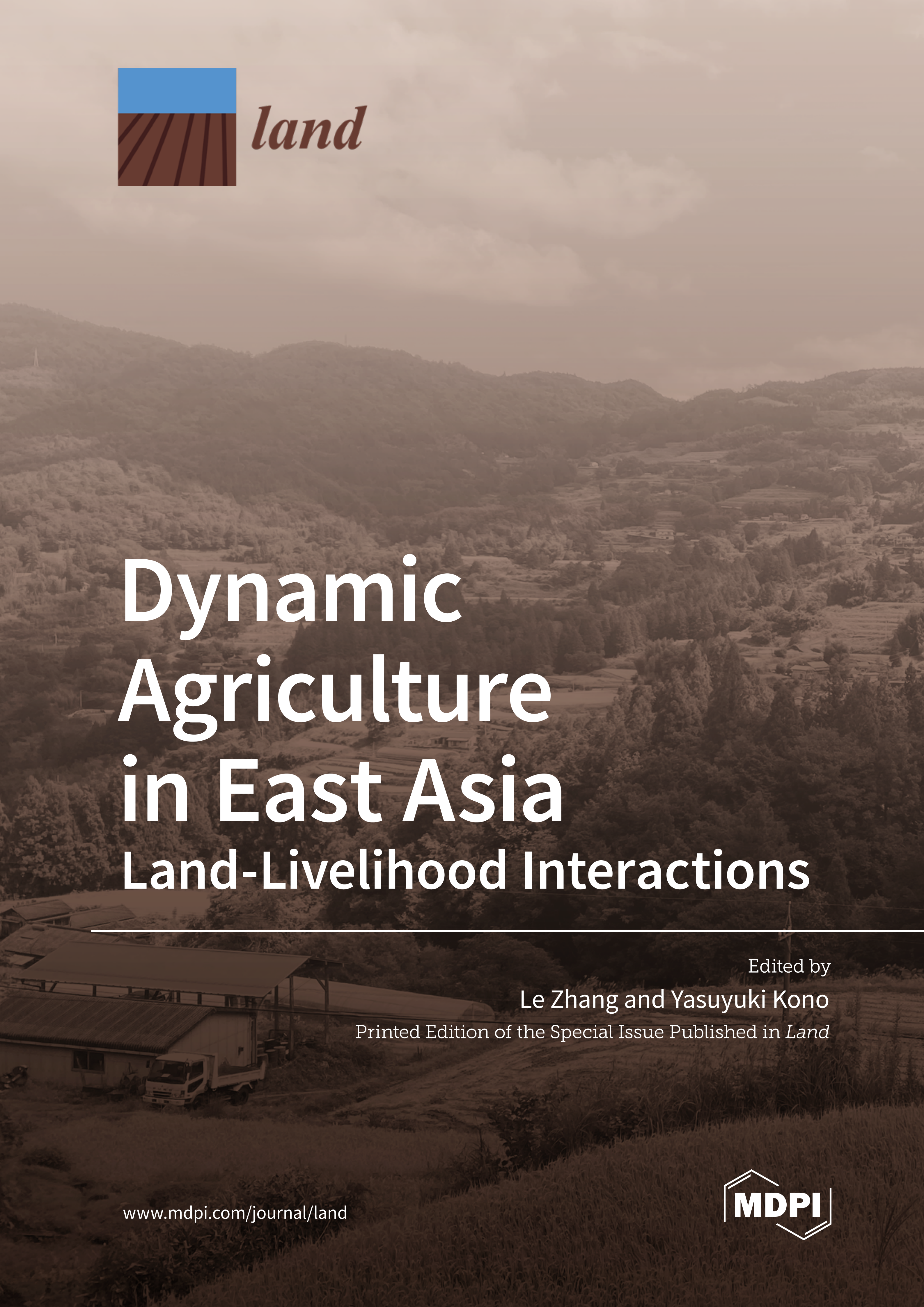

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# Dynamic Agriculture in East Asia

## Land-Livelihood Interactions

Edited by
Le Zhang and Yasuyuki Kono

Printed Edition of the Special Issue Published in *Land*

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# Dynamic Agriculture in East Asia: Land-Livelihood Interactions

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Editors

**Le Zhang**

**Yasuyuki Kono**

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# About the Editors

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# Preface to "Dynamic Agriculture in East Asia: Land-Livelihood Interactions"

Agriculture is an essential industry that provides products for sustaining human life. Changes in agricultural systems have a profound impact on food security and environmental health. As one of the most densely populated regions in the world, East Asia has evolved into having a relatively stable mode of smallholder agriculture and homogeneous rural societies in the past forty centuries. However, subsistence smallholder agriculture has been abandoned due to the massive industrialization and urbanization in this region since the end of the 20th century.

A livelihood is a means of gaining a living and encompasses the capacity, assets, and activities required for achieving livelihood goals. The livelihood enterprises of rural households can generally be divided into agricultural production and off-farm employment, while farmers must carefully consider how to invest their resources into the two enterprises since they are extremely limited in time and capital. Thus, farmers' attitudes and behaviors toward agricultural production essentially depend on their livelihood choices. As the carrier of agricultural production, the quantity and quality of land is another key factor that affects the form of agricultural systems. Therefore, the dynamic change in agricultural systems is essentially driven by rural livelihood transitions in the context of socioeconomic transformation, such as the introduction of smart farming, innovation of farm mechanization and reform of agricultural policy, while the process must be based on the state of land resources.

This reprint aims to clarify how the interactions of rural livelihoods and land create diverse and dynamic agricultural systems across the different socioeconomic and biophysical backgrounds in East Asia. The authors of the reprint articles are scholars from universities in China, Japan, Thailand and the USA, including Kyoto University, Jiangxi Normal University, Akita Prefectural University, Henan University, Henan University of Economics and Law, Henan Normal University, Shaanxi University of Science and Technology, Shaanxi Normal University, South China Normal University, South China Agricultural University, Sichuan Agricultural University, Guangzhou University, Kasetsart University and Kent State University. During the publishing of this book, the Guest Editors received financial support from the NSFC-JSPS Scientific Cooperation Program "Bilateral seminar on sustainable development of agriculture and rural community in China and Japan" (no. 42181340171; no. JPJSBP220217402) and assistance from Ms. Ning Mao, the managing editor of the journal *Land*.

**Le Zhang and Yasuyuki Kono**

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# Coupling Coordination Analysis of Livelihood Efficiency and Land Use for Households in Poverty-Alleviated Mountainous Areas

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**Abstract:** The interaction between livelihood means and land use pattern of households is the core of the interactive coupling of the human-land system. This study focuses on Qinba mountainous area in southern Shaanxi province, a typical poverty-alleviated mountainous area. With the help of the coupling coordination degree model, kernel density estimation, and trend surface analysis, this study constructs the coupling coordination degree of livelihood efficiency and land use for households, and analyzes the differences between households' livelihood efficiency and land use level, as well as the coupling coordination relationship between households livelihood efficiency and land use in different types and regions. The research conclusions are as follows. (1) For households in the Qinba mountainous area, southern Shaanxi province, the livelihood efficiency is at a medium level of 0.681, the land use is at a low level of 0.127, while the coupling coordination degree 0.526 is at the primary coordination state. (2) With the increase of nonagricultural degree, the coupling coordination degree of households increases first, and then decreases. (3) The coupling coordination degree for households east-to-west is "sagging", while south-to-north diagram is "hogging". (4) The distribution of the coupling coordination degree for agriculture-dependent households east-to-west (the "sagging" diagram) is opposite to the other types of households. By analogy, the distribution of the coupling coordination degree for nonagriculture and agriculture-dependent households north-to-south (the "hogging" diagram) is opposite to the other types of households. The coupling coordination between the households' livelihood efficiency and land use level is affected by the households' regional development level, natural resources, geographic location, infrastructure availability and many other factors. Making appropriate livelihood development plans based on the types of households and regional space can both effectively improve the livelihood conditions, as well as offer guidance in promoting regional human-land activity coordination and ensuring sustainable development.

**Keywords:** livelihood efficiency; land use; coupling coordination; types of households; poverty-alleviated mountainous areas

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## 1. Introduction

The human-land relationship and its evolution are key issues for rural development, and the core content of research on human-land relationship is to reveal the interaction and influence mechanism between the population system and the land system, coordinate the human-land relationship, and promote regional sustainable development [1]. At present, the tense human-land relationship and land in China's mountainous areas, as showcased here by the Qinba mountain area in southern Shaanxi province, reveal a shortage of per capita cultivated land, its lower quality, weak agricultural infrastructure and lower economic benefits. This situation seriously restricts the development of households, preconditions the massive migration of the rural labor force, and increasingly highlights the problems in nonagricultural rural industries, obsolete production lines and poor natural resources [2]. Furthermore, with the development of urbanization, disordered development of land resources, extensive exploitation and utilization of land resources, degradation of land ecological functions have become increasingly intensified [3]. How to coordinate the relationship between households' livelihoods and land use, promote the economical and intensive utilization of land resources, and facilitate a continuous increase in households income, has become primary issues in the development of agricultural and rural areas and the implementation of a rural revitalization policy.

The human-land relationship is an open giant system formed by the interaction of two complex systems: geographical environment and human activities. In related research, scholars have carried out research on "man", "land" and "human-land relationship". In terms of "man", scholars have conducted research on livelihood capital, livelihood strategies, livelihood means, livelihood vulnerability and livelihood output, among others, mainly from the perspective of sustainable livelihood [4–8] and pointed out that the fundamental reasons for the backward development of rural areas are insufficient and irrational allocated livelihood capital stock, poor feasibility of livelihood means, and limited livelihood approaches [9]. To fundamentally solve the above-mentioned problems and improve the livelihood ability of the households and effectiveness of rural development, it is necessary to carry out research on efficiency evaluations that match the livelihood means to explore the process characteristics and mechanism of livelihoods [10]. In terms of "land", scholars have mainly explored the behavior, efficiency, structure, influencing factors, and spatial-temporal differentiation of land use [11–15]. For regions with obvious differences in landform, such as plains, hills, and mountains, the level of intensive use of households has significant differences [16]. At the same time, the social and economic development level, policy environment, resource endowment, land fragmentation, land transfer, family characteristics of households, agricultural production subsidies, and the proportion of economic crops and other factors also have an impact on the land use level of households [17–19].

Livelihood reflects the selective utilization of resources by human beings [20]. The regional differentiation of the natural geographical environment and the regional differences of socio-economic conditions make human beings exhibit different resource value orientations, utilization modes and utilization levels in resource utilization [21]. As the main body of land resource utilization and protection, household livelihoods (livelihood capital, livelihood strategy, etc.) are closely related to the utilization of land resources (utilization structure, utilization efficiency, etc.). Therefore, scholars focus on the relationship between household livelihood and land use and explore this from two aspects. Some research focuses on the impact of household livelihood on land use. The evolution of livelihood capital endowments and livelihood means of households leads to changes in land use efficiency, intensity and structure [22], which also have direct or indirect impacts on the ecological environment system [23,24]. Generally speaking, households with higher human capital and natural capital are more dependent on resource utilization [25], and diversified livelihood means can help to improve land use efficiency of households and reduce livelihood risks [26]. Other research focuses on the impact of land use on the livelihoods of households. Related research focuses on analyzing the impact of land degradation, changes in land use pattern, land use type, and land use intensification on livelihood capital and livelihood strategies of households [27,28]. The change of land use mode can effectively improve the livelihood adaptability of households. There are significant differences in land use efficiency of households with different livelihood strategy types, and household diversified and nonagricultural livelihood strategies can help to improve land use efficiency and reduce livelihood risk [29]. The efficient use of land resources helps households increase their income, improve their economic status, reduce their vulnerability, improve the accessibility of assets and the sustainability of resource management [30]. On the contrary, it has a wide and profound impact on community poverty, residents' livelihood mode, population migration and mobility [31].

In essence, the available research on human-land relationships have paid more attention to a single aspect of either livelihood or land use, and mostly discussed a one-way impact, ignoring the mutuality and interaction between the two. In addition, previous studies have mostly focused on the relationship between a single segment of livelihood (such as capital strategy or efficiency) and land use, but seldom do they explore the interaction and spatial distribution law between livelihoods and land use of households from the perspective of process and efficiency systematically. In fact, the two major subsystems of the man-land system, the livelihood system and the land use system of households, change in an interwoven way. The change in the livelihood system leads to change in the land use system, which induces further change in the livelihood system [32]. For regions with different landforms, resource endowments and economic development levels, the relationship between household livelihood and land use is also different. Especially for the Qinba Mountain Area in southern Shaanxi, a typical poverty-alleviated mountainous area, there are obvious differences between household livelihood and land use in various regions. Therefore, taking Qinba mountainous area as the research subject, this study analyzed the coupling coordination relationship between the livelihood efficiency and land use of households in different types and regions in the Qinba mountainous area by constructing a model for the coupling coordination degree of livelihood efficiency-land use of households, hoping to provide a decision-making reference for promoting the coordinated development of the livelihood and land use of households to design regional sustainable development policies.

The main contributions of this study are as follows. (1) An innovative concept of "livelihood efficiency" as the standard for evaluating household livelihood via development capacity and quality is introduced, along with a new perspective and method for sustainable livelihood research. (2) Pay attention to the mutuality and impact between household livelihood and land use practices, exploring the relationship between them from the perspective of process design and implementation efficiency, which enriches and expands the research of "human-land relationship". (3) Starting from the household and spatial levels, we explore the coupling coordination relationship between household livelihood efficiency and land use, ensuring practical and targeted countermeasures, along with suggestions for households of different types and regions.

The next Section 2 introduces the current situation, data sources and research methods related to the Qinba mountain area in southern Shaanxi. Section 3 presents the results of household livelihood efficiency and land use intensity analyses, as well as the coupling degree, development degree, and coupling coordination degree from the perspective of household types and regional distribution. Section 4 summarizes the research, draws conclusions, and puts forward relevant solutions or countermeasures.

## 2. Materials and Methods

### *2.1. Research Area*

Qinba is a $7.03 \times 10^4$ km$^2$ mountainous area south of Shaanxi province (i.e., 34.19%), covering 3 cities, Hanzhong, Ankang, and Shangluo, and a total of 28 districts, as well as counties such as Ziyang, Shiquan, Zhen'an, and Ningqiang (Figure 1) [33]. As a typical poverty-alleviated mountainous area, Qinba has a complex geological structure, weak infrastructure, poor transportation network, insufficient land supply, limited income source for households, and rigid agricultural production. This has led to low livelihood capacity and efficiency for households [34,35]. As a national key ecological area, it steadily maintains the roles of "ecological security", "resource reserve" and "landscape designer". In order to maintain ecosystem security, households in the area have sacrificed a number of development opportunities, the utilization intensity of land resources is low, and the "rich poverty" phenomenon has become chronic in the area. Nowadays, promoting high-quality development limited by resource conservation and environmental protection policies to strike a balance between survival and development for land use by the households is an acute practical challenge in Qinba.

