RESEARCH ARTICLE

International Journal of Agriculture, Environment and Food Sciences 2023; 7(2): 374-383
DOI: https://doi.org/10.31015/jaefs.2023.2.16

The shortest way to diffuse agricultural innovations: A network study in the paddy sector in Türkiye

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Abstract
The study revealed the diffusion processes of agricultural innovations and the influential advice sources in the diffusion process by using the network approach. The study sought to answer the questions of how agricultural innovations diffuse in the paddy sector, how agricultural innovations can be delivered to paddy farmers in the most concise form, and what are the typical characteristics of influential advice sources. Data were collected using questionnaires from paddy farmers, input suppliers, rice mills, and other relevant people and organizations in 2017. Social network analysis was used to analyze farmer advice networks, and Ordinal Logistic Regression was used to identify the common characteristics of influential actors in the network. The research results indicated that the farmers were a bridge between innovation creators and other farmers. The local pesticide dealers were the intermediary position among the paddy farmers with the innovation creators. Collective action, membership in agricultural organizations, social status, and project experience were influential factors in being an advice source. The study found that agricultural innovations in the paddy sector can diffuse most quickly from innovation creators to local pesticide dealers and farmers.

Keywords: Diffusion of innovations, Advice networks, Paddy, Ordinal logistic regression, Türkiye

Citation: Aydogan, M., Demiryurek, K. (2023). The shortest way to diffuse agricultural innovations: A network study in the paddy sector in Türkiye. International Journal of Agriculture, Environment and Food Sciences, 7 (2), 374-383

Received: 03 May 2023
Revised: 25 May 2023
Accepted: 27 May 2023
Published Online: 20 June 2023

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INTRODUCTION

In developing countries where agriculture is the dominant sector, the diffusion of new technologies plays an essential role in income growth due to productivity in agriculture. The World Bank (2012) defines agricultural innovation, which is the product of a complex process, as a product of the relationships, resources, and capacity that emerge from the combination of actors in a wide range of fields related to agriculture.

The increasing complexity of new technologies causes the perspectives on innovations to change. Today's agricultural innovations require a wide range of participation from different actors, including joint development in institutions and technologies (Bandiera and Rasul, 2006). Van de Ven (2017) points out that innovation is a process involving many stakeholders and argues that innovation's primary function is to create shared knowledge. The common point of the definitions in the literature is that agricultural innovation is a complex process with multiple actors, focusing on the relationship between actors and continually evolving (Joffre et al., 2018; Klerkx and Begemann, 2020). Groups such as farmers, research institutes, universities, input providers, intermediary organizations, pressure groups, capital owners, and regulators occur in these systems.

Generally, the previous studies analyzing the diffusion of agricultural innovations used reductionist approaches and models. These approaches and models consider the actors in the same category as a single actor and they are limited in showing which actors in the system are more effective. Instead, the network approach is more advantageous than reductionist approaches in revealing the relationship patterns between actors with numerical and visual analysis. Demiryurek (2010) argued that the diffusion of the agricultural innovation process could be better analyzed using social network analysis (SNA). With SNA, it is possible to reveal the role of actors in the innovation network, which characteristics of the actors are helpful in these roles, and when they fulfill their roles. On the other hand, along with the decreased budgets allocated to agricultural services worldwide, the concept of leader farmers, opinion leaders, and advice sources became essential with the transition to participatory and decentralized extension (Cook et al., 2021; Lin et al., 2021). This change increased the importance of advice networks in the diffusion processes of agricultural innovation, and social network analysis emerged as an essential tool to reveal the advice sources in the networks.

Network studies in agriculture were often used to explain the diffusion of innovations, and the adoption of innovations by farmers was interpreted as a function of the farmer's position in the social network (Isaac et al., 2007; Carruthers and Vanclay, 2012). The fact that a farmer with many people in his/her social network was aware of innovations meant that other farmers in that farmer's network might also be aware of innovations and new practices (Valente, 2005). The reason for this study is to reveal the diffusion process of agricultural innovations in farmer social networks.

