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Geographical space and service use in agriculture: The view from the perspective of multilayer networks

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Abstract

Location theory has shown that the location of businesses follows specific patterns: primarily, the site of production, transportation costs, markets, and workforce are considered the main factors influencing business location. However, less research focuses on the spatial distribution of service use of actual businesses. Based on empirical data collected in the Hungarian counties Vas and Zala, the paper shows how the service use of agricultural producers is distributed in space. Using a questionnaire, we show that services are primarily used in nearby towns, although in some exceptional cases, small villages can also function as service providers to agribusinesses. Based on the results, we argue that agricultural producers' business connections are best described as multilayer networks in which layers are interconnected. We assume, based on a shift towards more intensive service use of agricultural producers due to the advances in agriculture 4.0, that on these layers, physical roads will maintain their importance; parallel, however, the weight of digital connections will increase.

Keywords: agricultural services, service use, spatial distribution of service use, multilayer network

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Introduction

Business activities and business connections both shape and are influenced by geographical space. On the one side, geographical proximity may influence which business actors a given business interacts with: it is more likely that a business uses, for example, a banking service with a bank branch in the same city/town. On the other side, business relations may also shape geographical space: transporting raw materials or energy carriers ends in building roads, harbours, or settlements.

Classic location theories start from transport costs: the physical distance of consumers, producers and available workforce define the location of businesses (Laulajainen, R. and Stafford, H.A. 1995). In the case of services, however, transport costs are irrelevant since, in most cases, no physical transportation of goods or raw materials takes place (Cuadrado-Roura, J.R. 2013). This is especially true for online service providers. Since services' main function is not the transport of physical goods, the distribution and use of services cannot be described by traditional location theories. Network theories and network representations, however, offer a suitable method to capture the distribution of service use in space.

The paper examines the service use through the lens of networks: we argue that business networks are multilayer networks consisting of several layers. We show on the example of agricultural producers why the networks may be considered as multilayer networks.

Agricultural producers are an especially interesting subject in three respects: First, in most cases, the location of the agricultural producer is given since it is connected to the land it uses.

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Second, the importance of agricultural producers is increasing, since the stability of food supply chains is paramount for society (Rosol, M. 2019; Moragues-Faus, A. *et al.* 2020). Food chain stability is closely connected to sustainability and climate change: climate change forces us to rethink agricultural production (Conte, B. *et al.* 2021), and new approaches to agricultural products foster innovation in food production (Mouat, M.J. *et al*. 2019). Food supply chains can function, however, only if the agricultural producer is able to produce agricultural products, which implies it must rely on a large number of services in its own supply chain: for example, on forecasting, plant service, or machine service.

Although agriculture has been gaining importance in recent days, and although it relies on several services, research has not analysed how these services are distributed in space. The first research question, thus, tackles the problems of service use of agricultural producers: RQ1) How does the spatial proximity of traditional service providers influence the service use of agricultural businesses? By analysing how services connected to agriculture are distributed in space, we may shed light on the dynamics of how agricultural producers choose services. On the other hand, the results may help to plan the location of services connected to agricultural producers.

The third peculiarity of agricultural producers is due to recent advances in technology: an increasing turn towards digital services in agriculture is observable resulting in agriculture 4.0 (Singh, S. *et al.* 2020). These digital services can help to mitigate or overcome the negative effects of climate change (O'Grady, M. *et al.* 2021).

Since service use has undergone a change due to the pandemic and since future agriculture is relying increasingly on digital, online services, which also influence local service use, a shift towards online service use can be anticipated. The second research question seeks an answer to the question: RQ2) What are the possible impacts of digital agriculture and online service use on agricultural producers in the future?

The theoretical goal of the paper is, to show through the example of agricultural producers, that network science can be used to describe service use of businesses and that multilayer networks provide a theoretical framework to describe business connections of agricultural producers. The third research question is connected to the overall goal of the paper: RQ3) How can business connections be described within the framework of network theory?

The paper analyses the spatial distribution and the network structure of services connected to agricultural producers. In the case of service networks, we show that at least two layers exist: a layer which needs physical connections to agricultural producers and physical movement of people providing or using service at physical places and another layer for online services, where service use means only data exchange. We argue that the second layer is likely to become more important in the future due to recent shifts in service behaviour and due to the advance of agriculture 4.0. We also show that connected to agricultural producers more network layers exist.

In the first part of the paper, we summarize the factors influencing the location of agricultural producers, then describe how agricultural producers use services. In the second part we analyse based on empirical data – collected via a questionnaire from a small sample of agricultural producers in West Hungary – the interconnectedness of agricultural producers and service providers. In a last step we discuss findings in light of network theory and of recent and upcoming changes in agricultural service use.

Throughout the paper, we will use two notions: agribusinesses and agricultural producers. The notion of agribusiness itself is rarely defined in scientific literature (Grigg, D. 2005): it is often used in a wider sense for the whole agribusiness sector, including input suppliers, agricultural producers, merchandisers, processors, and retailers (e.g. Gunderson, M.A. *et al.* 2014; Leitão, F.O. *et al.* 2024), but also in a more restricted sense as a business producing agricultural products in the primary sector (e.g. Mariyono, J. 2020). In order to avoid confusion, we use in the paper two notions: we use agribusiness in the former meaning as a comprehensive concept for businesses in the agribusiness sector. In the case of individual businesses producing agricultural products, we use the notion of agricultural producer.

Geographical space and agribusinesses

The interconnectedness of geographical space and business activities is a long-studied subject in geography (Ponsard, C. 1983; Wallace, I. 1985; Colombo, S. 2020). In the classic location theory, transport costs are the decisive factor in business site selection: costs of overcoming geographical distance is the central driving force behind location choice and the geographical differentiation of economic activities (Glückler, J. and Panitz, R. 2021).

Von Thünen used concentric circles to describe the relationship between land rents, product prices, and the location of agricultural production, considering transportation costs and the quality loss of perishable goods during the transport (Prykhodko, I. 2017; Szőke, V. 2023). The general idea of Thünen has been used and refined by several scholars (e.g. O'Kelly, M. and Bryan, D. 1996).

Weber's model assumes that the location of raw materials is given, the spatial distribution of consumption is known, and transport costs depend on weight and distance. According to his model, three factors determine the business location: transport costs, labour costs, and agglomeration effects (Heineberg, H. 2007; Szőke, V. 2023).

Christaller's central place theory focuses on city-region relationships and the connections between central places (Heineberg, H. 2001): in his model, he examined settlements in a given area according to their size and function while assuming their cooperation. In his theory, he distinguishes between settlements with different central roles: *Oberzentrum*, *Mittelzentrum*, *Unterzentrum* and *Kleinzentrum*, where each level of centres has different functions, providing different services at each centre role (Gebhardt, H. 2011).

Location theories, however, must also consider the characteristics of the given sector or business to choose the best location: R&D companies may, for example, consider knowledge flow (Colombo, L. *et al*. 2024), entrepreneurs may prefer to locate their business close to other entrepreneurs (Schäfer, S. and Brenning, A. 2024) while gold mines prefer locations with less corruption and security (Tole, L. and Koop, G. 2011).