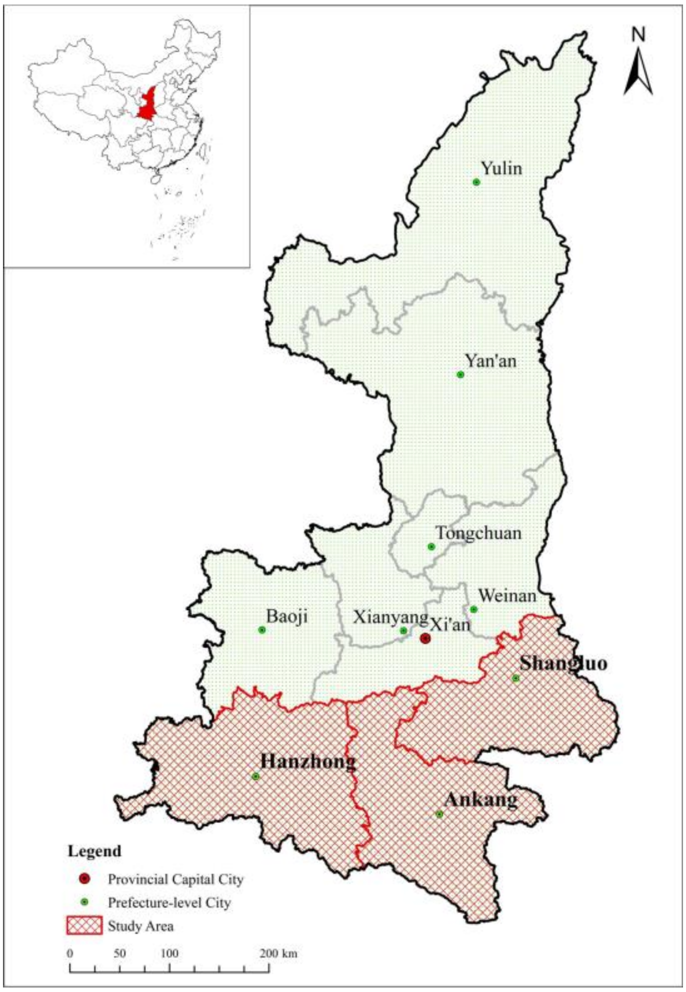



**Figure 1.** Location of administrative divisions of three cities in southern Shaanxi.

*2.2. Data Sources*

The research data reflect the results of a field household survey conducted by the research team in Qinba in August 2020. The samples of the formal survey represent the interviewee household information selected via stratified random sampling as "sample city-sample district and county-sample town-sample village-households". A total of 796 questionnaires were collected from 24 districts and counties in the three cities of Hanzhong, Ankang, and Shangluo. This survey has two parts: household livelihood, and production (planting and breeding). A total of 746 valid data points were obtained after screening households' livelihood data. A total of 639 valid questionnaires were obtained after screening household livelihood and production data, with an effective questionnaire rate of 80.28%. At present, the population migration from the Qinba mountain area in Southern Shaanxi is alarming. Most of the remaining rural population are the elderly and disabled groups, or people engaged in nonagricultural activities. The lack of a large number of household production statistics makes the effective questionnaire rate of this study relatively low. The basic characteristics of sample households are shown in Table 1. It can be seen from Table 1 that this survey covered households of different age groups, and the ratio of males and females was basically equal, among which 68.23% received education not exceeding junior high school. By comparing the survey data against the statistical data of Shaanxi province, Hanzhong city, Ankang city, Shangluo city, it can be concluded that the samples obtained are consistent with the actual local conditions, and thus representative to a certain extent.

**Table 1.** Basic characteristics of sample households.

| Index | Category | Frequency Number | Frequency Rate |
|---|---|---|---|
| Gender | Male | 351 | 54.93% |
| | Female | 288 | 45.07% |
| Age groups | ≤20 years old | 47 | 7.35% |
| | 21–35 years old | 135 | 21.13% |
| | 36–50 years old | 259 | 40.53% |
| | 51–65 years old | 143 | 22.38% |
| | ≥66 years old | 55 | 8.61% |
| Education level | Primary school and lower | 224 | 35.05% |
| | Junior high school | 212 | 33.18% |
| | High school or technical secondary school | 89 | 13.93% |
| | Junior college or higher | 114 | 17.84% |
| Population size | ≤2 | 42 | 6.57% |
| | 3–4 | 391 | 61.19% |
| | ≥5 | 206 | 32.24% |

### *2.3. Variable Selection*

#### 2.3.1. The Evaluation Index System of Household Livelihood Efficiency

Livelihood efficiency reflects the feasibility of households to survive and seek development, which is a comprehensive reflection of the allocation status, utilization effect and management decision-making level of the capital elements that are used for the livelihood of households in their livelihood activities [36]. Based on the research results of household livelihoods [37–39] and the actual conditions of households in Qinba, this study constructed an evaluation index system of household livelihood efficiency (Table 2) using livelihood input (human capital, physical capital, natural capital, financial capital, social capital, and information capital) as the input index, and livelihood output (income level, welfare level, employment opportunities, rural attachment, ecological protection awareness) as the output index.

#### 2.3.2. Evaluation Index System of Household Land Use Level

Based on the related research results for land use [40] and the actual land use conditions for households in Qinba, this study constructed the evaluation index system of household land use level (Table 3) from the perspective of the land use intensity, land use structure, land use benefits, and land use trends.

**Table 2.** The evaluation index system of household livelihood efficiency.

| Evaluation Index | | Variable | Definition and Description of Variable |
|---|---|---|---|
| Livelihood input | Human capital | Age | 0.5: ≤20 years old; 2: 21–35 years old; 3: 36–50 years old; 1.5: 51–65 years old; 0.8: ≥66 years old |
| | | Education level | 1: Primary school and lower; 2: Junior high school; 3: High school or technical secondary school; 4: Junior college or higher |
| | | Health status | 1: very bad; 2: bad; 3: fair; 4: good; 5: very good |
| | | Population size | Number of family members |
| | Physical capital | Number of livestock | 0: 0; 1: 1–10; 2: 11–20; 3: 21–30; 4: ≥31 |
| | | Daily supplies | Quantity of daily supplies (pieces) |
| | | Transportation/vehicle tools | Number of transportation/vehicle units (vehicles) |
| | | Housing condition | Number of rooms (rooms) |
| | Natural capital | Cultivated land area | Gross cultivated land area (mu) |
| | | Planting area | Actual planting area (mu) |
| | | Whether production water can be used as domestic water | 0: no; 1: yes |
| | Financial capital | Gross annual income | 1: 10,000 and below; 2: 10,000–20,000; 3: 20,000–50,000; 4: 50,000–100,000; 5: more than 100,000 |
| | | Loan/money borrowing opportunities | 0: no; 1: yes |
| | | Channels for obtaining loans/borrowing funds | Number of channels for obtaining funds |
| | Social capital | Whether family has cadres | 0: no; 1: yes |
| | | Trust of neighbors and villagers | 1: Almost none; 2: Minority; 3: Half; 4: Majority; 5: Almost all |
| | | Channels for getting help in time of livelihood difficulties | Number of channels for getting help |
| | | Participation in the election of village cadres | 0: no; 1: yes |
| | Information capital | Number of information obtaining devices | Number of devices used to obtain information |
| | | Channels for obtaining information | Number of channels for obtaining information |
| | | Timely acquisition of policy, market and other information | 0: no; 1: yes |
| Livelihood output | Income level | Income change condition | 1: Significantly reduced; 2: Reduced; 3: No change; 4: Improved; 5: Significantly improved |
| | Welfare level | Improvement of education and medical care | 1: Significantly reduced; 2: Reduced; 3: No change; 4: Improved; 5: Significantly improved |
| | Employment opportunities | Improvement of employment channels | 1: Significantly reduced; 2: Reduced; 3: No change; 4: Improved; 5: Significantly improved |
| | Rural attachment | Sense of pride and attachment to hometown | 1: Significantly reduced; 2: Reduced; 3: No change; 4: Improved; 5: Significantly improved |
| | Ecological protection consciousness | Ecological protection consciousness and values | 1: Significantly reduced; 2: Reduced; 3: No change; 4: Improved; 5: Significantly improved |

**Table 3.** The evaluation index system of household land use level.

| Evaluation Index | | Variable | Definition and Description of Variable |
|---|---|---|---|
| Land use level | Land use intensity | Per capita cultivated land area | Gross cultivated land area/gross family population (mu/person) |
| | | Irrigation condition | 0: no; 1: yes |
| | | Idle land | 0: no; 1: yes |
| | | Land circulation | 0: no; 1: yes |
| | Land use structure | Agricultural structure | 1: No planting and no breeding; 2: Only planting; 3: Only breeding; 4: Planting and breeding |
| | | Land input | Gross planting and breeding area (mu) |
| | | Labor input | Number of labor force aged 20–65 (person) |
| | | Funds input | Input cost of seeds, pesticides, chemical fertilizers, agricultural film, machinery (yuan) |
| | Land use benefits | Gross agricultural output value | Gross income from planting and breeding (yuan) |
| | | Gross agricultural output | Gross output of planting and breeding (jin) |
| | Land use trend | Changes in planting labor input | 1: Decrease; 2: Unchanged; 3: Increase |
| | | Changes in planting capital input | 1: Decrease; 2: Unchanged; 3: Increase |
| | | Changes in breeding labor input | 1: Decrease; 2: Unchanged; 3: Increase |
| | | Changes in breeding capital input | 1: Decrease; 2: Unchanged; 3: Increase |

## 2.4. Research Methods

### 2.4.1. Coupling Coordination Degree Model

The coupling coordination degree model was introduced to analyze the coupling coordination relationship between household livelihood efficiency and land use levels to effectively reveal the interdependence and restriction mechanism between the two. In the model, the coupling degree reflects the degree of interdependence and interaction of livelihood efficiency system vs. land use system, the development degree reflects the overall benefit or level of livelihood efficiency system vs. land use system, and the coupling coordination degree refers to the degree of benign coupling in the interaction of the two systems, which can reflect the degree of coordinated development of livelihood efficiency system vs. land use system [41,42]. With reference to previous research [43–46], the coupling degree, development degree, and coupling coordination degree of household livelihood efficiency and land use can be divided into the following grades (Table 4).

**Table 4.** Grade division standard for coupling degree, development degree, and coupling coordination degree.

| Coupling Degree | Coupling Type | Development Degree | Development Type | Coupling Coordination Degree | Coupling Coordination Type |
|---|---|---|---|---|---|
| 0–0.199 | Severe uncoupling | 0–0.199 | Severe lag | 0–0.199 | Severe incoordination |
| 0.200–0.399 | Slight uncoupling | 0.200–0.399 | Slight lag | 0.200–0.399 | Slight incoordination |
| 0.400–0.599 | Primary coupling | 0.400–0.599 | Primary development | 0.400–0.599 | Primary coordination |
| 0.600–0.799 | Intermediate coupling | 0.600–0.799 | Intermediate development | 0.600–0.799 | Intermediate coordination |
| 0.800–1.000 | Advanced coupling | 0.800–1.000 | Advanced development | 0.800–1.000 | Advanced coordination |

2.4.2. Kernel Density Estimation

Kernel density estimation is mainly used to estimate the probability density of random variables. Continuous density curves are used to describe the distribution pattern of the random variables to reveal the evolution trend of differences intuitively [47,48]. Stata16 software was used to draw a kernel density map to clarify the distribution characteristics of the coupling coordination relationship between household livelihood efficiency and land use at the household level.

2.4.3. Trend Surface Analysis

The trend surface is an approximate treatment of the actual surface, which represents the spatial distribution law and change trend of geographic elements or observed value [49,50]. With the help of the trend surface analysis tool in ArcGIS software, we explored the overall spatial differentiation trend of the coupling coordination relationship between household livelihood efficiency and land use.

## 3. Results

Based on the household livelihood efficiency measured using the DEA model and the household land use level measured with the entropy method, we obtained statistical results of the coupling coordination between household livelihood efficiency and land use with the aid of the coupling coordination degree model. Table 5 shows the overall condition of livelihood efficiency, land use level, coupling degree, development degree, and coupling coordination degree of households in Qinba.

**Table 5.** Statistics for coupling coordination between household livelihood efficiency and land use.

| Item | Category | Sample Size | Minimum Value | Maximum Value | Average Value | Standard Deviation |
|---|---|---|---|---|---|---|
| Livelihood efficiency | Comprehensive efficiency | 639 | 0.298 | 1.000 | 0.681 | 0.178 |
| | Pure technical efficiency | 639 | 0.342 | 1.000 | 0.759 | 0.184 |
| | Scale efficiency | 639 | 0.487 | 1.000 | 0.903 | 0.111 |
| Land use | Land use level | 639 | 0.013 | 0.838 | 0.127 | 0.065 |
| Coupling coordination | Coupling degree | 639 | 0.274 | 1.000 | 0.705 | 0.136 |
| | Development degree | 639 | 0.195 | 0.790 | 0.404 | 0.091 |
| | Coupling coordination degree | 639 | 0.307 | 0.888 | 0.526 | 0.070 |

Table 5 shows the coupling coordination between livelihood efficiency and land use of households in Qinba.

(1) Livelihood efficiency. Using DEAP2.1 software to calculate the household livelihood efficiency, the average values of comprehensive efficiency, pure technical efficiency and scale efficiency are 0.681, 0.759, and 0.903, respectively, based on which, it can be concluded that the livelihood efficiency (comprehensive efficiency) of households in Qinba is at a relatively medium level. Comparatively speaking, the comprehensive efficiency value is at its lowest, which indicates that various livelihood capital of households in Qinba have not been optimally allocated, and there is still much opportunity for improvement in livelihood efficiency. The scale efficiency of households is at a relatively high level, which indicates that the overall effect and scale of the input and output for local households is good.

(2) Land use level. The minimum, maximum and average land use level of households in Qinba are 0.013, 0.838, and 0.12,7 respectively, which indicates that the overall land use level by local households is quite different and low.

(3) Coupling degree. The average coupling degree between livelihood efficiency and land use of households in Qinba is 0.705. The overall coupling degree is at the intermediate coupling state, indicating a high degree of interaction between household livelihood efficiency and land use.

(4) Development degree. The average development degree of livelihood efficiency and land use development of households in Qinba is 0.404. The overall development degree is at the primary development state, which indicates that the overall development level of household livelihood efficiency and land use is relatively poor.
(5) Coupling coordination degree. The average coupling coordination degree between livelihood efficiency and land use of households in Qinba is 0.526. The overall coupling coordination degree is at the primary coordination level, which indicates a relatively low degree of the benign influence as well as the benign coupling of household livelihood efficiency and land use.