The literature has numerous studies on the diffusion of agricultural innovations and identifying the key players in this process (Tran et al., 2019; Parry et al., 2020). Studies on the diffusion of innovations in Türkiye have generally considered technology transfer and focused on farmers' adoption of these technologies (Hasdemir and Taluğ, 2012). In addition, some SNA studies have been conducted on the diffusion of agricultural innovations in Türkiye (Demiryürek, 2010; Aydoğan et al., 2016; Demiryürek et al., 2017; Aydoğan and Demiryürek, 2018; Aydoğan et al., 2018). However, the common feature of these social network studies (Skaalsveen et al., 2020; Lin et al., 2021) was that they examined the diffusion of agricultural innovations in a single layer, specifically focusing on the farmer level. Considering that the sources of advice change rapidly over the years, the fact that farmers' awareness of agricultural innovations also changes frequently over time makes it necessary to conduct similar studies on the same issue. Identifying the actors and their typical characteristics that are effective in the diffusion processes of agricultural innovations can contribute to the problem's solution. However, farmer advisory networks are not only composed of farmers but are a complex environment. Therefore, it would be appropriate to analyze farmers' advisory networks in layers.

Using the network approach, the study identified the diffusion processes of agricultural innovations and the sources of advice that are effective in the process. Unlike previous studies, the study analyzed the diffusion process in three layers: farmer, local, and national. In the second stage of the study, the question of the characteristics of the advice sources who are effective in the diffusion processes of agricultural innovations have brought them to this position sought answered.

MATERIALS AND METHODS

Research area

An average of 980 thousand tons of paddy is produced annually in Türkiye. The provinces with the highest paddy production are respectively Edirne (40.2%), Samsun (15.0%), Balıkesir (14.0%), Çanakkale (10.2%), and Çorum (5.9%) in Türkiye. Paddy production in Samsun is mostly carried out in Bafra, Terme, Alaçam, Çarşamba, and Yakakent districts. Bafra district paddy production areas constitute 67.6% of the total paddy production areas of Samsun Province and approximately 14.9% of Türkiye's total paddy production (Turkstat, 2022).

Bafra district is essential in terms of both agricultural production and commercials. In the Bafra district, there are 13 paddy mills, the Chamber of Agriculture, Grain Producers and Paddy Producers Union, 35 pesticide dealers and seed dealers, and 36 machine-equipment dealers. Also, Ondokuz Mayıs University Faculty of Agriculture, Black Sea Agricultural Research Institute, Samsun Metropolitan Municipality Rural Services Department, and the Rural Development Agency implement projects and research in the region. Eventually, the Bafra district was selected as a research area since it can represent the entire Samsun province and other actors related to the paddy sector (Figure 1).

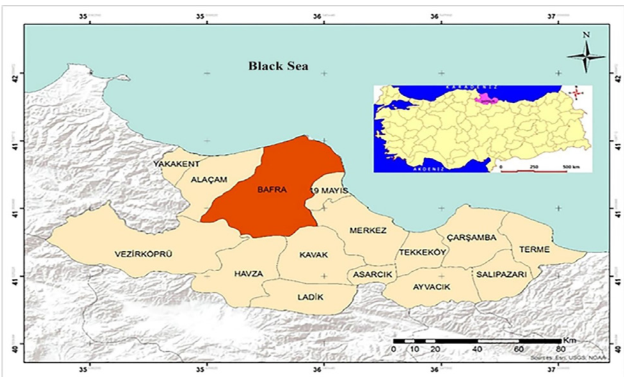

Figure 1. The research area: the map of Bafra district of Samsun province

Materials

The study's primary material is the data obtained through questionnaires and interviews with paddy farmers, farmer organizations, rice mills, pesticide dealers, seed dealers, researchers, scholars, and agricultural consultants in the Bafra district of Samsun province. Also, the data were enriched and commented on with group discussions with the stakeholders and observations. Previous studies, institutions and organizations' databases, and statistical reports were also used. The data were collected from the production period of 2017 years.

The simple random sampling method was used to determine the paddy farmers to survey (Yamane, 1967). A questionnaire was conducted with 70 farmers determined within a 10% margin of error and a 90 % confidence interval through sampling from 1798 paddy farmers that constituted the main population. In-depth interviews were conducted with three farmer organizations, eight rice mills, seven pesticide dealers, three seed dealers, two researchers, three scholars, and three agricultural consultants who agreed to participate in the study. The snowball sample technique was also used to define the advice sources and important actors from interviews with farmers and other stakeholders.

