ISSN 0354-8724 (hard copy) | ISSN 1820-7138 (online)

Networks, Agriculture and Geography: How business connections of agricultural enterprises shape the connection of settlements in Western Hungary

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Received: August 29, 2022 | Revised: December 11, 2022 | Accepted: December 19, 2022
doi: 10.5937/gp27-39849

Abstract

Networks and network science are not new: since the middle of the 20th century, networked structures are analyzed in geography. In recent years, however, with the emergence of network science, with the availability of big data, with improved computational capabilities and new software, the knowledge and analysis of networks have improved substantially.

Present paper uses network science in economical geography: it analyzes the connections between settlements in western Hungary based on the business connections of agribusinesses. For the research, we used a questionnaire asking for purchase and sales connections of the selected agribusinesses and analyzed the results from the perspective of network science.

Results show that in an agribusiness network the purchase network is more complex than the selling network and that in spatial networks connected to agribusinesses not large cities, but small towns and villages play a central role.

Keywords: agribusinesses; networks; business relationships

Introduction

Networks

Networks are systems consisting of nodes connected by edges. Networks exist all around us: for example in our social life, where connections between people can be described as networks (cf. Barabási, 2016); in the interaction of constituents in cells (cf. Albert, 2005); or in the physical space, where roads between settlements represent connections (cf. Xie & Levinson, 2009). Networks and networked structures are described in mathematics since the seminal paper of Euler from 1736 analyzing the problem of the *Seven bridges of Königsberg* as graphs (Barabási, 2016).

Networks are thus systems with nodes, connected by edges. In the simplest form networks are not directed and weighted: only the existence of a connection between nodes is important. Think for example of roads between two cities: traffic can flow from City A to City B and from City B to City A.

Connections however can be seen as weighted: weighted connections mean that information or

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goods flow in one direction in larger quantity, and into the opposite direction in a smaller quantity or not at all. Think for example of a mine mining iron ore and transporting the ore via railways to a nearby harbor. In this case, the movement of the trains will be in both directions: from the mine to the harbor trains will be laden with thousands of tons of ore while in the other direction (harbor to mine) they will move empty.

In directed networks, the direction between nodes is important: it exists just in one direction. For example, a lot of papers – like this paper – cite the book of Peter Haggett (Haggett, 1965), the works of Peter Haggett cite however not every one of the papers citing him. Thus the citation exists in one direction, it does not exist however in the opposite direction.

In the past, networks were discovered and used in different disciplines (most prominently in sociology) to explain how systems of nodes function (cf. e.g. Granovetter, 1973; Milgram, 1967). The results of analyses of networks were however examined just inside the given field; no general characteristics of networks themselves were analyzed.

The field of network science is experiencing a renaissance since the end of the 20th century: Barabási et al. (1999) explored and described general characteristics of networks, Watts (1999) analyzed small worlds extensively and Castells (1996) described his idea of a networked society, just to mention a few.

In the 21st century new data collection methods and the increasing computational power enabled us to analyze networks that contain not just a few, but millions of nodes with millions of connections (cf. e.g. Onnela et al., 2007). Today methods rooting in network analysis are used in almost all scientific fields, from economy (e.g. Easley & Kleinberg, 2010), to sociology (Light & Moody, 2021), to medicine (Loscalzo et al., 2017) and several journals (e.g. *Networks, Journal of Complex Networks, Applied Network Science, Network Science*) are published on the field.

Networked geography

Networked structures are not new to geography: such structures are assumed and analyzed since the mid-20th century (cf. e.g. Barthélemy, 2022; Uitermark & van Meeteren, 2021). In the 1950s and 1960s a turn in geography was taken which aimed at the spatial definition of geography (Uitermark & van Meeteren, 2021). Geographers of that period focused more on interaction and dynamics (Uitermark & van Meeteren, 2021). In this era, an approximation to mathematical methods like graphs was observable, as shown for example in the works of Haggett (1965), and Haggett and Chorley (1969). It was possible to use graphs as an abstraction of spatial networks; and by using graphs for different entities, the similarities in the network structures could be analyzed (for an overview see e.g. Tinkler, 1979; Uitermark & van Meeteren, 2021).

As a critique of these first attempts to analyze networked structures was formulated by several scholars in the early 1970s, mainly pointing out that 1) in these analyses the method is the constant, which is a weak connection when comparing for example river networks with street networks; and that 2) networks and the function of different networks needs to be explained in light of specific geographical knowledge; meaning that the simplification of real-world geographical data to networks and the conclusion deriving from the analysis of these networks needs to be done very carefully (Uitermark & van Meeteren, 2021). It was also noted, that geographical space changes over time, and it is also paramount to incorporate the changes and flows into geographical analysis (Uitermark & van Meeteren, 2021). Barthélemy (2022) points also out, that analyzing networks in geography must consider also space since the length of edges is important: thus, the network structure and network connections are influenced by spatial proximity.

