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Social Network Analysis of Farmers after the Private Cooperatives' "Intervention" in a Rural Area of China—A Case Study of the XiangX Cooperative in Shandong Province

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Abstract: In China, private-owned cooperatives are becoming increasingly involved in agricultural production. In order to find the key characteristics of smallholders' social networks after the appearance of cooperatives and better organize different farmland operators, this study completed a field survey of 114 smallholders who adopted farmland trusteeship service of a private-owned cooperative in China and applied the social network analysis to reveal the following results. (1) Compared to the theoretical ideal value, smallholders' social networks showed low network density, efficiency, and little relevancy. (2) In the social network of mechanical-sharing, neighbor, kinship, and labor-sharing relationships, some isolated nodes existed, but no isolated nodes are found in the synthetic network. (3) The mechanical-sharing relationship among smallholders was stronger than the other relationships. (4) Machinery owners, farmers whose plots are on the geometric center and experienced older farmers showed higher centralities in the network, but village cadres did not. (5) The centralities and QAP correlation coefficients among different networks inside the cooperative were lower than that inside a single village. As a result, this paper confirmed that the ability of cooperatives to organize farmers' social networks is not ideal. Farmers' trust of farmland to a cross-village cooperatives does not help them to form a larger social network than their villages. In the future, the answer to the question of "who will farm the land" will still lie with the professional farmers and highly autonomous cooperatives.

Keywords: private-owned cooperative; transformation of rural community; social network analysis; farmland trusteeship service; smallholders

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1. Introduction

The Professional Farmers' Cooperative is an organization of smallholders, which realizes members' mutual assistance by providing marketing, processing, transportation, and storage of agricultural products, as well as technical and information services related to agricultural production and operation [1]. The cooperative system has long existed around the world. In 1844, in response to retail operations, textile workers in England established the world's first cooperative in the town of Rochdale [2]. After the formation of the International Cooperative Alliance in 1895, the development of the global cooperative movement was strongly encouraged [3]. Over decades of development, cooperatives in Europe and the United States evolved into mature organizations with deep agricultural commercialization, large-scale individual organization, and sound institutional protection [4,5]. Highly evolved cooperatives have valuable implications for China in terms of government support, policy protection, and innovative development [6].

The evolution of the professional farmer cooperative system in China has been a long historical process [7]. For many years, smallholders in China faced problems such as low

production efficiency, poor organizational capacity, etc. [8]. The organization of smallholders is based, fundamentally, on villages [9], but villages have limited capabilities for organizing the agricultural production of smallholders. To feed the large native population, the Chinese government has been devoted to the primary problem of organizing small farmers to enable efficient agricultural production. As early as the 1980s, the Chinese government introduced the household contract responsibility system [10,11], which resolved the problem of food self-sufficiency and poverty among smallholders. Following reforms and the opening of the country, China's agricultural production changed from a situation of chronic shortage to a balanced total quantity with sometimes surplus crops [12,13]. However, problems such as the structural surpluses of farmers' agricultural products and the slow growth of farmers' income emerged. Accordingly, the professional farmer cooperative emerged. Since the 21st century, the Party Central Committee and the State Council attach great importance to the development of cooperatives. Over the years, the "No. 1 central documents" have proposed support for the development of cooperatives. The report of the 20th Congress of the Communist Party of China emphasized "consolidating and perfecting the basic rural management system, developing a new type of rural collective economy, and developing new agricultural business entities and social services" as the important initiatives for rural revitalization [14]. Under "Big Country, Small Farmers" [15], the professional farmer cooperative system was a new type of agricultural business entity and a new way of organizing the rural collective economy, becoming a fundamental carrier for farmers' joint operations [16,17]. As a result, the number of cooperatives in China has grown rapidly from 689,000 in 2012 to 2,243,600 in 2022, and they have made an important contribution to large-scale farmland production [18].

One of the most common forms of cooperation between cooperatives and smallholders is farmland trusteeship, which means after the smallholders transfer their arable land to the cooperative, the cooperative will take charge of all production processes [19] and pay land rent and a bonus to smallholders. After being disconnected with agricultural production, the smallholders can spare more time to seek non-farm incomes in towns or cities, which is beneficial to rural families' well-being [20]. At present, researchers have carried out some studies on cooperative and smallholders. In terms of factors affecting the smallholders' farmland trusteeship service, it was found that social capital, information services disseminated by neighbors, relatives, and friends have a positive impact on farmland trusteeship [21], while younger age of the family as well as higher non-farm income will have a negative impact on the smallholders' farmland trusteeship [22]. When researching the dilemmas of farmland trusteeship, most studies focus on the problem of coordinating the interests of smallholders and cooperatives [23,24], the insufficient legal protection system of trusteeship, and the emergence of composite fragmentation of farmland trusteeship [25–27]. Previous research has provided valuable insights to observe cooperatives, but some questions of smallholders' social networks after the appearance of a cooperative are still unknown as follows.

In "acquaintance society" in rural China [28], the information dissemination and exchange among farmers is rapid [29]. Cooperatives can be seen as small social networks that can connect smallholders [30]. In the social network of a cooperative, farmers can share information and co-produce through their connection with the cooperative, which can help them obtain more contacts outside of their villages [31]. However, because the private-owned cooperatives are profit-driven, it is uncertain if the smallholders are "pushed out" of the social network. Moreover, because smallholders will separate from agricultural production after farmland trusteeship, whether smallholders become isolated in rural social networks is full of uncertainty [32]. In addition, because villages have played important roles in organizing rural smallholders for a long time in China [33,34], whether private-owned cooperatives can perform better than an administrative village when organizing smallholders' social networks is a matter of concern. This paper raises the following questions:

1. After placing farm land in a trust with the cooperative, what will the smallholders' social networks look like?
2. Will the cooperative help to form a lager smallholders' social network than villages?
3. Are there influential or isolated smallholders in the social network?

In order to answer these questions, this paper did a case analysis to quantify the structural characteristics of the social network based on the field investigation of a cooperative and farmers, so as to find the optimization path of the new model of arable land utilization in the future. The research in this paper can help to find the answer to "who will farm the land", especially in a country of rapid economic growth and a mass of farmers flocking to non-farm jobs.

2. Theoretical Foundation and Hypotheses

Social network refers to the relatively stable relationship system formed by the interaction between individual members of society [35]. It is a social structure composed of many nodes: nodes usually refer to individuals or organizations, and social networks represent various social relations through which various people or organizations are connected. Social relations often include friendship, classmate relationships, business partnerships, race faith relationships and so on [36]. After firstly being proposed by Brown in 1940 [37], the social network theory has developed into a variety of branches, including structural hole theory, social capital theory, strong and weak relationship theory, etc., and is widely used in the research of enterprises, cities, individuals, and other objects [38–41]. Since the social connection of rural life and production often occurs among individual smallholders [42], this method is suitable for the quantitative analysis of farmer's social networks in this paper.

According to the branch of social network theory, "structural hole" theory was proposed by Ronald Bott [38]: for three nodes A, B, and C, if A is connected to B, and A is also connected to C, but there is no connection between B and C, then there is a structural hole between B and C. When looking at smallholders' social networks, we can also find this (Figure 1). For instance, in the neighbor relationship, two structural holes exist: A and C, B and D. However, when there are enough relationship types, most of the structural holes may be "covered". If A and C have no connection in one relationship, but they have connection in another relationship, then in the synthetic social network, A and C showed no structural hole [43]. As a result, in the comprehensive social network formed by various relationships of kinship, neighbor and machinery sharing, etc., among smallholders, it is highly possible that there is no structural hole. In other words, in a complex social network of multiple relationships, it is very likely that no isolated node exists. Then, Hypothesis 1 is proposed:

H1: *Though isolated nodes exist in single networks, there are no isolated nodes in the comprehensive social network of the smallholders.*

The theory of social network structure emphasizes the understanding of the position and role of individuals in society from the relationship between it and others [44]. In this process, power, material, information, and other resources will be embedded in the social network and obtained through the relationship between individuals [45]. The more social capital a person has, the more "interest exchanges" will happen between him and others, and finally help him play a "central" role in the network [46]. As a result, the "central" nodes will show more links with other nodes, like A in the kinship network of Figure 1. In smallholders' social networks, because different people hold different types of capital, some special smallholders will show higher influence in different kinds of networks. For instance, older farmers have reach planting experience, and others are more likely to study planting technologies with them. As a result, older farmers may show prominent influence of sharing technical information with other farmers during the agro-production [47]. Secondly, rural officials hold political power and more opportunities

of information exchange with the upper government, thus more individuals tend come to them to obtain policy-oriented information or to seek opportunities to gain a greater distribution of benefits [48]. As a result, rural officials may show a central role in the smallholders' network. Thirdly, machinery owners are the main supplier of short-term rental of machinery during the harvest season, which easily help them to draw links with other smallholders who do not have machines [47]. As a result, smallholders with the above advantage of social capital will become central nodes in the network and have more links with others. Hypothesis 2 is proposed:

H2: *Machine owners, village officials and experienced elders will become central nodes in the network and show higher centralities in smallholders' social networks.*

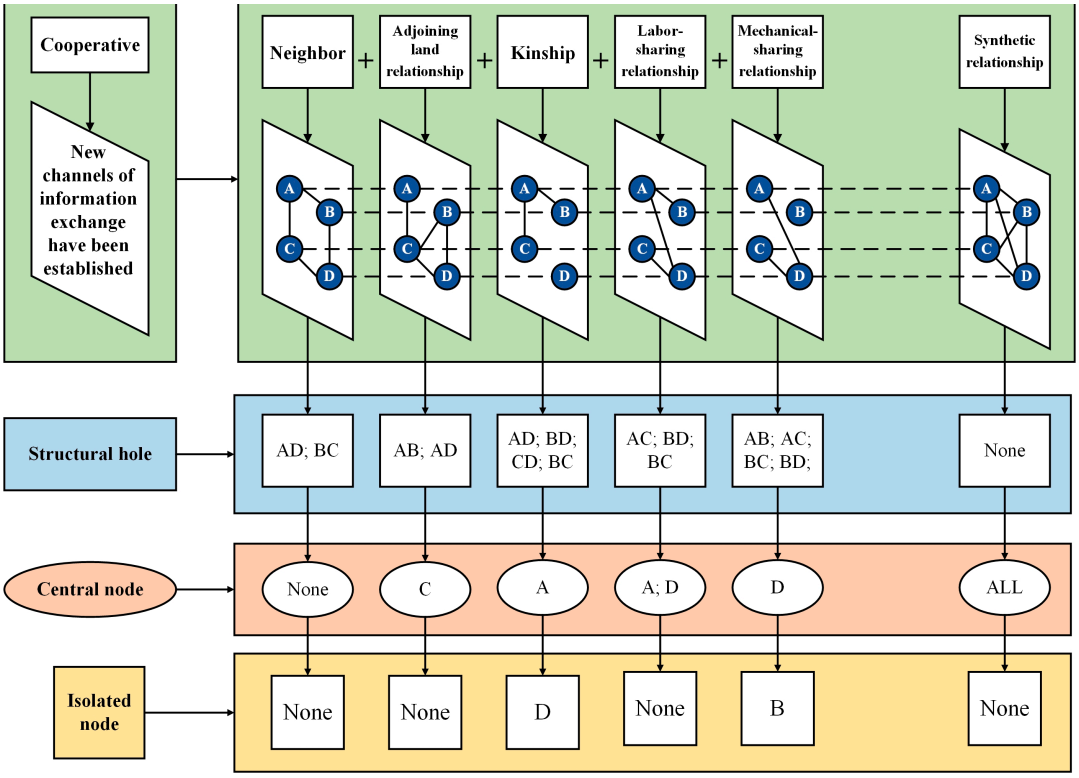

Figure 1. Schematic diagram of theoretical relationship of structural holes. Note: In the figure, A, B, C, D represents nodes respectively.