In a sense, the overall livelihood efficiency of households in Qinba is relatively high, but the overall land use level of households is low, which weakens the coupling coordination between the local household livelihood efficiency and land use to some extent. In the future, more attention needs to be paid to the land use practice by the households so as to promote the sustainable, coordinated, and high-quality development of their livelihood and land use levels.

### *3.1. Analysis of the Differences in Household Livelihood Efficiency*

With reference to previous research [51,52], this study divided households into four types, namely pure-agriculture households, agriculture-dependent households, nonagriculture-dependent households and nonagriculture households according to the nonagriculturalization degree (the proportion of nonagricultural income to gross income was 0–10%, 10–50%, 50–90% and 90–100%, respectively). It was found that the difference in livelihood efficiency of different types of households in Qinba is small, and they are all at a relatively medium level. Specifically speaking, the pattern of livelihood efficiency of various types of households is: nonagriculture households (0.692) > pure-agriculture households (0.688) > agriculture-dependent households (0.674) > nonagriculture-dependent households (0.648). In other words, with increase in the nonagricultural degree, the livelihood efficiency of households decreases at first, and then increases, the distribution being "U-shaped". The livelihood efficiency of the specialized (pure-agriculture, nonagriculture) households is higher than that of dependent (agriculture-dependent, nonagriculture-dependent) households, which means that one-way production concentrates on resource utilization to improve livelihood efficiency, while diversified production methods may lead to over-dispersion of resource utilization and reduce livelihood efficiency.

ArcGIS software was used to explore the spatial distribution pattern and distribution law of households' livelihood efficiency. Comparing the livelihood efficiency of households in different regions (cities), it can be concluded that the livelihood efficiency of households in Hanzhong city is the highest (0.695), followed by Shangluo city (0.679) and Ankang city is the lowest (0.673). From the perspective of districts and counties, the livelihood efficiencies of households in Lueyang county, Yang county, Shiquan county, Zhen'an county, and Shanyang county are relatively low, and those of households in Zhenba county and Langao county are relatively high. Using the trend surface analysis tool, it can be seen that the livelihood efficiency of households shows an "inverted U-shaped" structure, i.e., high in the middle and low on both sides, from east to west. The curvature is small, which means that the difference in the livelihood efficiency of households from east to west is small. The livelihood efficiency of households shows a "U-shaped" pattern, i.e., low in the middle and high on both sides, from south to north. The curvature is relatively large, and the livelihood efficiency of households in the southern region is significantly higher than that in the northern region. This is mainly because the geographic environment, terrain and landform have a certain impact on their livelihood efficiency. From the perspective of topography, Hanzhong city is high in the north and low in the south, Ankang city is high in the north and south, and low in the middle, while Shangluo city is high in the northwest and low in the southeast. Compared with the low mountain plain area, the mountainous area has complex terrain, poor traffic conditions and weak infrastructure. The geographical environment results in the relatively poor livelihood ability and livelihood efficiency. For example, the distribution characteristics of livelihood efficiency is opposite to its topographic characteristics for households in Hanzhong city, which shows the characteristics of being low in the north and high in the south from south to north. In addition, the geographic location and the regional social and economic development level also have an impact on the efficiency livelihood. For example, as the political and economic development center of Shangluo city, Shangzhou district is close to Xi'an. The superior geographical location contributes to the relatively high livelihood efficiency.

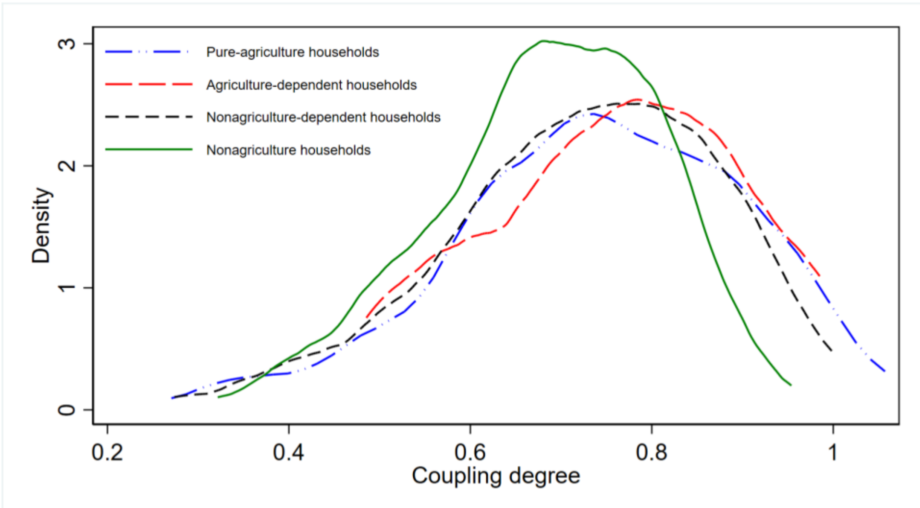
### *3.2. Analysis of the Differences in Household Land Use Level*

The difference in land use level of different types in Qinba is small, and they are all at a relatively low level. Specifically speaking, the land use levels of various types of households show the following pattern: agriculture-dependent households (0.162) > pure-agriculture households (0.159) > nonagriculture-dependent households (0.134) > nonagriculture households (0.114). In other words, with the increase in the nonagricultural degree, the land use level of households increases first, and then decreases, the distribution of which is an inverted U-shape. It was found that the land use level of agriculture-dependent households is higher than that of the pure-agriculture households. This is because that agriculture-dependent households may constantly adjust their land use structure to take into account both agricultural and nonagricultural production activities, and the nonagricultural income can be further invested in agricultural production to improve the land use level. However, due to the limitation of land area, land quality, market prices and other factors, for pure-agriculture households, it is difficult to improve their land use efficiency, which results in the lower land use level.

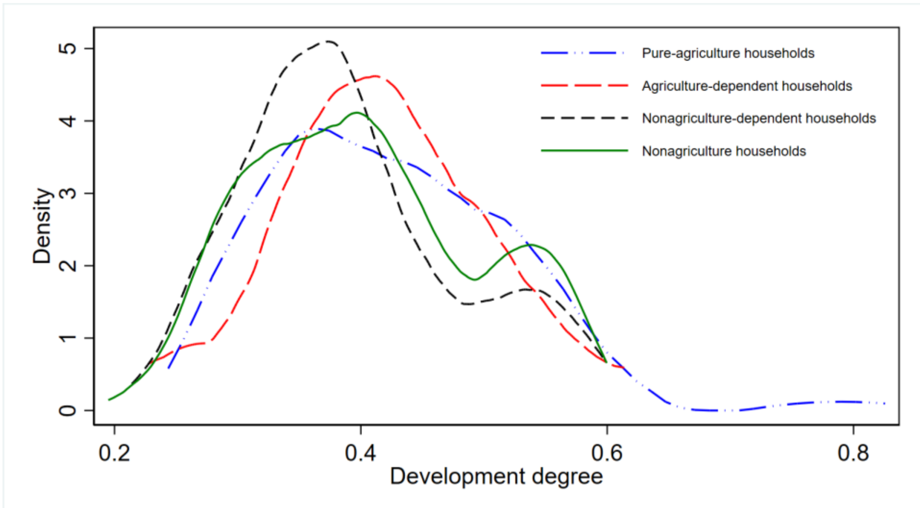
The land use level of households in Qinba is at a relatively low level, among which the land use level of households in Hanzhong city is the highest (0.137), followed by Ankang city (0.124), and Shangluo city is the lowest (0.119). From the dimension of districts and counties, the land use levels of households in Lueyang county, Mian County, Hanyin County, Shangzhou District, and Langao county are lower, while those of households in Yang county, Xixiang county, Shiquan county, and Ziyang county are higher. From east to west, the land use level of households presents an inverted U-shape pattern, high in the middle and low on both sides, with a relatively large curvature, that is, the land use level of households in the central region is significantly higher than that in the eastern and western regions. From north to south, the land use level of households is in an inverted U-shape pattern, high in the middle and low on both sides, and the curvature is small, that is, the difference in land use level of households from east to west is small. Affected by the terrain and landscape, in areas with higher terrain such as Lueyang county and Mian County, the complex terrain, surface relief, and the land fragmentation restrict the intensive use of land resources by households and weakens the land use level by households. In the lower terrain areas such as Xixiang county and Shiquan county, the flat and wide land is more convenient for households to engage in agricultural production and large-scale operations, so the land use level is higher.

### *3.3. Coupling Coordination Relationship between Different Types of Household Livelihood Efficiency and Land Use*

Different types of households have certain differences in the selection and combination of livelihood strategies, and possession and utilization of land resources, which differentiates the coupling coordination relationship between different types of household livelihood efficiency and land use. To this end, this study starts from the type of households to further analyze the difference characteristics of the coupling coordination relationship between livelihood efficiency and land use at the household level. Among them, Table 6 shows the statistical results of the coupling coordination between different types of household livelihood efficiency and land use, and Figure 2 shows a kernel density estimation diagram of the coupling coordination relationship between livelihood efficiency and land use of different types of households.




(**a**)

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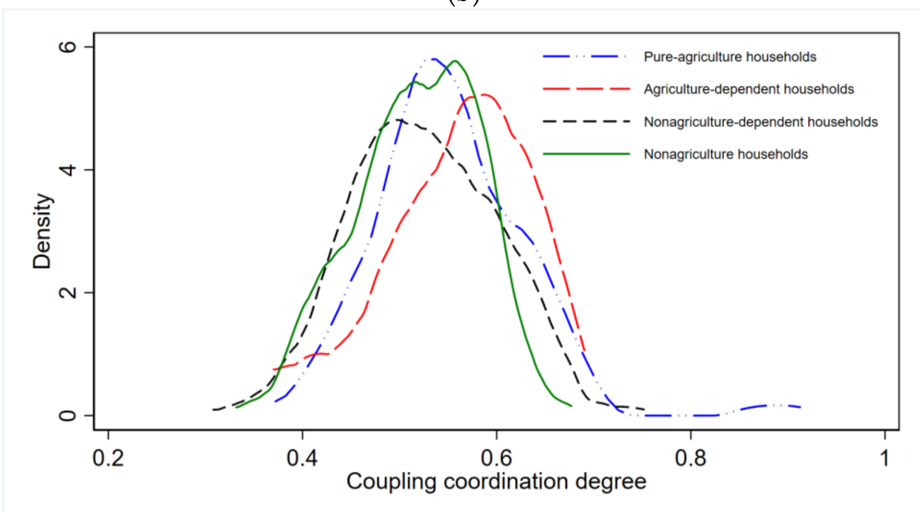



(**c**)

**Figure 2.** Kernel density estimation diagram of the coupling coordination relationship between livelihood efficiency and land use of different types of households. Coupling degree (**a**), development degree (**b**), coupling coordination degree (**c**).

**Table 6.** Statistical results of the coupling coordination between different types of household livelihood efficiency and land use.

| | **Livelihood Efficiency** | **Land Use Level** | **Coupling Degree** | **Development Degree** | **Coupling Coordination Degree** | **Sample Size** | **Percentage** |
|---|---|---|---|---|---|---|---|
| Pure-agriculture households | 0.688 | 0.159 | 0.741 | 0.424 | 0.552 | 78 | 12.21% |
| Nonagriculture-dependent households | 0.674 | 0.162 | 0.759 | 0.418 | 0.558 | 39 | 6.10% |
| Nonagriculture-dependent households | 0.648 | 0.134 | 0.724 | 0.391 | 0.525 | 137 | 21.44% |
| Nonagriculture households | 0.692 | 0.114 | 0.685 | 0.403 | 0.518 | 385 | 60.25% |

### 3.3.1. Coupling Degree Analysis of Different Types of Households

It can be seen from Table 6 that the coupling degree between the livelihood efficiency and land use of various types of households in Qinba is at an intermediate coupling state. The comparison shows that the coupling degree of various types of households presents the following pattern: agriculture-dependent households (0.759) > pure-agriculture households (0.741) > nonagriculture-dependent households (0.724) > nonagriculture households (0.685). That is to say, with the increase in the nonagriculturalization degree, the coupling degree of households increases first, and then decreases, the distribution of which is an inverted U-shape. It was found that the coupling degree of agriculture-dependent households is always higher than that of specialized households in agricultural and nonagricultural production activities, that is, the coupling degree of agriculture-dependent households is always higher than that of pure-agriculture households, and the coupling degree of the nonagriculture-dependent households is higher than that of the nonagriculture households. This is because compared with pure-agricultural households, nonagriculture households and other specialized households, the livelihood activities of agriculture-dependent households involve agricultural activities and nonagricultural activities. A diversified livelihood means draws the household livelihood system and the land system closer, which in turn increases the coupling degree of agriculture-dependent households.

Judging from the kernel density estimation diagram of the coupling degree between livelihood efficiency and land use in Figure 2, the coupling degree is different for various types of households. Comparing the curves of various types of households, it can be seen that the peaks of nonagricultural households are the steepest, indicating that the land use level concentration of nonagricultural households is the highest. The curves of various types of households all show a left-skewed distribution, indicating that there is a difference in the coupling degree of households, and the coupling degree of various types of households is mostly at a higher level. The main reason is that the livelihood activities of nonagricultural households are mainly nonagricultural activities, and the land use level is smaller, and the mutual influence and interaction between the household livelihood system and the land system are smaller and relatively concentrated, while the livelihood activities of pure-agricultural households, agriculture-dependent households and nonagricultural-dependent households all involve the use of land resources. The difference in land use levels results in the relationship between different types of household livelihood systems and land systems showing different development trends.

### 3.3.2. Development Degree Analysis of Different Types of Households

It can be seen from Table 6 that the development degree between the livelihood efficiency and land use are different for various types of households in Qinba. Among them, the development degree of nonagriculture-dependent households is at the slight lag state, and the development degree of pure-agricultural households, nonagricultural households, and agriculture-dependent households is at the primary development state. Specifically, the development degree of various types of households presents the following pattern: pure-agricultural households (0.424) > agricultural-dependent households (0.418) > nonagricultural households (0.403) > nonagriculture-dependent households (0.391). That is to say, with the increase in the nonagriculturalization degree, the development degree of households decreases first, and then increases, the distribution of which is U-shaped. It was found that in the agricultural and nonagricultural production activities, and the development degree of the specialized households, is always higher than that of the agriculture-dependent households. The development degree of pure-agriculture households is higher than that of agriculture-dependent households, and the development degree of nonagriculture households is higher than that of nonagriculture-dependent households. This is because specialized households tend to use one or several resources to maximize their benefits. The centralized development strategy enables households to effectively use resources and increase their overall benefits, while agriculture-dependent households tend to use multiple resources to maximize the benefits. However, due to the limitations of education, resources, and technology, households have insufficient resource management levels, which limits their overall benefits.