Network analysis in geography is experiencing a new boom in the 21st century, when data (later big data) is available in digital format; and also several software for network analysis are available (cf. e.g. Barthélemy, 2022; Bosco, 2006; Glückler & Panitz, 2021; Uitermark & van Meeteren, 2021). It must be noted, however, that geographical network analysis must take into account, that 1) in human geography networks are formed around collective goals, 2) in human acting social reality is considered and 3) humans interact while constituting networks (Uitermark & van Meeteren, 2021). Uitermark and van Meeteren (2021) also point out, that network analysis in geography 1) needs to consider the actual geographical space; 2) it has to be holistic; both abstract and incorporating actual contexts; 3) needs to understand that networks in geography are not abstract, but depict real connections; 4) that connections must be carefully considered since not all connections can be seen as equal; and 5) network analysis is best used together with other methods. Völker (2021) points out, however, that geographic network research does not need its own methods: it can well build on the existing methods of (general) network analysis.

Today network analysis is used to analyze a wide area of geographical data from broad overviews such as Barthélemy (2011, 2022), Daraganova et al. (2012), Glückler (2010) or Uitermark and van Meeteren (2021) to human geography in general (Glückler & Panitz, 2021) to urban networks and geography (Derudder & Neal, 2018; Lewinson & Krizek, 2008; Neal 2012) to transportation geography (see e.g. Derudder et al., 2008; and papers in *Geojournal* 71/1) and to medical geography (Smyth, 2005) (see e.g. also the issue *Tijdschrift voor Economische en Sociale Geografie* 2021/4).

Geography and economy or business-related research also uses network approaches from the seminal paper of Glückler (2007) e.g. to the longitudinal analysis of the function of ports (Ducruet & Itoh, 2022; Rousset & Ducruet, 2020) or maritime networks (Álvarez et al., 2021), to the connectedness of rural and urban business activity (Mahmud, 2021), to the location of services in cities (Zhao et al., 2020) to knowledge flow and innovation (Broekel et al., 2014., Bell & Zaheer, 2007; Maggioni et al., 2007; Maggioni & Uberti, 2011), to industrial geography (Sorenson, 2005) to public transportation (Ding et al., 2019; Hajdu et al., 2020) or to migration (Connor, 2019), just to mention a few.

Connected to agriculture, however, less research analyzes networked structures. One of the more researched topics in the triangulation of geography, agriculture, and networks is connected to food networks) where the interactions of food, food production, food consumption and networks are described (e.g. Niles & Roff, 2008), and to Actor-Network Theory, which analyzes the interconnectedness of human and non-human actors in an agricultural system (c.f. Watts & Scales, 2015).

Research lacks, however, papers and analyses which use the methods of network research to the functions of agricultural businesses. The goal of current paper is to fill in this research gap: it aims to show on the example of Hungarian agricultural businesses, how business relations are distributed in geographical space and how these relations can be analyzed from the network point of view.

Based on the literature, we assume that tools and methods of network science are appropriate to analyze the central role of settlements in networks: we set the goal to show on the example of small-scale data, that network analysis can provide a deeper inside into the business-related connections between settlements.

Since agricultural businesses are situated where arable land is (mostly further away from larger cities), and since some of the businesses providing equipment for agribusinesses needs large areas to store goods, we hypothesize that in the agribusiness network smaller settlements can play a central role.

Based on this hypothesis, we search for answers to the following research questions:

- RQ1) Are large cities automatically centers in the agribusiness network?
- RQ2) Which factors influence whether a settlement has a more or less central role in an agribusiness network?

To achieve this goal, in the next part we summarize the geographical and agricultural characteristics of the analyzed area.

Agricultural geography of the area – an overview

Hungary's agriculture is significant due to its natural geography and economic geography, as 79% of Hungary's land is arable land and 57% is agricultural land (KSH, 2021). The share of agriculture in GDP was 13.7% in 1989-1990 in Hungary (Berényi, 2011), by 2020 this share decreased to 4.1% (KSH, 2020).

The paper analyzes business connections and spatial relations of agribusinesses in the Hungarian counties Vas and Zala. Both counties are situated in western Hungary: Vas county has an area of 3,336 km², while Zala has an area of 3,784 km². The cities

Table 1. Cities and towns of Vas and Zala county, by population

Vas county		Zala county	
City / Town	**Population (2019.01.01)**	**City / Town**	**Population (2019.01.01)**
Szombathely	78 407	Zalaegerszeg	57 403
Sárvár	15 226	Nagykanizsa	46 649
Kőszeg	11 865	Keszthely	19 289
Körmend	11 179	Lenti	7 348
Celldömölk	10 555	Zalaszentgrót	6 172
Szentgotthárd	8 819	Hévíz	4 523
Vasvár	4 130	Letenye	3 937
Bük	3 624	Zalalövő	2 857
Vép	3 293	Zalakaros	1 988
Csepreg	3 277	Pacsa	1 576
Répcelak	2 630		
Jánosháza	2 430		
Őriszentpéter	1 141		

Source: own editing, based on Vas megye (2022) and Zala megye (2022).

Table 2. Production of the main arable crops in Vas county in 2015

Crop	Yield		Yield average	
	tons	country = 100,0%	tons/ha	country = 100,0%
wheat	247 214	4,7	5,240	102,0
maize	179 941	2,8	6,110	107,4
sunflower	16 977	1,1	2,420	96,4
rapeseed	37 188	6,1	2,300	87,5

Source: KSH, 2016.

and towns of both counties are summarized in Table 1.

The agricultural land of the counties is 260 and 274 thousand hectares, respectively. The agricultural land of Vas is characterized by a fragmented structure. In Vas county wheat, maize sunflower and rapeseed are the main crops (Table 2); sugar beet and spring barley are also cultivated in the county (Grosz, 2007).

est in Hungary. 72% of individual farms produce exclusively for their own consumption.