"Structure of Grade" is a social network theory of China localization proposed by Chinese sociologist Fei Xiaotong [49]. He thinks that in traditional Chinese society, the social network formed by each individual is made up of social relationships such as kinship and geographic ties, and the strength of the relationships vary according to the proximity of random individuals. Due to many factors such as historical accumulation and heterogeneity of households, their impacts are different within administrative villages and inter-village cooperatives. The theory of "Structure of Grade" is highly applicable to Chinese rural society [50], because the villages are acquaintance societies established through clans, bloodlines, religious belief, geographical proximity, and similar production patterns [51,52]. After adopting the farmland trusteeship service, on the one hand, smallholders will make the acquaintance of more people in the cooperative, and they will share information and technology, which leads to the expansion of the smallholders' social network. On the other hand, smallholders who adopt farmland trusteeship service will spare more time to do non-farm work or seek new ways to make a living in cities [53], which may increase the spatial distance between smallholders and establish a larger social network than a

village, a cooperative, or a city like in Figure 2 [54]. This kind of social network may be completely different from the characteristics of traditional Chinese villages, because the contact between residents in traditional Chinese villages is often confined to the village. Then, Hypothesis 3 is proposed:

H3: *The cross-village social network among these smallholders will be stronger than that within a single village.*

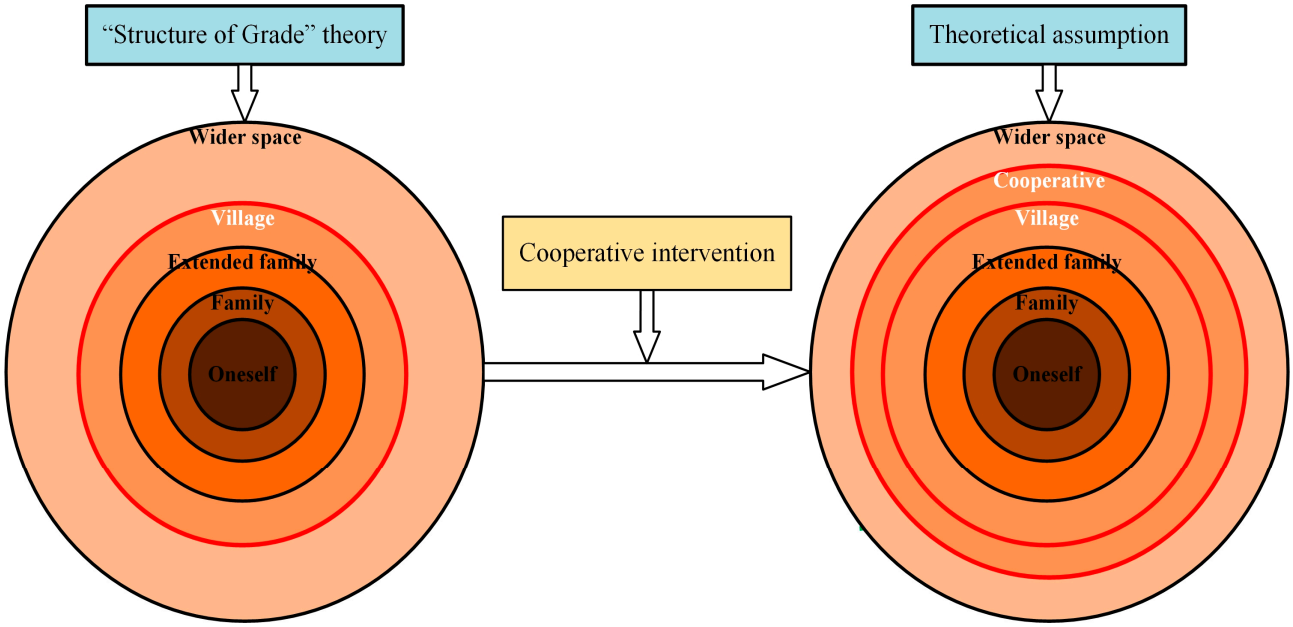

Figure 2. "Structure of Grade" theory and its hypotheses. Note: Different colors represent the closeness of the network relationship, and the darker the color, the closer the network connection.

3. Study Area Overview

As of 2023, there are 2.216 million cooperatives legally registered in China. Among them, the number of cooperatives in Shandong Province occupies the first place in the country, with more than 240,000. The development of cooperatives is relatively high in Shandong Province. The Xiangshi Agricultural Planting Farmer Cooperative selected in this paper is located in Gaoqing County, Zibo City, Shandong Province (Figure 3); it was established in March 2022.

The cooperative consists of 114 smallholders from the villages of Zhusihuang and Hegouzhao, including 43 smallholders from the former and 71 smallholders from the latter. More than half of the cooperative's farmers were middle-aged or elderly. Moreover, due to the limited benefits of farming, many farmers choose to do odd jobs elsewhere. The business scope of the cooperative includes cereal planting; agricultural machinery services; cereal sales; and production, sales, processing, transportation, and storage of agricultural products, and other related services. The main grain crops are corn and wheat.

The cooperative was selected for the following two reasons. First, this cooperative is a cross-village cooperative; studying it not only allows us to understand the problems that arise within the cooperative but also allows us to compare the organizational capacities of the villages and the cooperative. Second, the population above 50+ in the study area accounts for 60%. A large proportion of the labor force is aging and withdrawing, which is typical of traditional Chinese rural communities.

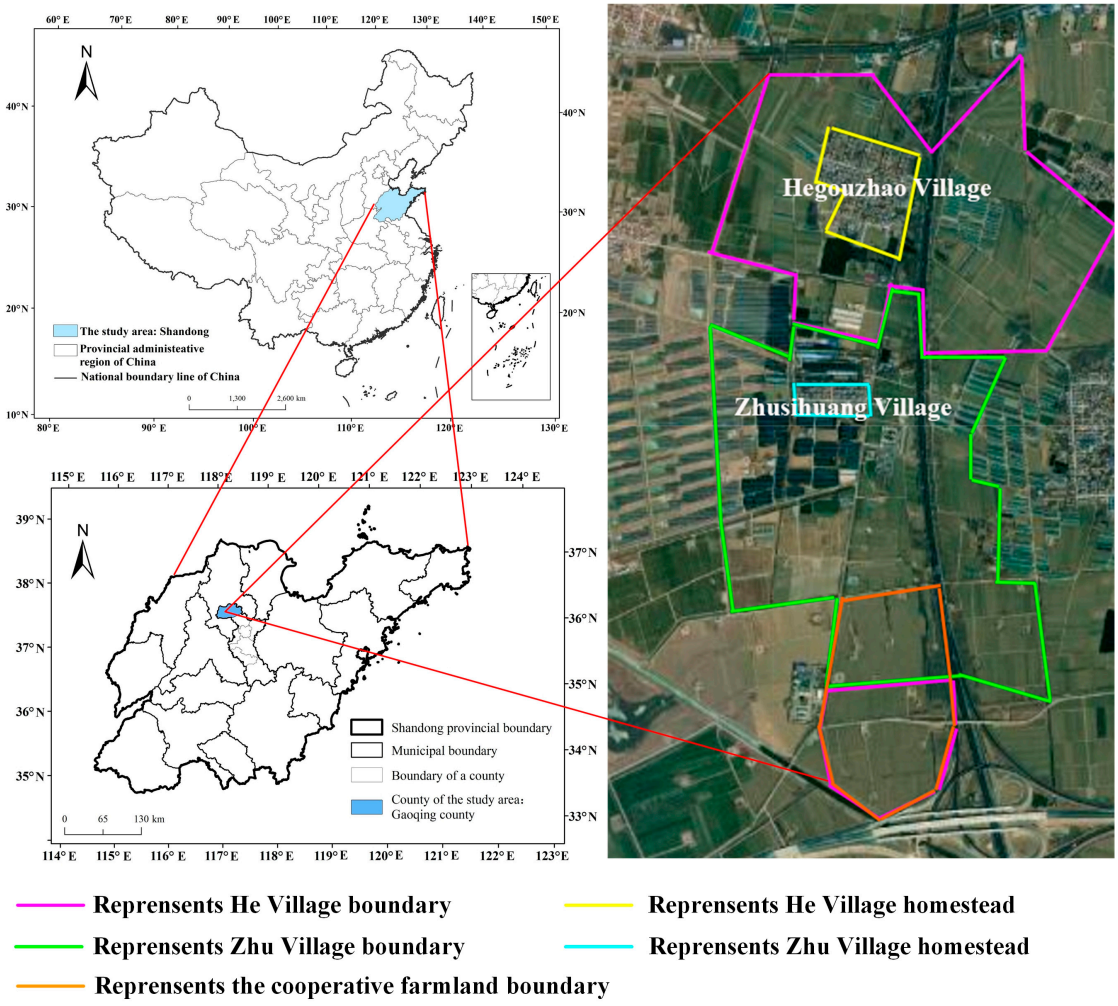

Figure 3. Research area bitmap.

4. Research Data and Methods

4.1. Research Data

The cooperative provides a full trusteeship service for the smallholders. Specifically, smallholders only need to rent their farmland to the cooperative and receive dividends based on the current year's harvest. After that, the cooperative manages the entire production chain, including sowing, irrigation, fertilizer application, sprinkling, handling, harvesting, and sales instead of the smallholders. In total, the study area has 240 households, in which 114 smallholders have adopted the farmland trusteeship service of the cooperative.

The interview of the 114 smallholders was implemented in January to February in 2022 and July to August in 2023 and included the basic situation of the smallholders who adopted the farmland trusteeship service, including the family members, age, sex, income, educational level, part-time jobs, etc. In addition, different relationships among the 114 smallholders (including the mechanical-sharing relationship, adjoining land relationship, and neighbor, kinship, and labor-sharing relationships) were recorded by the nomination method. Specifically, each interviewee was required to identify those smallholders with whom they shared a relationship. Smallholders who did not live in the village during the research period were contacted by telephone for consultation on the points above. At the same time, we conducted a second telephone survey to make sure that smallholder farmers were able to recall more farmers. SPSS 18.0 software was used to test the reliability and validity of the survey data, and the results were shown as having a reliability of 0.845 and validity of 0.806, which proved that the survey results were reliable.

Through the investigation, it was found that, firstly, elderly farmers were the main farmers in the study area, followed by middle-aged farmers, and few young farmers, with an average age of 52. Secondly, most of the interviewees were women, because most of the men worked outside the home during the survey period, but households are dominated by men. Thirdly, the farmland occupied by the cooperative was 30.93 hm^2, the farmland in the plot had poor fertility, and the possibility of waterlogging was relatively large, so farmers were willing to trust this part of the farmland.

4.2. Construction of the Social Network among Smallholders

Social Network Analysis (SNA) is a structural analysis method that integrates graph theory or mathematical models to quantify the relationships among members of existing social networks [36,55–57]. It is already widely used in economics, sociology, and management [58–60]. This paper mainly used Ucinet 6.0 software to realize social network analysis. The basic principle of the software is to build a network by constructing a matrix and use many of the network analysis indicators to describe the social network. At the same time, we also borrowed the Netdraw tool to visualize the network [61].

To construct the social network model, this study used matrices to show different relationships among smallholders. The explanatory descriptions of the five relationships between the smallholders are shown in Table 1.