Judging from the kernel density estimation diagram of the development degree between livelihood efficiency and land use in Figure 2, the development degree is different for various types of households. Comparing the curves of various types of households, the peaks of nonagriculture-dependent households are the steepest, followed by agriculture-dependent households and nonagriculture households. The curve of pure-agricultural households is the flattest, indicating that the concentration of development degree of the nonagriculture-dependent households is the highest while the differentiation of the pure-agricultural households is the largest. It can be seen from the shape of the curve that the pure-agricultural households show a significant right-skewed distribution with a longer tail, indicating that there is a large gap in the development degrees among the pure-agricultural households indicating a state of polarization, with most of them at a low-medium level. In addition, the curves of nonagricultural-dependent households and nonagricultural households also show a right-skewed distribution with two peaks, indicating that the development degree of nonagricultural-dependent households and nonagricultural households are at a state of polarization, but with a smaller degree of differentiation. This is because under the restrictions and driving force of land, technology, capital and population, the livelihood efficiency and land use level of pure-agricultural households are obviously polarized, resulting in a state of polarization of the overall benefit and level of pure-agricultural households, i.e., the development degree is polarized. At the same time, the difference in nonagricultural income has polarized the livelihood efficiency of nonagricultural-dependent households and nonagricultural households and further differentiated the development of households.

#### 3.3.3. Coupling Coordination Degree Analysis of Different Types of Households

It can be seen from Table 6 that the coupling coordination degree of the livelihood efficiency and land use of various types of households in Qinba is at a primary coordination state. The comparison shows that the coupling coordination degree of various types of households presents a pattern of agriculture-dependent households (0.558) > pure-agriculture households (0.552) > nonagriculture-dependent households (0.525) > nonagricultural households (0.518). That is to say, with the increase in the nonagriculturalization degree, the coupling coordination degree of households increases first, and then decreases, the distribution of which is an inverted U-shape. The coupling coordination degree of agriculture-dependent households is always higher than that of the specialized households in agricultural and nonagricultural production activities, i.e., the coupling degree of agriculture-dependent households is always higher than that of pure-agriculture households, and the coupling degree of the nonagriculture-dependent households is higher than that of the nonagriculture households. In addition, the coupling coordination degree of pure-agricultural households and agriculture-dependent households is higher than the average level (0.526), and the coupling coordination degree of nonagricultural households and nonagriculture-dependent households is lower than the average level. This is because compared with specialized households, agriculture-dependent households comprehensively use all resources from agriculture and nonagriculture, and the comprehensive and coordinated use of multiple resources also raises the coupling coordination degree of the livelihood efficiency and land use of agriculture-dependent households. The main resource of pure-agricultural households and agriculture-dependent households' production activities is only their land resources. Coordinating the use of land resources and other resources is the basic activity of households. Long-term practice and experience raise the coupling coordination degree of households.

Judging from the kernel density estimation diagram of the coupling coordination degree between livelihood efficiency and land use in Figure 2, the coupling coordination degree is different for various types of households, but the difference is small. Comparing the curves of various types of households, the peaks of pure-agricultural households and nonagricultural households are steeper, and the peaks of agriculture-dependent households and nonagriculture-dependent households are flatter, indicating that the concentration of coupling coordination degree of pure-agricultural households and nonagricultural households is relatively high, and the coupling coordination degree of agriculture-dependent households and nonagricultural-dependent households is highly differentiated. The pure-agricultural household curve has a significant right-skewed distribution, indicating that the coupling coordination degree of pure-agricultural households is polarized, and the coupling coordination degree of households is mainly concentrated at the middle level. The curve of agriculture-dependent households has a significant left-skewed distribution, indicating that the coupling coordination degree of agriculture-dependent households shows a gap, and most of them are at an intermediate level. This is because nonagricultural households are mainly engaged in nonagricultural activities, and their use of land resources is smaller, which makes the coupling coordination degree of households more concentrated. Affected by plantation structure, culturing structure, and land resources, pure-agricultural households have a certain degree of differentiation in the process of coordinating the use of various resources, resulting in a polarized coupling coordination degree. Nonagricultural-dependent households and agricultural-dependent households may comprehensively use land resources and other resources, and the differences of resource utilization cause differentiation in the coupling coordination degree of households.

### *3.4. Coupling Coordination Relationship between Household Livelihood Efficiency and Land Use in Different Regions*

Affected by specific environment, and social and cultural factors, the spatial characteristics and patterns of household livelihood efficiency and land use level in various regions also vary. To this end, this study starts from a regional perspective to further analyze the characteristics of the spatial differences in the coupling coordination relationship between household livelihood efficiency and land use. Table 7 shows the statistical results of the coupling coordination between household livelihood efficiency and land use in different regions (cities).

The Table 7 shows the coupling coordination degree of household livelihood efficiency and land use in Ankang city, Hanzhong city, and Shangluo city in Qinba. (1) Coupling degree. The coupling degree of households in Qinba mountainous area in Southern Shaanxi is at an intermediate coupling state. Among them, the coupling degree of households in Hanzhong city is the highest (0.721), followed by Ankang city (0.698), and Shangluo city is the lowest (0.697). (2) Development degree. The development degrees of households are different in Qinba. Among them, the households of Hanzhong city have the highest development degree (0.416) and are at the primary development state. The households of Shangluo city are second (0.399), and are at the slight lag state. The households of Ankang city have the lowest development degree (0.398), and are at the slight lag state. (3) Coupling coordination degree. The coupling coordination degree of households in Qinba is at a primary coordination state. Among them, the coupling coordination degree of households in Hanzhong city is the highest (0.541), and Ankang city and Shangluo city are basically the same (Ankang city is slightly higher). In general, the coupling degree, development degree, and coupling coordination degree of households in Hanzhong city are significantly higher than those of Ankang and Shangluo, while the difference between the households in Ankang and Shangluo is smaller. The main reason is that the plain area of Hanzhong city is larger compared with those of Ankang city and Shangluo city. This brings more convenience to local social and economic development and land resource utilization.

**Table 7.** Statistical results of the coupling coordination between household livelihood efficiency and land use in different regions (cities).

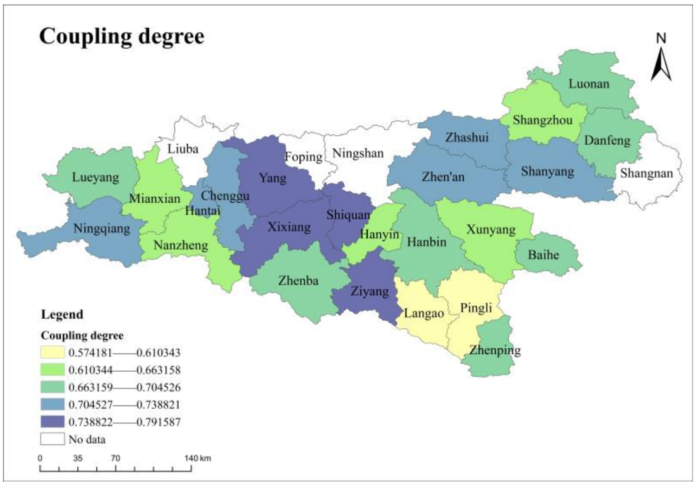
| | Livelihood Efficiency | Land Use Level | Coupling Degree | Development Degree | Coupling Coordination Degree | Sample Size | Percentage |
|---|---|---|---|---|---|---|---|
| Ankang city | 0.673 | 0.124 | 0.698 | 0.398 | 0.520 | 272 | 42.56% |
| Hanzhong city | 0.695 | 0.137 | 0.721 | 0.416 | 0.541 | 195 | 30.52% |
| Shangluo city | 0.679 | 0.119 | 0.697 | 0.399 | 0.520 | 172 | 26.92% |

In order to further analyze the characteristics of households at the regional level, this study used ArcGIS software to visually analyze the data of 24 sample districts and counties in Qinba, and used trend surface analysis tools to further analyze the trend of the overall differentiation in space of coupling coordination relationship between household livelihood efficiency and land use. Figure 3 is a spatial distribution diagram of the coupling coordination relationship between household livelihood efficiency and land use in different regions (districts and counties), and Figure 4 is a trend surface diagram of the coupling coordination relationship between household livelihood efficiency and land use in different regions (district and county).

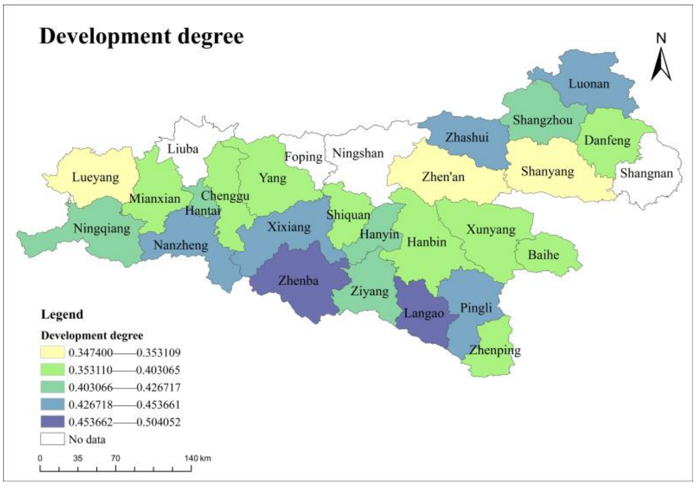
### 3.4.1. Coupling Degree Analysis of Households in Different Regions

Figures 3 and 4 show that the coupling degree of households in Qinba is concentrated in the range of 0.574–0.792, at the primary coupling state and the intermediate coupling state. The coupling degree of households in Langao county is at the primary coupling state, and the coupling degrees of households in other districts and counties are at the intermediate coupling state. In comparison, the coupling degree of households in Langao county and Pingli county is relatively low, and the coupling degree of households in Yang county, Xixiang county, Shiquan county, and Ziyang county is relatively high. The coupling degree of households presents an inverted U-shaped pattern, high in the middle and low on both sides, from east to west. The curvature is small, and the areas with high coupling degree are concentrated in the junction area of Hanzhong city and Ankang city. The coupling degree of households from north to south shows an inverted U-shaped pattern, high in the middle and low on both sides, with a relatively large curvature, and the coupling degree of households in the northern district is significantly higher than that in the southern district. In general, the spatial coupling degree is in a pattern of high in the middle and low on both sides.

This is because in high terrains such as Langao county and Pingli county, the land use level of households is lower, and the relationship between household livelihood activities and land use is weaker, resulting in a lower coupling degree. In the lower terrain areas, such as Xixiang county, the land use level of households is relatively higher, and the link between household livelihood and land use is also closer.




(**a**)

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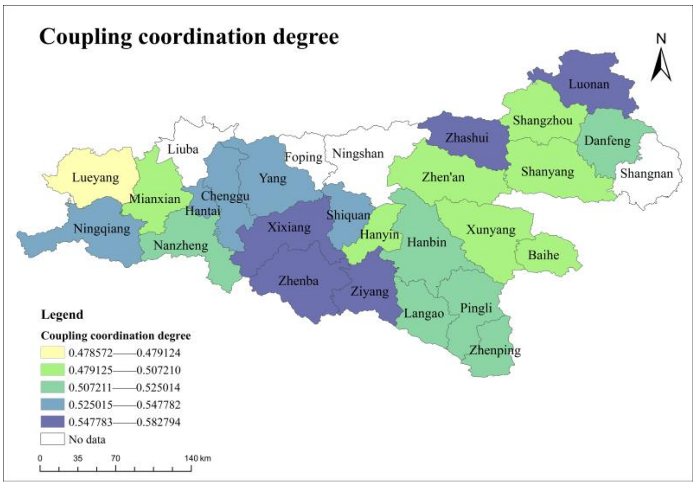
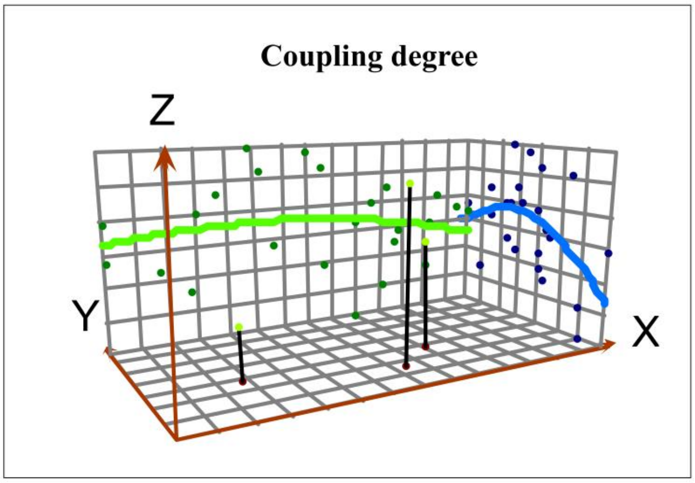



(**c**)

**Figure 3.** Spatial distribution of the coupling coordination relationship between household livelihood efficiency and land use in different regions (districts and counties). Coupling degree (**a**), development degree (**b**), coupling coordination degree (**c**).

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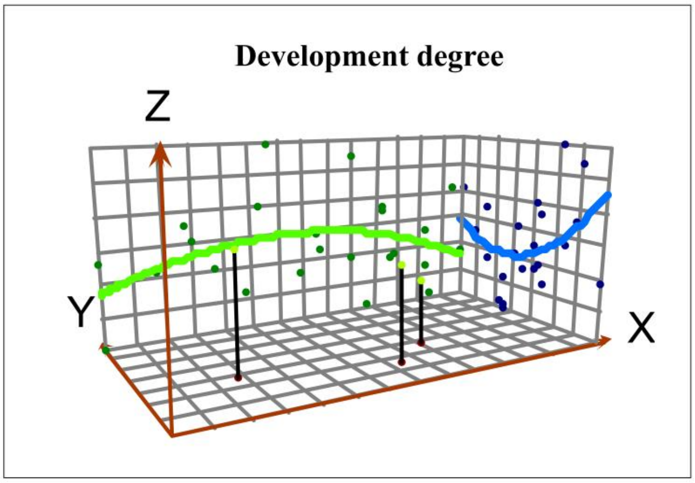


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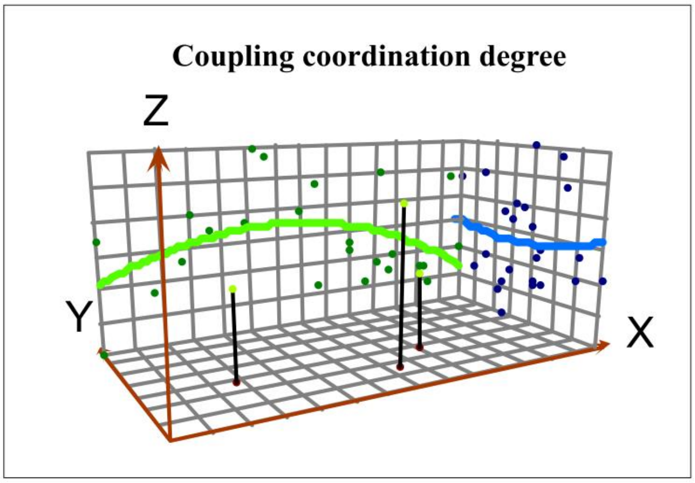



(**c**)

**Figure 4.** Trend surface diagram of the coupling coordination relationship between household livelihood efficiency and land use in different regions (districts and counties). Coupling degree (**a**), development degree (**b**), coupling coordination degree (**c**).