Methods

The average, frequency, and ratio statistics were performed for the paddy farmers' socioeconomic characteristics using R Statistical Software. In the research, the use of new certified paddy seeds, advanced new tools, and machinery, the seedling method in paddy farming, applying new approaches in marketing, adoption of sustainable agricultural, soil analysis, risk management practices, and participating in on-site training activities were recognized as agricultural innovations. We analyzed the diffusion process of agricultural innovations in the paddy sector and the visualization of relations by Social Network Analysis concepts. The NodeXL package program was used for SNA analysis. The analyses were conducted in a three-layer network model. The first layer (farmer layer) identified the leader farmers from whom farmers obtain advice on agricultural innovations and reveal how diffusion processes of innovation occur among farmers. For this purpose, three different relational questions were asked to the farmers: i) Which farmers do you get advice from? ii) Who are the people or institutions that you get advice about paddy in the Bafra district? iii) Who are the people or institutions where you get advice about paddy in Türkiye? A relational network database was created with the answers received. The network was named the Farmer-to-Farmer Innovation Advice (FFIA) network. This network included paddy farmers who were interviewed only within the scope of the research and other farmers with whom these farmers were in contact concerning innovations (Lin et al., 2021).

In the second layer, the Local Innovation Advice Network (LIAN) was created to reveal the diffusion process of innovations and identify influential actors in the Bafra district locally. The LIAN included the input providers (fertilizers, pesticides, seeds, so forth), processors and marketing agents (factories, intermediaries, paddy mills), and the organizations that technically support the paddy sector (universities, research institutes, public extension services), and farmers. The representatives of the institutions were asked the question of who is influential in the diffusion processes of agricultural innovations related to paddy in the research region (local layer) and throughout Türkiye (national level).

The third layer determined the influential actors in the diffusion processes of paddy-related innovations throughout Türkiye. The data used in creating the third layer were obtained from the actors interviewed in the first and second layers, and the created network was named Paddy Innovation Advice Network (PIAN). The direction of the relations in the networks created in all three layers showed the consulted or advised actors or leader farmers. The circle size showed the importance of the actors, and the distances between actors were not taken into account in all three layers.

Eigenvector centrality is an SNA method that measures the influence of an actor in a social network. An actor with high eigenvector centrality is an important actor in the network (Scott, 2011; de Nooy et al., 2018). Eigenvector centrality scores were used to determine the leadership roles of the FFIA actors. According to the eigenvector values, the actors in the network were divided into four groups by Hierarchical Clustering Analysis. The factors influencing the leadership role of actors were analyzed using the Ordinal Logistic Regression Model (OLR), one of the nonparametric analysis methods. OLR analysis was carried out to determine the factors that affect being a source of advice.

The OLR was used because the dependent variable (Y) had more than two categories. The general representation of the OLR model is as follows (Eq.1).

$$Ln\,(Y_j) = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n \qquad \text{(Eq.1)}$$

On the left side of equation (1), *Ln(Yj)* is the dependent variable; on the right side of the equation, αj is the coefficient of the equation, βi is the coefficient of the predictor variables, and Xi is the predictor variable. The fourth category was accepted as the reference category in interpreting the model's coefficients.

RESULTS

The socio-economic and farming characteristics of paddy farmers

The average age and agricultural experience of the paddy farmers were 52.6 and 30.7 years, respectively. Considering that those between the ages of 18 and 40 are considered young farmers, it could be said that the farmers' age was relatively high. The farmers' average

Table 1. The socio-economic characteristics of paddy farmers

The socio-economic characteristics	Count	Average	Std. deviation
Age (year)	70	52.6	10.3
Agricultural experience (year)	70	30.7	12.9
Year of formal education	70	6.6	2.5
Household size	70	4.7	2.8
The number of women working on the farm	38	1.5	0.8
The number of men working on the farm	70	1.7	1.4
The number of agricultural organizations	70	3.4	1.1

Table 2. Farm characteristics of paddy farmers

Farm characteristics	Count	Mean	Std. deviation
Land size (ha)	70	11.4	13.9
Animal presence (LSU)	53	19.7	40.7
Paddy production area (ha)	70	8.1	10.1
GAP paddy production area (ha)	30	14.7	12.5
Labor requirements per unit area (person/ha)	70	6.0	5.0

formal schooling or education was 6.6 years (Table 1).

The household size contributes positively to farms, enabling farmers to obtain the labor force and meet farm work from the family. The household size of the paddy farmers consisted of an average of 4.7 people. An average of 1.7 of the male population in the family work on the farm, and women participate in agricultural activities on 54.3% of the farms. The average household size of paddy farmers (4.7 people) was more than the average household size (3.4 people) in Türkiye (Turkstat, 2020). Additionally, each paddy farmer was a member of at least one agricultural producer organization and an average of three agricultural producer organizations.

