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The Impact of Agricultural Socialized Service on Grain Production: Evidence from Rural China

Ruisheng Li [1,†], Jiaoyan Chen [2,†] and Dingde Xu [1,3,*]

[1] College of Management, Sichuan Agricultural University, Chengdu 611130, China; liruisheng@stu.sicau.edu.cn
[2] College of Leisure and Tourism, Chengdu Agricultural College, Chengdu 611130, China; chenjiaoyan@cac.edu.cn
[3] Sichuan Center for Rural Development Research, College of Management, Sichuan Agricultural University, Chengdu 611130, China
* Correspondence: dingdexu@sicau.edu.cn; Tel.: +86-13408598819
† These authors contributed equally to this work.

Abstract: Although China's grain production has reached nineteen consecutive harvests, the uncertainty of the current domestic and international environment has put more pressure on further increasing grain production in the future. For the past few years, agricultural socialization services have been crucial in boosting grain production and farmers' revenue by addressing the issue of land cultivation and farming methods. In this regard, the question of whether and how agricultural socialized services may resolve the present grain production conundrum is extremely practical. Therefore, the study employs the China Rural Revitalization Survey data of 3709 households. Based on the 2SLS model, stepwise regression method, and moderated effects model, it creatively takes into account a variety of agricultural production segments, investigates the mechanism of services on grain production from the standpoint of improved production efficiency and plot concentration, and further examines the effects of aging populations and regional variations in grain production areas. The study found the following: (1) The average proportion of grain production area of farmers in the sample is 49%, and 42% of farmers have purchased agricultural socialization services. (2) Agricultural socialization services can significantly promote farmers' grain cultivation behavior by facilitating connected transfers in and inhibiting connected transfers out to take advantage of plot concentration, and boosting the use of agricultural machines to enhance output efficiency. (3) The aging of the agricultural population will, to a certain extent, strengthen the promoting effect of agricultural socialization services on grain cultivation. Agricultural socialization services affect grain cultivation more in main grain-producing areas. Therefore, emphasizing the role of agricultural socialization services in accelerating the shift to moderate-scale operations, decreasing the non-grain component of the planting structure, and promoting the implementation of policies tailored to actual production needs are important steps to safeguard the production capacity of grain in different regions.

Keywords: agricultural socialized service; grain production; land transfer; population aging; major grain-producing area

Citation: Li, R.; Chen, J.; Xu, D. The Impact of Agricultural Socialized Service on Grain Production: Evidence from Rural China. *Agriculture* **2024**, *14*, 785. https://doi.org/10.3390/agriculture14050785

Academic Editor: Mauro Viccaro

Received: 26 April 2024
Revised: 15 May 2024
Accepted: 17 May 2024
Published: 20 May 2024

1. Introduction

Grain security is a matter of national prosperity and people's livelihood [1,2]. Due to the fact that China is a large nation with a sizable population, nourishing the 1.4 billion people has always been a primary concern for the government. Since 2004, China's No. 1 central document has focused on grain security for 21 consecutive years, constantly emphasizing the need to stabilize grain supply and ensure that the rice bowl is in one's own hands. Since the 18th National Congress of the People's Republic of China, General Secretary Xi Jinping has repeatedly emphasized in public that "ensuring national grain

security should always be a top priority". And in 2023, the Law of the People's Republic of China on the Guarantee of Grain Security was enacted as a companion to the National Security Law of the People's Republic of China, becoming the first macro-level systematic law on China's grain security. It underscores the critical significance of grain provision in the pursuit of national security and social stability. Recently, China's grain production capacity as a whole has increased steadily, as grain production has received increased support from all sectors and regions. In 2023, the national grain output was 695 million tons, an increase of 8.88 million tons year on year, stabilized at more than 650 million tons for nine consecutive years, and emergency grain aid was provided to more than 30 countries around the world. The strengthening of "China's grain, China's rice bowl" has not only ensured the security of grain rations for China's residents but also made a positive contribution to solving the problem of world hunger and maintaining world grain security.

Despite the fact that China's grain production has increased over the years and essentially resolved the issue of total demand, there is still a significant demand for grain in terms of structure and quality. As a result, a substantial portion of the feed and industrial grain still requires importation. In 2023, China imported 162 million tons of grain, up 11.7% year on year, of which 99.41 million tons were soybeans. Over the past decade, the volume of China's imports of major grain crops has been on a fluctuating upward trend. Some of China's grain demand is still more dependent on the international market, and facing the grain gap is still not to be underestimated. However, current international regional conflicts continue to intensify, commodity and energy markets remain volatile, and extreme weather events occur frequently [3]. These factors have led to an unstable state of international grain production and trade. The global food supply chain is unusually volatile, and the difficulty and risk of grain supply have increased [4,5]. The Report on the State of Grain Security and Nutrition in the World, released by the Food and Agriculture Organization of the United Nations, shows that more than 345 million people around the world are at risk of severe grain insecurity in 2023, an increase of 210 million people from 2019 [6]. The challenging international circumstances have significantly impacted China's grain production, supply, and foreign trade. Therefore, in the face of the inevitable international grain supply crisis, the ability to consolidate domestic grain production bases and maintain stable self-sufficiency will be a key factor in maintaining a stable global food market and alleviating global hunger.

From a practical point of view, domestic grain production is now also burdened by the double pressure of declining arable land resources and an aging agricultural population. On the one hand, as domestic industrialization and urbanization continue to advance in recent years, arable land resources in rural areas are under constant pressure. Driven by vested interests, the tendency for arable land to be converted for non-agricultural and non-grain purposes is intensifying [7]. The data of the Third National Land Survey show that the national arable land has decreased by 7.53 million hectares in 10 years. The non-agricultural and non-grain development of arable land not only leads to the destruction of the original tillage layer and agricultural conditions of the soil, increasing the difficulty and cost of quality restoration, but it is also not beneficial to the sustainable use of land resources. Additionally, it will encourage farmers to forsake grain farming and explore other crops with better rewards, jeopardizing China's grain self-sufficiency [8]. On the other hand, the agricultural population is aging due to the steady exodus of young, robust workers from rural regions. In the 2020 seventh census, 23.81% of rural residents were 60 or older, compared to 15.54% in cities. Agricultural workers tend to avoid agricultural risks as much as possible as they grow older, and their working ability gradually declines, which leads to a negative attitude toward agricultural investment, which is not conducive to the adoption of new production methods and the scale integration of finely fragmented plots of land. In addition, the workforce scarcity in agriculture makes hiring labor harder and affects output efficiency, which will undoubtedly further compress the profit space of grain cultivation and reduce the motivation of farmers to cultivate grain [9]. Under such

a realistic dilemma, efficient utilization of arable land resources and ensuring sustained production of grain crops is a pressing issue that needs immediate attention.

