Online restaurants and meal-kits Cloud retails Robotics for delivery and services
	Industry	Cooperatives, tech organizations, seed and chemical fertilizer producers, investors	Food safety traceability systems, - Logistics and transport, Digital processing technologies Innovative food Food waste monitoring IoT systems 3D food printers Smart kitchens, Food tasting machines
Small Data	Farm system	Tech developers, producers of agricultural equipment's and ma-chineries, seed and chemical fertilizer producers, digital tech giants	Farm management software,- Sensors, cameras, IoT systems, Robotics, mechanization, and equipment Novel farming systems Financial tech for farmers, apps for credits
	Farm unit	Farmers, Tech developers, farm advisors	Agribusiness market, trading platforms, Networking and GPS technologies Non-food extraction and processing for biomass use, feedstock technologies
	Animal, plant data	Framers, firms, retailers,	Ag-biotech, on-farm input for crop and livestock manage-ment

Whenever the individual unit datasets are integrated, for instance through Internet of Things (IoT),) and analyzed, for instance using Artificial Intelligence (AI) techniques, the extracted real time information can become useful for optimized management decisions. The AI techniques are used to analyze aerial images, maps, heat maps, photos, and videos as input for image processing, cloud computing, machine learning or deep learning. The integration enables macro-level analysis at industry and market level.

Big data is not only used for strategic purposes, but, obviously, also for environmental management and nature reservation. For example, data from geo-spatial technologies improve the modelling of crop production, and when combined with data from satellite images develop daily models of non-market values, such as nature reservation. Additionally, farmers that reduce nutrient use through digital technologies and data use attract consumers who desire more info about the sources and sustainability of their food.

Matching Supply and Demand of Agrifood Data

In every step of the value chain in agrifood, from primary production at farms to processing, distribution, sales and also consumption, data can be and is being made available. [3] Data that is useful or actually demanded at one level may need to be generated at another level in the food supply chain, however. The circumstances under which food is produced, for instance, determine how healthy but also how perishable it is. Consumers may want to know this, but also food processors and distributors as well as supermarkets. Different requirements can be expected about food-data to come from different players. This gives rise to (at least) three different yet related reasons why food-data does not become available as expected: (1) datafication (supply) is at a distance from data use (demand), (2) strategizing by parties around data quality, interoperability, and standardization, and (3) data completeness.

The ability, willingness, and opportunity to process food-data differs by player. Different data about the human health relevant circumstances under which grapes grew are needed when producing wine compared to when processing grapes for immediate consumption by consumers. Consumers might also want to know about these health relevant production circumstances, yet most would. In every (sub) supply chain, thus, a "market information regime (MIR)" (Anand and Peterson 2000) will be emerging in which kind, standardized shape, and other aspects of how provision of data is institutionalized (cf. Dolfsma 2019). Institutions and MIRs are not neutral, however, and may cognitively or strategically advantage some over others.

For one, players at the stage where most food-data is produced, at primary production, may not realize what food-data consumers need as the two are at a distance from each other (cf. Olson and Olson 2000). How small food-data is to be presented may not be obvious. In addition, for consumers, small food-data may not be enough. They also may want to know how food was processed (if) and distributed. Small food-data from each phase may not readily integrate and be readily interpretable for consumers. What is important information for processors—for instance concerning how ripe grapes are picked and how much sun and rain they have enjoyed, and thus how much sugar must be added for the fermentation process to produce wine with a particular quality in the time that can be taken—is not important for

[3] While this section focuses very much on agrifood, we submit that it offers some relevant insights for other sectors or supply chains too, as insights from earlier processes of datafication show that similarities between industries in this respect exist (cf. Geurts et al. 2022 on the music industry). Still, agrifood is a peculiar industry in many ways too (Dolfsma, Isakhanyan, and Wolfert 2021; Wolfert 2021).

consumers. Consumers may just want to know how much pesticides have been used, and of which kind. Or similar food-data is expected, say about shipping, presented in a different manner: supermarkets may want to know how long food was transported to them, and in what circumstances, to gauge perishability; consumers may want to gauge their food's overall environmental footprint including due to transport. Distance between where data is produced and where it is used means agreement on what data is needed, when and how it is needed, is more difficult to agree on or impose.