### 3.4.2. Development Degree Analysis of Households in Different Regions

Figures 3 and 4 show that the development degree of households in Qinba is concentrated in the range of 0.375–0.504, at the slight lag state and the primary development state. The development degrees of households in Lueyang county, Zhen'an county, Shanyang county, Yang county, Baihe county, Shiquan county, Danfeng county, XunYang county, Zhenping county, and Hanbin District are at the slight lag state, and the development degrees of other districts and counties of households are at the primary development state. In comparison, the development degrees of households in Lueyang county, Zhen'an county, and Shanyang county are relatively lower, while the development degrees of households in Zhenba county and Langao county are relatively higher. The development degree of households shows an inverted U-shaped pattern, high in the middle and low on both sides, from east to west. The curvature is small. The development degree of households from north to south shows a U-shaped pattern, low in the middle, high on the sides, and the development degree of households in the southern district is significantly higher than that in the northern district.

The main reason is that the households' land use level and livelihood efficiency are relatively lower in areas with higher terrain and lower levels of economic development, resulting in a lower household development degree, while in areas with lower terrain and higher levels of economic development, household land use level and livelihood efficiency are relatively higher resulting in a higher household development degree.

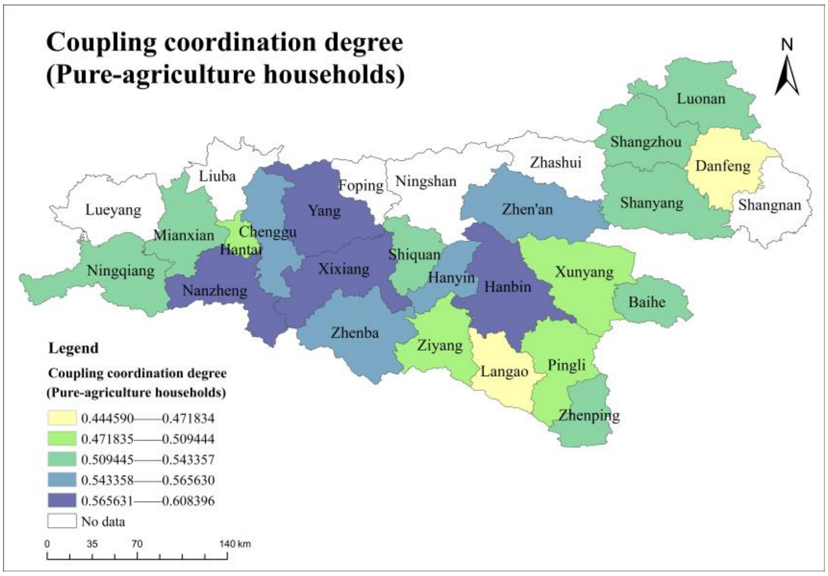
### 3.4.3. Coupling Coordination Degree Analysis of Households in Different Regions

Figures 3 and 4 show that the coupling coordination degree of households in Qinba is concentrated in the range of 0.479–0.583, and they are all at a primary coordination state. The coupling coordination degree of households in Lueyang county is relatively lower, and the coupling coordination degrees of households in Xixiang county, Zhenba County, Ziyang county, Zhashui county, and Luonan county are relatively higher. The coupling coordination degree of households shows an inverted U-shaped pattern, high in the middle and low on both sides, from east to west. The curvature is relatively large, that is, the coupling coordination degree of households in the central region is significantly higher than those in the eastern and western regions. The coupling coordination degree of households from north to south shows a U-shaped pattern, low in the middle, high on the sides, and the curvature is small, that is, the difference of coupling coordination degree of households from north to south is small.

This is because in areas where the development trend of household livelihood efficiency and land use level are the same, the household coupling coordination degree shows a similar development pattern. On the one hand, household livelihood means and land use methods continue to be adjusted and optimized, which helps in building a virtuous circle with the household livelihood system and the land use system. On the other hand, due to the constraints of resource endowments, geographic environment and education level, it is difficult for households to achieve the effective allocation of livelihood resources, and the coupling coordination level between households' livelihoods and land is also relatively lower. For example, the coupling coordination degree of households shows a development trend similar to that of the livelihood efficiency and land use level from east to west (inverted U-shaped). In areas where the development trend of household livelihood efficiency and land use level is opposite, the coupling coordination degree is affected by the combined effect of the livelihood efficiency and land use level, and present different characteristics. On the one hand, with reduction of the importance of land resources, the land use level is an important loop that reflects the benign relationship between household livelihoods and land use, and it has a relatively large impact on the coupling coordination degree of households. On the other hand, social resources, information resources and financial resources have a certain impact on the land use patterns of households and affect the coupling coordination degree by promoting or inhibiting the land use level. For example, from north to south, affected by the land use level, the difference in the coupling coordination degree of households is small, while under the effect of livelihood efficiency, the coupling coordination degree of households presents a U-shaped distribution.

*3.5. Spatial Differentiation of the Coupling Coordination Relationship between Household Livelihood Efficiency and Land Use in Different Types and Regions*

For households of different types and regions, the coupling coordination relationship between their livelihood efficiency and land use is different. In order to further explore the coupling coordination relationship between household livelihood efficiency and land use, and from a spatial perspective, this study compared and analyzed the spatial characteristics of the coupling coordination relationship between different types of household livelihood efficiency and land use in different regions. Figure 5 shows the spatial distribution of coupling coordination degrees of different types of households.

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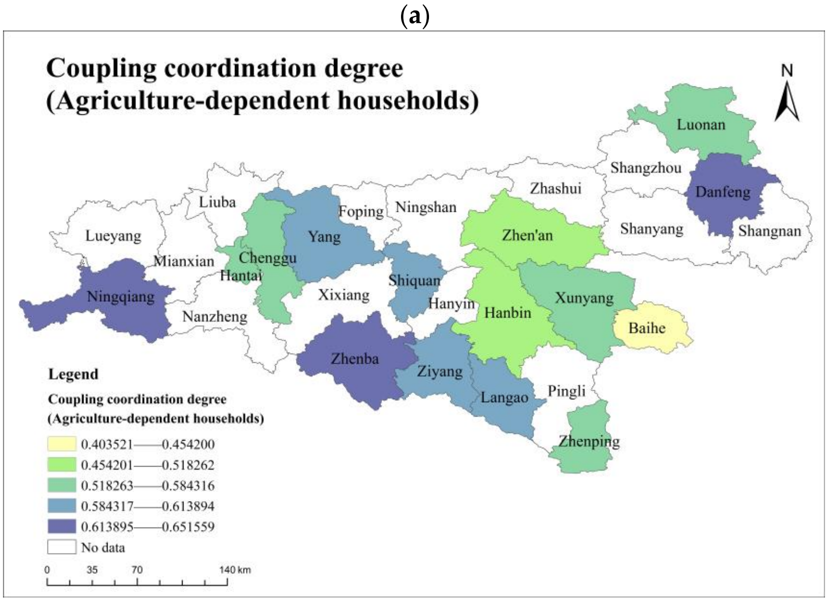
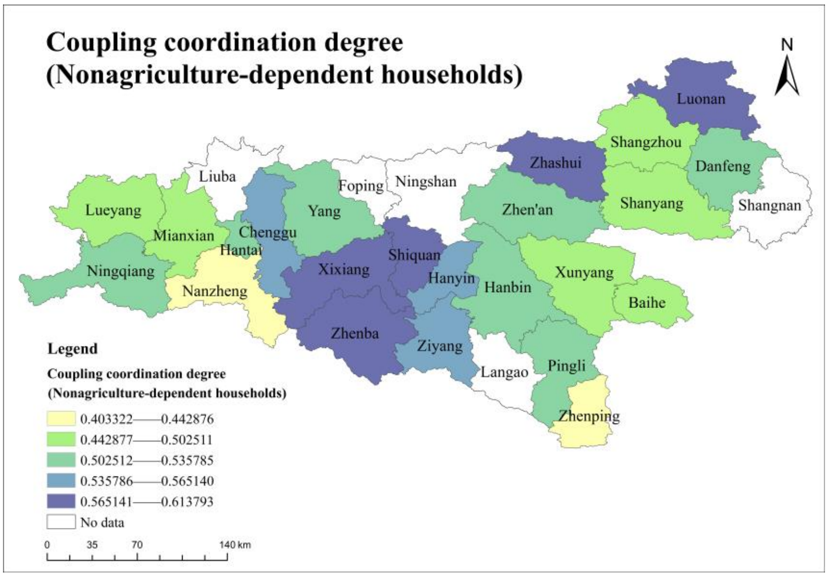



(**b**)

**Figure 5.** *Cont*.

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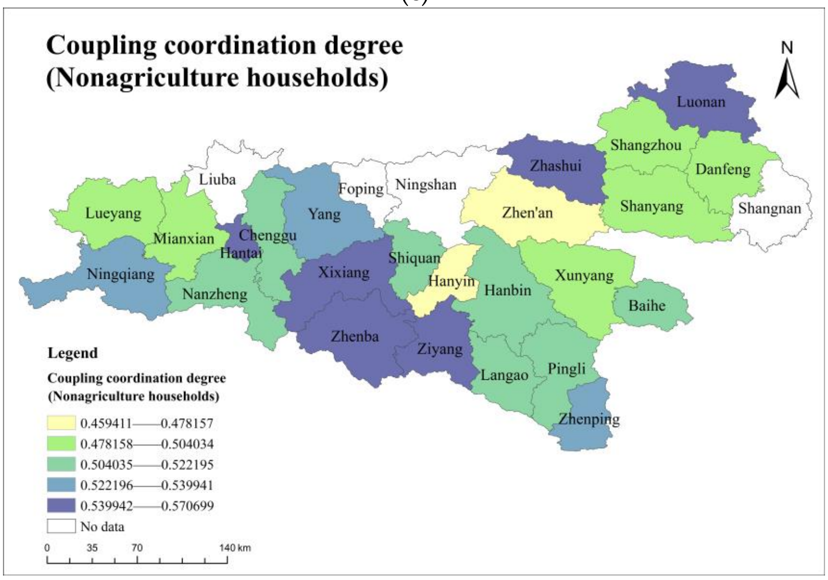


(**d**)

**Figure 5.** The spatial distribution of coupling coordination degrees of different types of households. Coupling coordination degree (pure-agriculture households) (**a**), coupling coordination degree (agriculture-dependent households) (**b**), coupling coordination degree (nonagriculture-dependent households) (**c**), coupling coordination degree (nonagriculture households) (**d**).

### 3.5.1. The Spatial Differentiation of the Coupling Degree of Households in Different Types and Regions

According to the spatial distribution and trend of the coupling degree of different types of households, it can be seen that there are primary coordination state, intermediate coordination state, advanced coordination state for every type of household in all districts and counties. Specifically, the following summarizes the spatial rules on the coupling degrees of each type of households.

(1) The concentration of coupling degree is different for various types of households. Among them, the difference of nonagricultural households is smaller (the concentration range is 0.566–0.802), and the difference of pure-agricultural households is larger (the concentration range is 0.404–0.903).

(2) The coupling degrees of different types of households are different for various districts and counties. Comparing various types of households, the coupling degree of pure-agriculture households in Hantai district and the coupling degree of agriculture-dependent households in Ziyang county are lower. The coupling degree of pure-agricultural households and nonagriculture-dependent households in Zhenping county, the coupling degree of nonagricultural households in Luonan county and the coupling degree of pure-agricultural households in Danfeng county are lower.
(3) The spatial distribution patterns of the coupling degree are different for various types of households. From east to west, the distribution coupling degree of nonagricultural households and agriculture-dependent households (U-shaped) is opposite to those of other types of households (inverted U-shaped). From north to south, the coupling degree of agriculture-dependent households (U-shaped) is opposite to those of other types of households (inverted U-shape).

This is mainly because the land use level has a greater impact on the coupling degree of households. The livelihood activities of pure-agriculture households, nonagriculture-dependent households and agriculture-dependent households all involve agricultural production, which result in the spatial similarity of the development pattern of coupling degree of households and the land use level. As for nonagricultural households, nonagricultural activities weaken the impact of land use, and different livelihood means differentiate household livelihood and land use and affect the households coupling degree. Driven by the land use level and livelihood efficiency, the coupling degree of households also shows a spatially differentiated development trend.

#### 3.5.2. Spatial Differentiation of the Development Degree of Households in Different Types and Regions

According to the spatial distribution and trend of the development degree of different types of households, it can be seen that there are slight lag state and primary development state for each type of household in all districts and counties. Specifically, the development degree of each type of households has the following spatial rules.

(1) The concentrations of development degrees are different for various types of households. Among them, the difference of nonagricultural households is smaller (concentration range is 0.300–0.489), while the difference of agricultural-dependent households is larger (concentration range is 0.261–0.551).
(2) The development degrees of different types of households are different in various districts and counties. Compared with various types of households, the development degrees of pure-agriculture households and agriculture-dependent households in Hantai district are relatively lower. The development degrees of pure-agriculture households and nonagriculture-dependent households in Ziyang county are relatively lower. The development degrees of nonagriculture-dependent households and agriculture-dependent households in Zhenping county are relatively higher. The development degrees of pure-agriculture households and agriculture-dependent households in Luonan county and the development degree of nonagriculture households in Danfeng county are relatively lower.
(3) The spatial distribution patterns of the development degrees are different for various types of households. From east to west, the distribution of the development degree of pure-agriculture households (U-shape") is opposite to those of other types of households (inverted U-shaped). From north to south, the distribution of the development degree of agriculture-dependent households (inverted U-shaped) is opposite to those of other types of households (U-shaped). The development degree of nonagriculture-dependent households is characterized by being high in the north and low in the south from north to south, while the development degree of other types of households is characterized by being low in the north and high in the south.