This can be solved by expanding agricultural socialization services and encouraging grain specialization and scale [10,11]. Agricultural socialization service involves farmers and other economic entities delegating some or all of the agricultural production process to service groups. Compared with traditional agricultural production methods, agricultural socialization services can help farmers engage in more specialized and modernized agricultural production under the premise of maintaining their land rights and income. Specifically, on the one hand, agricultural socialization services assist farmers in overcoming production factor shortages and minimizing wastage of arable land resources due to lack of cultivation and inefficient farming practices. On the other hand, agricultural socialization services can often carry out production activities on most of the farmland in the same village, thus stabilizing farmers' confidence in expanding their business scale, and facilitating the consolidation of scattered plots and the realization of appropriate scale management. Existing studies have also shown that agricultural socialized services have helped alleviate relative rural poverty, encourage smallholders to save and increase their incomes, and promote farmland protection [12–15]. As for grain production, studies suggest that socialized agricultural services may boost grain production efficiency and encourage farmers to extend their grain production area [16,17].

In general, agricultural socialization services can, to a certain extent, address the current question of "how and who will cultivate the land" [13,17]. However, further research is needed to better understand agricultural socialization services and farmers' grain cultivation behavior. Regarding methods, most current research mostly concentrates on the adoption or non-adoption of a specific behavior in determining farmers' use of socialized services. However, socialized services represent a comprehensive service system encompassing various agricultural production processes, including the stages of pre-, mid-, and post-production. Consequently, it is challenging to comprehensively and effectively represent the adoption of agricultural socialized services. With respect to the study's substance, there is a relative lack of analysis to explore the mechanism by which agricultural socialized services influence the behavior of farmers engaged in grain cultivation. This includes an examination of the specific changes that have occurred in the production process of farmers as a result of the adoption of socialized services and the potential for these changes to have a positive impact on grain cultivation. To elucidate this relationship, this study is based on the China Rural Revitalization Survey database and employs measurement tools such as the 2SLS model, the mediated effects model, and the instrumental variables approach to systematically investigate the mechanism of action and discrepancies in the impact of agricultural socialization services on farmers' grain cultivation behavior. The marginal contributions of this paper are as follows: It begins by constructing a conceptual framework to facilitate comprehension of the way in which agricultural socialization services influence the grain cultivation decisions of producers. A micro-level perspective is utilized to examine the influence of these services on the decision-making process of producers. The paper then conducts an empirical analysis of the function, mechanism, and heterogeneity of agricultural socialization services in relation to the grain cultivation behavior and decisions of farmers. This is accomplished by employing the instrumental variable method and large-sample survey data to resolve the endogeneity issue that the model faces. Adhering to this methodology guarantees the integrity and reliability of the research findings.

2. Theoretical Analysis

Agricultural socialization services refer to the various services provided by agricultural social organizations (such as agricultural enterprises, government services, agricultural universities, rural cooperatives, and agricultural specialists) to meet the needs of agricultural production for the benefit of farmers or other agricultural subjects [10,14]. The services include technology, capital, information, law, and many other aspects [18,19]. The services cover all aspects of agricultural production, such as planting, sowing, fertilizing,

medicating, irrigating, and harvesting. In China, the main service model of socialized agricultural services is the flexible and diversified agricultural production trusteeship for farmers. Farmers can choose and pay for services according to the needs of agricultural production. The government has also repeatedly issued relevant policies to promote the development of agricultural socialization services. In reality, the socialization of agricultural services is a product of the high level of development of the division of labor and marketization in agriculture. A comprehensive agricultural socialization service can help and lead farmers toward modernization and specialization.

The multi-objective utility theory posits that farmers do not pursue a single path and goal in production decision-making. And the implementation of each decision will follow the logic of maximizing the overall utility. As the basic unit of agricultural operation, farmers often analyze the feasibility and convenience of grain cultivation according to the needs of family life and their own resource endowment. This analysis guides their decisions on grain cultivation behavior. The ongoing division of arable land parcels and the diminishing human capital in households have impeded the advancement of agricultural productivity, thereby creating an unfavorable environment for attaining the optimal operational scale [11]. Due to the basic national conditions of many people and little land, as well as the massive outflow of the rural labor force, to safeguard agricultural productivity and revenue, growers must use more fertilizers, insecticides, and other production elements or grow higher-value non-grain crops. The proliferation of agricultural socialized services affords farmers the chance to surmount the limitations presently encountered in the realm of smallholder production and administration. Specifically, first, the integration of market demand via the provision of agricultural services can reduce the cost of factor procurement with regard to factor substitution. This is achieved through the use of specialized, systematic production processes to optimize the input of production factors [20]. This approach avoids predatory development's traditional natural resource production paradigm. Furthermore, it ensures the sustainability of agricultural production. Secondly, expanding the scope of socialized services, when viewed through the lens of the professional division of labor, enables the primary service provider to maximize the benefits of the professional division of labor, encourages the widespread use and adoption of advanced technology and agricultural machinery, and standardizes the operation of each link, thereby increasing the efficiency of agricultural production [21]. Thirdly, from the perspective of family income, farmers can guarantee agricultural production and output without affecting the family's living conditions by purchasing production services while releasing more labor resources to non-agricultural industries and easing the pressure on family income [22]. Agricultural socialization services provide better choices for farmers in terms of improving farming conditions and safeguarding family income, thus stabilizing farmers' motivation to adopt services and their willingness to work in agriculture.