Sufficiently available big food-data will, overall, allow food supply chains to function in a way that a large global population can be fed high-quality food, while contributing to the SDGs and also reducing food waste. Yet, individual players, at each stage, may not equally benefit or not to the same degree as others. Quality of the small food-data produced (shared) might not be at the level needed to be seamlessly integrated so that a degree of interoperability is reached that makes big food-data useful. Players must not just understand what data-needs others in a supply chain have, but must also believe that their interests are not hurt, and they can even expect a fair remuneration from any effort to make food-data available. Players in a domain can themselves come with standards for data, or an outside or government agency can develop and impose a standard. The European Agricultural Statistical System standards are used to manage the common market for agricultural products in the EU. Data on agricultural prices, yields, production structures, and import/export flow are used for European common market management.

Even when there is agreement in a supply chain as to in what institutional shape data should be produced and shared, food-data may not be shared. At each level, for food-data production data might be incompletely produced or shared (exchanged) with other levels (compare table 1). This can be done inadvertently, or on purpose to protect or improve a player's strategic position. Food-data can also be incomplete because data for a level in the supply chain may be partially or even fully lacking. This can again be inadvertent or with purpose, but is now more likely to be the latter as it is more likely to be the result of joint decision making of different independent organizations. In agrifood, this may be a cooperative decision not to share or exchange food-data; cooperatives are quite common in agrifood (Bijmans, Muradian, and Schuurman 2016).

In addition, data generated in agri-food systems are often owned through contractual agreements between private agri-food players (e.g., farmers that generate data) and IT companies (digital technology provider). These players may not consider potential externalities of data exchange. Few large companies where data can be concentrated are seen as a threat as some fear data monopolies to arise, providing the opportunity for anti-competitive behaviors (Dolfsma and Van der Eijk 2018). These may be existing companies such as the John Deere company, or parties not currently active in agrifood.[4] While companies may have economic and strategic concerns, such as gaining a market share (preferably fast as a first-mover) and their negotiating power, others have broader ethical or alternatively narrower personal considerations (Ryan, Isakhanyan, and Tekinerdogan, 2023). It is feared by some that that "datafying" agri-food creates inequalities because some farmers will not be able to purchase digital machines, do not have proper infrastructure to use digital devices, or do not have the skills to use the data driven machines (Ryan 2020).

[4] These may be producers of agricultural equipment's and machineries, seed producers and chemical fertilizer producers, hardware and software providers, enterprises and start -ups offering data analysis services, farmers, trade unions, telecommunication companies, farm advisors, public sector institutions, non-profits, universities, research institutes, and innovation hubs.

Some Policy Recommendations

To further expand agricultural, food-data availability and quality, standardization for farm data sharing should be developed protecting those sharing their data and also those using it (cf. Walter et al. 2017). Open source and open data should be encouraged to push towards greater interoperability. This will help to reduce conflicts, unfounded expectations, and avoid legal issues from data misuse. Clear, unified data-sharing security standard applied within the agri-food sector to ensure the protection of data ensure greater trust (cf. Rijswijk et al. 2022).

Creating digital data libraries may help to foster standardization of data, and also foster the use of data for public purposes such as monitoring impacts on the environment or food safety. Common policies with regard to the way data should be stored in libraries and the conditions under which data can be used. A more democratic governance by well-informed stakeholders should be promoted.

Some are better able than others (farmers) to manage their own data—consent agreement together with authorizations and a data locker system can be considered. Besides, developing digital and data skills among all actors in the agrifood supply chains to use data in management is important.

Responsible data sharing should be facilitated by co-creation of values and norms leading to more trust between stakeholders. Code of conducts and legislation can support this. The EU Code of Conduct for Agricultural Data Sharing by Contractual Agreement (EUCC) is a good example. In several other continents similar codes exist or are developed. A code of ethics could be developed for technology developers and technology service providers, to help realizing trusted data sharing practices, at firm and chain levels, including a richer set of values then for example in the current EUCC (Copa Cogeca et al. 2018). There should not be an overreliance on contracts and voluntary codes to stimulate, let alone ensure, ethical conduct.

To prevent monopolies or a market dominated by a few big players, which would be in breach of the European competition law, policymakers need to protect those sharing data and their intellectual property by regulations against unwanted distribution of data (Van der Burg, Wiseman, and Krkeljas 2021). Policy itself can also greatly contribute to data sharing by stimulating data markets, technology accessibility and open data (e.g., animal registers, cadastre, pesticide registers, etc.), which are important to help farmers easily show their compliance with subsidy- and eco-schemes (Wolfert 2021).

Conclusions

If agrifood is to feed the world's population without having the current impact on the environment, it needs to change sooner rather than later. The extensive use of Information Technology, and also of the use of the food-data that is generated with it, is expected to allow agrifood to do so. In this article we focus on datafication of agrifood and raise a number of reasons why agrifood has not benefited as much from datafication as one would expect.

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