Which factors influence, however, the location of agribusinesses? These spatial economic models all included agriculture explicitly or implicitly in their considerations. Lucas, M.T. and Chhajed, D. (2004) point out focusing on agricultural location theory, that in the middle of the 20th century, planar models (space is a continuous phenomenon), discrete models (number of locations for facilities is finite) and network models (transportation networks influence location) existed. They argue that agricultural location is complex: production (farm), processing facilities, and transportation to the consumer must be all included in the equation while deciding on location. Geographical proximity to other actors played an essential role in the business activities of agribusinesses until the middle of the 20th century (Molema, M. *et al.* 2016). Today, it is observable that the proximity to the consumer is the most crucial factor: since infrastructure and demand do not exist in sufficient quantity and/or quality at agricultural areas, food processing is located near the consumer (near cities) and not in agricultural areas (Cohen, J.P. and Paul, C.J.M. 2009). Thus, transportation plays a relevant role in agriculture.

Overall, connected to transportation, a dual process is observable (Shih, W.C. 2022). On one side, from the late 19th century to the late 20th century, the importance of proximity decreased as technical advancement first enabled the transport of goods over longer distances and later contributed to decreasing transportation costs (Nichols, T.E. 1969), which again led to a change in agricultural production (O'Kelly, M. and Bryan, D. 1996). As a result, in the 21st century, extended supply chains and global connectedness lead to a complex approach to agri-food business, including agricultural production and food industry (De Backer, K. and Miroudot, S. 2014).

On the other side, in recent years, we experienced three new barriers connected to distance and the transportation of agricultural goods: first, the coronavirus pandemic showed us that borders function as real obstacles, making impossible or slowing down the movement of persons and goods (Hamid, S. and Mir, M.Y. 2021). Second, the war in Europe showed how fragile agriculture-connected supply chains are: not only crops themselves but for crop production essential goods such as fertilizers or even diesel fuel are in shortage (Ekin, E. 2022). Finally, a third factor influencing agricultural transportation and product demand is the increasing consumer demand for local products (Marino, D. *et al*. 2018). Agricultural location theories of the future have, thus, to consider not only advances but also new challenges caused by recent events and consumer trends and expectations.

Besides the above-mentioned location-connected contexts, a less researched factor is connected to agribusinesses: agricultural producers' service use. Agricultural producers today must rely on a wide range of specialized and general services for production and administration. Therefore, the geographical distribution of services may be relevant since service use, as shown below, will increase in the future.

Service use and agribusinesses

As we have seen, spatial proximity and transport costs influence agricultural production. Since the share of used services in agricultural production is increasing in all countries of the European Union (Kolodziejczak, M. 2018), research connected to service use in agriculture can contribute not only to agribusiness theory but can also have real-world implications, for example, to choosing locations for service providers.

Molema, M. *et al*. (2016) recommend thinking of agricultural producers as parts of networks: the network view enables one to see the interdependencies of the actors of networks. They argue, that in an agribusiness network, the main actors are: (1) farmers, (2) suppliers (machinery, seedlings), (3) food processing industry, (4) financiers, (5) knowledge institutions, (6) consumers and consumer organizations, (7) distributors and (8) governmental organizations, where financiers, knowledge institutions and governmental organizations are service providers for agriculture. These actors' interrelationships and functions are complex and change over time.

Similarly, Sonka, S.T. and Hudson, M.A. (1989), and also Gunderson, M.A. *et al.* (2014) name besides genetics and seed stock, input suppliers, agricultural producers, merchandisers, processors, retailers, and consumer services (in general), and finance and R&D as part of the agribusiness sector. Edwards, W. and Duffy, P. (2014) name several farm-related services in their chapter, grouped into finance-related services (e.g. bookkeeping and tax preparation, farm accounting, insurance) and production-related services (e.g. machinery services, crop scouting, veterinary services). Besides these services, a turn is observable in agriculture: more and more services – partly digital – are offered for agricultural producers (Klerkx, L. *et al.* 2019).

Used, available, and future services appear often connected to the 4.0 turn in agriculture (Winter, J. [2020] connected to industry 4.0). Since the beginning of the 21st century, we can speak of agriculture 4.0 (or smart farming or digital agriculture, Klerkx, L. *et al.* 2019): with the development of information technologies, sensors have become cheaper and more advanced, agricultural (soil-, weather-, plant- and machinery-related) data can be collected and processed quickly, in real-time. Agriculture 4.0 (or agri-food 4.0; e.g. Arora, C. *et al.* 2022) uses many data sources, connects data intelligently, makes forecasts based on the data – it can even collect and process data and find solutions for an individual plant or animal (Klerkx, L. *et al.* 2019).

In this new agriculture, an increasing role of and the demand for non-physical services – which enable accurate data collection, data processing, and data analysis – is observable. A lot of these new technologies are connected to communication services, for example, mobile phone services (Baumüller, H. 2017), or cloud-based services (Eastwood, C. *et al.* 2019). For a recent overview of the technologies, challenges, and solutions, see, for example, Klerkx, L. *et al.* (2019) or Debauche, O. *et al.* (2021).

The digital transformation in general (Rha, J.S. and Lee, H.-H. 2022), the transformation to digital agriculture, and the recent advances in technology and society make it evident that connected to agriculture, more and more services will be provided online. The use of services in agriculture, thus, will be both offline and online: on the one hand, services that call for physical presence, like physical repair of machines or calibrating new equipment, will be done on-site. On the other hand, it can be presumed that services that do not call for physical proximity will be used more and more online.

In order to see the service use and the spatial distribution of service use, it is essential to collect and analyse empirical data connected to agricultural producers. Next, we analyse data collected from agricultural companies in West Hungary, in the counties Vas and Zala.

Research materials and methods

A survey was conducted between late 2019 and early 2021 in West Hungary, in the counties Vas and Zala, to analyse the service use of agricultural businesses.

The county of Vas covers an area of 3336.1 km^2 (HCSO 2016), of which 49.94 percent is agricultural land (43.46% arable) (HCSO 2023). 3.3 percent of the agricultural, forestry and fishing enterprises in the country are located in the county (AKI 2021a). Zala county covers an area of 3783.87 km^2 (HCSO 2016), of which 40.65 percent is agricultural land (34.57% arable) (HCSO 2023). 4.2 percent of the agricultural, forestry and fishing enterprises operating in the country are located in the county (AKI 2021b). The agricultural land of the counties is 260,000 hectares for Vas and 274,000 hectares for Zala county (Szőke, V. 2023). Agriculture was important for Vas county in the last two centuries, and even today agriculture adds more to the GDP (7%) of the county as the Hungarian average (5%; Lenner, T. and Palkovits, I. 2014). In Vas county, wheat, maize, sunflower, and rapeseed are the main crops; sugar beet and spring barley are also cultivated. In Zala county, wheat and maize are the most produced crops. The agricultural land of both counties is characterized by a fragmented structure (Szőke, V. 2023). *Figure 1.* shows the map of the two counties.

The questionnaires consisted of 14 questions, partly business-related (for example, the number of employees and machines used on the farm) and partly connected to the business connections of the agricultural producers. In addition, we asked from where (which settlement/foreign country) the agricultural producers

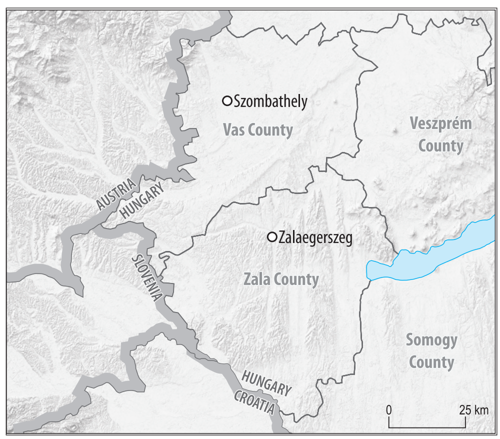

Fig. 1. Geographical position of Vas and Zala counties in West Hungary. County seats: Szombathely and Zalaegerszeg. *Source*: OpenStreetMap.

regularly bought products or raw materials, where (which settlement/foreign country) agricultural products were sold (Szőke, V. and Kovács, L. 2023), and on which settlements services were used. Connected to services, we asked for service frequency and place of service use of the following services: machine service, accounting, financial auditing, bank, legal services (lawyer, notary), and plant expert. Although the questionnaire contained empty lines for participants, where they could have written other used services, no other services were named. Questionnaires were distributed online based on the recommendation of agricultural experts (snowball sampling).