The study calculated that the farmers' average land size was 11.4 hectares, more than the land size (6.0 ha) per farmer in Türkiye (Table 2). The farmers' average paddy land amount was calculated as 8.1 hectares, and the average land size of farmers who practiced good agricultural practices (GAP) was 14.7 hectares. Six workers per hectare were needed for rice cultivation. Farmers' animal assets were converted into a livestock unit (LSU) to ensure homogeneity in comparison. The majority of the farmers (75.7%) had animals and an average of 19.7 LSU animals per farm.

Half of the farmers had another income source other than agricultural activity. As 71.4% of these farmers earned a wage income (active wage employee, retired, and so forth), 28.6% had commercial activities. The majority of

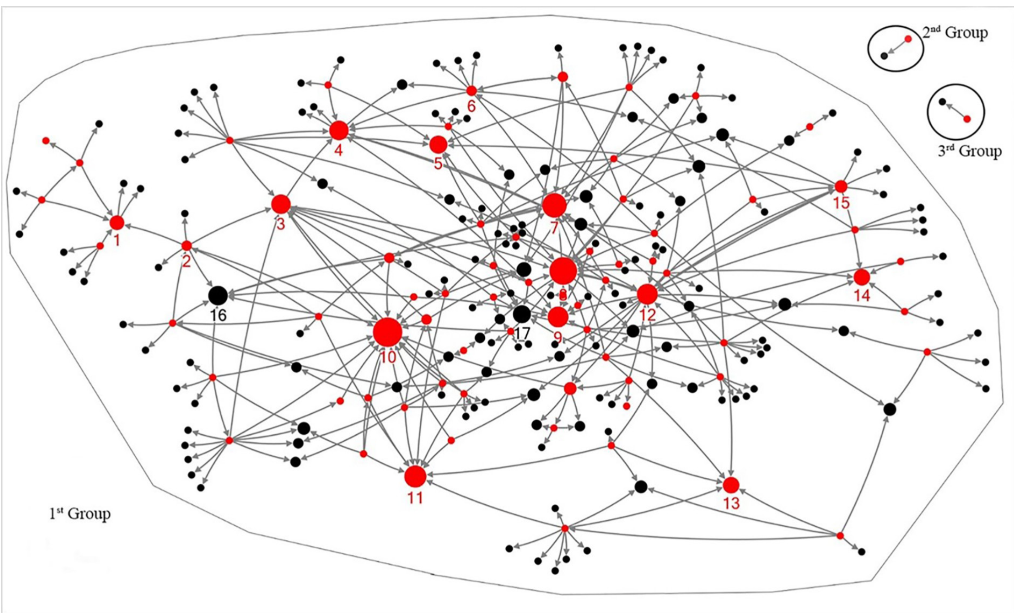

Figure 2. The model of farmer-to-farmer innovation advice network

paddy farmers (97.1%) had social security. 34.3% of the farmers carried out commercial livestock activities in the study. While more than half of the farmers (55.7%) had a soil analysis done, those applying risk management practices such as insurance and product diversification (42.9%) were lower. It can be said that participation in locally organized on-site training activities was high (61.4%) in the research area.

The Diffusion Process of Agricultural Innovations in Networks

Farmer-to-Farmer Innovation Advice (FFIA) Network

In Figure 2, the red-colored circles represented the interviewed farmers, and the black circles represented the farmers' advice sources. The FFIA network had 228 paddy farmers. The number of relations (edges) between these farmers in the network was 338. Also, the network has three separate groups (components) in the network, independent of 224 farmers with the highest number of farmers among these groups and two farmers in the group with the fewest farmers. In other words, most of the farmers in the network were in contact with each other. The distance between farmers in the network was determined as nine steps at most. The average distance in the network was 4.4 steps, and this meant that a farmer could reach any advice source after 4.4 steps (farmer). The density of the network was calculated as 0.0591. This means that only 5.9% of the relationships had the potential to be established in the network setup. The average in-degree score was calculated as 3. In other words, any farmer in the network consulted with an average of 3 different farmers about innovations.