This is because the development degree of households is mainly affected by livelihood efficiency and land use level. In the entire space, the development degree of household livelihood efficiency is significantly higher than that of the land use level, which subjects the development degree of households to more impact by the changes of livelihood efficiency and presents a similar development pattern.

#### 3.5.3. Spatial Differentiation of the Coupling Coordination Degree of Households in Different Types and Regions

According to the spatial distribution and trend of the coupling coordination degree of different types of households, there are primary coordination state, intermediate coordination state for pure-agriculture, agriculture-dependent, and nonagriculture-dependent households in all districts and counties, but the coupling coordination degree of nonagriculture households is at the primary coordination state in all districts and counties. Specifically, the coupling coordination degree of various types of households has the following spatial patterns.

(1) The concentrations of coupling coordination degrees are different for various types of households. Among them, the difference between nonagriculture households is smaller (the concentration range is 0.459–0.571), and the difference between agriculture-dependent households is relatively larger (the concentration range is 0.404–0.652).
(2) The coupling coordination degrees of different types of households are different in districts and counties. Comparing various types of households, the coupling coordination degree is lower for pure-agriculture households in Hantai district, pure-agriculture households in Ziyang county, nonagriculture-dependent households in Zhenping county, pure-agriculture and agriculture-dependent households in Luonan county and pure-agriculture and nonagriculture households in Danfeng county.
(3) The spatial distribution patterns of coupling coordination degree are different for various types of households. From east to west, the distribution of the coupling coordination degree of agriculture-dependent households (U-shaped) is opposite to those of other types of households (inverted U-shaped), and the coupling degree of agriculture-dependent households is characterized by being high in the west and low in the east from north to south. The distribution of the coupling coordination degree of agriculture-dependent and nonagriculture households (U-shaped) is opposite to those of other types of households (inverted U-shaped). The difference of coupling coordination degree of agriculture-dependent households in south-north direction is small, and the coupling coordination degree of nonagriculture-dependent households is characterized by being high in the north and low in the south.

This is mainly because the coupling coordination degree not only reflects the relationship between household livelihood efficiency and land use level, but also reflects the degree of benign coupling between them. Land use is the basis and primary condition for the mutual influence of household livelihoods and land use, and livelihood efficiency reflects the benign influence of household livelihoods and land use to a certain extent. Under the combined effect of land use level (primary) and livelihood efficiency (secondary), the coupling coordination degree of different types of households shows different development trends. For example, under the influence of land use level, the coupling coordination degree of nonagriculture-dependent households shows a trend of being high in the middle and low around in space. However, affected by the livelihood efficiency, the coupling coordination degree of nonagriculture-dependent households is characterized by being high in the north and low in the south.

## 4. Discussion

### *4.1. Optimization Measures*

With the development of society and economy, the household livelihood system and land system in mountainous areas gradually show a more resistant and restrained state, which not only causes a waste of livelihood resources but also threatens the country's farmland security and food security. To solve this problem, it is necessary to guide the coordinated development of the household livelihood system and land system and maximize the livelihood efficiency while improving the households' land use level. To this end, improvements can be made from the perspectives of the types of households and geographical space, among other things. The following are some suggestions.

(1) Develop differentiated livelihood optimization plans based on different types of households. ① Pure-agriculture households can improve their coupling coordination by improving agricultural infrastructure, adjusting land planting structure (food crops, cash crops.), expanding land planting scale, optimizing agricultural production methods, adjusting agricultural production structure (planting, breeding). ② For agriculture-dependent households, they can optimize their agricultural production structure to improve their livelihood efficiency and land use level. On the other hand, they can broaden the scope of their nonagricultural activities, enrich the types of nonagricultural activities, and choose more suitable and efficient nonagricultural activities to coordinate the relationship between agricultural activities and nonagricultural activities and improve the livelihood efficiency. ③ Nonagriculture-dependent households can flexibly adjust their land use methods according to their working hours and work content to maximize the use of livelihood resources. For example, they can optimize the planting structure and breeding structure by planting mulberries, walnut trees, and wild pepper trees, among other things, to improve their livelihood efficiency. ④ Nonagriculture households can adjust the land use form according to their working location and work content. For example, land can be transferred and contracted, and mulberries, walnut trees, traditional Chinese medicine herbs, fruit trees and other crops with less input can be planted. In addition, they can join rural production cooperatives and use land resource to obtain a certain income dividend.
(2) Develop appropriate livelihood development strategies according to different geographical spaces. On the one hand, it is also advisable to develop the livelihood development strategies according to the regional livelihood efficiency and land use level. ① In areas where the livelihood efficiency and land use level are generally low, such as Lueyang county and Shanyang county, it is advisable to help households choose production methods with higher livelihood efficiency, more reasonable land use structure, and higher land use efficiency, to improve the households' livelihood efficiency, land use level and the coupling coordination level. ② In areas with lower livelihood efficiency and higher land use levels, such as Shiquan county and Yang county, restrictions on land resources make it difficult for households to improve their livelihood efficiency. In this case, households need to develop appropriate nonagricultural activities to supplement the agricultural production to improve livelihood efficiency. ③ In areas with high livelihood efficiency and low land use levels, such as Langao county and Pingli county, the low land use level weakens the coupling coordination relationship between households' livelihood efficiency and land use. In the future, it is necessary to innovate livelihood methods and land use methods, and improve the land use level on the basis of ensuring the livelihood efficiency. ④ In areas where the livelihood efficiency and land use level are generally high, such as Luonan county and Zhenba County, the coupling coordination degree of household livelihood efficiency and land use can be continuously improved by improving the infrastructure, optimizing the ecological environment, and increasing employment opportunities. And the coupling coordination degree cannot focus on a single aspect of livelihood efficiency or land use level. On the other hand, it will be effective to develop corresponding plans according to regional characteristics. ① In areas with higher terrain, it can not only guide households to plant or breed agricultural products with higher added value according to local characteristics, but also promote the development of production and life models such as building parks on the mountains, building communities under the mountains, and turning households to workers. ② In areas with lower terrain, households can improve their productivity through scale, informatization and mechanization, and they can also use diversified livelihood means to increase income. ③ In areas with a high level of economic development,

the income of households can be increased through various production modes such as specialization in production, concurrent employment, and large-scale production. ④ In areas with a low level of economic development, the income of households can be increased by means of labor transfer, and the living standards of households can be improved by attracting investment and improving infrastructure.

(3) Comprehensively improve the livelihood ability and livelihood conditions of households according to the types of households and the characteristics of the geographical space. In order to promote the coordinated and sustainable development of household livelihood efficiency and land use, not only should the households' own livelihoods be taken into account, but also the external livelihood environment needs to optimized, so as to achieve the high-quality development of households through the "internal and external integration" method. Specifically, improvements can be made of the following aspects: ① Improve the utilization quality and level of land resources. On the one hand, the quality of land use can be improved by implementing a "slope-to-terracing" project, constructing irrigation facilities, transforming farmland, water-electricity-road networks, and improving rural development supporting facilities. On the other hand, land use level can be improved from the perspectives of the market, system, and types of households. For example, the government can guide households to plant crops with higher efficiency and less time and energy, and at the same time, the government can encourage households to work out by land transfer, land lease, and land shares. ② Encourage households to change production methods. When choosing a mode of production, households should comprehensively consider their own family conditions and the local environment. For example, households with less land resources can switch to part-time or full-time nonagricultural activities to increase their income levels, households with more land resources can improve their livelihood efficiency through large-scale production and mechanized production, while households with medium-level land resources can engage in agricultural and nonagricultural production at the same time. Households with formal nonagricultural jobs can engage in agricultural production during holidays and after work, and households without formal nonagricultural jobs can go out to work during the slack time or engage in part-time jobs in the surrounding towns. ③ Promote the development of characteristic industries. It is necessary to promote the development of characteristic industries and realize the commercialization of agriculture by households based on the advantages of regional resources and environment. For example, households can be encouraged to plant special cash crops such as tea, traditional Chinese medicine herbs, peppers, konjac, and walnut trees. Households can be guided to increase their income by adopting methods such as "rice-fish symbiosis", "rice-shrimp symbiosis" and "under-forest economy". Households can be encouraged to rely on regional tourism development plan to engage in farmhouses, picking gardens, stay home on farm, handicrafts, characteristic agricultural products, etc. ④ Improve the level of education and medical care. The education level and health status of the households themselves are the basis for carrying out livelihood activities. To this end, the ability of households can be guaranteed and improved by carrying out skill training, regular physical examinations, delivering market information, and organizing medical activities in the countryside.

In general, in order to improve household livelihood capacity and livelihood quality and realize regional coordinated and sustainable development, households and the government need to participate together. For households, it is necessary to stimulate their initiative, enthusiasm and creativity, and encourage them to improve their livelihood quality by improving production technology, adjusting production strategies and optimizing the allocation of livelihood resources. For the government, it needs to guide and support households. On the one hand, government departments need to constantly improve the "hard environment" in rural areas. Water conservancy, electric power, roads, networks and other infrastructure are the basis for households and rural development. Government departments should not only actively improve the infrastructure of each region, but also invest in the construction of relevant facilities according to the characteristics of different regions to promote regional development. On the other hand, government departments need to promote and improve the "soft environment" in rural areas. Creating a good medical and educational environment can not only improve the comprehensive quality of households, but also provide guarantee for the development of households.

### *4.2. Limitation*

There are still some limitations in this study. (1) This study only calculates the livelihood efficiency, land use level, coupling degree, development degree and coupling coordination degree of households, and analyzes the differences between households of different types and regions, but there is no in-depth analysis of the reasons behind the differences, and it does not explore the relevant factors through quantitative analysis. Therefore, in the future research, it is necessary to further verify the viewpoint of this study, design the index system from the perspectives of geographical environment, regional development level, infrastructure level, livelihood risk and livelihood capital, and further analyze the key factors affecting the coupling coordination relationship between household livelihood efficiency and land use. (2) When analyzing the spatial characteristics of households, this study mainly used ArcGIS software to visually display the relevant results from a spatial perspective, and used the trend surface analysis tool to explore the spatial differentiation trend of the coupling coordination relationship between household livelihood efficiency and land use. However, in general research, exploratory spatial data analysis (ESDA) is often used to explore the differentiation characteristics at the spatial level. In the future, a variety of methods should be used to supplement and improve the relevant research content.

## 5. Conclusions

The coupling coordination relationship between household livelihood efficiency and land use refers to a state in which the livelihood system and the land system interact to optimize the overall situation and develop jointly driven by natural, economic, social, location, and market factors. From the perspective of households themselves and the external spatial environment, an in-depth analysis of the coupling coordination relationship between household livelihood efficiency and land use can provide reference for the comprehensive, coordinated and sustainable development for households in the area studied and similar regions. Through the analysis of the relevant results, the following conclusions can be drawn.

(1) The overall livelihood efficiency of households in Qinba is at a medium level. The overall land use level is quite different and low, the coupling degree is at the intermediate coupling state, the development degree is at the primary development state, and the coupling coordination degree is at the primary coordination state. In order to promote the sustainable, coordinated, and high-quality development of household livelihood efficiency and land use, we should not only focus on household land use, but also improve household livelihood efficiency through a variety of methods, such as optimizing livelihood structure and improving production technology.

(2) From the perspective of the types of households, with the increase of nonagricultural degree, the coupling coordination degree of households increases first, and then decreases. Under the influence of household livelihood methods and land use methods, there are certain differences in the coupling coordination relationship between various types of household livelihood efficiency and land use. Among them, pure-agriculture households have the highest development degree; agriculture-dependent households have the highest land use level, coupling degree, and coupling coordination degree; nonagriculture-dependent households have the lowest development degree and livelihood efficiency; nonagriculture households have the highest livelihood efficiency, lowest land use level, coupling degree, and coupling coordination degree.

(3) From the perspective of spatial distribution pattern, the coupling coordination degree for households east-to-west is "sagging", while south-to-north diagram is "hogging". Under the influence of topography, social and economic development level, geographic location and infrastructure, the coupling coordination relationship between household livelihood efficiency and land use are different in regional space. Compared with the central region, the livelihood efficiency, land use level, coupling degree, development degree, and coupling coordination degree of households in the western and eastern regions are relatively lower; the livelihood efficiency, development degree, and coupling coordination degree of households in the northern and southern regions are relatively higher and their land use level and coupling degree are lower.

(4) From the perspective of the households themselves and the external spatial environment, the distribution of the coupling coordination degree for agriculture-dependent households east-to-west (the "sagging" diagram) is opposite to the other types of households. By analogy, the distribution of the coupling coordination degree for nonagriculture and agriculture-dependent households north-to-south (the "hogging" diagram) is opposite to the other types of households. Under the combined influence of household livelihood ability and the external environment, the coupling coordination relationship between different types of household livelihood efficiency and land use are different in space. For example, the livelihood efficiency and development degree of pure-agriculture households are spatially characterized by being low in the middle and high around, and the land use level, coupling degree, and coupling coordination degree are spatially characterized by being high in the middle and low around the sides; the livelihood efficiency and development degree of agriculture-dependent households are spatially characterized by being high in the middle and low around, and the land use level, coupling degree, and coupling coordination degree are spatially characterized by being low in the middle and high around.

The coupling coordination relationship between household livelihood efficiency and land use is affected by regional development level, resource, geographic location, infrastructure level and many other factors. The household livelihood efficiency, the interaction among various elements in the land use system and the feedback mechanism should be deeply analyzed in the future to reveal the coupling coordination mechanism between household livelihood efficiency and land use. In addition, different intervention optimization plans can be designed for different types of households in different regions, and an integrated livelihood efficiency and land use coupling coordination composite system may be constructed. The optimization schemes may be simulated with the help of the composite system, in order to provide a scientific, reasonable and operable reference for establishing a diversified and multi classification comprehensive optimization system of coupling coordination of livelihood efficiency and land use.

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# Farm Business Model on Smart Farming Technology for Sustainable Farmland in Hilly and Mountainous Areas of Japan

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**Abstract:** Farmlands in Japan's hilly and mountainous (HM) areas face the critical challenges of aging farmers, depopulation, and disadvantageous conditions for farm management and economic performance, leading to the abandonment of farmland. Rice farming in HM areas is rarely profitable; however, it occupies 40% of Japanese agricultural production and affects food security. We proposed a farm business model to utilize smart farming technology (SFT) for rice production in the HM areas and analyzed the financial performance of the case study. The farm business model applying SFT has three stakeholders: collective activity by the farmers, farm operations by the enterprise, and a government subsidy. The model conceptualizes diversifying farm business into rice farming and other business units. Three scenarios of SFT in the farm business model consist of combinations of conventional and SFT machines: conventional machines, intermediate SFT, and advanced SFT. The results of the financial analysis on the case study were consistent with the theoretical framework of farm business models. This study revealed that the elasticity of labor productivity on fixed assets of advanced SFT (0.94) was more productive than intermediate SFT (0.63). To utilize SFT to sustain farmland in HM areas, balance between financial security and profitability, and linkage of the enterprise and community are indispensable.