Table 1. Description of the five relationships formed by smallholders.

Name	Explanations of Relationships
Neighbor (NR)	A neighbor relationship means that the house sites of the smallholders are adjacent to each other. If smallholder i and smallholder j are neighbors of each other's house sites, then $x_{ij}(NR) = x_{ji}(NR) = 1$ in the matrix, otherwise $x_{ij}(NR) = x_{ji}(NR) = 0$.
Adjoining-land relationship (ALR)	An adjoining-land relationship means that the arable lands of the smallholders are adjacent to each other. If the arable lands of smallholder i and smallholder j are adjacent, then $x_{ij}(ALR) = x_{ji}(ALR) = 1$ in the matrix, otherwise $x_{ij}(ALR) = x_{ji}(ALR) = 0$.
Labor-sharing relationship (LSR)	A labor-sharing relationship means that the smallholder shares their labor force in farming, harvesting, and other family affairs. If smallholder i provides labor force to smallholder j, but smallholder j does not provide labor to smallholder i, then $x_{ij}(LSR) = 0$, $x_{ji}(LSR) = 1$ in the matrix. Otherwise, if smallholder i and smallholder j provide labor force to each other, then $x_{ij}(LSR) = x_{ji}(LSR) = 1$.
Kinship (KR)	If smallholder i and smallholder j are in kinship with each other, then $x_{ij}(KR) = x_{ji}(KR) = 1$ in the matrix, otherwise $x_{ij}(KR) = x_{ji}(KR) = 0$.
Mechanical-sharing relationship (MSR)	If smallholder i provides agro-machinery to smallholder j, but smallholder j does not provide agro-machinery to smallholder i, then $x_{ij}(MSR) = 0$, $x_{ji}(MSR) = 1$ in the matrix.

Taking the labor-sharing relationship as an example, the labor-sharing relationship matrix of the cooperative is an $n \times n$ matrix (n = 114, the total number of the smallholders). The elements of the matrix ($x_{ij}(LSR)$) are binary (0, 1) elements to represent the labor-sharing condition of one smallholder to another. For example, the labor-sharing relationship matrix $X(SLR)$ is denoted as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix}$$

The establishment of the remaining four relationship matrices is the same as above.

Finally, a synthetic-relationship social network (SR) was established by integrating the five relationships. For example, if $X_{ij}(KR) = 1$ in the kinship, and $X_{ij}(LSR) = 1$ in the labor-sharing relationship, but $X_{ij} = 0$ in other matrices, then $X_{ij}(SR) = 1$ across the entire

social network matrix, which means that smallholder I and j have at least one relationship in the cooperative.

4.3. Measurement of the Social Network of Smallholders

To describe the characteristics of the cooperative network and village network, this study calculated the network density (*ND*), network efficiency (*NE*), network hierarchy (*NH*), and network correlation (*NC*) in the network between cooperative smallholders [30].

The network density (*ND*) represents the number of connections that exist in a network. The closer the network density is to 1, the more connections the members have on average [62]. Assuming that there are N members in the network, the maximum number of connections in the network is theoretically N $(N-1)$. If the actual number of connections held by the members in the network is L, the network density can be expressed as

$$ND = L/N(N-1) \quad (1)$$

The network efficiency (*NE*) is a measure of redundant lines that exist in a network that make the network less stable. The closer the network efficiency is to 0, the lower the number of redundant lines in the network and the more stable the network [63]. M denotes the number of redundant lines. *NE* is calculated as follows:

$$NE = 1 - M/\max(M) \quad (2)$$

The network hierarchy (*NH*) is the asymmetric accessibility among directed network members. The closer the network level is to 1, the more hierarchical the network is, which presents the central node on the network [63]. Assuming that the number of symmetric reachable point pairs in the network is K, the *NH* can be expressed as

$$NH = 1 - K/\max(K) \quad (3)$$

The network correlation (*NC*) indicates the connectivity of nodes in a network. The closer the NC value is to 1, the fewer isolated nodes there are in the network and the better the network connectivity is [63]. If a network has N nodes, and the number of node pairs that are not reachable to each other is V, then the network correlation degree (*NC*) is expressed as follows:

$$NC = 1 - 2V/N(N-1) \quad (4)$$

To verify whether elders, officials, and machinery owners become the central nodes in the social network, we used centralities of degree, closeness, and betweenness to confirm their role in the network. The implication of centrality is as follows.

The degree centrality [64] is the most intuitive index that reflects the position where a node is located in the network. A node with a higher degree centrality has more connections to other nodes and is more prestigious within the network because of the close "ties" he/she has.

The closeness centrality [65] indicates the proximity of a node to other nodes, which is calculated by the sum of the shortest distances from a node to all other nodes in the relationship matrix [66]. In a network, when a node with a high closeness centrality has a short distance to any of the remaining nodes, the closer he/she is to the geometric center of the network.

In a cooperative network, a node can be considered important if it is necessary to pass through him/her to establish a connection with another node. This indicator of node centrality is called betweenness centrality [65], and it can reflect the ability of a node to control resources. Specifically, a node has a high degree of betweenness centrality if he/she is on the shortest path of other nodes' links.

It is worth noting that there are no theoretical extremes for the three centralities. With the increase in lines in the network, the number of lines between nodes will change, and the three kinds of centrality will also change.

The QAP (Quadratic Assignment Procedure) is a method for comparing all the values in two matrixes [67]. It gives the correlation coefficient between two matrices by comparing the corresponding lattice values of each matrix, then performing a nonparametric test on the coefficients. The QAP correlation analysis can investigate whether two matrices are correlated to each other [68,69]. In this study, the QAP correlation analysis was applied to different types of relationship matrixes to identify the potential relation among different types of relationship networks and to reflect the hidden bond of complex connections between people in a rural community, especially in rural cooperatives.

5. Results Analysis

5.1. Overall Characteristics of the Social Network of the Smallholders Who Adopted Farmland Trusteeship Services

To visualize the spatial association network, the five relationships between the smallholders were drawn using the visualization tool Netdraw in Ucinet 6.0 software (Figure 4, Appendix A) [61]. Due to space limitation, only the synthetic relationship is shown in Figure 4, and the visualization results of the remaining five single relationships are shown in Appendix A. In Figure 4, the blue nodes represent the smallholders of Hegouzhao village, and the red nodes represent the stallholders of Zhusihuang village. The lines indicate that there is a relationship between farmers, and the arrows in the figure indicate that this is a directed network. Interestingly, in this study, the synthetic social network formed two "groups", which correspond to the smallholders of the two villages (Figure 4). In other words, from the visualization of the synthetic social network, there is no intersection between the smallholders of the different administrative villages, but they are accessible within individual villages. Moreover, though some isolated nodes existed in the networks of mechanical-sharing, neighbor, kinship, and labor-sharing relationships (Figures A1–A5), no isolated nodes appeared in the synthetic network (Figure 4), which supports Hypothesis 1.

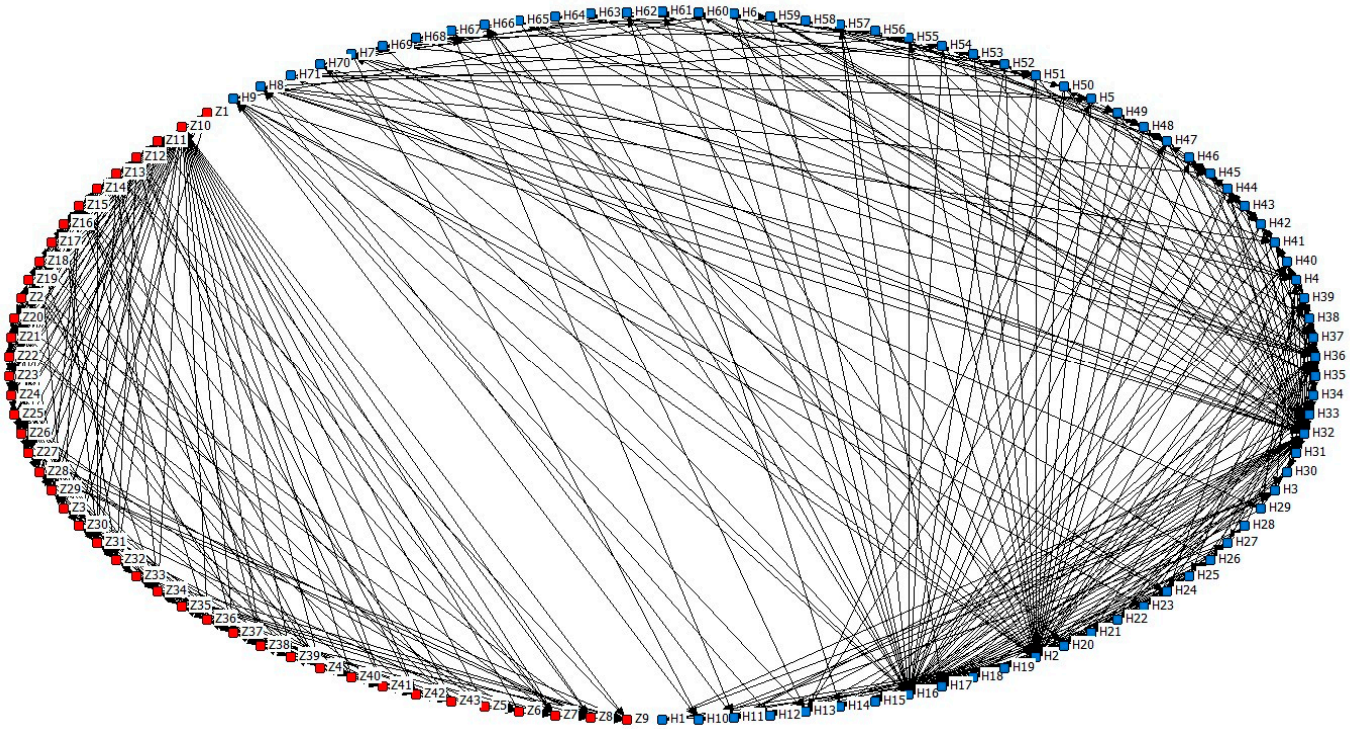

Figure 4. Network diagram of synthetic relationships among smallholders who adopted farmland trusteeship service. Note: The blue nodes represent the smallholders of Hegouzhao village, and the red nodes represent the stallholders of Zhusihuang village. The lines indicate that there is a relationship between farmers.

This study separately calculated the *ND*, *NE*, *NH*, and *NC* for the villages of Zhusihuang and Hegouzhao and for the entire cooperative (Table 2).

Table 2. Overall network index analysis for the villages of Zhu, He, and the cooperative.

		Neighbor	Adjoining−Land Relationship	Labor−Sharing Relationship	Kinship	Mechanical−Sharing Relationship	Synthetic Relationship
ND	Cooperative	0.024	0.018	0.006	0.010	0.018	0.060
	Zhu village	0.073	0.047	0.022	0.022	0.045	0.166
	He village	0.035	0.029	0.009	0.017	0.032	0.103
NE	Cooperative	0.967	0.999	0.911	0.928	0.946	0.883
	Zhu village	0.964	1	0.854	0.765	0.940	0.832
	He village	0.969	0.998	0.974	0.954	0.949	0.892
NH	Cooperative	0	0	0.692	0	0.979	0.052
	Zhu village	0	0	0.708	0	0.990	0
	He village	0	0	0.678	0	0.975	0
NC	Cooperative	0.286	0.484	0.020	0.028	0.409	0.526
	Zhu village	0.864	1	0.070	0.043	0.821	1
	He village	0.426	0.892	0.027	0.058	0.761	1

Note: network density (*ND*), network efficiency (*NE*), network hierarchy (*NH*), and network correlation (*NC*).