It is important to note that Vas County has a larger wheat area than Zala County, with 74% more wheat harvested in 2020 than in Zala County. In the case of maize, the opposite is true, with Zala county having a larger area due to better natural conditions, which is why 58% more maize was harvested in Zala.

Table 3. Production of the main arable crops in Zala county in 2015

Crop	Yield		Yield average	
	tons	country = 100,0%	tons/ha	country = 100,0%
maize	284 408	4,4	6,330	111,2
wheat	141 997	2,7	5,250	102,1
sunflower	16 050	1,0	2,380	94,8
rapeseed	18 039	3,1	2,320	88,2

Source: KSH, 2016.

In Zala county wheat and maize are the most produced crops (Table 3). The agricultural land in Zala is characterized by a fragmented structure, the average agricultural area of individual farms is one of the lowest in Hungary. Among arable crops, rapeseed cultivation shows also a difference between the two counties: in 2020, the harvest in Vas County was twice as high as in Zala County.

Data and methods

Data collection

Data was collected via a questionnaire in western Hungary, in the counties Vas and Zala (in detail see Szőke, 2022). The initial goal was to ask 100 agribusinesses using snowball sampling. The goal was not achieved, however: more than 50% of the contacted businesses refused to answer the questionnaire, although all data was collected and analyzed anonymously. The agribusinesses refusing an answer argued that their businesses are easily identifiable even anonymously, since in a given settlement just a few agribusinesses exist.

The questionnaires consisted of 14 questions. Data collection was between late 2019 and early 2021, on digitally distributed (email) questionnaires. Initially, also on-site data collection was planned for 2020; the coronavirus pandemic made this however an exception.

The questions were partly business-related – for example number of employees, machines used on the farm – and partly they were connected to the networks created via business connections, e.g. asking from where (which settlement or foreign country) the agribusiness regularly bought products or raw material and where (which settlement or foreign country) the agricultural products were sold. The questionnaire also asked for the used services and settlements where these services were used.

In current paper, we analyze only the connections between settlements based on purchasing and selling activities of agribusinesses.

Data analysis

The received questionnaires were analyzed: from the received 46 questionnaires we could use at the end only 30: 10 questionnaires were from other counties, while 6 questionnaires had serious data gaps; therefore we had to omit them from the analysis. The questionnaires with data gaps could not be used since exactly the needed information (settlement names) was missing. Since network analysis can only work with data where nodes also have edges, these answers were not used.

The data was first entered into MS Excel for data processing. For secondary data – agribusinesses and agricultural performance in general – the data of the Hungarian Central Statistical Office (Központi Statisztikai Hivatal) was used.

For analyzing, grouping and cleaning data Microsoft Excel, for network analysis Gephi 0.9.7 on Windows was used. Gephi is a free software designed for network analysis and visualization (Gephi, 2022). In order to implement data for Gephi, the input data needs to be arranged according to the input criteria of the software. In our case, for every context (purchase, selling, purchase and selling superimposed) two .csv input files were created. In one of the files the nodes were defined (id, name (label), settlement type, county); in the other, the existence of a connection was marked, together with the direction and weight of the connection. For the best visualization, we chose the layouts "Label adjust" and "Yifan Hu", because after testing, these algorithms provided the best results.

Results

General characteristics of the agribusinesses

The focus of the activity of the analyzed businesses according to county is presented in Table 4.

Table 4. Activity of agribusinesses who completed the questionnaire by county and by activity

Scope of activity of agricultural enterprises	Vas county	Zala county	Total
crop production	15	2	17
animal husbandry	2	4	6
crop and animal production	4	3	7
total	21	9	30

Source: own editing.

The agribusinesses engaged in crop production (including enterprises engaged both in crop and animal husbandry) farm an average of 259.58 ha. The enterprises in Vas county are more involved in arable crops, with an average area of 305.26 ha, while in Zala county the enterprises are more involved in apple, pine, thuja, and fir tree cultivation, which means that the average area cultivated is smaller, 86.00 ha.

Networks of agribusinesses

Purchasing networks

In the following, we analyze the connection between settlements based on the business connections of the analyzed agribusinesses, based on Szőke (2022). We analyze the agribusinesses of both counties together. The network of purchases is a directed network, characterized by the following indices (Table 5):

A value of modularity indicates that clear communities are formed – in our case 10 – and a value of 0.4 < indicates that these communities are well separated. As for the purchases from abroad, cities were just in some cases indicated by the respondents, therefore we used the country names to indicate a connection to the given country. The weighted network (weight = number of connections) is complex, the weighted centers are Rádóckölked and Körmend (Figure 1).

Table 5. Network indicators of the supply chain network of crop production enterprises. * = calculated by Gephi 0.9.7 on Windows. Settlements with a smaller degree as 3 are not named.