In the actual production process, farmers must consider not only the maximization of income but also the potential risks associated with the process of production investment. Cash crops offer high profit margins but require high-tech planting techniques and a significant number of manual labor inputs, which result in higher capital and time costs when purchasing production services. Furthermore, the lengthy growth cycle of cash crops necessitates a substantial investment in infrastructure at the early stages of production. Additionally, the average farmer lacks access to market price information, which impairs their ability to anticipate the price trajectory of agricultural commodities over time. This increases the market's overall level of uncertainty. In contrast, grain crops have a relatively short growth cycle, relatively stable prices, no long-term capital hedging problem, and a relatively concentrated factor input time. Agricultural machinery has a stronger substitution effect on labor [11,12,22]. Therefore, farmers who have a demand for agricultural socialization services tend to choose grain crops with lower costs and risks and are more adaptable to the characteristics of service supply in order to realize their expected returns [10]. Agricultural machinery is often unable to operate effectively in the field, necessitating the investment of a substantial number of human laborers. The

process is complex, and the cost of supervision is high. The current grain cultivation has a more mature and perfect production technology and operational processes that facilitate large-scale batch operation of machinery [23]. This is conducive to the service organization undertaking a wider range of grain growers in the production service business. The realization of agricultural machinery operations on a large scale effectively saves the cost of both sides.

Overall, as the market for socialized agricultural services improves, farmers will demand more production services. Grain crops can reduce the cost of production services through more concentrated labor hours and more labor substitution. This will lead to a shift in farmers' cultivation decisions towards grain crops. Therefore, the following H1 is proposed:

H1. *Agricultural socialization services can help farmers transition their cropping systems to focus on grains.*

Agricultural socialization services on grain cultivation concentrate cultivated land and boost production efficiency. On the one hand, the agricultural socialized service market has enabled the repurposing of plots of land that were previously unattainable and less productive, stimulated the connection between land transfer supply and demand, and provided farmers with the opportunity to integrate arable land resources and expand their operational scale [10,11,24]. In the actual production process, although scattered and trivial land transfer can expand the scale of operation, it further deepens the degree of land fragmentation. Furthermore, it is still unable to overcome the disadvantages of small plot size. In contrast, continuous, centralized transfer can simultaneously expand the business scale and plot size. This reduces production factor and spatial transfer costs and simplifies the planting process. Similarly, in order to maintain the integrity of the operating plots as much as possible, farmers often prioritize remote and small plots and avoid transferring plots that are connected to the current operating plots when they make the decision to transfer out of arable land. Therefore, for some farmers with high farming advantages and motivation, when expanding their business scale, they tend to mitigate the adverse effects of farmland fragmentation by transferring into connected farmland and transferring out of remote plots. The Technology Acceptance Model posits that the expansion of plot size facilitates the production of grain crops, which are land-intensive products. This expansion also enables the realization of economies of scale, and farmers perceive grain cultivation behavior to be more straightforward and beneficial [17,21]. Consequently, they exhibit a greater propensity to cultivate grain crops, which provide evident benefits with regard to labor division. Conversely, production specialization frequently requires the use of diverse types of agricultural machinery, thereby increasing the financial burden on producers due to the acquisition cost of such equipment. The proliferation of socialized agricultural services has significantly lowered the bar for farmers to acquire large-scale agricultural machinery, enabling them to lease or buy such services instead of investing in their own, thereby easing the constraints on agricultural funds. Therefore, H2–H4 are proposed as follows:

H2. *Agricultural socialization services indirectly influence grain cultivation behavior by inducing farmers to transfer to connected arable land to take advantage of plot contiguity.*

H3. *Agricultural socialization services indirectly influence grain cultivation behavior by inhibiting farmers from transferring out of connected farmland and maintaining the integrity of plot concentration.*

H4. *Agricultural socialization services indirectly affect grain cultivation behavior by influencing farmers' mechanized production levels.*

Some farm households will experience a clear intergenerational division of labor as a result of a large number of laborers relocating to rural areas for non-agricultural

work; that is, the younger and stronger members of the family will engage in non-agricultural work, while the older members will remain in the village to continue agricultural production [9,14,22]. Physical and cognitive constraints pose significant challenges for elderly farmers when it comes to performing labor-intensive crop production exclusively through manual labor. In order to mitigate the impact of labor scarcity, these farmers often reduce operational scale, augment mechanized inputs, and implement other strategies. At this time, alternative elements of grain production are the least difficult to obtain, and labor division in production and the convenience of mechanized operations are comparatively greater. Furthermore, the reallocation of household labor and the subsequent rise in non-agricultural income alleviate the financial strain associated with agricultural production. This, in turn, can enhance the capacity of elderly farmers to finance agricultural socialized services, thereby fostering the overall advancement of such services. Moreover, this improvement in financial capacity facilitates the adoption of modern agricultural technologies and mechanization [25,26]. The existence of agricultural socialized services and non-agricultural income has changed the purpose of some elderly farmers engaged in agricultural production from profit maximization to self-sufficiency, thus increasing the rigid demand for production services and family rations. In addition, under the influence of traditional concepts, elderly farmers who tend to economize and avoid risky lifestyles tend to compare the consumption and returns of different crops, thus resisting the higher service costs, investment costs, and market risks of cash crops, and generating a "grain-oriented" planting preference. The aging of the household population increases the market demand for agricultural socialization services, thus promoting the influence of agricultural socialization services on grain cultivation. Therefore, H5 is proposed (Figure 1):

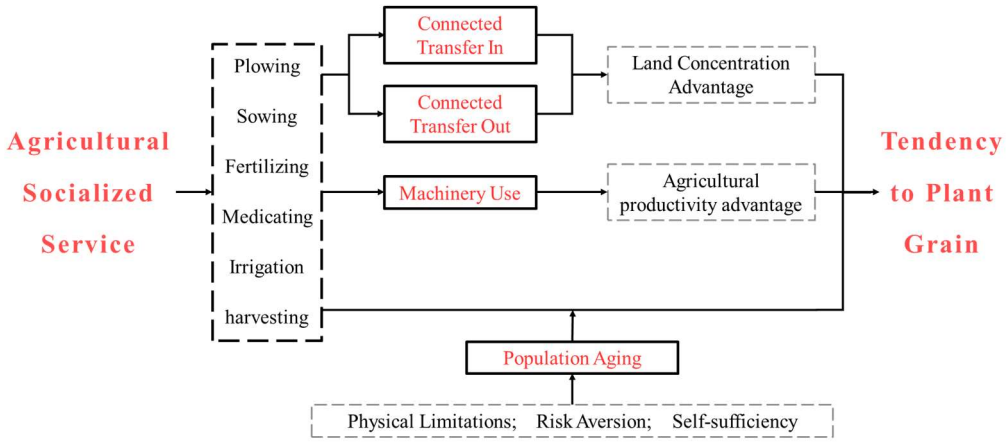

Figure 1. Theoretical framework diagram.