In terms of the neighbor and adjoining-land relationships, Zhusihuang, Hegouzhao, and the entire cooperative all exhibited low *ND* and *NE*, but Zhusihuang had a higher *NC*. In terms of the network of the labor-sharing relationship, Zhusihuang, Hegouzhao, and the entire cooperative all exhibited low *ND*, *NE*, and *NC* but showed higher *NH*. In terms of kinship, all four social network indicators for Zhusihuang and Hegouzhao, as well as for the entire cooperative, showed a low correlation. From the perspective of the mechanical-sharing relationship, Zhusihuang, Hegouzhao, and the entire cooperative all exhibited lower *ND* and poorer *NE*, yet they exhibited higher *NC* and *NH*.

In terms of the synthetic relationship, Zhusihuang, Hegouzhao, and the entire cooperative all demonstrated poor *NE* and low *NH*, but Zhusihuang had a slightly higher *ND* than the other networks, which represented a higher number of network affiliations there. In addition, the *NC* of both villages was 1, which demonstrated that there were no isolated nodes in the synthetic network of the two villages and that the network connectivity was effective. This discovery also supports Hypothesis 1. However, the *NC* of the cooperative was lower, indicating that the connection between farmers was accessible everywhere only within the village, rather than the cross-village cooperative, which did not support Hypothesis 3. Considering the overall network characteristics, all networks exhibited low *ND*, poor *NE*, and little *NC*. Therefore, the effect of farmers' social network formed under the role of the cooperative was not ideal.

5.2. Important Smallholders with High Centrality in the Social Network

The centralities of degree, closeness, and betweenness for each smallholder in various relationships were calculated by Ucinet 6 software to reveal the status and role of each smallholder in the cooperative (Figure 5). This study also separately calculated the network centralities for smallholders in both Zhusihuang and Hegouzhao, which can be seen in Tables S1 and S2 in the Supplementary Material. Specific data on each farmer's centralities in every network of the cooperative are also in the Supplementary Material (Tables S3 and S4)). It is worth noting that the three centralities have no theoretical extreme value, and the value of centralities will change with the number of node lines' change in the network.

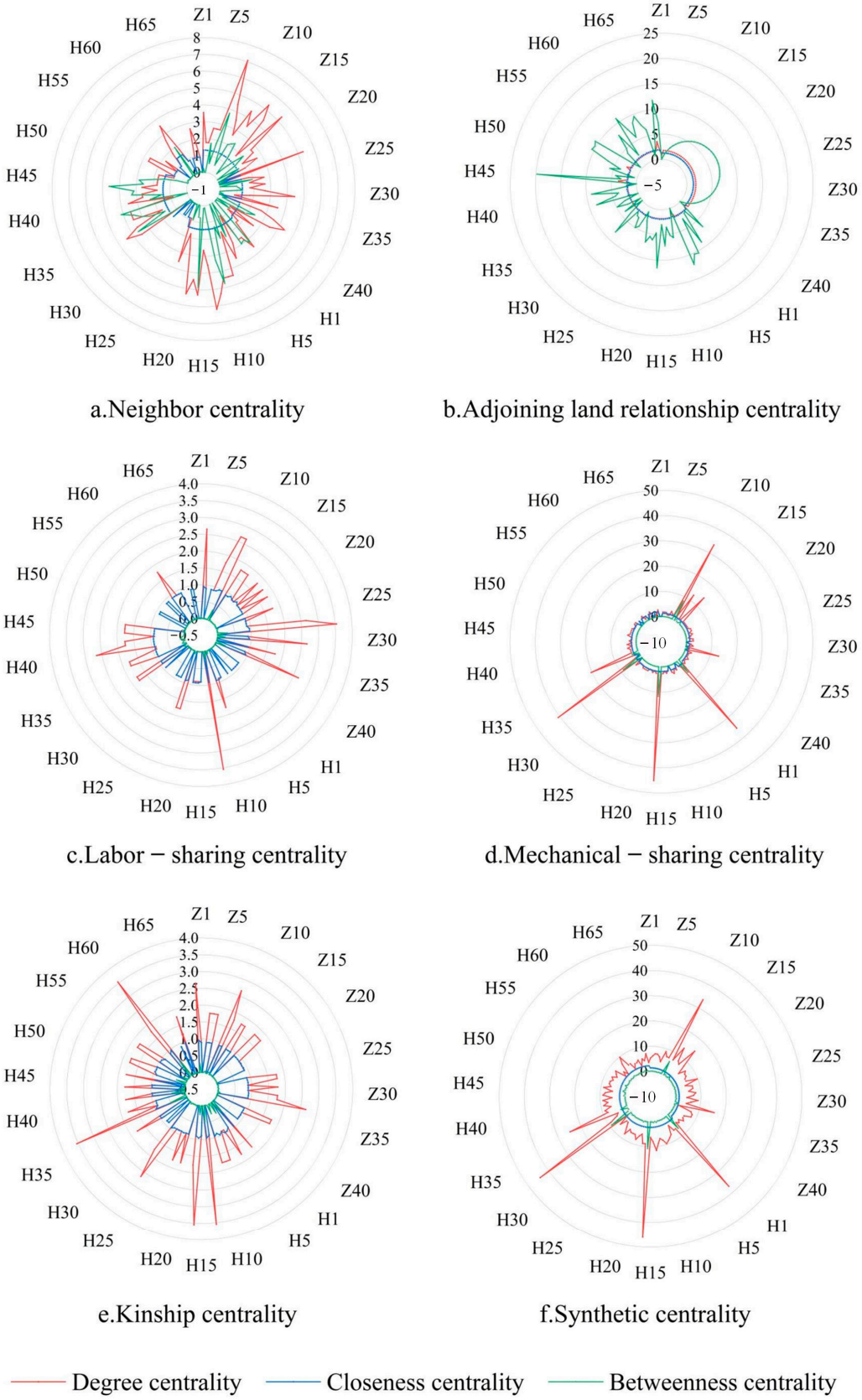

Figure 5. Six types of relationship centrality of smallholders who adopted farmland trusteeship service. Note: Red represents degree centrality, blue represents closeness centrality, and green represents betweenness centrality.

In the neighbor relationship (Figure 5a), Z7 and H13 exhibited a higher degree centralities, 7.08 and 6.20, respectively. The closeness centralities of H11, H33, and H36 were much higher than the mean value of all the smallholders (1.17), which indicated that these smallholders were close to the geometric center of the cooperative neighbor network (Figure 6).

Figure 6. Homestead distribution of smallholders who adopted farmland trusteeship service. Note: The white stars in the picture represent the smallholders who did not adopt the farmland trusteeship service. The rectangles represent the smallholders who adopted the farmland service, and the numbers within them are the smallholder codes.

In the adjoining-land relationship (Figure 5b), H45 had the highest centralities of degree, closeness, and betweenness. The mean values of its centralities of degree, closeness, and betweenness were 1.79, 1.61, and 4.99, respectively. It was because when the cooperative was established, it incorporated smallholders whose plots were adjacent to each other.

In the labor-sharing relationship (Figure 5c), Z28 showed the highest centralities of degree and closeness, 3.54 and 0.95, respectively, and its betweenness centrality ranked second among all smallholders.

For the mechanical-sharing relationship (Figure 5d), H16, H32, and H2 ranked as the top three centralities. According to the review of the machinery owners, H16 owned a combine harvester machine, and he was responsible for helping villagers harvesting wheat and corn in the village. H32 owned a seeding machine, and he was responsible for helping villagers to sow food crops in the village. H2 owned a rotary plow, which was responsible for loosening and turning the soil. The difference in the number of machines owned within the village, and the personal relationships in the rural community, resulted in different sizes of centrality for the three smallholders. Numerically, H16 had the highest centrality due to the high levels of labor required during harvesting.

In the kinship network (Figure 5e), H60 showed the highest centralities of degree, closeness, and betweenness, 3.54, 0.97, and 0.54, respectively.

The centralities of degree and betweenness in the synthetic social network (Figure 5f) were larger, with H16 attaining 46.02 and 10.67, respectively, and H16, H32, H2, and Z10 occupying the top four places of centrality.

Through investigation, it was found that the reason for the high centrality of H60 in kinship relationships is his age (he was the eldest one in the village) and there being more relatives in the younger generations of H60's family. In the mechanical network, it was also confirmed that the machine owner has higher centralities. However, officials did not show high centrality in any network. As a result, Hypothesis 2 is partially supported.

5.3. Complex Correlations of Different Relationships among Smallholders

In terms of the adjoining land relationship in the cooperative, this was significantly correlated to the mechanical-sharing relationship, labor-sharing relationship, neighbor, and kinship. Similar results were found when looking at the individual networks for both Zhusihuang and Hegouzhao (Figure 7, Row 5). In terms of the mechanical-sharing relationship, this was remarkably associated with the labor-sharing relationship, neighbor, and kinship (Figure 7, Row 4). The labor-sharing relationship was significantly correlated to neighbor and kinship relationships (Figure 7, Row 3). The same results were found for Hegouzhao (Figure 7, Row 13). However, considering Zhusihuang separately (Figure 7, Row 8), we discovered that the cross-village labor-sharing relationship was only significantly correlated to kinship. The neighbor network was significantly correlated to the kinship network at the 1% level (coefficient 0.175), and the same results were found for both Zhusihuang (coefficient 0.131) and Hegouzhao (coefficient 0.181).

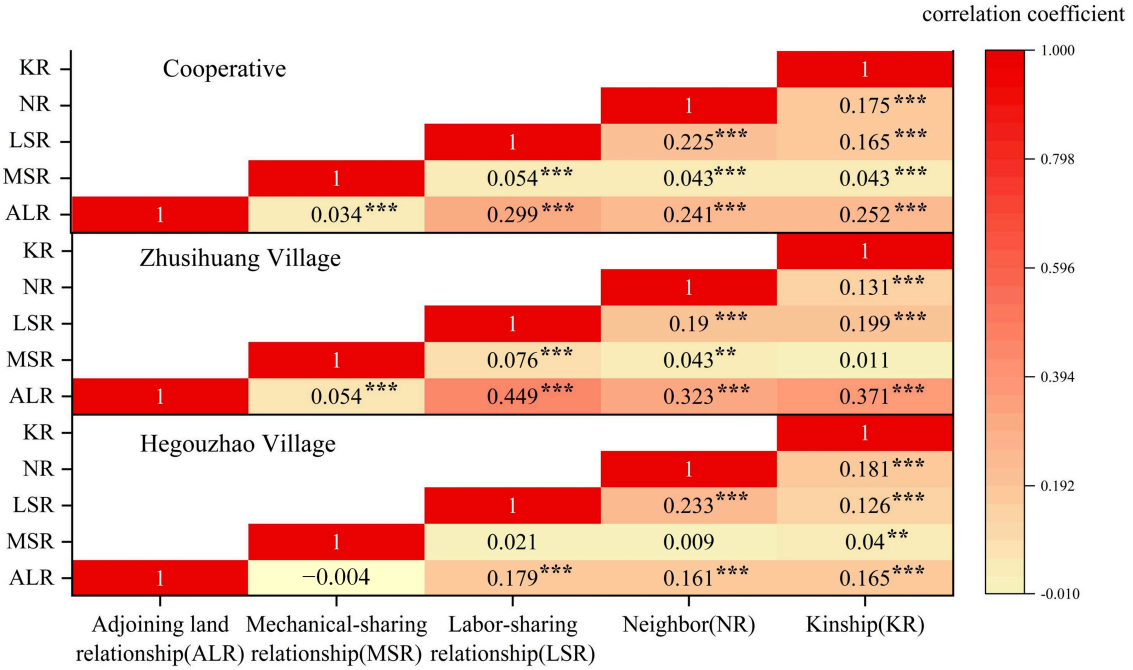

Figure 7. QAP correlation analysis of five relationships between the cooperative, Zhusihuang village and Hehouzhao village. Note: ① **, *** in the figure represent two relationships significant at the 10%, 5%, 1% level, respectively. ② ALR, MSR LSR, NR, KR, indicated, adjoining-land relationship, mechanical-sharing relationship, labor-sharing relationship, neighbor relationship kinship, respectively.