**Keywords:** smart farming technology; rice; hilly and mountainous areas; sustainable farmland; Japan

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## 1. Introduction

Japan's geography consists of almost 7000 narrow and long-shaped islands and a mountain area occupying about three-quarters of the land. Japanese people have been cultivating rice since the late Jomon era (around 400 BC) and rice is widely grown in almost all prefectures. As of 2020, there are about 4325 thousand hectares (ha) of farmland involving 2352 thousand ha of paddy field [1], with 40% located in hilly and mountainous (HM) areas [2]. In Japan, there are four categorizations of agricultural areas: urban areas, flat areas, hilly areas, and mountainous areas [3], where hilly and mountainous areas are usually called HM areas. In general, HM areas are considered disadvantaged areas for agriculture [4,5] because they are topographically and/or economically disadvantaged for agriculture compared to flat and urban areas [6]. Therefore, many farms located in HM areas are facing difficulties in maintaining farming. Under this condition, the Japanese government is working hard to maintain agriculture in HM areas [5,6]. Therefore, why HM areas should be maintained and how the role of HM areas is important for Japan should be considered.

Table 1 shows the summary of HM areas and characteristics of farms in HM areas compared with other areas, which consist of urban and flat areas. Approximately 11% of population in Japan lives in HM areas. Furthermore, cultivated land, the number of farms, and agricultural production generated about 40% of total Japanese food production. The sustainable agriculture in HM areas is indispensable for Japanese food security [5]. However, the disadvantageous conditions of HM areas require higher costs and generate lower profitability. Characteristics of farms in HM areas in Japan are summarized in five features [7].

1. Small scale farmland area: 59% of farms cultivate farmlands less than 1.0 ha;
2. Small amount of labor input: 50% of farms use less than one laborer per day;
3. Small number of sales: 42% of farms make sales less than 500,000 yen per year;
4. Rice is the main crop: 60% of farms produce rice;
5. Many abandoned farmlands by many households: abandoning farmlands is worse than other areas.

**Table 1.** Summary of HM areas and characteristics of farms in HM areas.

| **Characteristics of Farms** | | **HM Areas** | **Other Areas** |
|---|---|---|---|
| Population | | 11% | 89% |
| Cultivated land | | 38% | 62% |
| Number of farms | | 43% | 57% |
| Agricultural production | | 41% | 59% |
| Farm size (ha) | <1.0 | 59% | 49% |
| | 1.0–3.0 | 29% | 36% |
| | 3.0–10.0 | 8% | 11% |
| | >10.0 | 3% | 4% |
| Labor input (heads/day) [1] | <1.0 | 50% | 45% |
| | 1.0–3.0 | 42% | 42% |
| | >3.0 | 8% | 13% |
| Sales size (1000/year) | <500 | 42% | 38% |
| | 500–1000 | 17% | 17% |
| | >1000 | 33% | 35% |
| Main product | Rice | 60% | 56% |
| | Vegetables | 12% | 19% |
| | Fruits | 13% | 12% |
| | Livestock | 6% | 4% |
| | Others | 9% | 9% |
| Abandoned farmland | Farmland [2] | 18% | 10% |
| | Landowner [3] | 42% | 28% |

[1] Total yearly work hours/(220 days × 8 h). [2] Ratio of abandoned farmland in each area. [3] Ratio of landowners who own abandoned farmlands. Source: Ministry of Agriculture, Forestry and Fisheries [7].

Rice production in HM areas usually requires higher costs and more intensive workers than in other areas. Additionally, HM areas have disadvantages including smaller plot size, longer distance to another plot, sloped and narrow roads, and inconvenient irrigation facilities. Thus, rice farmers are restricted from working efficiently [8–10]. Moreover, HM areas have faced critical challenges such as aging farmers, depopulation, and an unfavorable climate [5,6], causing more serious problems in farm management, the slow adoption of smart farming technology (SFT), and the abandonment of farmland. As a result, the rice farmlands continuously declined over the years, especially in HM areas.

SFT or smart agriculture describes an advanced type of farming technology utilizing robot technology, and information and communications technology (ICT) to promote labor-saving, precision, and high-quality production [11]. SFT is expected to reduce the labor load and working time for farm production, improve farm profit through expanding farm size, and enable sustainable agricultural farmland [12,13]. For example, rice farming in Japan requires heavy agricultural activities and is labor-intensive; however, utilizing SFT improves farm productivity by reducing labor costs and working time. GPS-guided machines such as tractors or planters, remote-controlled weeding machines, drones for spraying chemicals, and other equipment can make the work more efficient for farmers [6]. Therefore, farmers in an advantageous area or with large-scale farmland can make an effort and benefit from the SFT machines and expand their farming area for improved profit [10,14]. Currently, SFT-enabling precision working devices and GPS-guided machines such as tractors, are commonly used in large scale farms, especially in flat areas. However, many SFT machines are too expensive for rice farmers in HM areas, where the economy of scale is limited due to terrain disadvantages. Such limitations imply minor benefits of SFT and some difficulties in developing economies of scale in such areas. The main cost of utilizing SFT is the depreciation cost, which usually cannot be covered by revenue generated from rice farming in HM areas [14,15]. Despite these constraints, preventing farmland abandonment in HM areas is essential for supporting the local community and traditional life, and protecting the natural landscape and environment [16].

Currently, farmers in HM areas consider the introduction of SFT too expensive for rice production in Japan [6,17]. In summary, farmers working in the HM areas can only purchase SFT machines if they are supported by the government. Supporting initial investment for purchasing SFT can encourage farmers to introduce SFT into rice production. However, farmers must operate a profitable farm business using SFT to reserve internal resources such as depreciation costs and maintain sustaining farmland in the HM areas [14]. Therefore, the research question of this study is, "How can farmers continue to economically utilize SFT in rice production in the HM areas?". This study examines the farm business model to utilize SFT for sustainable farmland in the HM areas and provides case evidence on a hamlet in a HM area, Hyogo prefecture, Japan. The theoretical framework of the farm business model was derived from the enterprise operating a diversified business of rice farming and other business units. Business performance analysis of the enterprise implementing SFT was compared in three scenarios: conventional machines, intermediate SFT, and advanced SFT.

## 2. Factors of Sustaining Rice Farmland in HM Areas

The Japanese government aims to preserve farmland in the HM area for national food security. The government is working strenuously to prevent the increasing abandonment of farmland. The national government enacted a symbolic law, "Direct Payment Grant for HM area (DPG)", in 2000 to address this issue [18]. DPG provides the support grant based on differences in production costs between the HM areas and other areas. In the case of rice farming, a maximum of 210,000 yen per ha is annually subsidized per farm. To maintain farmland in the HM area and receive the grant approval, the beneficiary of DPG must not be an individual farmer, but a farmer organization consisting of farmers and/or landowners in the same area. Therefore, farmers and/or landowners must practice collective activities to continue receiving grant support. This DPG regulation requires collective activities among farmers because it is difficult for individual farmers to prevent abandonment of their disadvantaged farmlands.

Initially, the farmer organization was necessary to maintain all members' farmlands with a collective responsibility to receive the grants. However, some organizations facing aging and depopulation had to withdraw from the program because the members gradually reduced. Moreover, the government reforms the regulation of DPG every five years to adjust to the changes in current circumstances [18]. Therefore, for 2020–2024, the fifth DPG does not involve the collective responsibility regulations, which significantly impacts farmer organizations operating the farmland to continue committing to DPG.

What motivates Japanese farmers living in HM areas to continue farming even though profitability is difficult? There are three main reasons. First, some farmers practice ingenuity and innovative approaches proactively to find business opportunities to profit in the HM area. However, few farmers have these skills, and some struggle with low farm profitability [19,20].

Second, rice farming is a part of life, especially for older farmers who have family living in the hamlet or HM area [20]. Despite the fact that they could live off of a pension without farming, they find fulfillment in farming and keeping farmlands as family assets. They also feel pleasure in gifting the produce to family members, relatives, and/or friends. Rice is considered to be a special crop that strengthens relationships among members of a rural community [21].

Third, farmers keep farming, believing that they can contribute to sustaining the community and farmland through rice cultivation. In other words, farmers have a sense of responsibility to the community, and quitting rice farming causes challenges in the utilization of farming and community facilities such as irrigation. Therefore, additional maintenance works and costs for facilities result in worsening farming conditions and a poor community environment if they are imposed on other farmers [22]. This has accelerated the abandonment of farming and farmland in the HM areas. This behavior of farmers is based on ethics as a mutual assistance or collective responsibility among farmers belonging to a community [21]. Moreover, this ethical issue is cultural and provides a traditional sense of value in farming and daily life in Japanese rural society settling for several generations [23]. Therefore, this ethic has bonded family farming and daily life in the community. For example, the maintenance activities of canals for rice farming were found to be conducted not just by farmers but the whole community, including non-farming families [24].

It may even be possible to suggest that these three reasons motivate farmers consisting of part-time farmers mainly to continue family farming in the HM area to sustain their farmlands. In recent years, farmers with small family farmlands have reconsidered their functions to maintain community and regional farming. Some farming families work on maintaining farmlands through generating multi-functions including non-monetary benefits such as vitalization, motivation, and healthy life [25,26].

However, Figure 1 shows that the number of farmlands declined moderately over the past 20 years, given that the expansion of farmland underwent far fewer changes than the abandonment of farmlands.

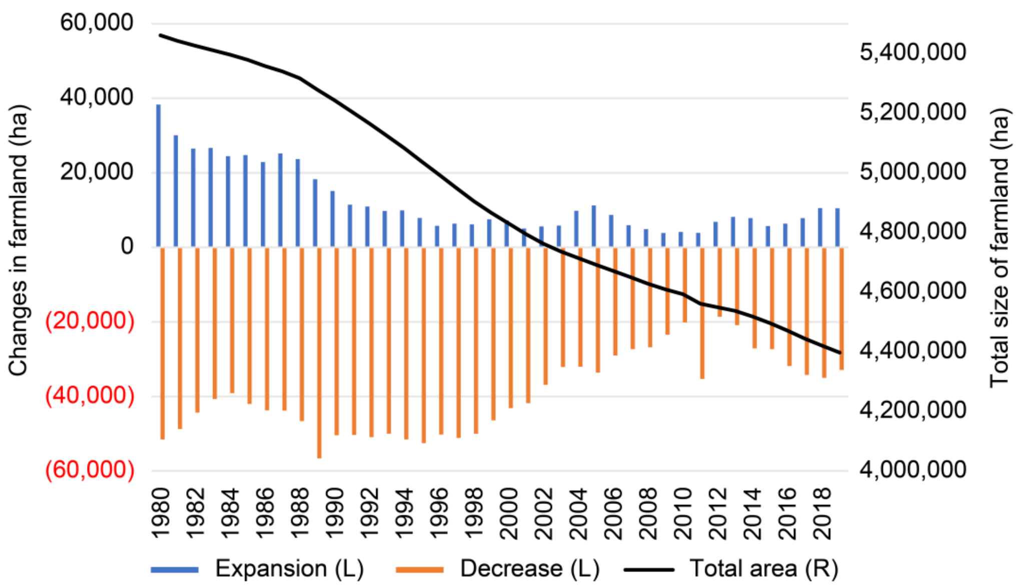


**Figure 1.** Changes in farmland area in Japan (ha) from 1980 to 2018. The number in parenthesis means the decreasing number of farmland (ha per year). Source: Ministry of Agriculture, Forestry and Fisheries [1].

Quitting rice farming in the HM areas is mainly caused by business irrationality and overburdened labor [2]. The first reason is the difficulty in making a profit from rice farming. Figure 2 presents the dramatic decline of producers' rice prices but a slight decrease in its cost over the past 30 years, shrinking the profitability of rice production. Figure 2 shows that the total production cost of rice farming for small-sized farms (0.3–0.5 ha) has not changed, while the total production cost for large-sized farms (more than 5 ha) decreased gradually. This indicates that the cost gap brought on by farm size has widened. Small-sized farms have been lessening their profitability due to two main factors: the worsening rice market situation and cost inefficiency under topographical limiting conditions. Therefore, abandoned farmland is increasing, especially in the HM areas, becoming a serious problem.

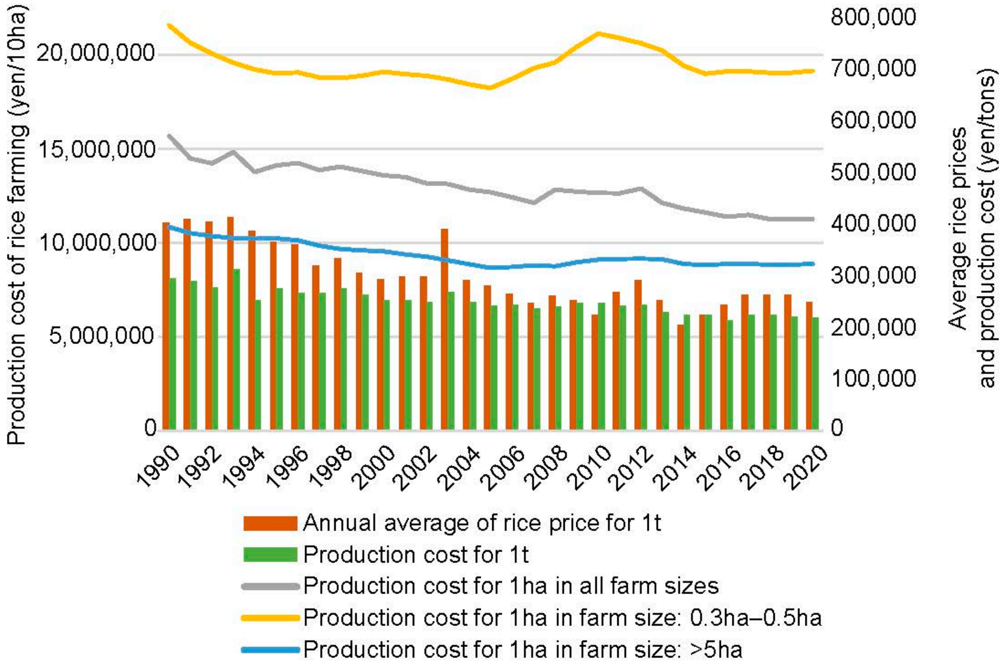


**Figure 2.** Changes in rice production cost and average rice price (yen/tons) during 1990–2020. Source: Ministry of Agriculture, Forestry and Fisheries [27]. Costs and prices are deflated by consumer price index (2020 = 100) [28].