In the current results section, we analyse only connections between settlements based on the service use of agricultural producers.

Data analysis

To see the connections between service providers and service users, we construct networks between settlements where the agricultural producer is situated and where it uses a given service (e.g. accounting is done on the settlement where the accounting firm is situated). For analysing, grouping, and cleaning data, Microsoft Excel, for network analysis Gephi 0.9.7 on Windows was used.

To use networks describing business relations is obvious: networked structures have been assumed and analysed since the mid-20th century (e.g. Uitermark, J. and van Meeteren, M. 2021; Barthélemy, M. 2022). In geography, network analysis started in the 1960s (Haggett, P. and Chorley, R.J. 1969) and was resurrected with the emergence of network science at the end of the 20th century (Barabási, A.-L. 2016). For an actual, detailed overview of geographical network use, see Barthélemy, M. (2011, 2022), Glückler, J. and Panitz, R. (2021) or Uitermark, J. and van Meeteren, M. (2021), for a special geographical context, for example, transportation see Derudder, B. *et al*. (2008) or Derudder, B. and Neal, Z. (2018) or network theory can also be used to identify the boundaries of a smaller touristic region (Madarász, E. and Papp, Z. 2013) or describe tourist movements in a given region (Nod, G. and Aubert, A. 2022).

The general character of network theory enables its use in economics and business theory (e.g. Easley, D. and Kleinberg, J. 2010). Network approaches may be used, for example, to analyse the connections between different industries (Cortinovis, N. *et al*. 2020; Turkina, E. *et al.* 2021), to analyse the impact of transportation networks on employment (Koster, H.R.A. *et al.* 2022), to show how strong links are connected to economic performance and weak links to growth (Zhu, S. *et al.* 2021) or to analyse regional economic resilience (Tóth, G. *et al.* 2022).

Research results

Business-related data is not easily collected from agricultural companies: agricultural producers in Hungary are often unwilling to give data connected to business activities. They fear that providing information about business connections and about confidential, business-related data can be used by their competitors and by official authorities since – although data collection is anonymous – some agricultural producers may be easily identified based on a small number of facts (Szőke, V. 2023). This is why, for data collection, we had to use the snowball method: Familiar agricultural producers were contacted, we collected data, and the businesses helped contact new businesses. In the end, we managed to collect data from 30 businesses. *Table 1* shows a detailed summary of the main characteristics of the businesses.

Due to the small number of analysed businesses the data collection cannot be representative: the goal of the empirical data collection was to show on the example of a small number of agricultural producers the real, existing connections to service providers. The collected data and the diversity of the agricultural producers (larger and smaller producers, diversity of activities, spatial distribution) make it possible, how-

Table 1. Distribution of agricultural producers who completed the questionnaire by county and by activity

Distribution of agricultural producers		Number of businesses, pieces
By agricultural sector		
Crop production		Vas 15, Zala 2: *total 17*
Animal husbandry		Vas 2, Zala 4: *total 6*
Crop production and animal husbandry		Vas 4, Zala 3; *total 7*
Number of employees (persons)		
1–2		17
3–5		5
6–10		4
11–15		1
16–20		0
20 <		3
By area (crop production; crop production and animal husbandry, ha) (together ca. 6200 ha cultivated)		
0–10		4
11–20		1
21–50		7
51–100		2
101–200		2
201–500		5
1000 <		3
By number of animals (pieces)		
0–10		1
11–50		3
51–100		5
101–200		1
201–500		0
501–1000		0
1000 <		3
Cultivated plants		
Crops	Proportion of area, %	Estimated area, ha
Arable crops		
Wheat	32	2020
Rapeseed	21	1330
Maize	21	1290
Soy	13	815
Barley	9	550
Sunflower	1	85
Other non-arable crops		
Apple	0.6	40
Evergreens	0.2	10
Ornamental plants	0.1	5
Animals		
Sort of animals	Number of farmers breeding the animal	Number of animals
Poultry	2	74 500
Pig	4	6570
Cattle	5	400
Beehive	2	200
Mangalica*	1	10
Others**	1	24

*Specific Hungarian pig. **Horse, goat, alpaca, sheep. *Source*: Authors' own editing.

ever, to see the dynamics of service use in the given smaller areas. Since – to the best of our knowledge – service use of agricultural producers was not analysed previously, each result can provide new insight into how agricultural producers choose and use services.

The questionnaire asked the businesses about service use, the most common services, and the actual place of service use (settlement). *Figure 2* shows the most important services the agricultural producers use. The analysis of services is not exhaustive. On the one hand, we asked just for the most common services used by agricultural producers; on the other hand, the services provided by agricultural producers (e.g. tillage and harvest provided for other agricultural producers) are not analysed. The reason for latter is that during the pilot survey, we got negative feedback connected to our planned questions on the services provided by farmers: they reasoned that the information was confidential and essential for their business. This question was, therefore, deleted from the final questionnaire.

In the next step, we analysed where (on which settlement) these services are used. *Figure 3* shows the network structure according to the number of connections between services. The network is a directed network; the arrows point from the service-providing settlement to the settlement where the agricultural producers are located.

The most central settlements providing services are towns: Szombathely and Zalaegerszeg are the county seats of Vas and Zala counties, Körmend and Sárvár are smaller towns. Egyházasrádóc and Rádóckölked are villages with large (over 1000 ha) agricultural producers. Austria is in the network because two agricultural producers have bank accounts not only in Hungary, but also in Austria – they sell crops to Austria, Italy, and Slovenia and purchase input material and machinery from Austria and Germany. The network characteristics of the constructed network of service use were analysed by network-specific metrics *(Table 2).*

The γ-index – a density index that characterizes the degree of network complexity (Barabási, A.-L. 2016) – takes the value γ = 0.5490, which indicates a moderately complex network (Dusek, T. and Kotosz, B. 2016). A value of modularity indicates that clear communities are formed – in our case, 5 – and a value of 0.4 < indicates that these communities are well separated.

The data shows that service use is connected to nearby, mostly larger settlements that provide the service. For the most common services, it is crucial to have – when needed – physical contact, for example, in a bank when withdrawing cash. As we see from the network, most agricultural producers are part of the same network because the crucial services are provided in larger or smaller towns, necessarily connecting the agricultural producers to these cities. As some services are available only in towns – or are available in towns in a larger variety – the central elements are larger towns. Smaller agricultural producers may, however, use a smaller number of services: an agricultural producer in Tótszerdahely manages to use all necessary services in the immediate vicinity (within 10 km) of the agricultural producers.

Smaller towns and settlements (e.g. Hegyfalu, a village with less than 800 inhabitants) can also function as central elements. These settlements are central because they accommodate companies providing specialized services for agricultural producers.

Most of the analysed services have a dual character: an offline and an online component. For example, actual bank visits are seldom needed; online banking activity is, however, regular. The same is true for accounting: scanned versions of invoices are sent to the accounting firm regularly; paper versions, however, only once a month. Although service use is partly online, an actual spatial proximity is called for. These are services that are accessible and provided in every larger settlement.