In general, five types of social networks had strong correlations to each other. The main reason for this was the typical living–production mode in rural communities. Smallholders tended to associate with their nearest neighbors and relatives and to partners whose plots were close to each other in daily production and life. In addition, although the significance between the five network relationships in the entire cooperative was much higher than that of individual villages, the correlation coefficients were lower than the results within each individual village. In other words, cross-village cooperative linked the smallholders and formed a social network; nevertheless, the strength of the social networks of cross-village cooperatives was still weaker when compared with intra-village networks; that is to say, the influence of the village administrative divisions split the smallholders of the cooperative into two groups. Even with the existence of cooperatives, smallholders still tended to cooperate with their own village smallholders. This provides no evidence for supporting Hypothesis 3.

6. Discussion

6.1. Machinery Owners, Experienced Farmers, and Other Native Villagers Are Highly Influential in Rural Social Network

Hypothesis 1 is supported in this research. The evidence is that the visualization showed no isolated nodes in the synthetic network, though there were isolated nodes in single networks. Relevant studies also found structural holes and isolated nodes [70–72], but this paper highlighted the importance of observing smallholders' social networks through a comprehensive perspective., i.e., it is high likely to turn the network into a "hole-free" structure when enough relationships are stacked together.

Hypothesis 2 is partially supported in this study. The evidence is that elderly, machinery owners showed higher centralities, whereas rural officials did not. Other researches only proved the important influence of old farmers, but there is no literature explaining the central role of machinery owners [73,74]. As a result, our results add a new focus: machinery owners, experienced farmers, and other native villagers are highly influential in a rural social network.

In practice, local professionals, machinery owners, planting experienced people, and excellent village officials all have the potential be trained as "professional farmers", who can take charge of improving the farmland use efficiency [75]. These farmers are native villagers, which helps them to play a great role in the local social network. Relevant studies have also confirmed that some smallholders' production behavior and land transfer decisions will affect others' behavior [76]. Therefore, these influential native farmers will have a strong peer effect on others [77] and help to improve the overall utilization efficiency of cultivated land and promote the modernization of production.

To let the "professional farmers" enhance their roles in the social network and improve the production, some individualized measures are needed. For example, the village cadres should take the lead in organizing smallholders in the skills training, and they should uphold fairness and justice in the distribution of benefits between cooperatives and farmers. Moreover, large-scale farmland managers should provide short-term employment positions for smallholders, and machinery owners should provide machinery-sharing services in a wider spatial scope, to improve the level of socialized service of machinery by establishing machinery cooperatives. As older farmers often have valuable farming experience, "field teaching" by the elders can be used widely to share more agro-production experience. As a result, a better social network is established, people can be more connected, and an overall improvement in farmland-use efficiency can also be achieved through the enhancement of the native professional farmers' social network.

6.2. Private Cooperatives Did Not Perform Well in the Organization of Farmers

Hypothesis 3 is not supported in this study (Figure 8). The evidence is as follows. First, the visualization of the network showed that farmers only have connections within villages, rather than between two villages. Second, farmers' centralities of single villages are higher than that of the cooperative. Thirdly, the QAP coefficients between networks inside a single village are higher than those of the cross-village cooperative. Therefore, this paper proved that a private cooperative is not an ideal organization for farmers' social networks. The private-owned cooperative in this study turned out to be a "shell cooperative", which did not help to establish a larger network than a village. (Our field survey showed that there are only two actual managers on 30.93 hm^2 farmland of the cooperative. Farmers are hired by the cooperative to help out only in the busy season.) The relevant literature also points out the problems of shell cooperatives, such as inadequate management personnel, low professional technics of members, weak willingness and ability to help each other among smallholders, a lack of supervision and guidance, and a lack of funds and insurance [78–80]. These studies all support the views of this study: a private cooperative may not be the best choice for farmland land use.

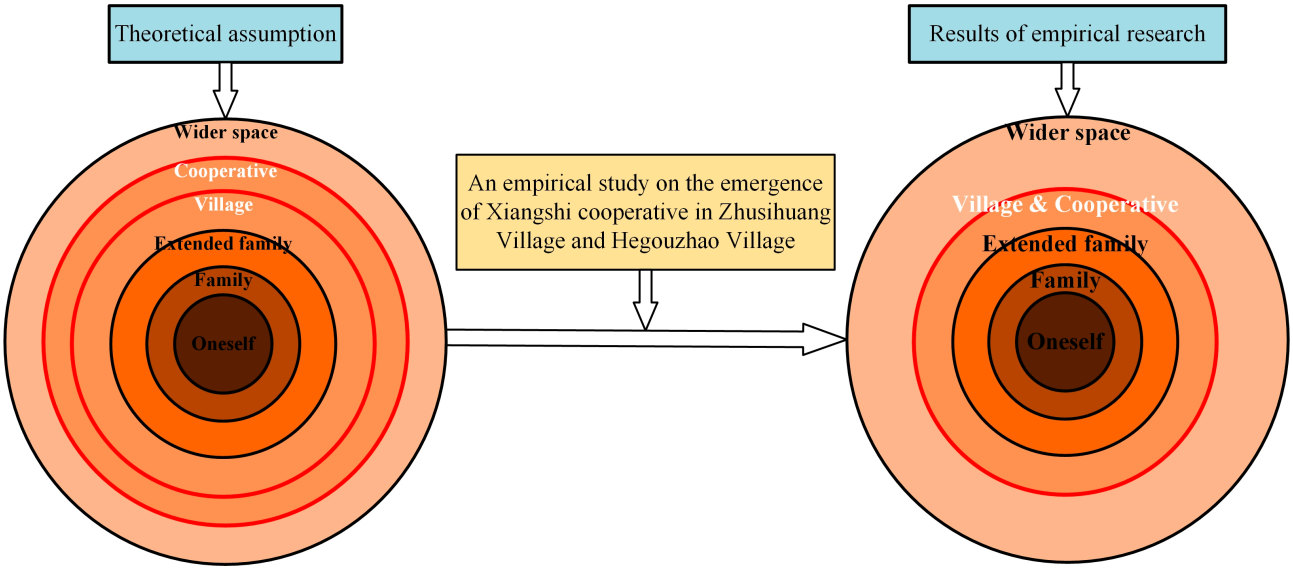

Figure 8. "Structure of Grade" empirical result. Note: In this study, the cooperative failed to establish a larger social network than villages and turned out to be a "shell" cooperative. Note: Different colors represent the closeness of the network relationship, and the darker the color, the closer the network connection.

However, some successful stories exist. For example, the Nanxiaowang Shengfeng Land Stock professional cooperative in Qingzhou City, China, established by the party branch of the rural committee, signed minimum income in the contract with smallholders, and greatly ensure the interests of farmers and production enthusiasm [81,82]. Another example is the Liangmancang vegetable professional cooperative in Henan Province, which is a highly autonomous cooperative. The cooperative jointly negotiates with the market to resist sale risks and raise the selling price. The decision-making is democratic, which guarantees the "public nature" of management [83].

To improve the development of cooperatives, the following measures should be taken. For fully trusteeship cooperatives, which have a large farmland area and take charge of the entire production chain, they are faced with high financial risk and should promote the point-to-point government-cooperative assistance. The financial assistance should cover planting, management, storage, transportation, and sale to improve the cooperatives' expectation and production enthusiasm and extend the life of such cooperatives. For non-fully trusteeship cooperatives, a dominant service should be enhanced in the cooperative. Focusing on the refinement and deepening of a service function can help cooperatives form their own development advantages. For sales cooperatives, they should make full use e-commerce to broaden the sales channels and improve the bargaining power in the market. For agricultural machinery service cooperatives, efforts should be made to up-grade the modernization of machinery, and subsidies should be provided for agricultural machinery in large-scale farmland.

6.3. "Who Will Farm the Land Tomorrow?": Joining Professional Farmers with Cooperatives Together

At present, the cooperatives are flourishing, but not all of them can organize farmers' production well. Professional farmers have rich experience and local advantages, but they are scattered and lack large-scale capital and land. In fact, cooperatives are justly complementary to their shortcomings. Therefore, building a synergistic development way of them can be an ideal solution to the problem "who will farm the land".

On the one hand, cooperatives should promote the concentration of cultivated land through short-term employment of farmers, and social service means such as farmland trusteeship and machinery. While fully relying on the advantages of professional farmers'

fine farming, cooperatives should make up for their disadvantages of insufficient scale and give technical guidance to professional farmers. On the other hand, taking "professional farmers + cooperatives + X" as a bridge, the multi-subject collaborative development model should be explored. As the main body most similarly to the management mode of smallholders, family farms have outstanding advantages in scale management, while agricultural enterprises are more mature in terms of market integration and management system, so professional farmers and cooperatives can ride the "hitch ride" of the two entities and develop a new model of "professional farmers + cooperatives + X" by means of shares and other means. Under this model, it can not only make up for the scale disadvantages of professional farmers, improve the anti-risk ability of cooperatives, promote large-scale production, and alleviate the fragmentation of cultivated land, but also realize the equal sharing of risks and the transformation and upgrading of multiple subjects, so as to achieve a win–win situation.

7. Conclusions

This paper examined the social network characteristics of smallholders who adopt farmland trusteeship services of a cross-village cooperative. The study used field research data from 114 smallholders in the Xiangshi cooperative, Shandong Province, China. The study discussed what a private cooperative can bring to the social contacts among smallholders and the rural community. The results are as follows:

(1) After adopting the cooperative's farmland trusteeship service, smallholders have some isolated nodes in single relationships, but no isolated nodes appeared in the synthetic social network.
(2) The relationships among smallholders are different, in which the mechanical-sharing relationship is the strongest, followed by weak kinship, neighbor, adjoining land relationship and labor-sharing relationships.
(3) Several central nodes emerged in the social network, they are farm machinery owners and older experienced farmers. Village officials did not show a strong influence in the network.
(4) The result of social network intensity, centralities and QAP analysis in the cooperative are worse than that within a single village. This indicates that the cross-village cooperative did not work well in breaking the village boundaries on farmers' connections. In other words, smallholders' close ties are still limited within the village.

These results implicated the importance of enhancing smallholders' social networks and improving the overall farmland use. In the future, joining professional farmers with cooperatives together will become a reasonable answer of "who will farm the land well" in a rapid urbanizing society. Differentiated policies for different types of smallholders and cooperatives were proposed in this study.

This study sinks the observation into smallholders of the village, which is helpful to provide first-hand findings for policy-making. Due to the difficulties of carrying out field surveys during the epidemic, this paper has the following limitation, which can make prospects for future related research. Firstly, a wider range of research area and wider field survey of private cooperatives are needed. Secondly, as the cooperative in this study was established in a short time, attention should be paid to more cooperatives that have been established for a longer time. Thirdly, differences of each age group of smallholders should be explored by a wider survey.