H5. *The deepening of household aging can increase the contribution of agricultural socialization services to grain cultivation.*

3. Materials and Methods

3.1. Data Sources

This paper evaluates the effect of agricultural socialization services on the grain cultivation of farmers, primarily using the China Rural Revitalization Survey (CRRS) data. CRRS is a national microdata survey program initiated by the Chinese Academy of Social Sciences, which interviews and collects data from farm households by penetrating rural areas nationwide. The dataset covers a variety of dimensions, such as household composition, employment status, agricultural production, customs and culture, and policy perceptions [27]. In selecting the study area to ensure the breadth and representativeness of the data, the project team selected one-third of the provinces (10 in total) for field research on a nationwide basis, according to various characteristics such as economic development, agricultural market, and terrain differences. In addition, five counties with

different levels of economic development were selected within each province using an equidistant random sampling method according to the ranking of GDP per capita. And the selection of townships and villages continued according to the same method to ensure the comprehensiveness of the data. In the end, 50 counties, 150 townships, and 300 villages were successfully surveyed (Figure 2). In selecting the farmers, the project staff strictly followed the principle of scientific sampling. The list of each village was carefully examined, and the farmers actually living in that village were examined one by one, and respondents were randomly selected according to the location of each farmer's house. Prior to the formal study, the right to information and consent of each farmer was ensured, fully respecting the individual wishes of the farmers. After a series of interviews, the project team successfully collected 3712 questionnaires from farmers. After rigorous data cleaning and calibration, 3709 valid samples were finally obtained.

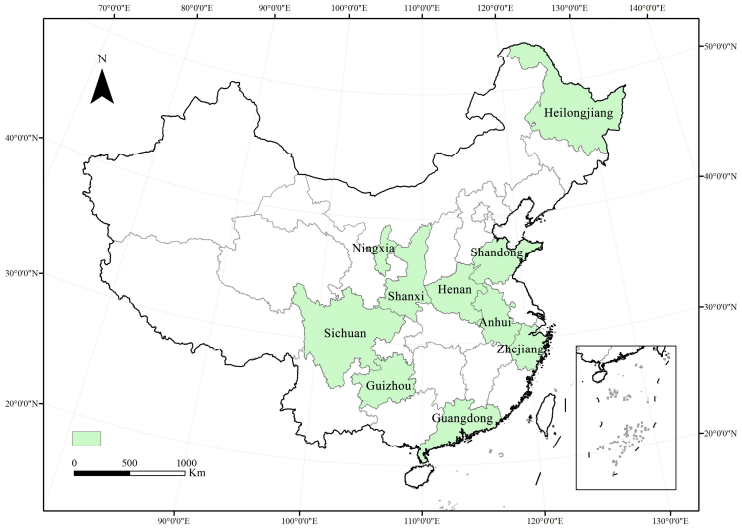

Figure 2. Map of study area.

3.2. Variable Selection

The dependent variable is farm household grain cultivation behavior (grain refers to crops such as wheat, rice, beans, corn, and potatoes). In this paper, the proportion of a farm household's grain cultivation is chosen to represent its grain cultivation behavior, specifically characterized by the proportion of the total area planted with grain crops in that farm household to the total area of cultivated land [28].

The explanatory variable is agricultural socialization services. If the farmer purchased socialized services in the previous year's agricultural production process, it is taken as 1; otherwise, it is taken as 0. Meanwhile, agricultural socialization services are a service system that includes a number of processes in agricultural production to depict better agriculture socialization service adoption. This paper focuses on the six segments of plowing, sowing, fertilizing, medicating, irrigation, and harvesting for production services by checking the data and ensuring that the data are available and authentic. If the farmer purchases socialization services in one of the segments, then the segment is taken as 1; otherwise, it is taken as 0 [29–31].

The mediating variables include three types of variables: connected transfer in, connected transfer out, and machinery use. The binary variables are connected transfer in and connected transfer out, which are assigned a value of 1 if the farm household transfers into a land that is connected to the current land and a value of 0 otherwise, and a value of 1 if the farmer transfers out a land that is connected to the current land and a value of 0 otherwise [9,23,32]. The percentage of the overall labor attributed to the machinery utilized by the farmer during the agricultural production process defines machinery use [13,33].

The moderating variable is the degree of household aging, which in this paper is characterized by the number of elderly members of the farm household as a share of the total number of members, and its moderating effect is measured by generating an interaction term with agricultural socialization services in subsequent calculations [34].

Theoretically, there may be omitted variables and reciprocal causality between agricultural socialization services and grain cultivation behavior, resulting in endogenous core explanatory variables. This paper takes the proportion of village-level socialized services (the proportion of other farm households within the village that purchase agricultural socialized services in addition to the current outdoor research) as the instrumental variable. The choice of the instrumental variable is mainly due to the following considerations: farmers' decision to purchase socialized services will be affected by whether other farmers within the same village purchase socialized services, the increase in production efficiency and agricultural income of other farmers will have an obvious driving effect on the farmers' intention to purchase socialized services, and the purchase decision of other farmers will not directly affect farmers' planting behavior. Therefore, the instrumental variable and the endogenous variable are highly correlated and independent of each other, which theoretically satisfies the exclusivity requirement.

This paper presents three kinds of control variables to reduce model estimate bias from omitted variables: first, household head characteristics, including the household head's gender, age, marital status, and education; second, household characteristics, including the members, the agricultural income, the non-agricultural employment, and the village leader household; and third, village characteristics, including the proportion of the village that can be irrigated, the topography of the village, the per capita disposable income, and the distance from village and county [28,35,36]. Meanwhile, regional dummy variables are generated to control for regional differences (Table 1).