Number of nodes:	N = 54
Number of connections:	E = 84
Outdegree (k_i^{out}):	Hegyfalu k_i^{out} = 9 Sárvár, Szombathely k_i^{out} = 7 Vasvár, Zalaegerszeg k_i^{oui} = 5 Bak, Körmend k_i^{out} = 4 Egyházasrádóc, Austria k_i^{out} = 3
Indegree (k_{iin}):	Rádóckölked k_i^{in} = 15 Körmend, Nagyrákos k_i^{in} = 7 Bük, Szeleste, Egyházasrádóc k_i^{in} = 6 Csönge k_i^{in} = 5 Egervár, Pethőhenye k_i^{in} = 4 Cák, Hegyfalu, Őrimagyarósd, Vép k_i^{in} = 3
Total degree of nodes ($k_i = k_i^{in} + k_i^{out}$)	Rádóckölked k_i = 15 Hegyfalu k_i = 12 Körmend k_i = 11 Egyházasrádóc k_i = 9 Bük k_i = 8 Nagyrákos, Sárvár, Szombathely k_i = 7 Szeleste k_i = 6 Csönge, Vasvár, Zalaegerszeg k_i = 5 Bak, Egervár, Pethőhenye, Vép k_i = 4 *Austria*, Cák, Nagykanizsa, Őrimagyarósd k_i = 3
Average Degree	1,5556
Avg. Weighted Degree*	2,611
Network Diameter*	3
Graph Density*	0,029
Modularity*	0,468
Avg. Clustering Coefficient*	0,064
Number of Communities*	10
Avg. Path Lenght	1,39

Source: own editing.

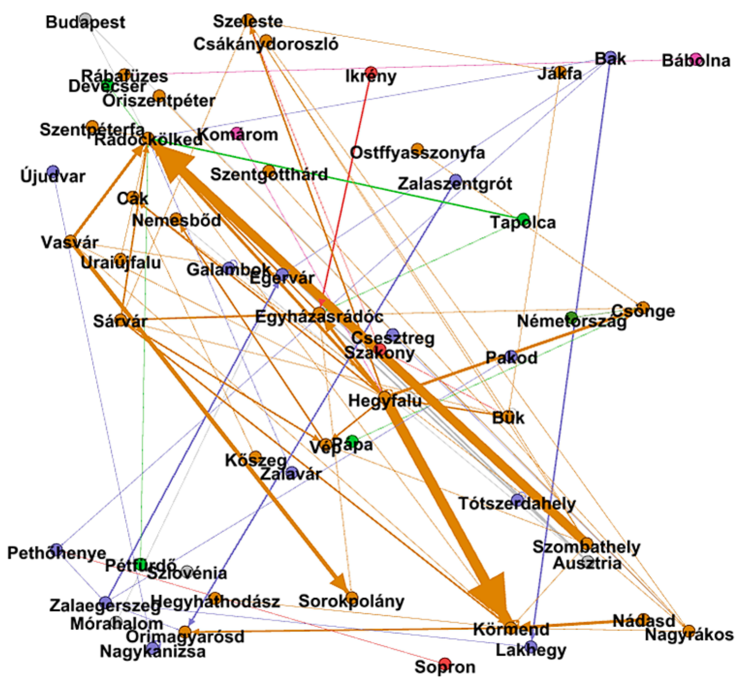

Figure 1. The network representing the purchasing relationships, weighted by the number of relationships. Brown indicates Vas county, blue Zala county. Ausztria = Austria, Németország = Germany, Szlovénia = Slovenia.
Source: Szőke 2022, using Gephi version 0.9.7.

Sales networks

The network of sales is a directed network, characterized by the following indices (Table 6).

As for the selling abroad, cities were just in some cases indicated by the respondents, we used the country names to indicate a connection to the giv-

Table 6. Network indicators of the sales network of crop production enterprises. Settlements with a smaller degree as 3 are not named.

Number of nodes:	N = 28
Number of connections:	E = 37
Outdegree (k_i^{out}):	Bük és Szeleste $k_i^{out} = 6$ Csönge, Rádóckölked $k_i^{out} = 5$ Körmend $k_i^{out} = 4$ Egyházasrádóc, Hegyfalu $k_i^{out} = 3$
Indegree (k_i^{in}):	*Austria* $k_i^{ine} = 7$ *Italy* $k_i^{in} = 5$ Egyházasrádóc $k_i^{in} = 3$
Total degree of nodes ($k_i = k_i^{in} + k_i^{out}$)	*Austria* $k_i = 7$ Egyházasrádóc, Körmend $k_i = 6$ Csönge, Hegyfalu, *Italy* $k_i = 5$ Szeleste $k_i = 4$ Bük, Vép $k_i = 3$
Average Degree	1,3214
Avg. Weighted Degree*	1,536
Network Diameter*	4
Graph Density*	0,049
Modularity*	0,484
Avg. Clustering Coefficient*	0,051
Number of Communities*	7
Avg. Path Lenght	1,617

** = calculated by Gephi 0.9.7 on Windows.*

Source: own editing.