In the case of new digital services for agriculture, the picture may be completely different. As we pointed out, solutions enabling smart farming and using the latest technology

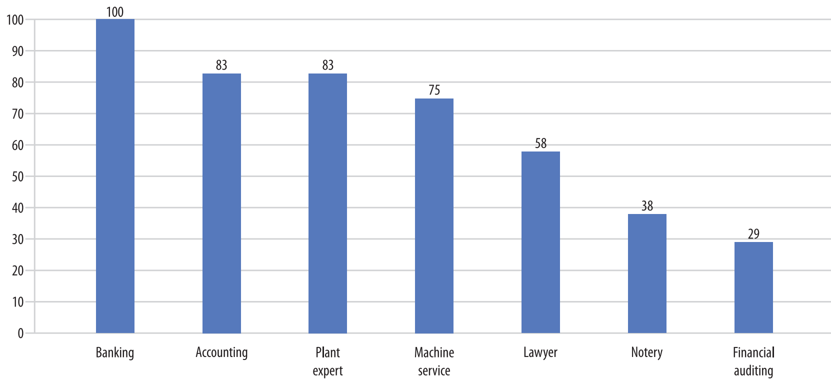

Fig. 2. Use of primary agricultural services of the companies in percent. *Source*: Authors' own editing.

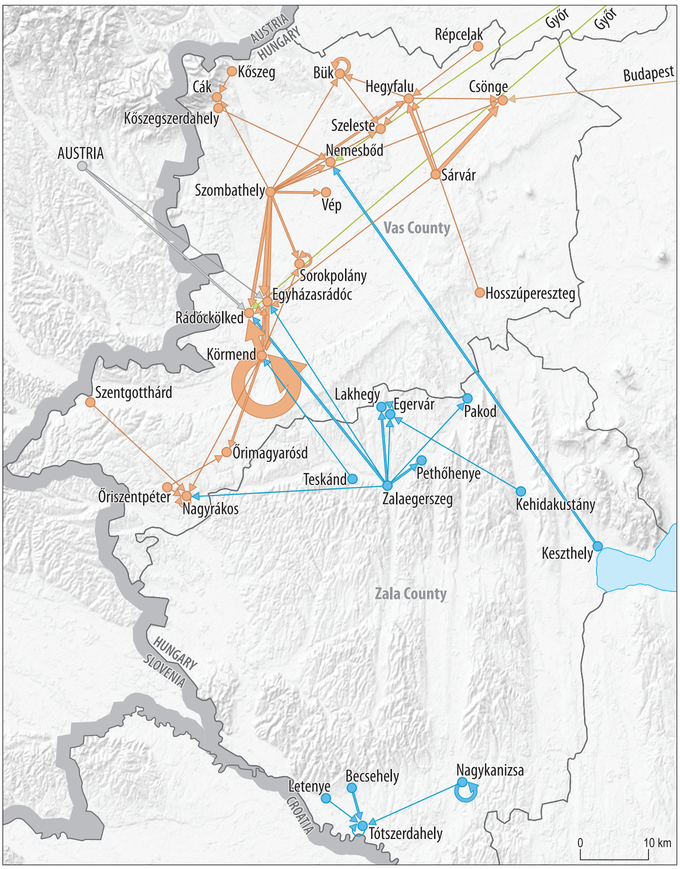

Fig. 3. The network representing the connectivity of service use, weighted by the number of connections. Thicker line marks the settlement from where more services are used. Settlements of Vas (brown coloured) and Zala (blue coloured) counties are placed according to their actual geographical location. (Győr and Budapest are out of Vas or Zala counties.) *Source*: Authors' own editing based on Szőke, V. 2023.

*Table 2. Network indicators on the use of services by agricultural producers**

Indicators	Hungarian settlements + *Austria*	*Value* (pc)
Outdegree (k_i^{out}):	Szombathely	*11* (1)
	Zalaegerszeg	*7* (1)
	Körmend	*6* (1)
	Hegyfalu, Sárvár	*3* (2)
	Austria, Bük, Győr, Nagykanizsa, Őriszentpéter	*2* (5)
	Becsehely, Budapest, Egyházasrádóc, Hosszúpereszteg, Kehidakustány, Keszthely, Kőszeg, Kőszegszerdahely, Lakhegy, Letenye, Nagyrákos, Répcelak, Sorokpolány, Szentgotthárd, Teskánd, Tótszerdahely	*1* (16)
Indegree (k_i^{in}):	Rádóckölked	*6* (1)
	Egyházasrádóc, Nagyrákos	*5* (2)
	Csönge, Hegyfalu, Nemesbőd, Tótszerdahely	*4* (4)
	Bük, Egervár, Körmend, Sorokpolány, Szeleste	*3* (5)
	Cák, Őrimagyarósd	*2* (2)
	Lakhegy, Nagykanizsa, Pakod, Pethőhenye, Vép	*1* (5)
Total degree of nodes (k_i): ($k_i = k_i^{in} + k_i^{out}$)	Szombathely	*11* (1)
	Körmend	*9* (1)
	Hegyfalu, Zalaegerszeg	*7* (2)
	Egyházasrádóc, Nagyrákos, Rádóckölked	*6* (3)
	Bük, Tótszerdahely	*5* (2)
	Csönge, Nemesbőd, Sorokpolány	*4* (3)
	Egervár, Nagykanizsa, Sárvár, Szeleste	*3* (4)
	Austria, Cák, Győr, Lakhegy, Őrimagyarósd Őriszentpéter	*2* (6)
	Becsehely, Budapest, Hosszúpereszteg, Kehidakustány, Keszthely, Kőszeg, Kőszegszerdahely, Letenye, Pakod, Pethőhenye, Répcelak, Szentgotthárd, Teskánd, Vép	*1* (14)
β Index / Average Degree	1.5556	
Average Weighted Degree**	3	
γ Index	0.5490	
μ Index	20	
π Index	28	
Network Diameter**	2	
Graph Density**	0.044	
Modularity**	0.478	
Number of Communities**	5	

*Number of nodes (N): 36, number of connections (E): 56. **Calculated by Gephi 0.9.7. *Source*: Authors' own editing based on Szőke, V. 2023.

are necessarily partly or wholly online services. For example, a weather forecast using no on-site devices is an online service, farmers can subscribe to (e.g. FarmCast). Similarly, services using satellite services are also online providers, like SkyWatch. These service providers are globally active, with no actual office in a given settlement or even in a given country. In Hungary, these services are used today not frequently, although the usage frequency is increasing.

Discussion

Spatial proximity and service use

Service as knowledge

In the first research question we searched for an answer to the following question: How does spatial proximity of traditional service providers influence the service use of agricultural businesses?

Business services form a subgroup of services: they show a large spatial concentration, both inside and outside of cities (Cuadrado-Roura, J.R. 2013). In the case of business services, a dual character is observable: for routine services and for Knowledge-Intensive Business Services (KIBS) (e.g. accountancy), proximity is relevant, for other services less so, since either the service provider travels to the service user, or telecommunication is used for services (Cuadrado-Roura, J.R. 2013). Thus, service providers of routine services often open offices in places where the service may sough after, while service companies without client contact are mostly situated near large cities with relevant infrastructure and qualified workforce (Cuadrado-Roura, J.R. 2013).

To be able to compare the network structures of different types of services, we draw networks to different services separately *(Figure 4).* The networks represent the connectivity of service use, weighted by the frequency of service use. Thicker lines mark the service used more often. Settlements of Vas (purple coloured) and Zala (green coloured) counties are placed according to their actual geographical location. As we can see from the results, different kinds of settlements function as nodes, depending on which services are analysed.