Table 1. Descriptive statistical analysis of variables.

Variable		Mean	SD [a]
Dependent Variable			
Grain Cultivation	Ratio of area under grain crops to total operating area	0.49	0.46
Explanatory Variable			
Socialization Services	Whether to purchase agricultural socialization services (1 = Yes; 0 = No)	0.42	0.49
Plowing	Purchase of services for plowing (1 = Yes; 0 = No)	0.24	0.43
Sowing	Purchase of services for sowing (1 = Yes; 0 = No)	0.09	0.29
Medicating	Purchase of services for medicating (1 = Yes; 0 = No)	0.06	0.24
Fertilizing	Purchase of services for fertilizing (1 = Yes; 0 = No)	0.05	0.21
Irrigation	Purchase of services for irrigation (1 = Yes; 0 = No)	0.04	0.19
Harvesting	Purchase of services for harvesting (1 = Yes; 0 = No)	0.24	0.43
Control Variables			
Sex	Sex of household head (0 = female; 1 = male)	0.52	0.50
Mar	Marital status of head of household (1 = married; 0 = unmarried)	0.73	0.44
Age	Age of household head (years)	44.27	21.73
Edu	The average years of education	7.93	4.28
Leader	Whether there is a village leader among the family members (1 = Yes; 0 = No)	0.12	0.32
Non-Farm	Share of household non-farm labor force in total labor force	0.35	0.27
Person	Number of persons in household (persons)	4.19	1.86
Agricultural Income	Ratio of household agricultural income to total income	0.24	0.33
Village-County	Logarithm of distance (in kilometers) of village councils from county governments	2.92	0.77
Per Income	Logarithm of per capita disposable income of villagers in the village (yuan)	9.55	0.68
Irrigate	Proportion of irrigable cropland area in villages to total cropland area	0.66	0.39
Topography	The topography of the village (1 = plain; 2 = hilly; 3 = mountainous)	1.92	0.84
Mediating Variables			
Connected Transfer In	Transfers in a land that is connected to the current land (1 = Yes; 0 = No)	0.09	0.29
Connected Transfer Out	Transfers out a land that is connected to the current land (1 = Yes; 0 = No)	0.06	0.24
Machinery Use	Share of machinery use in total workload	0.23	0.28

Table 1. *Cont.*

Variable		Mean	SD [a]
Moderating Variable			
Household Aging	Number of older persons in the household as a proportion of the total number of members	0.19	0.30
Instrumental Variable			
Village-Level Socialized Services	The proportion of other farm households within the village that purchase agricultural socialized services in addition to the current outdoor research	0.42	0.34

Note: [a] SD = Standard deviation.

As shown in Table 1, the average proportion of grain cultivation among the 3709 samples was 49%. In total, 42% of the farmers had purchased agricultural socialization services, and the proportions of purchased services for plowing, sowing, fertilizing, medicating, irrigation, and harvesting were 24%, 9%, 6%, 5%, 4%, and 24%, respectively. The proportion of surveyed farmers whose household head was male was 52%, 73% of the household heads were married, the mean age of the household head was 44.27 years, and the mean years of education was 7.93 years. The average number of household members in agricultural households was 4.19, the non-farm employment rate was 0.35, 12% of households had members who were village cadres, and the average share of agricultural income was 24%. Sixty-six percent of the arable land in the sample villages was irrigated, the mean topography was 1.92, the mean log distance between village and county was 2.92, and the mean log per capita village disposable income was 9.55.

Table 2 compares the differences in the proportion of grain crops cultivated among groups of farmers under different socialized service adoption scenarios. It can be seen that the average proportion of grain cultivated by the group of farmers who purchased socialized services was 87%, while the average proportion of grain cultivated by the group of farmers who did not purchase agricultural socialized services was 22%, with a difference of 65%, which was significant at the 1% level. Throughout every phase of agricultural production, producers who acquired agricultural socialization services cultivated a considerably greater proportion of grain than those who did not.

Table 2. Differences in grain cultivation.

	Percentage of Grain Cultivation	Mean Value Difference
Socialization Services = 1	0.87	0.65 *** (0.01)
Socialization Services = 0	0.22	
Plowing = 1	0.88	0.51 *** (0.02)
Plowing = 0	0.37	
Sowing = 1	0.89	0.44 *** (0.01)
Sowing = 0	0.45	
Medicating = 1	0.91	0.44 *** (0.03)
Medicating = 0	0.47	
Fertilizing = 1	0.87	0.40 *** (0.03)
Fertilizing = 0	0.47	
Irrigation = 1	0.91	0.43 *** (0.04)
Irrigation = 0	0.48	
Harvesting = 1	0.92	0.56 *** (0.02)
Harvesting = 0	0.36	

Note: *** refer to $p < 0.01$.

3.3. Model Setup

The study employs the OLS model to estimate the impact of agricultural socialization services on the proportion of grain cultivated by farmers. Furthermore, this paper chooses the proportion of village-level socialized services as an instrumental variable and estimates it using the 2SLS model with the following estimation equation:

$$Y_i = \alpha_0 + \alpha_1 X_i + \alpha_2 \Sigma Con_i + \varepsilon_i \quad (1)$$

Among them, Y_i represents the proportion of grain cultivation by farmers; X_i is the purchase of socialized services by farmers; ΣCon_i is the control variables at the level of head of household, family, and village; α_0 is the constant term, ε_i is the random perturbation term; α_1 and α_2 are the regression coefficients.

This paper uses stepwise regression to carry out the test of the mediation effect, setting the following formula:

$$Y = cX + \varepsilon_1 \quad (2)$$

$$M = \alpha X + \varepsilon_2 \quad (3)$$

$$Y = c'X + bM + \varepsilon_3 \quad (4)$$

where Y denotes the proportion of grain cultivated by farmers, X denotes agricultural social services, M is the mediating variable, which denotes connected transfers in, connected transfers out, and machinery use, respectively, α, b, c and c' are all parameters to be estimated by the model.