In the FFIA network, some farmers were advice sources for other farmers. These farmers are shown in the network (Figure 2) as bigger than the others and were named with numbers and called leader farmers. The main characteristics of these leader farmers (Table 3) were that they engaged in other agricultural or non-agricultural activities and paddy cultivation in extensive lands (average 2.1 ha). Farmers 2 and farmer 7 worked as managers in agricultural farmer organizations and professional associations in the region, while farmer 1

Table 3. Some characteristics of the leader farmers

Actor Nu.	Properties
1	Retired senior manager
2	Beet Cooperative President, large-land farmer
3	Large-land farmer, a farmer who first tried paddy seedlings
4	Large-land farmer, a young entrepreneur
5	Large-land farmer, cattle breeder
6	Large-land farmer, fuel dealer
7	Large-land farmer, former president of the Bafra Chamber of Agriculture
8	Large-land farmer, Tractor dealer
9	Large-land farmers, agricultural products marketing company owner
10	Large-land farmers, agricultural products, and fertilizer dealer
11	Retired from the municipality, owner of the laser leveling system
12	Combine harvester and livestock owner
13	Organic farmer, former MP, rancher
14	Buffalo and cattle ranch owner
15	Rancher

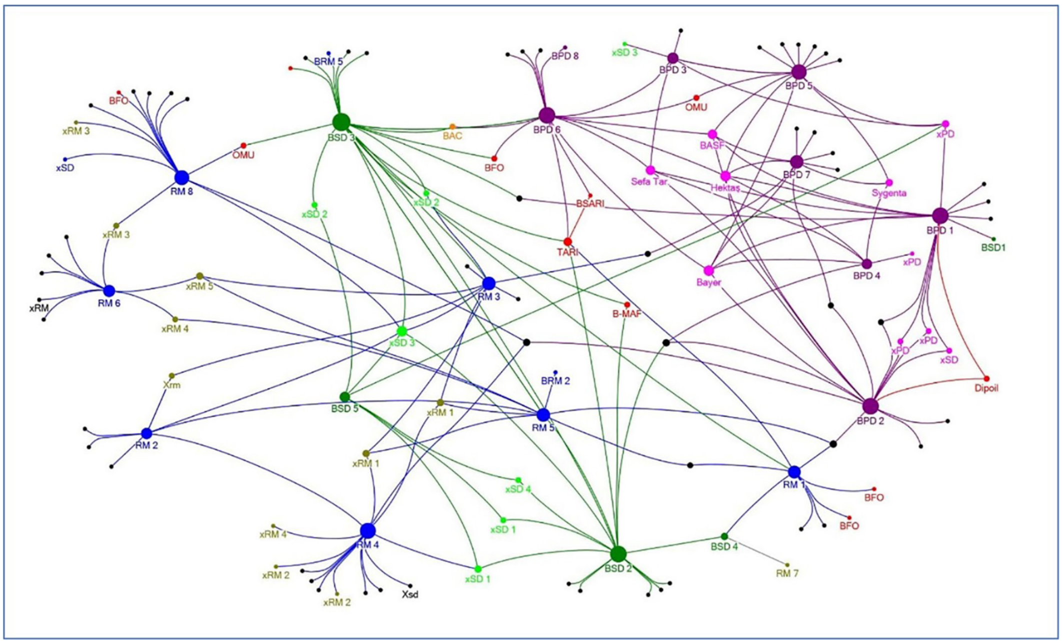

Figure 3. The actors in the local innovation advice network

had senior management experience in the private sector.

Similarly, farmers 5, 12, 13, 14, and 15 were engaged in professional cattle breeding besides paddy farming. Remarkably, the farmers in this group (5, 12, 13, 14, and 15) consisted of extended families and all family members worked in everyday agricultural activities. Farmers 3, 4, 8, and 10 were the first farmers to make seedlings, a new technique in paddy cultivation, on a large scale in Bafra. Of the other leader farmers, farmer 6 was petrol dealer, and farmers 9 and 10 owned companies selling agricultural inputs and products and paddy cultivation. The farmers 16 and 17, were the elected village headmen.

Local Innovation Advice Networks (LIAN)

In the LIAN (Figure 3), each sector and geographical area were represented differently. Blue circles symbolized rice mills (RM), green circles symbolized seed dealers (SD), purple circles symbolized pesticide dealers (PD), black circles symbolized farmers and red circles symbolized the experts working in public institutions in the Bafra district. Also, the lighter tone of each color indicated the actors outside the Bafra district.

The LIAN network has 125 actors, and the number of relations between these actors was 181. All actors in the network had a relationship, even if indirectly. The distance between actors in the network was determined as eight steps at most, an average of 3.9 steps, and it means that an actor who wanted to reach an innovation advice source anywhere in the network could reach this after four actors. The network density was calculated as 0.024. The average network degree was 2.9. It can be said that the actors in the network consulted with an average of 3 different actors regarding innovations. The LIAN was analyzed for the gatekeeper (broker) roles, and the results indicated that no gatekeeper could control the diffusion of innovations through the network. However, it could be said that the seed dealers (SD) and pesticide dealers (BPD) were closest to the gatekeeper role.