Moreover, we suggest that the development model of "professional farmers + cooperatives + other new agricultural entities" should be further studied. The profit distribution, mechanism of individuals' action, and production efficiency should be studied.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture14050649/s1, Table S1. The top five smallholders of the three centralities of Zhusihuang in six relationships. Table S2. The top five smallholders of the three centralities of Hegouzhao in six relationships. Table S3. Smallholders' centralities in the cooperative

(neighbor, adjoining-land relationship, labor-sharing relationship). Table S4. Smallholders' centralities in the cooperative (kinship, mechanical-sharing relationship, synthetic relationship).

Author Contributions: Conceptualization, Q.S.; Methodology, G.Y.; Software, Q.S.; Formal analysis, Q.S. and G.Y.; Resources, G.Y., Q.S., W.W., Z.Z., S.Z. and G.L.; Investigation, G.Y., Q.S., W.W., Z.Z., S.Z. and G.L.; Data curation, Q.S., W.W. and Z.Z.; Writing—original draft preparation, Q.S.; Writing—review and editing, G.Y.; Visualization, Q.S.; Validation, S.Z. and G.L.; Supervision, G.Y.; Project administration, G.Y.; Funding acquisition, G.Y. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study did not require ethical approval.

Data Availability Statement: The data presented in this study are available on request from the corresponding author (accurately indicate status).

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

From the network diagram, it can be roughly seen that the neighbor relationship (Figure A1) and adjoining-land relationship (Figure A2) among the smallholders formed two along "groups". There are very few and fragmented associations existing between the kinship (Figure A3) and labor-sharing relationship (Figure A4), and there are many alone smallholders that have no relationships with others (on the left side of Figures A3 and A4). Different from other relationships, the mechanical-sharing relationship shows significant central nodes, which share numerous association lines with other smallholders (Figure A5).

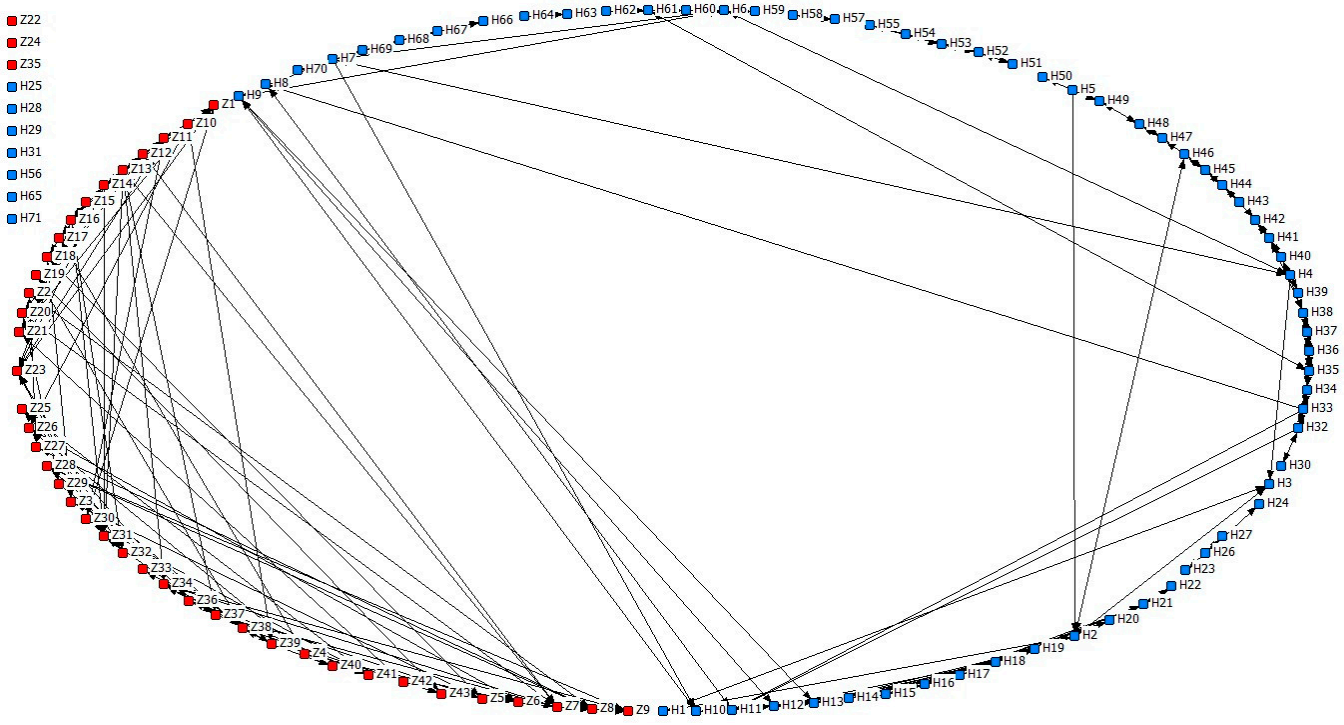

Figure A1. Network diagram of neighbor among smallholders.

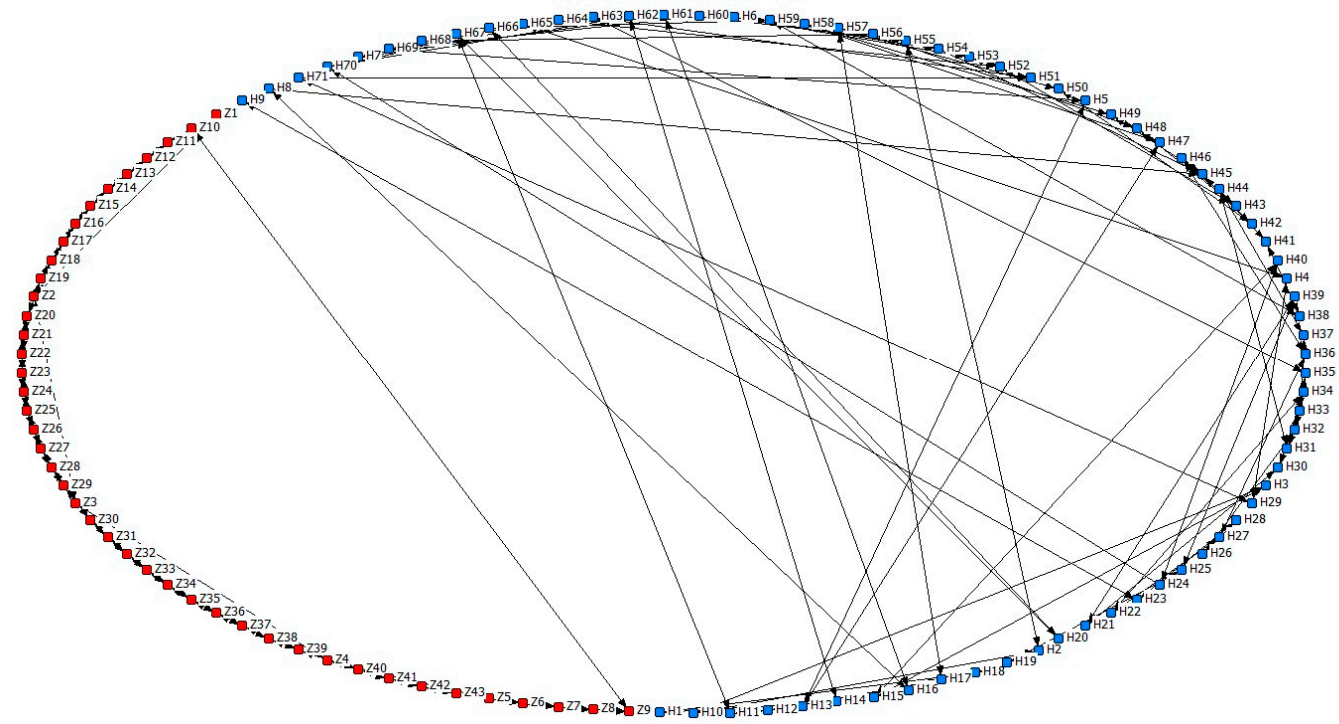

Figure A2. Network diagram of adjoining land relationship among smallholders.

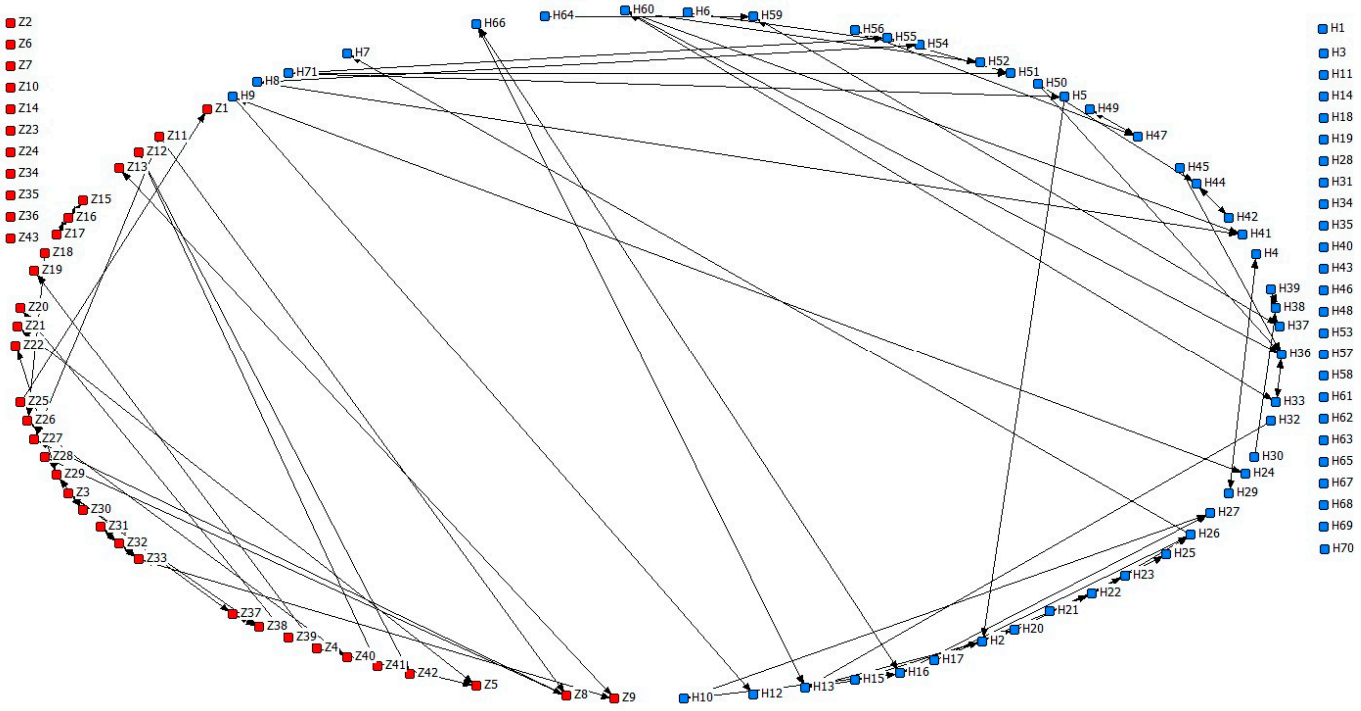

Figure A3. Network diagram of kinship among smallholders.