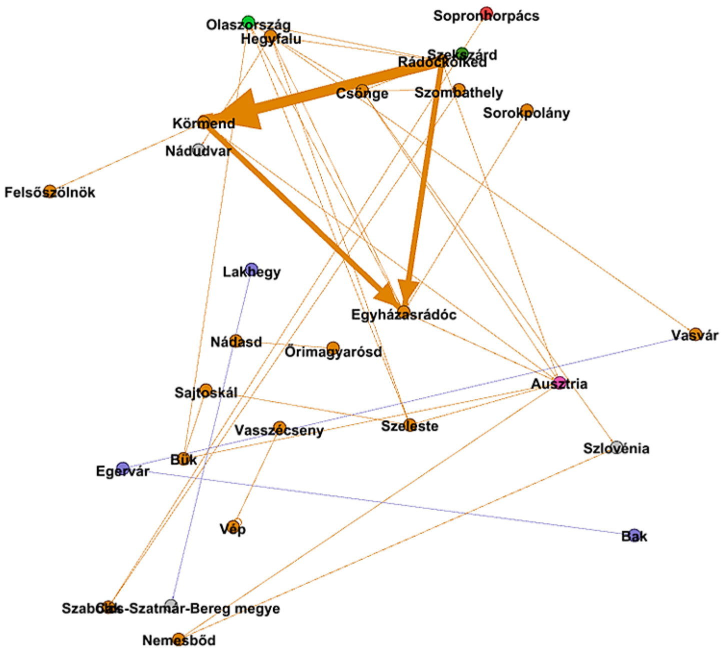

Figure 2. A network representing the selling relationships, weighted by the number of relationships. Brown: Vas county, blue: Zala county. Ausztria = Austria, Olaszország = Italy, Szlovénia = Slovenia.
Source: Szőke 2022, using Gephi version 0.9.7.

en country. The weighted network (weight = number of connections) is complex, the weighted centers are Rádóckölked and Körmend (Figure 2). In the network 7 communities are formed – and a value of 0.4 < indicates that these communities are well separated.

Austria is the node in the network with the most connections (high number of indegree), followed by Egyházasrádóc and Körmend, where there are enterprises with large areas of land that sell their products. These large farmers also buy crops from other farmers. The weight by the number of connections is however not the best visualization describing selling; therefore Figure 3 shows the network of selling relationships, weighted by the weight of the sold products (tons).

The complex network of selling and purchasing

The network of purchasing and sales contacts was superimposed and the number of connections was examined. The node with the highest degree is Rádóckölked: the reason is, that in the village a large area farmer and several small area farmers filled in the questionnaire.

In the complex network, 62 nodes exist, with 121 connections. The complex network is depicted in Figure 4. As we can see the largest part of the network is connected, only some settlements in Zala county are not part of the network. The agricultural businesses in these settlements are small, mostly producing for their own consumption.

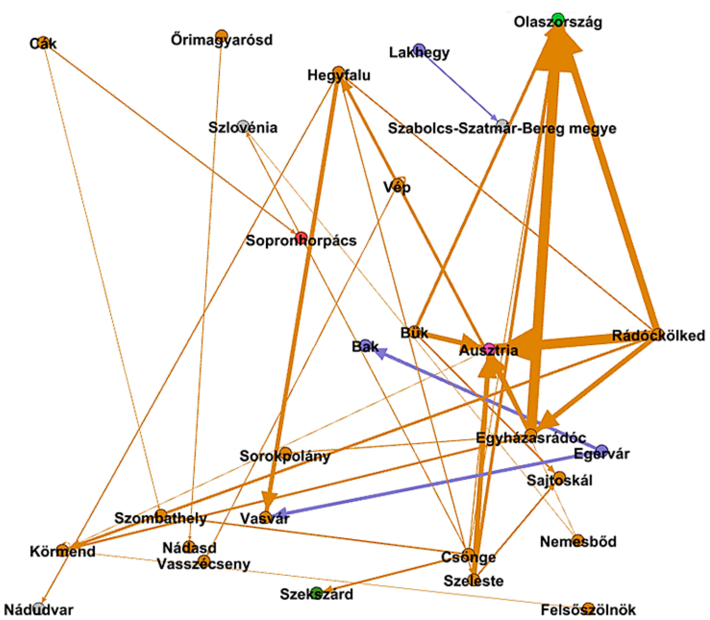

Figure 3. The network representing the selling relationships, weighted by the weight of the sold products (tons). Quantities calculated according to yield data of the Hungarian Central Statistical Office. Brown: Vas county, blue: Zala county. Ausztria = Austria, Olaszország = Italy, Szlovénia = Slovenia.

Source: own editing, using Gephi version 0.9.7.

As we can see, the structure is the same but weighed with the sold quantity of crops it is clear that the most important nodes are not settlements in Hungary, but the countries where the crop is sold: Austria and Italy. The village Egyházasrádóc is an important node, too: a farmer in the village buys crop from smaller farmers, stores them for a longer time, and sells it. Weighed by tons Körmend is less important.

Since the network drawn by Gephi is not drawn according to the geographical location and distribution, Figure 5 shows how the settlements are distributed in the geographical space. It can be seen that the densest network is inside Vas and Zala counties and that – although geographical proximity influences connections – there are well business connections outside this smaller area.