In this paper, the following moderating effects model is established by adding the interaction terms of the moderating variables and the core explanatory variables:

$$Y_i = \alpha_0 + \alpha_1 X_i + \alpha_2 Z_i + \alpha_3 X_i \times Z_i + \alpha_4 \Sigma Con_i + \varepsilon_i \quad (5)$$

where Z_i denotes the degree of household aging; the interaction term between the degree of household aging and socialized services is represented by $X_i \times Z_i$; the remaining variables retain their definitions from Formula (1).

4. Results

4.1. Analysis of Regression Results

Prior to regression, the model underwent covariance testing. The variance inflation factors of the variables ranged from 1.04 to 2.88, all of which were significantly below 5. This suggests that there was no apparent issue of multicollinearity among the variables. The results of the baseline regression analysis, which examined the relationship between socialized services and grain production, are presented in Table 3. The coefficients of agricultural socialized services are all significantly positive at the 1% level, according to the results of the benchmark regression. Furthermore, the coefficients of the explanatory variables remain significant when the instrumental variable method is applied; the chosen instrumental variables have a substantial impact on agricultural socialized services; and there is no weak instrumental variable problem. Therefore, H1 is verified.

Table 4 shows the results of the regression of the purchase of socialized services in each segment of agricultural production on grain cultivation. Specifically, other things being equal, the proportion of grain grown by farmers who use socialized services in plowing, sowing, fertilizing, medicating, irrigation, and harvesting increases by 42.5%, 29.5%, 29.3%, 24.1%, 31.6%, and 53.5%, respectively, compared to those who do not use socialized services.

Table 3. Regression results.

	Grain Cultivation			
	OLS	**2SLS**	**OLS**	**2SLS**
Socialization Services	0.656 *** (0.010)	0.770 *** (0.017)	0.607 *** (0.013)	0.773 *** (0.029)
Sex			0.010 (0.010)	0.010 (0.010)
Mar			−0.011 (0.018)	−0.025 (0.019)
Age			0.000 (0.000)	0.001 (0.000)
Edu			−0.000 (0.001)	0.000 (0.001)
Leader			−0.018 (0.016)	−0.020 (0.016)
Non-Farm			−0.067 *** (0.020)	−0.057 *** (0.020)
Person			0.008 ** (0.003)	0.006 * (0.003)
Agricultural Income			0.105 *** (0.019)	0.046 ** (0.021)
Village-County			0.021 *** (0.007)	0.013 * (0.008)
Per Income			−0.043 *** (0.011)	−0.045 *** (0.011)
Irrigate			−0.025 (0.019)	−0.035 * (0.019)
Topography			0.033 *** (0.008)	0.042 *** (0.009)
Village-Level Socialized Services		0.892 *** (0.016)		0.745 *** (0.025)
_Cons	0.217 *** (0.008)	0.169 *** (0.010)	0.564 *** (0.112)	0.516 *** (0.110)
Regional	Yes	Yes	Yes	Yes
Weak Identification		950.96 ***		487.08 ***
N	3709	3709	3709	3709

Note: *, **, and *** refer to $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

Table 4. Impact of socialization services in various segments on grain cultivation.

	Grain Cultivation				**Marginal Effect**
Plowing	0.425 *** (0.014)				0.425
Sowing		0.295 *** (0.019)			0.295
Medicating			0.293 *** (0.021)		0.293
Fertilizing				0.241 *** (0.024)	0.241
Irrigation				0.316 *** (0.025)	0.316

Table 4. *Cont.*

	Grain Cultivation						Marginal Effect
Harvesting						0.535 *** (0.015)	0.535
Control	Yes	Yes	Yes	Yes	Yes	Yes	
Regional	Yes	Yes	Yes	Yes	Yes	Yes	
_Cons	0.729 *** (0.124)	0.719 *** (0.131)	0.699 *** (0.132)	0.724 *** (0.132)	0.750 *** (0.133)	0.622 *** (0.121)	
N	3709	3709	3709	3709	3709	3709	

Note: *** refer to $p < 0.01$.

4.2. Robustness Tests

This study performs the following robustness tests to validate benchmark regression results: (1) Replace the dependent variable with the area under grain cultivation, characterized by the logarithmic area of grain crop cultivation (mu) of this farmer. (2) Replace the dependent variable with the decision to grow grain, assigning a value of 1 if the farmer chooses to grow grain crops, and 0 otherwise. (3) Raise the observation perspective from the micro-farmer level to the meso-village level, replacing the dependent variable with the proportion of grain cultivation in the village (village grain crop area as a percentage of farmland) and the core explanatory variable with the proportion of socialized services in the village (the proportion of the farmers in the village that have purchasing proportion of socialized services). The robustness of the benchmark regression results is confirmed in Table 5, where agricultural socialized services continue to exert a significant positive influence on grain cultivation even after three re-measurements.

Table 5. Robustness tests.

	Area	Decision	Village Grain Cultivation
Socialization Services	1.525 *** (0.045)	3.489 *** (0.173)	
Village Socialization Services			0.466 *** (0.018)
Control	Yes	Yes	Yes
Regional	Yes	Yes	Yes
_Cons	1.769 *** (0.268)	0.126 (0.551)	1.010 *** (0.144)
Chi2		722.528	
N	3709	3709	3709

Note: *** refer to $p < 0.01$.

4.3. Mechanism Analysis

This section primarily uses the mediation effect model to validate studies H2–H4 in order to demonstrate how agricultural socialization services affect farmers' grain cultivation behavior. In particular, the following three pathways primarily verify the mechanism of agricultural socialization services' function in grain cultivation: (1) agricultural socialization services → connected transfer in → grain cultivation; (2) agricultural socialization services → connected transfer out → grain cultivation; (3) agricultural socialization service → machinery use → grain cultivation.

4.3.1. Mediating Effects of Connected Transfers In and Connected Transfers Out

In Table 6, agricultural socialization services can improve the quality of arable land and activate the transfer market to a certain extent, and farmers can realize the improvement

of the scale and quality of the operation by transferring into arable land connected to the operation plot or reducing the transfer out of connected plots, thus increasing the proportion of grain cultivation. Therefore, H2 and H3 can be verified.