In the case of *plant experts and veterinarians* (see *Figure 4*, A), spatial proximity is an important factor: these services are sought after at the same settlement or nearby settlements (approx. 10 km). In this regard, smaller settlements are also central: in several cases, these experts are in the same settlement as the agricultural producers. Plant expert/veterinarian services can be regarded as Knowledge-Intensive Business Services, thus, the proximity is in line with previous findings (Cuadrado-Roura, J.R. 2013).

In the case of *machinery services* (see *Figure 4*, B), new settlements are central: the service providers are not in close vicinity; they are 20 km or even 100 km away. Central nodes are smaller settlements and towns. In these cases, service providers travel to the agricultural producer, for example, to repair machines. Since, however, these services are used less frequently, proximity is not important (Cuadrado-Roura, J.R. 2013).

When we look at services connected to administrative tasks, we see different structures again. In the case of *legal services* (see *Figure 4*, C), these services are seldom sought after, and service providers are mostly in larger cities. *Accountancy services* (see *Figure 4*, D), are again provided from larger settlements. *Banking services* (see *Figure 4*, E), are used primarily in larger towns, sometimes in smaller towns. Banking services are, however, often used online. These services can be considered as routine services or Knowledge-Intensive Business Services, thus, proximity is important (Cuadrado-Roura, J.R. 2013).

Results are also in line with Shearmur, R. and Doloreux, D. (2020), who show on the example of vine production, that specialized services connected to specific knowledge are mostly used close to the production site, while less-specific services like logistics or marketing are used from towns. As Shearmur, R. and Doloreux, D. (2020) point out, knowledge for some services is not necessarily located in towns: specific knowledge may be located near to producers. We confirm these findings: specific knowledge may be located in smaller settlements, and the most specific knowledge for agricultural producers – plant experts/veterinarians – is sought after from the close vicinity of the producer. The findings also confirm that knowledge must not only be associated with and located in towns or cities (e.g. De Ávila Serrano, R.V. 2019): knowledge is industry-specific, and specific knowledge may be produced on smaller settlements (Shearmur, R. and Doloreux, D 2020).

Online vs. offline services

In the case of services, in general, a shift towards more online service use can be anticipated. The second research question – RQ2) What are the possible impacts of digital agriculture and online service use on agricultural producers in the future? – seeks to analyse online and offline service use.

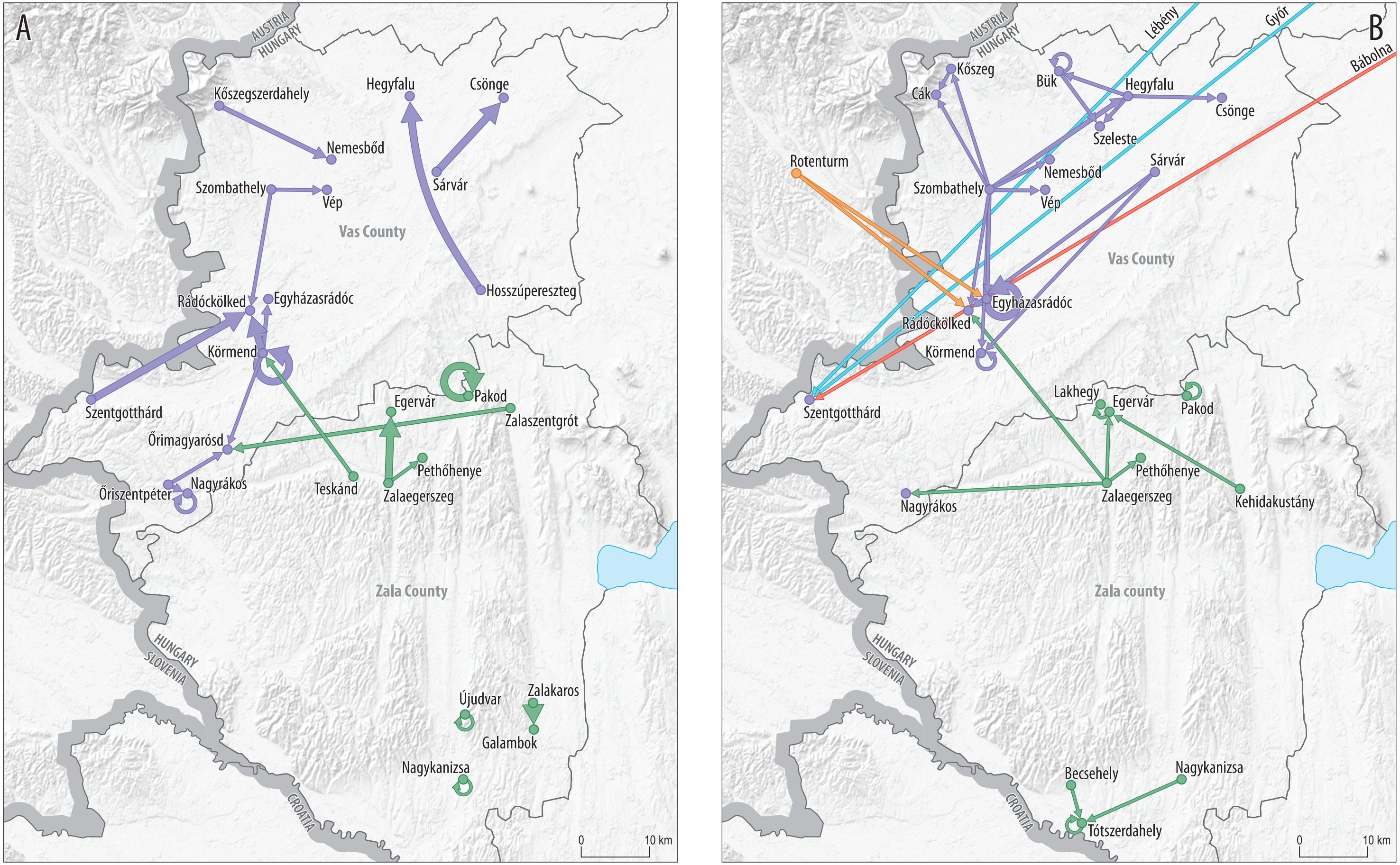

Fig. 4. The network structures of different types of services. Content of the lines and colours: explanations are in the text. A = Plants experts and veterinarians; B = Machinery services (Lébény, Győr and Bábolna are out of Vas or Zala counties; Rotenturm is settled in Austria.) *Source*: Authors' own editing based on Szőke, V. 2023.