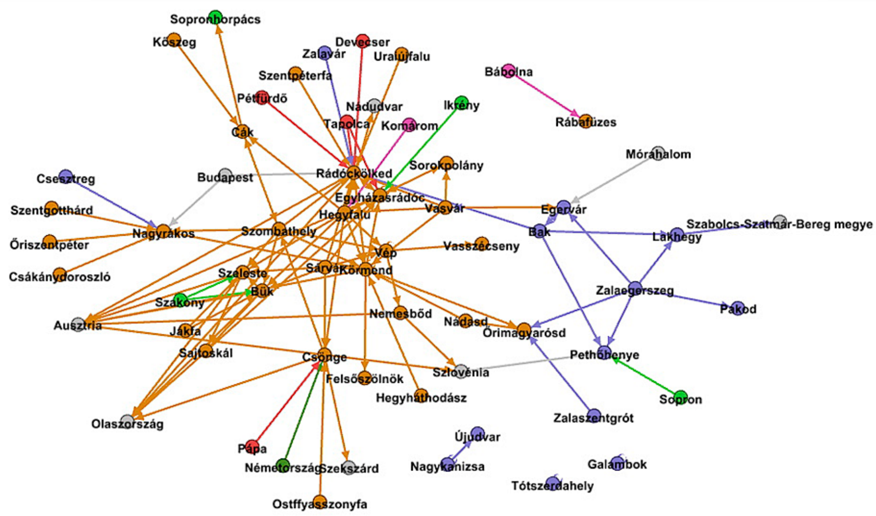

Figure 4. Purchasing and sales network. Brown: Vas county, blue: Zala county, green: Győr-Moson-Sopron county, purple: Veszprém and Komárom-Esztergom counties, grey: cities from other parts of Hungary and other countries. In the case of Galambok and Tótszerdahely purchasing happens at the same settlement. Ausztria = Austria, Olaszország = Italy, Szlovénia = Slovenia.

Source: own editing, using Gephi version 0.9.7.

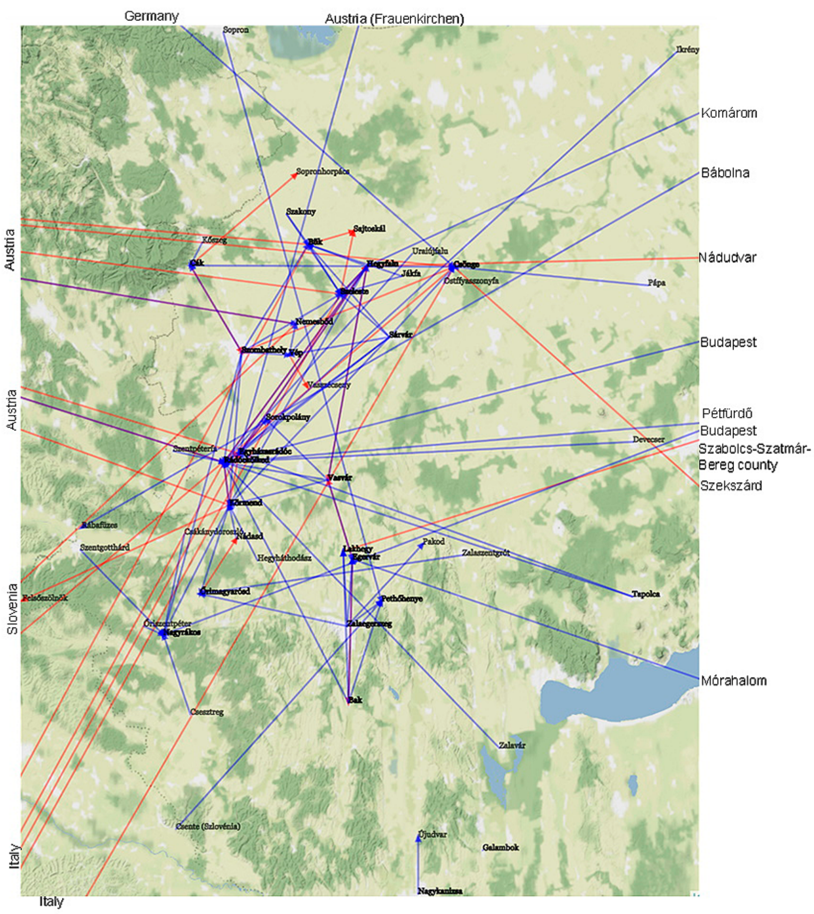

Figure 5. Map of the network of purchasing and sales connections. Blue: purchasing, Red: selling.

Source: Szőke 2022, source of the background map: https://leafletjs.com.

Discussion

Main characteristics of the networks

The main characteristics of the purchasing, selling and complex network are compared in Table 7.

The above indices all describe the complexness of a network (for an overview see Barabási, 2016; Kansky, 1963; or Szőke, 2022). The alpha index (α-index) is an indicator of the complexness of networks, the less connected networks are tree-shaped and the more complex ones contain several circuits or multiple edges (Dusek & Kotosz, 2016). If the α-index is close to 0, the network is tree-shaped, while if it is 1, it is fully connected (Erdősi, 2000).

Table 7. Main characteristics of the networks

	Purchase networks	Sales networks	The complex network of sales and purchasing
Number of nodes (N)	54	28	62
Number of connections	84	37	121
Beta Index (β) (Average Degree)	1,5556	1,3214	1,9516
Gamma Index (γ)	0,5385	0,4744	0,6722
Alpha Index (α)	0,3010	0,1961	0,5042
Pi Index (π)	28	9,25	12,1
Network Diameter*	3	4	10
Avg. Path Lenght	1,39	1,62	3,48

** = calculated by Gephi 0.9.7 on Windows*

Source: own calculations

The beta index (β-index) is another quantity measuring the complexity of networks: a larger β value denotes a more complex network structure, similar to the gamma index (γ-index) which describes the density of the network (Barabási, 2016). With the pi index (π) again the complexity of the network can be described: a larger value indicates a more complex network.