Paddy Innovation Advice Network (PIAN)

In the PIAN (Figure 4), each actor was represented with a different color and abbreviation, and the meanings of these signs representing the actors are given in Table 4. The PIAN network has 353 actors, and the number of relationships between these actors was 843. All actors in the network had a relationship, even if indirectly. The distance between actors in the network was determined as six steps at most, and the average distance was 3.6 steps. It could be said that an actor who wanted to reach an advisor anywhere in the network could reach this advisor after 3.6 actors. The network density was calculated as 0.016, it meant that only 1.6% of the potential relationships were established in the network. The average degree of the actors was calculated as 2.3.

In Figure 4, it was identified that the gatekeeper structure that could fully control the diffusion of innovation between the actors was absent. However, in the PIAN, the most influential actors in the diffusion of innovations were public institutions (BMAF), farmer organizations (BPO), pesticide dealers (PD), seed dealers (BSD), rice mills (BRM), and leader paddy farmers.

The factors influencing the leadership role of actors

The results of the goodness of fit test (Hosmer and Lemeshow test) indicated that the variables included

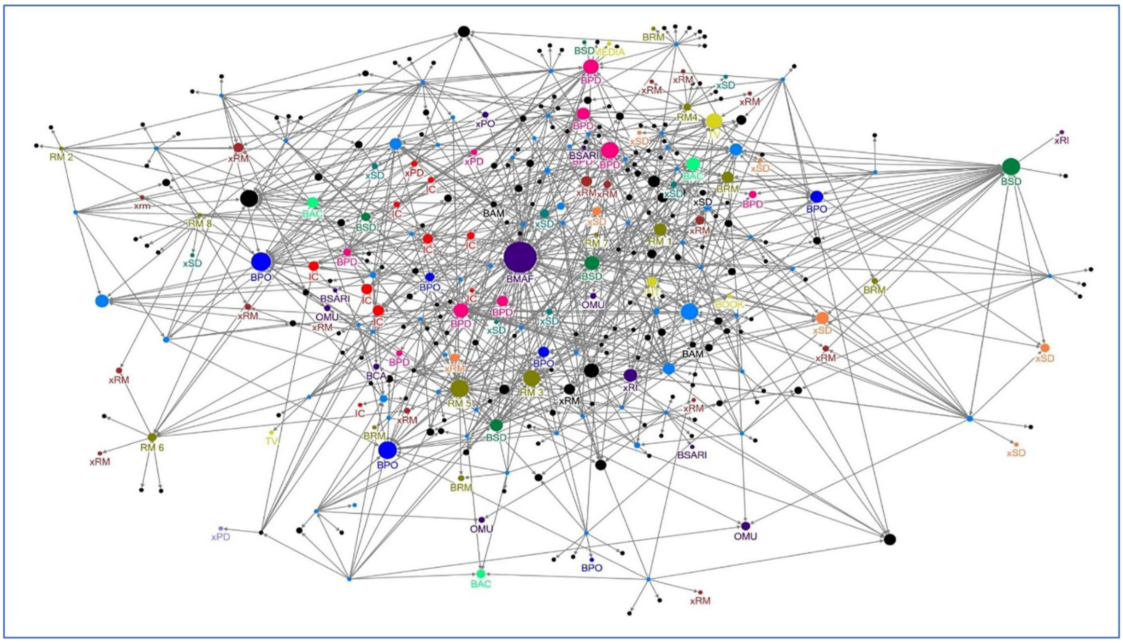

Figure 4. Paddy innovation advice network

Table 4. The meanings of the signs and abbreviations in the paddy innovation network

Signs and abbreviations	Meanings
● BMAF, OMU, TARI, and BSARI	Public institutions
● BPO	Farmer organizations
●	Interviewed paddy farmers
● BRM	Rice mills in Bafra district
● TSD	Seed dealers in the Thrace region (West of Türkiye)
● BPD	Pesticide dealers in Bafra district
● BSD	Seed dealers in Bafra district
● TV, Media, Lit.	Visual and printed media
● IC	National and international companies
● xRM	Rice mills in provinces outside the region
● xPD	Pesticide dealers in provinces outside the region
● xSD	Seed dealers in provinces outside the region
●	Other actors who were not interviewed but were in the system