Table 6. Mediating effects of connected transfers in and connected transfers out.

	Connected Transfers In	Grain Cultivation	Connected Transfers Out	Grain Cultivation
Socialization Services	0.337 *** (0.072)	0.604 *** (0.013)	−0.426 *** (0.089)	0.603 *** (0.013)
Connected Transfers In		0.074 *** (0.019)		
Connected Transfers Out				−0.085 *** (0.019)
Control	Yes	Yes	Yes	Yes
Regional	Yes	Yes	Yes	Yes
_Cons	−1.650 *** (0.435)	0.557 *** (0.111)	−2.321 *** (0.603)	0.564 *** (0.112)
N	3709	3709	3709	3709

Note: *** refer to $p < 0.01$.

4.3.2. Mediating Effects of Machinery Use

Table 7 reports the regression results of the mediating effect of machinery use between agricultural socialization services and grain cultivation. It can be seen that the improvement of agricultural farming conditions reduces the cost and difficulty of mechanical operations and frees farmers from the constraints of household resources. Mechanization of agricultural production increases farmers' preference for growing grain crops, thus promoting grain cultivation behavior. Thus, H4 is validated.

Table 7. Mediating effects of machinery use.

	Machinery Use	Grain Cultivation
Socialization Services	0.372 *** (0.007)	0.302 *** (0.018)
Machinery Use		0.820 *** (0.032)
Control	Yes	Yes
Regional	Yes	Yes
_Cons	0.304 *** (0.036)	0.315 *** (0.103)
N	3709	3709

Note: *** refer to $p < 0.01$.

4.4. Analysis of Moderating Effects

In Table 8, as the rate of household population aging accelerates, there is a corresponding rise in the market demand for agricultural socialization services. Consequently, this leads to a more pronounced influence of such services on grain cultivation. H5 is verified.

Table 8. Moderating effects.

	Grain Cultivation
Socialization Services	0.593 *** (0.015)
Socialization Services × Household Aging	0.062 * (0.034)
Household Aging	−0.101 *** (0.026)
Control	Yes
Regional	Yes
_Cons	0.592 *** (0.113)
N	3709

Note: * and *** refer to $p < 0.1$ and $p < 0.01$, respectively.

4.5. Further Analysis

In 2003, China designated 13 provinces (autonomous regions), such as Heilongjiang, Shandong, Hebei, and Sichuan, as major grain-producing areas, which are used to bear the heavy responsibility of grain production and supply. After nearly two decades of development, national grain security is increasingly dependent on producing areas. The primary producing areas accounted for 536.87 million tons of grain production in 2022, or 78.2% of the nation's total grain output. And while China's grain production has been steadily increasing, there are also serious concerns about grain supply in some areas. On the one hand, behind the continuous grain harvest is the overuse of resources and environment in the major grain-producing areas; some of the major grain-producing areas are facing problems such as over-exploitation of groundwater, soil fertility degradation, and the pressure to increase grain production is increasing. Furthermore, although the major grain-producing areas have made great contributions to national grain security, they have also borne the cost of slow economic development and backward industrial processes, widening the development gap between production and marketing areas. On the other hand, the grain shortage and demand in the major grain marketing areas are still large, and the grain self-sufficiency rate in some provinces is even less than 30%. A large amount of grain input not only creates more pressure on grain circulation but also poses a hidden danger to national food security [37,38]. This research utilizes regional grain production characteristics as a grouping criteria to determine the impacts of agricultural socialization services to address diminishing grain cultivation in marketing regions and overburdening grain output in producing areas.

In Table 9, agricultural socialization services facilitate farmers' grain cultivation behavior in all three regions, and their regression coefficients are significantly different, with the main grain production areas showing a stronger effect. One plausible explanation is that the primary grain-producing regions are built upon a solid foundation conducive to grain cultivation, with relatively perfect infrastructure and policy support for agricultural production, and most of them are located in the plains, so the difficulty of agricultural socialization services is relatively lower, and the improvement of production efficiency is more obvious, thus providing high-quality conditions for local farmers to cultivate grain crops.

Table 9. Impact of regional heterogeneity.

	Grain Cultivation		
	Grain Producing Areas	**Grain Marketing Areas**	**Grain Balancing Areas**
Socialization Services	1.010 ***	0.811 ***	0.517 ***
	(0.047)	(0.073)	(0.051)
Control	Yes	Yes	Yes
Regional	Yes	Yes	Yes
_Cons	0.764 ***	0.341 *	0.389 **
	(0.178)	(0.193)	(0.161)
Coefficient Differences	0.199 ***		0.295 ***
N	1815	727	1167

Note: *, **, and *** refer to $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

5. Discussion

As the world's major grain-producing and populous country with a large land area, the implementation of China's food security strategy will be conducive to maintaining a stable supply of global grain and alleviating the problem of hunger. At the same time, China's way of further increasing grain production and developing specialized and modernized agriculture through socialized services will also provide a template for other developing countries and a practical reference for the scientific development of agriculture in the world.

At present, China's food security is facing multiple pressures at home and abroad. First, the unpredictability of international grain trade has been heightened by intricate shifts in the global environment, and there is a substantial disparity in global grain demand. Second, the aging of agricultural labor and the rising trend of non-grain cultivation on arable land have significantly hampered the nation's ability to maintain a steady grain supply in the future. In this context, agricultural socialization services can alleviate the disadvantage of the labor force to a certain extent and improve the efficiency of agricultural production by applying advanced production technology and management, which may be a feasible means to alleviate the current pressure of increasing grain production [10,39,40]. Thus, this study uses the China Rural Revitalization Survey database and measurement tools like the 2SLS model, mediated effects model, and instrumental variables approach to examine the mechanism of action and discrepancies in agricultural socialization services' effects on farmers' grain cultivation.