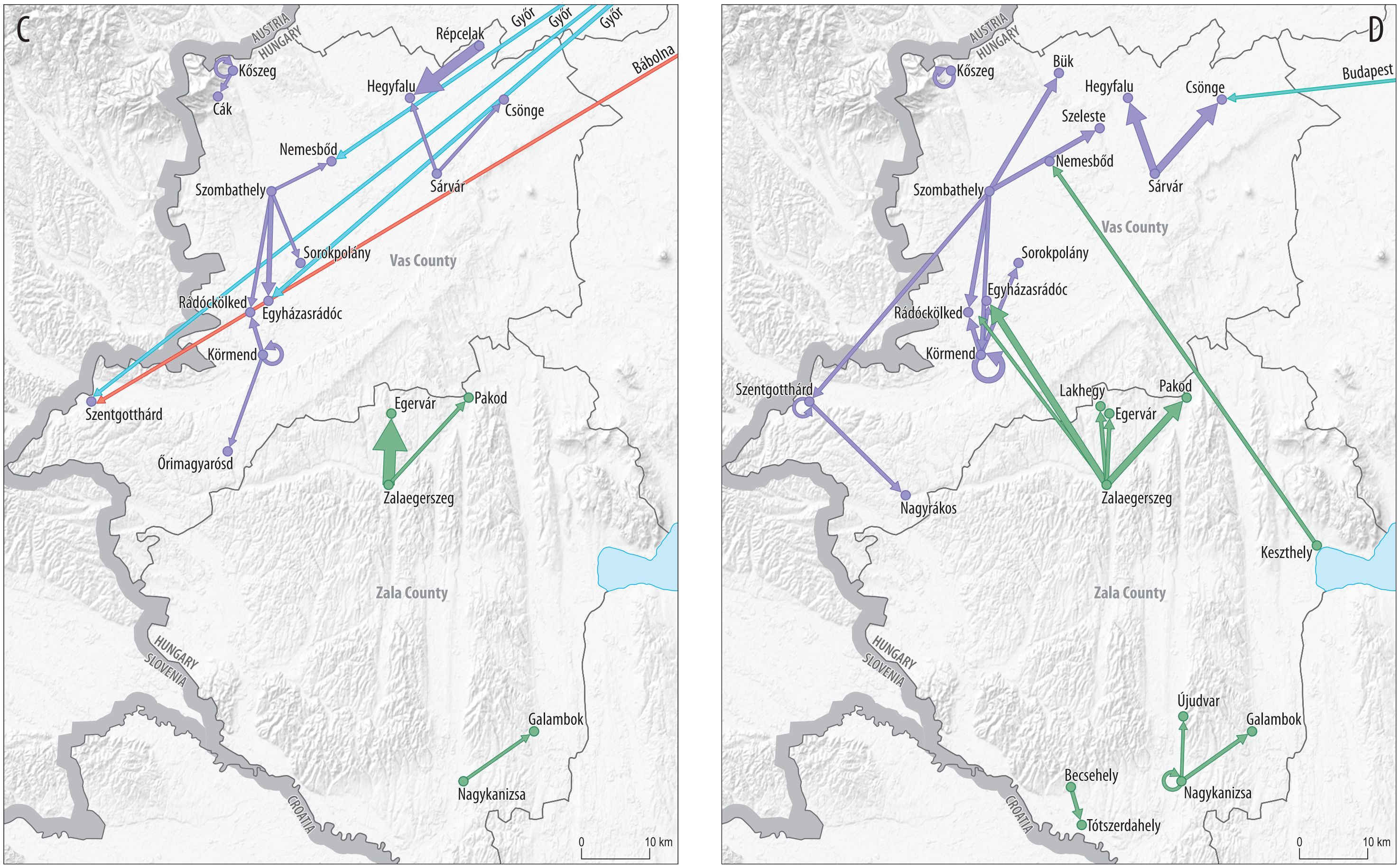

Fig 4. (Continued). The network structures of different types of services. Content of the lines and colours: explanations are in the text. C = Legal services (Győr and Bábolna are out of Vas or Zala counties); D = Accountancy-related services. *Source*: Authors' own editing based on Szőke, V. 2023.

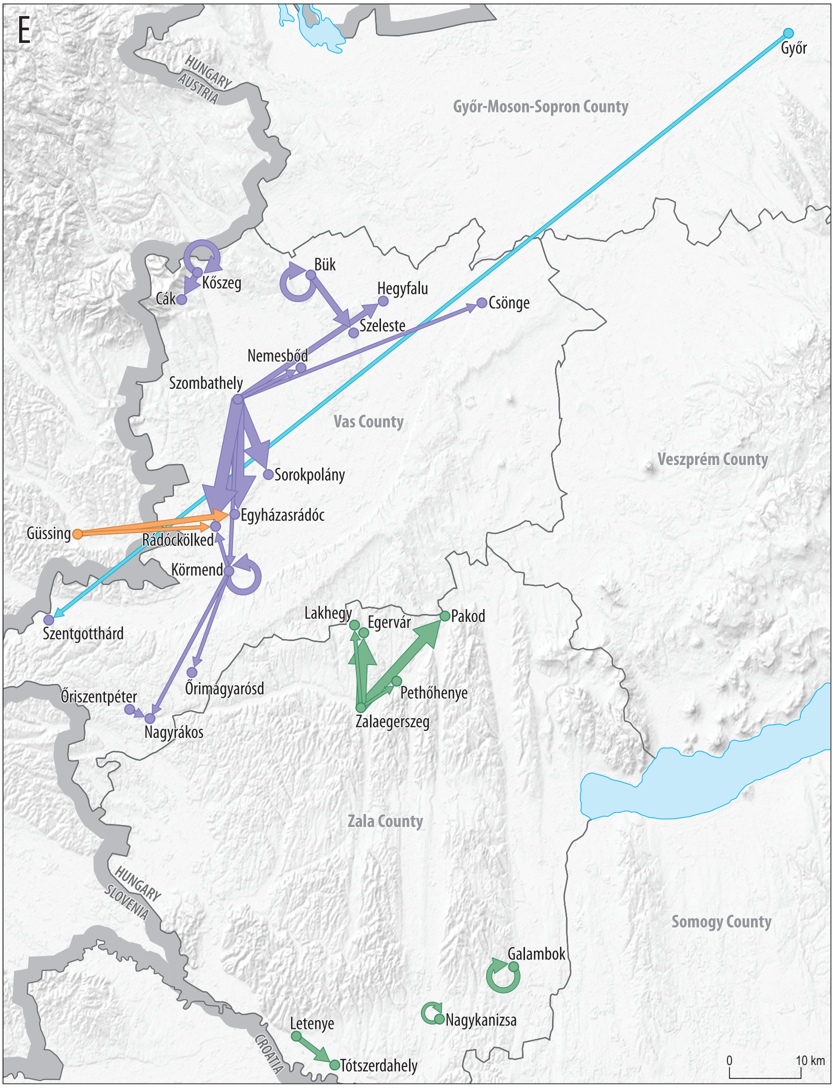

Fig 4. (Continued). The network structures of different types of services. Content of the lines and colours: explanations are in the text. E = Banking services (Győr is out of Vas or Zala counties; Güssing is settled in Austria.) *Source*: Authors' own editing based on Szőke, V. 2023.

The above data collection occurred partly during the pandemic; therefore, the initial questionnaire contained no questions connected to the change in service use habits; it only analysed service use at a given time. After seeing the results, however, we conducted short questionnaires with selected agricultural producers, explicitly asking for long-term changes in their service use habits. The goal of the new questionnaire was to see how service use changed after the pandemic. We collected data from six companies situated in Vas and Zala counties. Data collection was online in August and September 2022.

The respondents were chosen from the businesses filling out the original questionnaire.

Surprisingly, answers indicated that physical distance to the service provider became more critical during the pandemic. However, at the same time, all agricultural producers indicated that for most services (financial auditing, accounting, legal services, banking, meteorological services, government-related service use), either the online-offline service ratio remained the same over time or changed slightly or to a large extent in favour of online service use *(Figure 5)*.

For testing, we performed a hypothesis test to confirm whether there was a significant difference in the pre- and post-coronavirus values.

We hypothesised H_0: $\mu_1 = \mu_2$; H_1: $\mu_1 \neq \mu_2$ as an alternative hypothesis, and then used Student's t-test to test which services showed a difference at the 5 percent ($\alpha = 0.05$) significance level between pre- and post-coronavirus service use. To test the equality of variances, we used an F-test, and we accepted the H_0 hypothesis (H_0: $\sigma_1 = \sigma_2$; H_1: $\sigma_1 \neq \sigma_2$, with the exception of machine service). In the case of machine service, the equality of variances could not be proved by an F-test, so instead of Student's t-test, we performed Welch's t-test, in which case the equality of variances need not be satisfied. As a result of the t-tests, we could not accept H_0 for banking services because the t-value was outside the acceptance range, so the alternative hypothesis H_1 was accepted. Thus, for banking services, there is a significant difference ($\alpha = 0.05$) for the increase in the use of online services after the coronavirus pandemic.