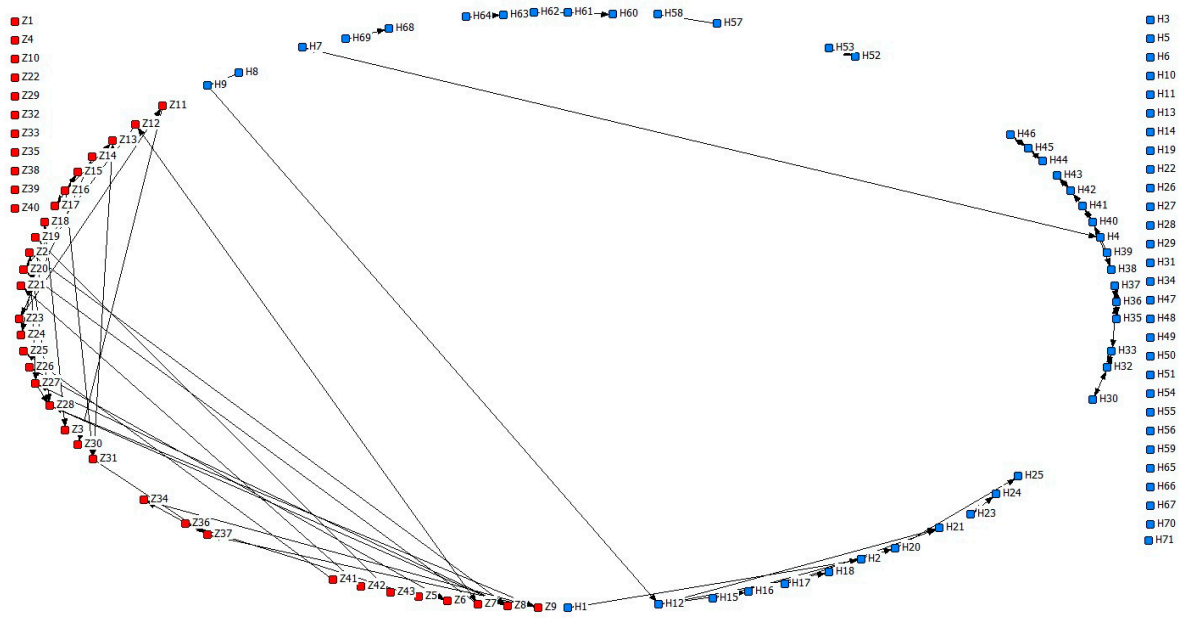

Figure A4. Network diagram of labor-sharing relationship among smallholders.

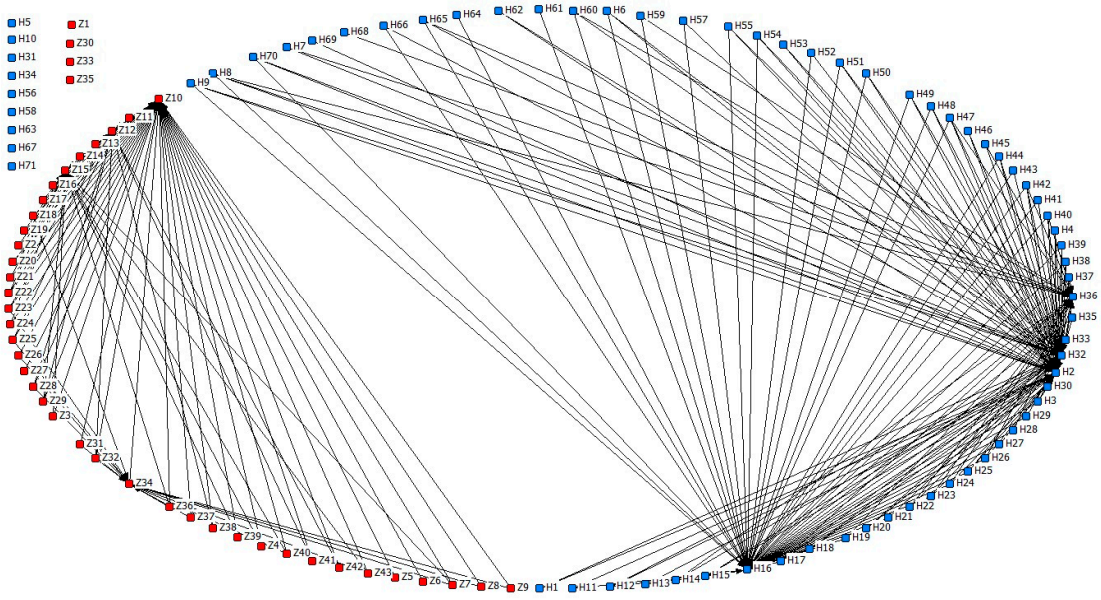

Figure A5. Network diagram of mechanical-sharing relationship among smallholders.

References

1. Liang, Q.; Lu, H.Y.; Deng, W.D. Between social capital and formal governance in farmer cooperatives: Evidence from China. *Outlook Agric.* **2018**, *47*, 196–203. [CrossRef]
2. Duan, L.F. The development history and experience of agricultural cooperatives in Europe and America. *World Agric.* **2018**, 37–42.
3. Ajates, R. An integrated conceptual framework for the study of agricultural cooperatives: From repolitisation to cooperative sustainability. *J. Rural Study* **2020**, *78*, 467–479. [CrossRef]
4. Barry, I.; Rousseliere, D. Do quality incentive payments improve cooperative performance? The case of small French agricultural cooperatives. *J. Agric. Econ.* **2022**, *73*, 938–948. [CrossRef]
5. Franzen, S. The value of farming: Multifaceted wealth generation through cooperative development. *Econ. Anthropol.* **2020**, *7*, 279–292. [CrossRef]
6. Skevas, T.; Grashuis, J. Technical efficiency and spatial spillovers: Evidence from grain marketing cooperatives in the US Midwest. *Agribusiness* **2020**, *36*, 111–126. [CrossRef]

7. Huang, Z.H.; Liang, Q. Agricultural organizations and the role of farmer cooperatives in China since 1978: Past and future. *Agric. Econ. Rev.* **2018**, *10*, 48–64. [CrossRef]
8. Wilmsen, B.; Rogers, S.; van Hulten, A.; Duan, Y.F. In the shadow of state-led agrarian reforms: Smallholder pervasiveness in rural China. *Agric. Hum. Values* **2023**, *41*, 75–90. [CrossRef]
9. Ito, J.; Bao, Z.S.; Su, Q. Distributional effects of agricultural cooperatives in China: Exclusion of smallholders and potential gains on participation. *Food Policy* **2012**, *37*, 700–709. [CrossRef]
10. Liu, Y.M. An application of adverse selection: Rural agricultural production in China since the 1950s. *Appl. Econ. Lett.* **2004**, *11*, 915–917. [CrossRef]
11. Qiu, Z.J.; He, Y.; Li, W.M. A note on the adoption of precision agriculture in eastern China. *Outlook Agric.* **2007**, *36*, 255–257. [CrossRef]
12. Su, L.F.; Tang, J.J.; Qiu, H.G. Intended and unintended environmental consequences of grassland rental in pastoral China. *J. Environ. Manag.* **2021**, *285*, 112126. [CrossRef]
13. Zheng, S.; Wang, Z.G.; Song, S.F. Farmers' behaviors and performance in cooperatives in Jilin Province of China: A case study. *Soc. Sci. J.* **2011**, *48*, 449–457. [CrossRef]
14. Ma, W.L.; Abdulai, A.; Goetz, R. Agricultural Cooperatives and Investment in Organic Soil Amendments and Chemical Fertilizer in China. *Am. J. Agric. Econ.* **2018**, *100*, 502–520. [CrossRef]
15. Su, Y.; Cook, M.L. Advances in agricultural cooperative research since 2007: A review of Chinese Agricultural Economics literature. *Ann. Public Coop. Econ.* **2020**, *91*, 519–543. [CrossRef]
16. Liang, Q.; Hendrikse, G.; Huang, Z.; Xu, X. Governance Structure of Chinese Farmer Cooperatives: Evidence from Zhejiang Province. *Agribusiness* **2015**, *31*, 198–214. [CrossRef]
17. Ma, M.L.; Zhu, H. Efficiency of Decisions under Membership Heterogeneity and Government Regulations: Insights from Farmer Cooperatives in China. *Econ. Dev. Cult. Change* **2020**, *68*, 1009–1040. [CrossRef]
18. Ye, Y.; Zhang, Z.; Deng, B. Evaluation on High Quality Development of Farmers' Professional Cooperatives—Based on 288 Investigation Data of Jiangmen Planting Farmers' Professional Cooperatives. *South Rural* **2021**, *37*, 29–33. [CrossRef]
19. Liang, Q.; Hu, W.; Jia, F. A hybrid form of agricultural organization: The case of the Beizhijiang vegetable cooperative in China. *Int. Food Agribus. Manag. Rev.* **2019**, *22*, 283–293. [CrossRef]
20. Ofori, E.; Sampson, G.S.; Vipham, J. The effects of agricultural cooperatives on smallholder livelihoods and agricultural performance in Cambodia. *Nat. Resour. Forum* **2019**, *43*, 218–229. [CrossRef]
21. Zhang, X.R.; Zhang, L.; Nie, T.Z. Study on the Impact of Social Capital on Farmers' Decision-Making Behavior of Adopting Trusteeship Services. *Sustainability* **2023**, *15*, 5343. [CrossRef]
22. Baiyegunhi, L.J.S.; Majokweni, Z.P.; Ferrer, S.R.D. Impact of outsourced agricultural extension program on smallholder farmers' net farm income in Msinga, KwaZulu-Natal, South Africa. *Technol. Soc.* **2019**, *57*, 1–7. [CrossRef]
23. Wang, W.; Zhang, J. Development Status, Existing Problems and Countermeasures of Ningxia's Agricultural Socialization Service System—Taking Land Trusteeship as an Example. *Ningxia J. Agric. Format* **2021**, *62*, 55–59.
24. Zhang, Y.; Huang, Z.H. Identifying risks inherent in farmer cooperatives in China. *China Agric. Econ. Rev.* **2014**, *6*, 335–354. [CrossRef]
25. Dou, S.; Xiao, Z.; Hu, W. The Complex Fragmentation Dilemma of the Land Trusteeship of by Supply and Marketing Cooperatives: Basing on the Case Analtsis of Ping'an Country, Shandong Province. *J. Nanjing Agric. Univ. (Soc. Sci. Ed.)* **2022**, *22*, 117–127.
26. Gu, X.; Liu, Y. Predicament and legal countermeasueres of rural land truateeship system under strategy of rural revilazation. *Jiangsu Agric. Sci.* **2023**, *51*, 241–246. [CrossRef]
27. Ma, W.L.; Zheng, H.Y.; Yuan, P. Impacts of cooperative membership on banana yield and risk exposure: Insights from China. *J Agric. Econ.* **2022**, *73*, 564–579. [CrossRef]
28. Xu, H.; Li, Y.; Zheng, Y.; Xu, X. Analysis of spatial associations in the energy-carbon emission efficiency of the transportation industry and its influencing factors: Evidence from China. *Environ. Impact Assess. Rev.* **2022**, *97*, 106905. [CrossRef]
29. Butts, C.T. Social Network Analysis with sna. *J. Stat. Softw.* **2008**, *24*, 1–51. [CrossRef]
30. Otte, E.; Rousseau, R. Social network analysis: A powerful strategy, also for the information sciences. *J. Inf. Sci.* **2002**, *28*, 441–453. [CrossRef]
31. Chang, C.L.-H. The dilemma of renqing in ISD processes: Interpretations from the perspectives of face, renqing and guanxi of Chinese cultural society. *Behav. Inf. Technol.* **2012**, *31*, 481–493. [CrossRef]
32. Li, Q.; Gao, M.H. Trust evolution, institutional constraints, and land trusteeship decisions among Chinese farmers. *Agric. Econ.-Zemed. Ekon.* **2023**, *69*, 485–497. [CrossRef]
33. Lin, X.; Song, C.; Wang, S. Multiple Social Networks in Grassroots Governance in Rural China. *Soc. Sci. China* **2018**, *39*, 26–45. [CrossRef]
34. Chen, F.F.; Xu, Z.G.; Luo, Y.F. False prosperity: Rethinking government support for farmers' cooperatives in China. *Ann. Public Coop. Econ.* **2023**, *94*, 905–920. [CrossRef]
35. Reyes, D.C.; Richardson, J.C.; Maeda, Y. The evolution of social presence: A longitudinal exploration of the effect of online students' peer-interactions using social network analysis. *Internet High. Educ.* **2024**, *61*, 100939. [CrossRef]
36. Wolfe, A.W. *Social Network Analysis: Methods and Applications*; Cambridge University Press: Cambridge, UK, 1997; Volume 24.
37. Radcliffe-Brown, A.R. On social structure. *J. R. Anthropol. Inst. Great Br. Irel.* **1940**, *70*, 1–12. [CrossRef]