Purchase network

- α-index: a value of 0.3010 indicates a less complex network. The number of directed cycles in the network is 30% of the maximum number of possible directed cycles.
- β = 1.5556: since the value is greater than 1, it means that the network has more than one directed cycle or multiple edges. The value of the index is higher for purchase than for the sales network, which means the purchase network is the more complex of the two.
- γ = 0.5385, indicating a less complex network
- π index: the π index of the purchasing network is 3 times higher than that of the sales network. The network of purchasing relationships is more complex than that of sales relationships.

Sales network

- α-index: a value of 0.1961 indicates a not connected network. The number of directed cycles in the network is 20% of the maximum number of possible directed cycles.
- β = 1.3214 since the value is greater than 1, it means that the network has more than one directed cycle or multiple edges.
- γ = 0.4744, which indicates a partly connected network

Purchase and sales network

- α-index: a value of 0.5042 indicates a moderately complex network. The number of directed cycles in the network is 50% of the maximum number of possible directed cycles.
- β = 1.9516: the β index of the purchasing + sales network is higher than that of the purchasing and sales network separately, indicating that the two networks together are more complex.
- γ = 0.6722, indicates a complex network.
- π index: the π index of the purchase and sales network is lower than that of the purchase network and higher than that of sales network. This seemingly contradictory result can be explained by the structure of the separate networks: the purchase network has a high number of nodes and a high number of edges, while the sales network has fewer nodes and fewer edges. If the two networks are superimposed, we will have slightly more nodes, but the number of links will increase at a higher rate; hence the π value will be lower.

Central settlements

The first research question seeked to answer the question, whether large cities are automatically centers in the agribusiness network (RQ1).

Our results show that agricultural enterprises with large arable lands have a more extensive and complex network of connections. This is the reason why in the network of purchase contacts (Figure 1) a village – Radóckölked – has the most contacts: it is due to the high number of respondents at the settlement and the extensive network of contacts of large agribusinesses. The next node is Hegyfalu, which is ranked 2nd due to its high out-degree. The settlement is one of the sites of KITE Zrt. from which many farmers in Vas County purchase fertilizers, pesticides, and machinery parts. Egyházasrádóc, Bük, Szeleste, and Csönge have a high indegree, because they are home to large-scale farmers with many connections, and are therefore considered to be important nodes in the network. Sárvár, Szombathely, Vasvár, and Zalaegerszeg, as well as Bak will have a high outdegree, as farmers buy various products from these settlements, e.g. fertilizers, pesticides, or spare parts for machines.

In the sales network, the indegree of settlements is large when farmers at the settlement have agribusinesses that purchase crops from neighboring (smaller) farmers. Similarly, purchasing countries – Austria and Italy – have a high indegree. It is important to note that the crop sold to Austria and Italy also has two possible uses:

a) bought from Hungary and resold by Austrian or Italian companies specialized in the trade of crops,
b) bought for processing, e.g. for pasta production.

The outdegree of a settlement in the sales network is depending on the number of farmers filling out the questionnaire from the given settlement since most farmers sell their products to only one or two buyers. This is the reason, why the sales network is less complex than the purchase network (see above). The small number of partners can be explained by the fact that in agribusiness trust, correctness, and long-lasting relationships are paramount (cf. Sadovska et al., 2020; Zander & Beske, 2014). This is, why existing partnerships are highly valued and why established selling partner networks just seldom change.

In the complex network (purchase and selling) the degree of Hegyfalu will be high due to the high number of purchasing out-degrees (fertilizers, pesticides, etc.), while the degree of Körmend will be high due to the high purchasing indegrees. In Egyházasrádóc, Bük, and Szeleste, larger farmers cultivate areas with significant purchases and sales, and therefore these settlements have a higher degree and a more important node function in the network. Szombathely, Sárvár, and Vasvár have high out-degrees in the purchasing network (=purchasing from the perspective of the agribusinesses) and also high indegrees in the sales network, which is because some of the agribusiness enterprises in these towns are involved in both product sales and partly (in a smaller degree) in buying crops or other products. In the case of agribusinesses, we see that according to the complex network of purchase and selling the most central nodes in the network are not large towns or cities: they are smaller towns or villages, where enterprises buy agricultural products (crops) from other agribusinesses.

We can conclude, that small towns and villages can also have a central role in an agribusiness network, thus the answer to RQ1 (Are large cities automatically centers in the agribusiness network?) is no, since smaller towns or even villages can play a central role in agribusiness networks.

Factors influencing central roles of settlements in business networks

As seen from the results and the discussion of the first research, smaller towns and villages can also function as centers in agribusiness networks. This leads us to the second research question – RQ2: Which factors influence, whether a settlement has a more or less central role in an agribusiness network? In the following, we summarize the factors responsible for the central role of a settlement in an agribusiness network.

As we see from the results, central nodes of agribusiness networks can be smaller towns or villages. These central roles can be shaped by three contexts:

1. the size of the agribusiness in the given settlement,
2. the activities of the agribusinesses in the given settlement and
3. the existence and scope of businesses important for agricultural production at the given settlement.