The analysis also included correlations analysis between the pre- and post-coronavirus service use for each service.

– Very strong correlation (±0,8 to ±1): auditing, legal services, notary, IT services, occupational safety and health, plant expert government-related services, land-registry services, training, online purchasing and commerce;
– Strong correlation (±0,6 to ±0,79): machine service, postal/parcel services, fire protection services;
– Moderate correlation (±0,4 to ±0,59): accounting services;
– Weak correlation (±0,2 to ±0,39): banking services.
– Correlation cannot be computed due to a constant value: meteorological services.

For banking services, we see that there is a weak correlation. The variances are the same in the pre- and post-coronavirus data series,

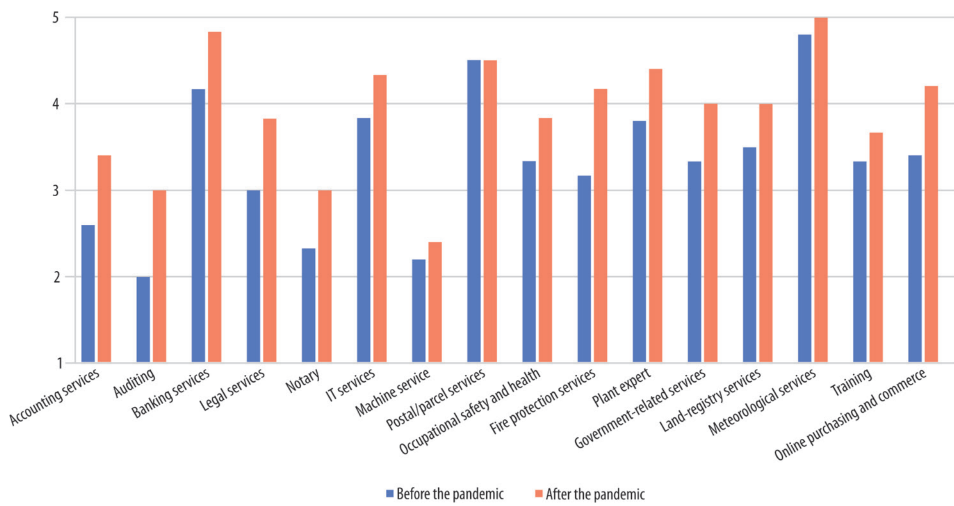

Fig. 5. Change in online service use between 2020 and 2022. Scores on Y axis: 1 = do not use / not used; 2 = only offline; 3 = rather offline, partly online; 4 = rather online, partly offline; 5 = only online. *Source*: Authors' own editing.

so the difference is not due to the difference in variances, but presumably to the fact that the surveyed firms have increased their use of online services to different degrees.

No participant indicated that the offline service use ratio increased during the given period. Results align with the increased use of digital and online technologies in all contexts of small businesses (e.g. Akmaeva, R.I. *et al*. 2020).

In the future, online services may increase since there is both a demand for and supply of these services (Gray, R.S. and Torshizi, M. 2021). Online service increase is also connected to the digital transformation of agriculture: digital transformation is taking place today, enabling more efficient production and more sustainable solutions (Rijswijk, K. *et al.* 2021; Mendes, J.A.J. *et al.* 2022). The pandemic also influenced digitalization and digital service use in agriculture (Avalos, E. *et al.* 2023). Thus, in agriculture, digitalization will likely increase, which implies more online service use (Lioutas, E.D. and Charatsari, C. 2021; Porciello, J. *et al.* 2022).

Layers of networks

Different purposes – different networks

The second part of the discussion tries to answer the third research question: RQ3) How can business connections be described within the framework of network theory?

In the case of services, a dual character is observable. On the one hand, physical movement is relevant for some services: For example, plant experts or veterinarians may travel to the agricultural producer to provide their services. On the other hand, for example, in the case of banking, services may be provided both online and at the office of the service providers: some banking services can be done via home banking (e.g. bank transfer), while others require personal presence, like cash withdrawal.

As we can see, we could assume two different networks for service providers: one that provides services for agricultural producers, where spatial proximity is relevant. In the analysed data, spatial proximity was the most important factor in the case of plant experts and veterinarians. In the case of other services, however, spatial proximity seems to be less important; nonetheless proximity is important, since physical movement is needed. In this networks information and people are traveling.

In the case of emerging digital services, however, no physical movement is necessary since data is sent online or stored and used in the cloud (Lezoche, M. *et al*. 2020; Panetto, H. *et al*. 2020). When we consider online networks of service providers, information travels on digital networks, and the service itself can be described as data exchange (and processing). Since data is exchanged on this network, no proximity – and no roads – are needed, just digital connections between the farm and the service provider.

Add to these networks further networks of agricultural producers: the network of suppliers of physical goods and the network of buyers of the agricultural products. These networks are very different from the above networks: transportation times and costs play an important role in these networks.

In a foregoing paper (Szőke, V. and Kovács, L. 2023), we analysed the purchase (supply network) and selling (sales network) relationships of the same agricultural producers we analyse in current paper. In the supply network, Hegyfalu (a small village) was the most central node, with 9 (outgoing) connections, followed by Szombathely and Sárvár with 7–7 and by Vasvár and Zalagerszeg with 5–5 connections (thus, settlements that provided supply for the analysed agricultural producers). In the case of sales networks, central nodes were Austria (7 connections), Italy (5) and Egyházasrádóc (3). These were the main settlements (countries) where the most produced agricultural goods were transported. In the case of the supply network, we identified 54 nodes with 86 connections, and in the sales network, 28 nodes with 37 connections (in comparison above, the service network for the same producers has 36 nodes and 56 connections; see *Table* 2).

Multilayer networks

From a network point of view, these different networks can be characterized as multilayer networks. Multilayer networks consist of networks on different layers, where nodes on different layers may connect the layers (Boccaletti, S. *et al.* 2014; Kivelä, M. *et al.* 2014). Multilayer networks exist in many contexts: connected to geography in city transportation, they can consist of layers according to different means of mass transportation (e.g. tram, bus) (Aleta, A. and Moreno, Y. 2019). Maritime connections (Ducruet, C. 2017) and human mobility (Belyi, A. *et al.* 2017) can be described also as multilayer networks.

We assume that the connection of businesses – in our case, agricultural producers – can be described by multilayer networks. Based on the results, we argue, that agricultural producers are the hubs of at least five different network layers:

1) a layer for suppliers of agricultural producers,

2) a layer for purchasers of goods produced by agricultural producers,

3) a layer of agricultural producers,

4) a layer for offline service providers,

5) a layer for online service providers.

All these layers have connections on the layer itself, but also between layers *(Figure 6).*

We describe the layers and connections between the layers from the perspective of agricultural producers (Layer 3).

On the layer of suppliers (Layer 1), businesses of the agribusiness sector are situated, providing supplies for the producers (Layer 3). The connections between these two layers represent roads. Movement is less frequent, but the transportation of goods suggests a good road infrastructure. Connected settlements are small settlements (producers) and settlements with relevant agribusiness supply businesses (larger, but also smaller settlements).