38. Granovetter, M.S. The Strength of Weak Ties. In *Networks in the Knowledge Economy*; Oxford Academic: Oxford, UK, 2003.
39. Bourdieu, P. The Forms of Capital. In *Readings in Economic Sociology*; Routledge: London, UK, 1986.
40. Burt, R.S. *Structural Holes: The Social Structure of Competition*; Sciences Po University Press: Paris, France, 1992.
41. Coleman, J.S. Social capital in the creation of human capital. *Am. J. Sociol.* **1988**, *94*, S95–S120. [CrossRef]
42. Diehl, J.A.; Bose, M. A sustainable livelihoods approach to measuring mobilization of resources through social networks among vulnerable populations: A case study of Delhi farmers. *J. Soc. Sci. Humanit. Open* **2023**, *8*, 100689. [CrossRef]
43. Lin, Z.; Zhang, Y.; Gong, Q.; Chen, Y.; Oksanen, A.; Ding, A.Y. Structural hole theory in social network analysis: A review. *J IEEE Trans. Comput. Soc. Syst.* **2021**, *9*, 724–739. [CrossRef]
44. Burt, R.S. Models of network structure. *J. Annu. Rev. Sociol.* **1980**, *6*, 79–141. [CrossRef]
45. Burt, R.S. The network structure of social capital. *J. Res. Organ. Behav.* **2000**, *22*, 345–423. [CrossRef]
46. Kreuter, M.W.; Lezin, N. Social capital theory. In *Emerging Theories in Health Promotion Practice Research: Strategies for Improving Public Health*; John Wiley & Sons: Hoboken, NJ, USA, 2002; Volume 15, p. 228.
47. Voaklander, D.; Day, L.; Dosman, J.; Hagel, L.; Pickett, W. Older farmers and machinery exposure—Cause for concern? *Am. J. Ind. Med.* **2012**, *55*, 1044–1050. [CrossRef]
48. Han, Z.; Lin, K.; Tao, P. Perceived quality of governance and trust in government in rural China: A comparison between villagers and officials. *Soc. Sci. Q.* **2019**, *100*, 1726–1743. [CrossRef]
49. Meng, F.X.; Se, Y. Three-dimensional Structure and Action Practice—A New Interpretation of Fei Xiaotong's Theory of "Structure of Grade". *J. Minzu Univ. China (Philos. Soc. Sci. Edit.)* **2016**, *43*, 29–36. [CrossRef]
50. Li, T.H.; Wu, B.; Guo, L.; Shi, H.; Chen, N.C.; Hall, C.M. Semi-Acquaintance Society in Rural Community-Based Tourism: Case Study of Moon Village, China. *Sustainability* **2023**, *15*, 5000. [CrossRef]
51. Angelucci, M.; De Giorgi, G.; Rangel, M.; Rasul, I. Village Economies and the Structure of Extended Family Networks. *BE J. Econ. Anal. Policy* **2009**, *9*, 16–31. [CrossRef]
52. Wang, Y.X.; Liu, Q.; Wu, Y.R.; Wu, H.Q. Can relationship bring more provision in rural public goods? Empirical evidence from rural China. *China Agric. Econ. Rev.* **2017**, *9*, 48–61. [CrossRef]
53. Zou, Y.; Wang, Q.B. Impacts of farmer cooperative membership on household income and inequality: Evidence from a household survey in China. *Agric. Food Econ.* **2022**, *10*, 17. [CrossRef]
54. Zheng, S.; Wang, Z.G.; Awokuse, T.O. Determinants of Producers Participation in Agricultural Cooperatives: Evidence from Northern China. *Appl. Econ. Perspect. Policy* **2012**, *34*, 167–186. [CrossRef]
55. Yuan, J.; Nie, F. Farmers' cooperatives alleviation, income increase effect and heterogeneity analysis -based on the survey data of rural households in poor areas of Western China. *China J. Agric. Resoure Reg. Plan* **2022**, *43*, 90–101. [CrossRef]
56. Zhu, J.; Wang, S.; Wang, X. Farmers' willingness on joining sugarcane cooperatives based on logit model and influencing factors-taking Laibin distsict as an example. *J. Anhui Agric. Sci.* **2023**, *51*, 223–226.
57. Crossley, N. Social Network Analysis. In *The Wiley Blackwell Companion to Sociology*; Blackwell Publishing Ltd.: Hoboken, NJ, USA, 2019.
58. Lin, C.Y.; Wu, L.; Wen, Z.; Tong, H.H.; Griffiths-Fisher, V.; Shi, L.; Lubensky, D. Social Network Analysis in Enterprise. *Proc. IEEE* **2012**, *100*, 2759–2776. [CrossRef]
59. Wang, H.; Wang, J. Study of fuzzy-clustering-based unweighted farmers' credit risk estimation and its application. *J. Nonlinear Convex Anal.* **2019**, *20*, 937–948.
60. Isaac, M.E.; Matous, P. Social network ties predict land use diversity and land use change: A case study in Ghana. *Reg. Environ. Change* **2017**, *17*, 1823–1833. [CrossRef]
61. Liu, J. *Lectures on Whole Network Approach a Practical Guide to UCINET*; Shanghai People′s Publishing House: Shanghai, China, 2009.
62. Rossi, A.R.; Ahmed, K.N. Role Discovery in Networks. *IEEE Trans. Knowl. Data Eng.* **2015**, *27*, 1112–1131. [CrossRef]
63. Yang, X.C.; Wang, M.J. Diversification and Spatial Differentiation of Villages' Functional Types in the New Period of China: Results from Hierarchical Urban-Rural Spatial Relations and Townships Size. *Land* **2022**, *11*, 171. [CrossRef]
64. Li, C.X.; Wu, K.N. Driving forces of the villages hollowing based on geographically weighted regression model: A case study of Longde County, the Ningxia Hui Autonomous Region, China. *Nat. Hazards* **2017**, *89*, 1059–1079. [CrossRef]
65. Wu, J.; Huang, X.; Wang, B. Social-technical network effects in open source software communities: Understanding the impacts of dependency networks on project success. *Inf. Technol. People* **2023**, *36*, 895–915. [CrossRef]
66. Greetham, D.V.; Stoyanov, Z.; Grindrod, P. On the radius of centrality in evolving communication networks. *J. Comb. Optim.* **2014**, *28*, 540–560. [CrossRef]
67. Cui, C.; Wu, X.L.; Liu, L.; Zhang, W.Y. The spatial-temporal dynamics of daily intercity mobility in the Yangtze River Delta: An analysis using big data. *Habitat Int.* **2020**, *106*, 102174. [CrossRef]
68. Liang, Z.Y.; Chen, J.; Jiang, D.Y.; Sun, Y.P. Assessment of the spatial association network of green innovation: Role of energy resources in green recovery. *Resour. Policy* **2022**, *79*, 103072. [CrossRef]
69. Dow, M.M.; Burton, M.L.; White, D.R. Network autocorrelation: A simulation study of a foundational problem in regression and survey research. *Soc. Netw.* **1982**, *4*, 169–200. [CrossRef]
70. Spielman, D.J.; Davis, K.; Negash, M.; Ayele, G. Rural innovation systems and networks: Findings from a study of Ethiopian smallholders. *Agric. Hum. Values* **2011**, *28*, 195–212. [CrossRef]

71. Adejuwon, O.O. *Bridging gaps in innovation systems for small-scale agricultural activities in sub-Saharan Africa: Brokers wanted! In Firm-Level Innovation in Africa*; Routledge: London, UK, 2020; pp. 15–33.
72. Hahl, O.; Kacperczyk, A.O.; Davis, J.P. Knowledge asymmetry and brokerage: Linking network perception to position in structural holes. *J. Strateg. Organ.* **2016**, *14*, 118–143. [CrossRef]
73. Ma, W.; Abdulai, A. The economic impacts of agricultural cooperatives on smallholder farmers in rural China. *Int. J. Sociol. Soc. Policy* **2017**, *33*, 537–551. [CrossRef]
74. Macharia, J.; Mugwe, J.; Mucheru-Muna, M.; Mugendi, D. Socioeconomic factors influencing levels of knowledge in soil fertility management in the central highlands of Kenya. *J. Agric. Sci. Technol. B* **2014**, *4*, 701–711. [CrossRef]
75. Chen, L.; Chen, Z. Analysis on the competency of new professional farmers and its influencing factors. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2020; p. 012040.
76. Peng, S.; Sun, H.; Wang, J.; Zhang, Y. Influence of farming household interactions on rural homestead withdrawal compensation from the perspective of social network. *Resour. Sci.* **2021**, *43*, 1440–1453. [CrossRef]
77. Bramoullé, Y.; Djebbari, H.; Fortin, B. Peer effects in networks: A survey. *J. Annu. Rev. Econ.* **2020**, *12*, 603–629. [CrossRef]
78. Li, M.; Yan, X.B.; Guo, Y.Q.; Ji, H. Impact of risk awareness and agriculture cooperatives' service on farmers' safe production behaviour: Evidences from Shaanxi Province. *J. Clean. Prod.* **2021**, *312*, 127724. [CrossRef]
79. Yifeng, Z.; Yunxing, R. The Formation of "Empty Shelled" Cooperative and the Mechanism and Effective Correction of Cooperative Alienation. *Issues Agric. Econ.* **2020**, *08*, 103–114. [CrossRef]
80. Yuan, P.; Cao, B.; Cui, H.Z. Formation Reasons, Negative Effect and Countermeasure of Empty-Shelled Farmers' Cooperatives. *Reform* **2019**, *4*, 39–47.
81. Yuanrong, C. New mechanism of land transfer: Cooperative + Industrial integration—A case study of Nanxiaowang Village in Qingzhou City. *Rural Sci. Technol.* **2021**, *12*, 36–38. [CrossRef]
82. Chaochao, S. Cooperation and development to promote rural culture—The development of Nanxiao Wang Shengfeng Land stock professional cooperative in Qingzhou City, Shandong Province. *China Farmers' Coop.* **2019**, *05*, 26–27.
83. Yanhong, H. The operation mode of "One specialty and multiple abilities" professional cooperative—Taking Pingyu County Grain full warehouse agricultural planting professional cooperative as an example. *Agric. Henan* **2022**, *07*, 64.