Table 5. Results of the ordinal logistic regression model

Predictor variables	Coeff. (β_j)	SE.	Wald	Sig.	Exp(β_j)
Age (year)	0.002	0.033	0.071	0.943	
Year of formal education	-0.836	0.446	-1.875	0.061*	0.4
Household size	0.119	0.119	1.003	0.316	
Agricultural experience (year)	-0.020	0.023	-0.881	0.378	
The number of membership in agricultural organizations	0.404	0.179	2.255	0.024**	1.5
The number of demonstrations and training attended	0.970	1.271	0.764	0.445	
Cooperation score (collective action)	2.607	1.073	2.429	0.015**	13.6
Social status (being selected head)	2.446	0.852	2.871	0.004**	11.5
The number of projects involved	1.360	0.731	1.859	0.063*	3.9

, **, * significant at 10%, 5%, and 1%, respectively*

in the model were in fit with the model ($p<0.05$). To the Nagelkerke R^2, the independent variables predicted 41.7% of the dependent variable changes and the model results are given in Table 5. Age, household size, agricultural experience, number of demonstrations, and education variables did not differ according to the groups ($p>0.05$). However, there were statistically significant differences among the groups and the predictor variables, the number of memberships in agricultural organizations ($p<0.05$), cooperation score ($p<0.05$), the social status ($p<0.05$), formal education year ($p<0.10$), and the project experience ($p<0.10$).

To the results, a high cooperation score increased the probability of farmers as a being consulted actor by 13.6 times. The increase in the social status of the farmers increased the probability of being as a consulted actor by 11.5 times. The increase in the agricultural project experience of the farmers increased the probability of being as a consulted actor by 3.9 times. As an increase in the number of agricultural producer organizations that farmers were members of, the probability of being as a consulted actor increased 1.5 times. The increase in the education period of the farmers increased the probability of being as a consulted actor 0.4 times.

DISCUSSION

Most previous studies on agricultural innovation networks have focused on relationships in the individual or institutional layer separately (Wu and Zhang, 2013; Skaalsveen et al., 2020). However, it may be more appropriate to examine all relationships in the network in layers and focus on transitions between layers. Focusing on the diffusion processes of agricultural innovations in the paddy sector, this study differs from others in examining network layers.

In the farmer-level network, the farmers have large kinship networks and have relationships with other farmers increasing the possibilities of reaching innovation sources outside their social networks. Van den Broeck and Dercon (2011) found that farmers can rely on social networks for agricultural information, and Kroma (2006) stated that farmers could rely on other farmers. Weyori et al. (2018) emphasized that leader farmers were the shortest way to disseminate information in agricultural innovation systems. In the study, it was determined that some farmers facilitated the diffusion of agricultural innovations among farmers. The research findings supported the results of previous studies, so it could be concluded that using leader farmers in extension programs would increase the effectiveness of dissemination in the paddy sector.

In the literature, innovation agents or brokers were defined as individuals or organizations that played a catalytic role in bringing together different actors and facilitating the interactions that lead to the development of innovations (Klerkx et al., 2009). Innovation brokers are located close to farmers, regional public institutions, and private R&D institutions in the network, thereby facilitating the diffusion of innovation (Madureira et al., 2019). In the local layer in the study, the pesticide dealers (PD) were the innovation brokers. The position of pesticide dealers in the network could be interpreted as accelerating the network's information transfer. Most of the pesticide dealers in the research area were local companies and were the dealers of large national/international companies. Thus, the arrival of a national or international innovation to the local speeding up.

Perhaps one of the most critical outputs of this study was that it revealed how the farmers, who were the advice source, came to this position. Actors central in referral networks provide significant opportunities for other actors in the network to implement new ideas and disseminate innovations (Battke et al., 2016; Guan et al., 2016; Brennecke ve Stoemmer, 2018; Tang et al., 2020). According to the research findings, farmers who cooperate have high social status, have more project experience, and participate in agricultural organizations are more likely to be a source of advice Gulati and Srivastava (2014) state that advice resources provide other actors in the network with tangible and intangible resources needed for innovation and psychological trust. Once the research findings are evaluated in this context, it can be concluded that farmers with high social status provide psychological trust to other farmers because actors with high social status are assumed to have more information about agricultural innovations due to their connections. In addition, Emerick and Dar (2021) found that field trials would be one of the most suitable options for poor farmers to reach innovations due to it is economical. Once the research results are combined with the findings of previous studies, it can be concluded that the farmers participating in field trials and making trial production with new agricultural technologies would be more likely to a more central position in the networks.