On the layer of purchasers (Layer 2) purchasers of agricultural goods are situated, which are part of the agribusiness sector. The connections between Layer 2 and Layer 3 represent again roads. Movement is less frequent, but the transportation of goods suggests a good road infrastructure. Connected settlements are small settlements (producers) and – mostly small – settlements, where agribusiness products are stored (traders) or processed.

Different services are situated on the layer for offline service providers (Layer 4): agriculture-specific and general services. The

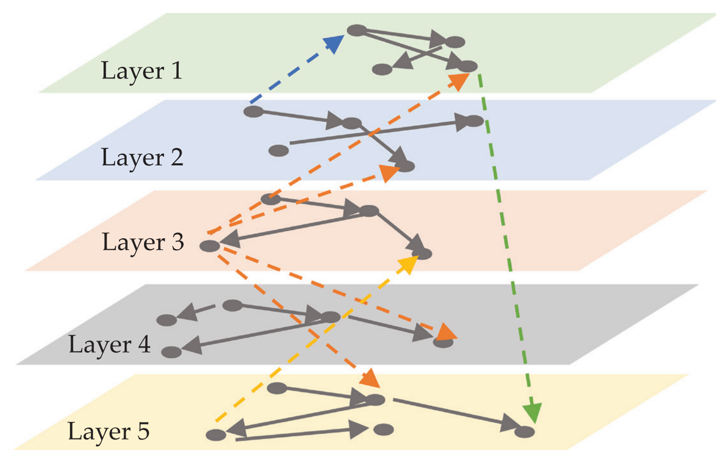

Fig. 6. A multilayer network of agricultural producers. Different colours represent different layers. Connections on layers are depicted grey, connections between layers are coloured. *Source:* Authors' own editing.

connections between Layer 4 and Layer 3 represent roads and/or digital connections. Physical movement was more frequent in the past, now physical movement is decreasing and online traffic is increasing. Connected settlements are small settlements (producers) and nearby small, middle or larger settlements, depending on the provided service.

On the layer for online service providers (Layer 5) businesses are situated, which provide almost exclusively online services, connected mostly to the digital turn in agriculture. The connections between Layer 5 and Layer 3 represent mostly digital connections. Connected settlements are small settlements (producers) and all kinds of other settlements (Layer 5). Here, we will find settlements with state-of-the-art knowledge: large or international metropolises, settlements with cloud computing, and international service providers.

Connections on the layers also exist: for example, nearby agricultural producers often cooperate, they help each other, for example, with contract work, or they may cooperate by purchasing supplies together. We may also propose a Layer 6 for employees (here not analysed). Employees also move between settlements: their home and the location of the agricultural producers are also connected via roads.

By changing the viewpoint, the above considerations indicate that successful agricultural enterprises of the past were those that had important physical connections (roads) to transport goods. These connections remain paramount since goods still need to be transported to the agricultural producer (e.g. input materials), and agricultural products need to be transported from the producer. The recent advances in technology and in behaviour connected to the pandemic, however, make digital connections more and more important.

Today and future agricultural producers need both networks: they need their physical network to transport supplies and products and for employees to move. They need, however, to be part of a similarly complex virtual network where data is moved. New technologies presented by agriculture 4.0 will work with the help of the digital network – failing to be part of this network means a future agricultural company may be less effective and competitive, since missing infrastructure connected to data-intensive solutions may slow down or block the implementation of agriculture 4.0 (Da Silveira, F. *et al.* 2023).

We also argue, that in the following years a shift between layers will be observable: as more and more digital services are (and will be) used in agriculture, the importance of Layer 5 increases. The importance of Layer 4 may decrease, but just slightly: one part of the new (online) services may decrease the importance of Layer 4; it cannot, however, vanish, since – as we have seen – in the case of a lot of services, physical proximity is relevant. The increasing importance of Layer 5 and of the formed long-distance connections are recent developments: the new layer emerged in the 1990s and is getting increasingly important as new technologies advance.

Describing business connections with different network layers adds to the researchability and to a more nuanced understanding of these connections. With different layers, layer structures, and different connections, business connections of agricultural producers may be quantifiable and describable in network terms and with network indexes and metrics. The use of the same indices and metrics can allow us to compare layers, connections, and whole structures more precisely and compare, for example, network dynamics or make suggestions where new nodes (e.g. a service provider) need to be placed.

Limitations

There are two limitations of the research. First, the collected data comes from a small part of Hungary (only two counties), representing the agribusinesses in the given counties. A second limitation comes from the fact that in the research snowball sampling was used, which means that the collected data is not independent: some of the agribusinesses providing data are closely connected.

These limitations are partly due to the fact mentioned above that data collection connected to actual business activities is not accessible. Thus, on the one hand, results connected to increased online service use based on current data collection may not be generalizable. On the other hand, the digital transformation of agriculture is described in many contexts; thus, a digital turn is taking place today, which implies the increased use of digital and online infrastructure (e.g. De Queiroz, D.M. *et al.* 2022; Kadry, S. *et al.* 2024). This turn and its implications allow for the more general discussion described above.

Conclusions

The paper analysed the spatial characteristics of service use of agribusinesses. Based on empirical data, we have shown that traditional services (such as banking or accounting) are used in smaller or larger settlements near agribusiness; towns function as service hubs for agribusinesses. We also pointed out that not only towns but also villages may function as hubs, assuming they provide at least one crucial service connected to agribusiness. We showed that business connections around agricultural producers may best described as multilayer networks, where network layers interact with each other.

As seen from the above considerations, online service use will likely increase in the future: the role of and the demand for non-physical services is advancing. As we have seen in our results, traditional services are also likely to be used more online due to the effects of the pandemic. This increase in online service use will result in several changes connected to geographical space. In the next session, we summarize how the digital turn may impact geographical space use connected to agriculture.

1) Transport and travel connected to agricultural service use will decrease. As more services are provided online and new services are partially or wholly online services, this will result in a decrease in the actual physical movement of both agribusiness employees and employees of service providers. The result will be less emissions and a slightly smaller road traffic load.

2) In cyberspace, however, agribusiness “space use” and network use will increase. Since agriculture 4.0 is about live and connected data and cloud computing, all this data needs to be transferred between the actual equipment and a central farm computer and between the farm and distant service providers. Thus, geography-related analysis of cyberspace structures must consider a shift to more extended use of cyberspace by agribusinesses (Batty, M. 1997).

3) The increased need for data transfer and processing will have physical results: a supporting infrastructure must be developed, either on single farms or in smaller regions. Since wireless data transfer is a key factor for agriculture 4.0, sufficient internet bandwidth is essential (Debauche, O. *et al.* 2021). Connected to this demand, new equipment and infrastructure (e.g. towers, relay stations) are needed.

4) As results indicate, for essential services, it is vital to maintain physical service access points as physical spaces or via mobile advisors. This is essential for agriculture service providers: as opposed to the assumption, the need for physical contact did not decrease.

5) Centres for more traditional agricultural services will be towns near agribusinesses. In contrast, centres for new, digital services will be located in knowledge-intense, primarily urban, large city areas, where service providers operate mainly globally.

Thus, recent changes in agricultural service use will have a double impact: while the use and need for physical space and structure will remain the same or slightly decrease, the infrastructure connected to digital agriculture – both in physical space and cyberspace – will increase, generating much more online traffic in and around agribusinesses.

Future research may analyse, through interviews, how location influences the choice of service providers connected to agribusinesses. The results would not only shed light on the underlying decision processes but also provide valuable information on how service providers may best choose a location for their services. Another research direction is carrying out detailed interviews connected to existing or planned digitalization in given agribusinesses. Results could show how future developments of a given agribusiness will impact the digital infrastructure around agribusinesses.

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