Since the production site of agribusinesses cannot be changed (they have to produce on the given land), therefore on one side the place of production is given. On the other side, it is inefficient storing large quantities of agricultural products in large cities: it is much more effective to collect them in smaller settlements, where

a) a business selling and storing agricultural products already has large storage space, or
b) a large farmer producing crops has facilities to store additional agricultural products.

These two kinds of companies shape the network as local collectors of agricultural products.

In the case of purchasing networks, important nodes with large outdegrees will be settlements where

a) agricultural input (e.g. seeds, fertilizers, insecticides, pesticides), and/or
b) for daily business necessary parts, tools and products (e.g. machine parts, screws, belts) can be bought.

Businesses selling these products are not exclusively supplying agribusinesses; e.g. screws or tools are needed also by a wide range of industrial companies. These businesses and specialized agricultural businesses often are situated outside of cities (cf. Szőke & Kovács, 2019), but also in smaller towns or villages, nearer to local agribusinesses, where purchasing land for business activities is much cheaper.

Thus, the agribusiness network has four main actors: 1) producers, 2) resellers 3) companies processing crops and reselling new products 4) companies providing input material and machine parts and tools for agribusinesses. None of these actors needs necessarily to be located in large cities.

From the above, RQ2 (Which factors influence, whether a settlement has a more or less central role in an agribusiness network?) can be answered. It can be concluded that in agribusiness purchasing and sales networks three kinds of settlements can have a central role:

1. large cities supplying agribusinesses with specialized equipment
2. smaller towns or larger villages having specialized businesses for agribusinesses and/or having businesses re-selling agricultural products,
3. villages where larger agricultural businesses are situated that both buy and sell crops.

Practical implications and future research

First results show that the network analysis approach applied to business connections can be used to identify connections between settlements. Since results show the existing business connections, this knowledge can be used by new businesses connected to the agribusiness sector, but also by local authorities for settlement development.

First, results could provide information for future businesses selling products for or buying crops from agricultural businesses. Based on the data it can be calculated and suggested where to place and open new businesses: placing businesses near producers, crop buyers or near usual traffic routes may increase the chance of success for future businesses.

Second, results clearly show (local) governments where targeted road development may be necessary. An agribusiness purchasing crops from smaller farms necessarily creates heavy traffic, which affects the condition of roads and the traffic situation on that road. Note that just one typical agribusiness producing crop on 1000 ha can generate a traffic of 3-400 truckloads of transport in the vicinity of the given agribusiness (cf. Szőke & Kovács, 2019).

Third, the results can provide input for local decision-makers, where infrastructure in a given settlement needs to be developed or tax reliefs provided in order to attract new businesses, which provide services according to the needs of nearby agribusinesses.

The results open up the possibilities of several new research directions. One possibility is to verify and refine the first results on a larger dataset by analyzing the connections of more agribusinesses in the same geographical area. A second possibility is to analyze the connections of agribusinesses in other counties, thus verifying the results in other geographical areas. It would also be interesting to compare the business connections of other economic sectors with those of agribusinesses, including e.g., production companies, touristic companies, service companies, etc., or even include the connections of local governmental organizations into the analysis. Thus, a more detailed and diversified network structure between settlements could be uncovered, where the peculiarities and the characteristic network structure of the given sector could be captured and analyzed.

There is another research direction that is worth taking in the future. One interesting outcome of the analysis is – when we compare the connections to other data obtained through the questionnaire –, that results suggest that the language knowledge of the farmers influences the business connections they form and maintain. The farmers who speak foreign languages – in several cases, the farmers were born abroad and settled in Hungary – tend to create business connections outside Hungary both for purchasing (e.g., buying equipment from Austrian vendors) and for selling (selling crops to Austria or Italy) purposes. This result is not surprising per se, shows, however, that sometimes neglected (not analyzed) soft factors such as spoken languages may explain spatial connections between businesses and between settlements. The result implies that when analyzing spatial structures, it is necessary to collect data that seems – at first glance – not to be connected to the given research goal since, as we see, in our case, such a factor provides the explanation for some spatial structures. Thus, a future research direction could be to identify all the factors – including human-related soft factors – which can influence and explain the spatial connection between businesses and, therefore, connections between settlements.

Conclusion

The paper sought to show the potential of the use of network research methods to analyze the connections between settlements. We pointed out that the analysis of networked structures in geography can describe complex relations between the actors of the network and can help to understand the complex interaction of these actors.

In the paper, we analyzed the purchase and sales networks around agribusinesses: with a questionnaire, we mapped out connections of agribusinesses in the Hungarian counties Vas and Zala, and we analyzed the resulting networks with Gephi.

Results showed that the network structures are different when we analyze the purchasing and the selling network: settlements that are central in one network do not necessarily play a central role in the other network. This is due to the different roles of settlements: while some settlements have more vendors selling input material, parts and goods for agribusinesses, others rather host businesses which collect crops.

After analyzing the network structure, and the role – and businesses – on the given settlement, we concluded that from the agribusinesses network's point of view, central nodes are not necessarily larger cities: small towns and villages can also have a central role, depending on the agri- or agriculture-related businesses situated in the given settlement.

Results implicate that network science has potential in geographical space research: with data obtained either from questionnaires or from databases, networked structures can be identified and analyzed. The tools and results of network analysis must be, however, connected to geographical knowledge – in our case, to knowledge of economic geography – to be able to give explanations for the results and to map out the practical use of the results.

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