When compared to prior research, this study's innovation is primarily evident in the following three aspects: (1) This paper considers multiple processes of agricultural production and tries to analyze the effects of planting, sowing, fertilizing, medicating, irrigation, and harvesting on the farmers' grain cultivation behavior. (2) Although both decentralized land transfer and connected land transfer can expand the operation area, decentralized land transfer cannot solve the problem of land fragmentation, and it is difficult to fully realize the advantages of land concentration. Therefore, in the mechanism analysis, this paper focuses on the connected land transfer, hoping to obtain more accurate and reasonable analysis results and provide references for subsequent research. (3) Under the background of the massive exodus of young workers from rural areas, most of the current agricultural production is dominated by elderly workers, and existing studies still disagree on whether the aging labor force will hinder grain cultivation. The current state of labor force aging is examined in this paper, along with the moderating influence of labor force aging throughout the entire impact process.

The study found that agricultural socialization services can promote farmers' grain cultivation behavior, thus contributing positively to national food security. This result is consistent with H1 and is in line with the main points of some recent studies [17,21,23]. In all aspects of agricultural production, other things being equal, the proportion of grain grown by farmers who use socialized services in plowing, sowing, fertilizing, medicating, irrigation, and harvesting increases by 42.5%, 29.5%, 29.3%, 24.1%, 31.6%, and 53.5%,

respectively, compared to those who do not use socialized services. In the mechanism analysis part, based on the existing studies [41–43], this study additionally discovered that agricultural socialization services have the potential to greatly influence the grain cultivation of farmers through the promotion of connected transfer in, inhibition of connected transfer out in order to capitalize on plot concentration, and encouragement of the utilization of agricultural machinery to enhance production efficiency. These results are consistent with H2–H4. Unlike some studies [44,45], this paper argues that the influence of agricultural socialization services on grain cultivation is amplified as the rate of household population aging accelerates. The possible explanation is that older farmers may find it difficult to produce labor-intensive crops with manual labor due to physical and cognitive limitations, so they reduce the scale of operation and increase mechanical inputs, etc., and grain just fits into this production process. Moreover, this measure is in response to the problem of declining grain cultivation in the main marketing areas and overburdened grain production in the main production areas [38,46]. This study delves deeper into the variations among grain-producing regions and concludes that agricultural socialization services facilitate the grain cultivation practices of farmers in all three areas, with the most pronounced effect occurring in the main grain-producing areas. Main grain production areas benefit from well-established infrastructure, policy support, and favorable geographical locations, resulting in lower costs and challenges in agricultural services. This leads to increased production efficiency and provides ideal conditions for local farmers to cultivate high-quality grain.

It is worth mentioning that there are still some shortcomings in this study. China's rural areas are presently beset by a diverse and complex situation, with substantial variations in land use and production choices observed across distinct regions and agricultural household groups. Therefore, analyzing farm households as a whole may slightly affect the accuracy of the results. In addition, the grain cultivation behavior of farmers may vary at different times and locations, so further observation of farmers' behavior from the perspective of time and space may lead to more valuable conclusions. Unfortunately, although the CRRS database is a relatively comprehensive and accurate database that we selected after comparison and testing, it is still unable to solve the above problems for the time being. Therefore, these shortcomings will be an important direction to improve and supplement the research in the future, and in the future, this study will select more detailed data to analyze the farmers' behavior more accurately.

6. Conclusions

The study systematically assesses the influence of agricultural socialization services on grain cultivation at the household level using a large sample of survey data. It primarily arrives at the following conclusions: (1) The average proportion of grain cultivation area of farm households in the sample is 49%, and 42% of farm households have purchased agricultural socialization services. (2) Agricultural socialization services can significantly promote farmers' grain cultivation behavior by promoting connected transfer in and inhibiting connected transfer out to take advantage of plot concentration and encouraging agricultural equipment usage to boost productivity. (3) The deepening of the aging of the household population will, to a certain extent, strengthen the promoting effect of agricultural socialization services on grain cultivation, and in the main grain-producing areas, the impact of agricultural socialization services on grain cultivation is stronger.

Based on the above conclusions, this paper puts forward the following policy recommendations:

(1) Consider the impact that agricultural socialization services have on the reduction of the "non-grain" structure of cultivation. It is imperative that we establish a favorable market environment for the majority of agricultural socialized services and enable diverse service providers to completely realize their growth potential. Optimize pertinent policies and regulations, augment production subsidies for diverse service organizations, enhance and compensate for the deficiencies of each service provision

link, and maximize the favorable effects of the socialized agricultural service market on local grain cultivation. Concurrently, prioritize the farmers in agricultural socialized services guidance and publicity, ensure that they are the primary force behind all types of new agricultural management, and fortify their favorable attitude toward agricultural socialized services.

(2) Further promote moderate-scale operation and facilitate the operation of machinery. Each region should actively cultivate the land transfer market, reintegrate arable land resources through standardized and market-oriented land transfer, make full use of the advantages of plot concentration, improve agricultural conditions, and reduce the production disadvantages caused by fine fragmentation of arable land. Simultaneously, the government should implement the conversion of cropland and mechanized roadways in order to mitigate the labor force constraint associated with grain cultivation via mechanized and extensive agricultural production, thereby achieving the sustainable utilization and protection of arable land resources.

(3) Provide an agricultural production service model with a wider range of services and more comprehensive coverage, taking full account of the current situation of an aging population. Attach importance to and actively respond to the demand for production services caused by the aging population, continuously extend the production chain, improve the service model, and solve the current problems of "no planting" and "poor planting" in rural areas through the whole process and a wide range of agricultural socialized services. Furthermore, in accordance with the current state of local grain production, municipalities should facilitate the growth of the socialized service market and make timely adjustments to the cultivation structure in order to increase the rate of grain self-sufficiency via policy mechanisms. It is imperative that the three regions collectively assume the substantial burden of guaranteeing food security, preserving land and production, and steadfastly maintaining China's rice bowl.

Author Contributions: Conceptualization, R.L. and J.C.; methodology, D.X.; formal analysis, J.C.; investigation, J.C.; writing—original draft preparation, R.L., J.C. and D.X.; writing—review and editing, R.L., J.C. and D.X.; supervision, D.X.; funding acquisition, D.X. All authors have read and agreed to the published version of the manuscript.

Funding: This project was funded by the Special Program for Cultivating Excellent Young Talents under the Dual Support Plan of Sichuan Agricultural University, a Key research base project of Sichuan Province Philosophy and Social Science (SC22EZD038), and Supported by Sichuan Rural Development Research Center (2023CR27).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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

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