According to the research findings, cooperating farmers are more likely to be a source of advice for other farmers. The cooperation between small farmers comes to the fore with its risk-sharing and welfare-enhancing features (Colombo and Perujo- Villanueva, 2017; Wardhana et al., 2020). Vissers and Dankbaar (2013) emphasize that agricultural collaborations lead to complex network relationships and facilitate the diffusion of innovation through information exchange. The findings of previous studies and the research results are synthesized; it can be concluded that the farmers who cooperate are accepted as a source of advice by other farmers because they may access information more quickly and not take risky actions. In the diffusion process of agricultural innovations, collaborative farmers can be considered accelerators.

The study and its findings were limited to the research area and the paddy industry. A similar study in another region or sector may not yield the same results. Since social relations were examined in the research, the variables influential in being a source of advice were mainly chosen from sociodemographic characteristics. In future studies, farmers' financial indicators can be added to the model along with sociodemographic characteristics. Another limitation of the study was the determination of the common characteristics of the consulted farmers. Future studies can also focus on the typical characteristics of intermediaries and accelerators in layers outside the farmer network (regional, national, international, so forth).

CONCLUSION

The study analyzed the diffusion of agricultural innovation processes, identified influential actors in the paddy sector in a three-layered network, and indicated how agricultural innovations could be delivered to farmers fastest and in the shortest way.

The results indicated that agricultural innovations in the paddy sector first diffused within layers in social networks and that sources of advice supported diffusion processes across layers. It was concluded that the sources of advice had two roles in the social network. Their primary role is to ensure that farmers are aware of innovations by carrying the information from the innovation source from top to bottom between layers and acting as an accelerator for farmers to adopt innovations. The second role of advice sources is to provide feedback on bottom-up innovations. According to the research results, three different sources of advice emerge. The sources of advice at the outermost periphery of the social network are representatives of international companies and paddy seed breeder researchers. The representatives of international companies connect with input providers at the middle periphery of the network, whereas seed breeder researchers establish two-way connections with both local input providers and consultant farmers. In the middle periphery of the network, pesticide dealers and seed sellers act as a source of advice. Significantly, local pesticide dealers are the intermediary positions among farmers (innermost periphery) and the national network (outermost periphery). The local pesticide dealers deliver the information or technology they received from innovation creators to farmers through the leader farmers. The local pesticide dealers have remarkable two-way roles in the network. The correct delivery of the requests from farmers to the innovation creators (and vice versa) depends on the local pesticide dealers' desire, responsibility, or communication skills. Thus, the local pesticide dealers' positions may pose a barrier to transferring information or innovations in the network. They can prevent the transfer of technology that would be newly introduced to the network for various reasons such as commercial concerns and higher commission payments by other companies.

Some farmers acknowledged the other farmers as a source of advice. The study concluded that an increase in the social and human capital of the farmers increased the probability of being a source of advice. Although it is a standard to start from leader farmers in programs to disseminate agriculture innovation, this method is open to discussion. Like leaders, farmers have more social relationships and more robust capital structures than others; their capacity to take risks is also more remarkable. They usually find the opportunity to reach the innovation aimed to be disseminated. Here, while farmers in the leader farmer's network achieve innovations quickly, the question of how farmers outside the leader farmer's network reached innovation arises. For this reason, the extension programs should include all farmers in case the farmers (isolated) might be out of the leader farmers' network and should be supported by farmer organizations and public extension services.

As a result, the study concluded that agricultural innovations could be delivered to farmers most concisely, following the ranking of innovation creators, local pesticide dealers, and leader farmers. Finally, this study positively contributes to the methodology and agricultural extension literature by proving that social network analysis could help identify influential actors and their roles in the diffusion process of agricultural innovations.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

This manuscript was produced from the doctoral dissertation entitled 'Agricultural Innovation Systems and Cooperation Networks: A Case Study from the Paddy Sector in Samsun Province of Turkey,' prepared by Mehmet AYDOĞAN at the Institute of Science, Ondokuz Mayıs University, under the supervision of Prof. Dr. Kürşat Demiryürek. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original.

Ethical approval

This article does not contain any studies with human or animal subjects. Ethics committee approval is not required

Funding

This work was supported by the Ondokuz Mayıs University Scientific Research Projects Fund under Grant number PYO. ZRT.1904.15.021.

Data availability

Not applicable.

Consent for publication

Not applicable.

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