## 3. Introduction of SFT to the HM Area

Rice farmers in the HM region incur two additional costs that are greater than those in other regions: physical burden, and average depreciation cost per ha attributed to inefficient work on small-sized farmland [15,29]. These two costs are interrelated and have accelerated the quitting of farming and abandonment of farmland in HM areas [20]. Previous studies indicated that farmland abandonment was affected by economic, social, and institutional factors, leading to limited opportunities for agricultural activities and profits [16,30,31]. This caused the farmland in HM areas to become uncompetitive compared to other areas. The cessation of farming activities resulted in different outcomes depending on the characteristics of each HM area. SFT is expected to ease the disadvantages of the HM area by making fieldwork efficient, lightening the labor burden, and increasing the competitiveness of mountain farming [13]. Regarding rice farming, there are many kinds of SFTs which can be adopted; for example, auto drive tractors, remote controlled irrigation systems, support of cultivation management systems, and multi-field cultivation management systems [32]. The implementations and conditions of SFT machines to rice paddy field were studied from the viewpoint of machinery work efficiency and investments on SFT [14], but not on business performance analysis. The results under scenarios without the limitation of land expanding showed that SFT machines can expand cultivation of farmland areas with reduced labor work hours and increased farm income. However, the additional costs for introducing SFT machines must be feasible for operating farm businesses and expanding cultivated farmlands.

In general, using SFT to expand operating farmlands is an ordinal way to reduce the average depreciation cost and develop economies of scale. However, the disadvantages of farmland in the HM areas in terms of higher cost and lower productivity attributed to geographical characteristics prevents effective farmland management and efficient economic performance [16,31]. Additionally, the average working time per ha in HM areas is longer than in other areas because the average plot size of farmland in HM is smaller [29]. Poor labor efficiency is another condition limiting farm expansion in the HM areas. When farmland operations reach their optimal scale, expanding farmland makes farming inefficient under any condition. This is the "diseconomy of scale", which limits the development and operations of farmland depending on the area's conditions [33]. The more disadvantageous the farmland conditions, the lower the chance of expansion of the farmland. Therefore, the expansion of a farmer's operation scale in the HM areas is generally smaller than in other areas. In particular, the average depreciation cost becomes larger than in other areas [15]; thus, farmlands in the HM areas have been limited in expansion and barely use SFT.

To overcome these challenges, diversifying a farm's business divisions is expected to improve financial performance and reduce risks [34–36]. This is called the "sixth industrialization", which was enacted by Japanese government since 2010. The main purpose of this program was to encourage farmers to increase their income by themselves through business diversification. The sixth industrialization means the comprehensive and integrated promotion of agriculture as the primary industry, the manufacturing industry as the secondary industry, and the retail industry as the tertiary industry, and the utilization of local resources. It is an initiative to create new added value by utilizing current resources [37]. Currently, the six industrialization was developed in a variety of business forms; for example, direct marketing, farmer's restaurants, farm stays, and educational programs. The sixth industrialization was expected to not only generate several economic values, but also work to revitalize family farming and community socio-economically [35]. However, it is necessary for farmers, especially in HM areas, who embark on the sixth industrialization to balance the investment and procure additional resources for diversifying their business [38]. Building networks among related stakeholders can procure additional resources and labor allocation for operating new business [39].

The development of diversifying businesses is supposedly helpful to maintain farming operations [34,40] and enhance cost effectiveness [6], such as the depreciation cost of SFT from direct and indirect ways.

One way is to utilize SFT machines effectively to operate the farming and business divisions with the addition of contract farm work businesses. Therefore, increasing the operation of SFT can directly improve economic performance. The other option is to make indirect use of the labor resource allocation that results from effectively integrating SFT into farm production and other business divisions. When SFT machines replace the labor workload, unused labor can be allocated to new business divisions and earn additional gains to compensate for the depreciation cost of SFT machines. Thus, diversifying business divisions should make using SFT machines possible by improving the financial condition. Three factors drive the availability of SFT on farm production: the cost of SFT machines, the performance of SFT machines to reduce labor, and total revenue, including other business divisions.

## 4. Methodology and Data Collection

This study was structured in two stages: developing a farm business model and proving the model via a case study. In the first stage, the farm business model was built based on the concept of diversifying business divisions to utilize SFT in the HM areas. Diversifying business was conceptualized on the sixth industrialization, which encourages farmers to generate additional income by diversifying their farm business to non-farm businesses [34,36]. The farm business model conceptualized diversifying farm business into rice farming and other business units with the conditions on labor constraint. Both rice farming and other business units are operated by the farm business enterprise.

The theoretical framework of the farm business model was derived from the enterprise operating SFT under the optimization approach [41]. The payoff of farm business model is calculated by the total sales of diversifying farm businesses minus the total costs. A farm business's payoff is optimized with labor constraint. Three scenarios of the farm business model included combinations of conventional machines, intermediate SFT, and advanced SFT. The choices of SFT machines drive labor allocation and machine cost.

The second stage applied a mixed methods approach in a survey, in-depth interviews, and accounting data to prove the farm business model. A hamlet in an HM area in Hyogo prefecture was selected as a case study. The survey was conducted as a part of the "Smart Agriculture Demonstration Project" supported by Ministry of Agriculture, Forestry and Fisheries [42] from April 2019 to March 2020. First, an in-depth interview was conducted with the community representatives to analyze the relationship between the community and the enterprise. Second, an in-depth interview was conducted with the president of the farm business enterprise to collect data on farm management and the introduction of SFT. Third, accounting data and a working record of the enterprise in 2020 were evaluated to simulate SFT's economic and business performance. To compare the business performance of three scenarios, a financial analysis, mainly focused on fixed costs and labor costs to clarify the efficiency and effectiveness of SFT machines, was carried out. Financial ratio analysis [43] is conducted by employing ten indicators: sales, ordinary deficit, fixed assets, fixed asset turnover, fixed cost, fixed cost ratio, labor productivity in total (yen/hour), elasticity of labor productivity in total for fixed cost, labor productivity (yen/hour), and elasticity of labor productivity in rice farming division (RFD) for fixed cost.

In Japan, the rice production method is so subtle that there is no yield gap between farmers or farmlands in the same area. This means rice production inputs are standardized. Therefore, this study captured two kinds of costs for rice farming: the depreciation cost of machines, and labor cost (unit: yen per ha). Three machine combinations, CON, SFT1, and SFT2, were analyzed. CON and SFT1 were simulated based on real accounting data and working records, where SFT1 included a drone for spraying chemicals and fertilizer. SFT2 was based on real accounting data and working records, and included a drone, tractor, and transplanter.

## 5. Theoretical Framework of the Farm Business Model

The theoretical framework proposed a farm business model to sustain farmland in HM areas by implementing SFT. The actors in the farm business model included farmers, the farm business enterprise, and the government. Farmers represented the community. The farmer and the enterprise were interested in optimizing their payoffs, behaving rationally, and working together (Equation (1)). The enterprise decided on two conditions: labor allocation and types of fixed cost of machine combination ($FCi$). The farm business model employed two types of business divisions: rice farming division (RFD) and other business division (OBD), labors (Lr, Lo) allocated into two business divisions (Equation (2)), three types of machine combination $i$ (where $i$ = CON, SFT1, SFT2), and three kinds of cost ($FCi$, $VCi$, $TCi$) (Equation (3)) to simulate the logic of introducing SFT to farmers in the HM area. The payoff maximization of farm business model for introducing SFT through diversifying business is as follows:

$$\max_{FC} \pi = S\ (Lr,\ Lo) - \ TCi \tag{1}$$

$$\text{Labor constraint } L = Lr(FCi) + Lo \tag{2}$$

$$\text{Total cost: } TCi = FCi + VCi(FCi) \tag{3}$$

where $\pi$ represents the payoff; Lr represents labor for rice farming; Lo represents labor for other business divisions; L represents total labor, which remains constant; CON represents conventional machines; SFT1 represents intermediate smart farming machines; SFT2 represents advanced smart farming machines; $FCi$ represents fixed cost of machine combination $i$; $VCi$ represents the variable cost of machine combination $i$; $TCi$ represents the total cost of machine combination *i*; S represents the total amount of sales, which includes the total sales from rice farming division and other business division.

Figure 3 shows the theoretical model of how an enterprise introduces SFT by operating two business divisions (RFD, OBD). Assume that the value of sales (S) from the two business divisions is greater than the cost of SFT and the labor allocated into the two divisions. The first quadrant shows that the enterprise has a constraint condition of total labor (constant L= Lr + Lo), to allocate for the rice farming division with a constant farmland area and other businesses division. Labor is allocated into two business divisions depending on the type of FC*i* to maximize their sales and profit. Each FC*i* type is utilized continually in a range scale of farmland because of its indivisibility. Additionally, the profitability of Lo depends on the business types of other business division (OBD). Therefore, the enterprise must find an optimal combination of labor allocation and type of fixed cost of machine combination (FC*i*).

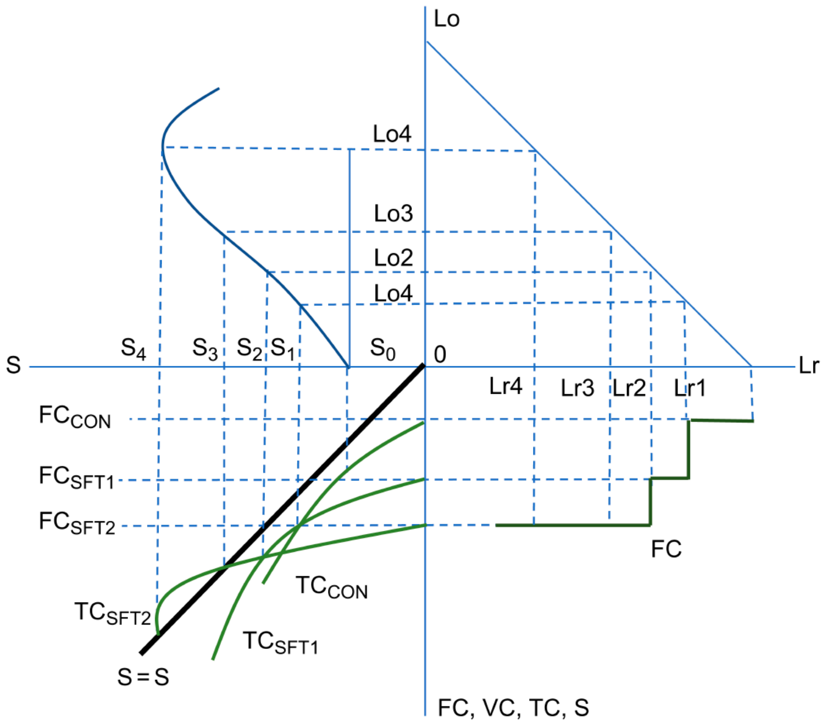


**Figure 3.** Theoretical model for introducing SFT by diversifying the business.

The second quadrant shows the total sales (S) obtained by labor allocation in the two business divisions. The simulation operated from stages 1 to 4, representing the optimal payoff depending on labor allocation into two business divisions. The total amount of sales started at S0 under the condition of Lr = L, where L is total labor. S0 is fixed sales of RFD. Sales added to S0 is of OBD. Then, the total sales began to increase with Lo, which resulted in additional sales of OBD. The sales continued to increase until they reached the maximum point at S4; after that, the sales started to decrease when excessive labor (Lo4 < Lo) was allocated in OBD. For example, a lack of cultivation management skills resulted in a declining rice yield, which affected not only the sales of rice but also the efficiency of other businesses.

The fourth quadrant shows that three types of machine combinations *i*, CON, SFT1, and SFT2, can be used to farm a constant land area for rice. Each machine combination costs FC*i* and had a labor allocation constraint. The more advanced the machine combination, the more expensive and labor-saving it was. The condition (FCCON < FCSFT1 < FCSFT2 and LrCON > LrSFT1 > LrSFT2) holds. For example, CON consists of conventional machines, and FCCON is the cheapest of the three combinations. However, just a few laborers can be allocated to OBD. Additionally, CON does not have enough workforce for rice farming when Lo is less than Lr1.

The third quadrant shows the relationship between the function of the total cost (TC*i*) consisting of both fixed cost (FC*i*), variable cost (VC*i*), and total sales (S). As long as CON or SFT1 was used, the total sales attributed to any labor allocations cannot cover TC*i*. SFT1 generated the optimal payoff between S1 and S2, but the sales cannot cover TC*i*. While SFT2 generated the optimal payoff between S2 and S3, sales cannot cover TC*i*. Eventually, sales between S3 generated by (Lr3, Lo3) to S4 generated by (Lr4, Lo4) surpassed TCSFT2 spent. In other words, the advanced smart farming machines (SFT2) scenario between S3 and S4 can make the business economically rational.

By implementing SFT under two conditions—effective labor allocation on diversifying farm business and the performance of SFT machines deriving the cost and potential benefits to society—the model can explain how to sustain farmland in the unfavorable conditions of the HM areas. Utilizing SFT to sustain farmland in the HM areas raises significant issues regarding farm business diversification, important partners, and cooperative actions among farmers and the enterprise.

## 6. Case Study of the Community and the Farm Business Enterprise

### *6.1. Summary of the Farm Business Enterprise*

The farm business enterprise was operating in Yabu city, Hyogo prefecture, since 2015. Since then, the enterprise embarked on a farming and food processing business. Its parent company, working mainly in the construction industry, embarked on the farming and food processing business four years earlier than the enterprise. The parent company established the enterprise based on its experience. The enterprise committed to participating in the "Smart Agriculture Demonstration Project" conducted by the national government from 2019 to 2020 [44]. With project support, it introduced SFT machines such as a GPS-attached tractor, rice transplanter, drone for spraying chemical materials, remote-controlled weeding machine, and others (such as a rice harvester with ingredient measurement).

The current business of the enterprise consists of rice production as the main division and four other business divisions: food processing, contracting farm work, bean production, and crop trading. The enterprise started rice production with 3 ha of farmland in 2015 and expanded the scale of farmland to 16 ha in 2020. The enterprise had three employees, along with clerical staff, to manage and expand its business.

The enterprise aimed to succeed in the farm business but was also willing to contribute to communities in the same area by maintaining rice production. Planting crops is important for building a sustainable community and maintaining farmland in the HM areas. The enterprise must cooperate with farmer organizations and the community to make rice production efficient and rational. The community convinces landowners to lend their farmlands to the enterprise and coordinates the process. However, some field works, such as irrigating paddy fields and weeding, are difficult to mechanize and require manual labor [45]. The enterprise pays the community members appropriate wages for the work that is deemed rational to consign to them. Without this cooperation, abandoned farmland would increase and the community would be increasingly depopulated.

### *6.2. Summary of a Community in the Hamlet*

In 2020, a hamlet of 30 households was located in the HM area in Yabu city. The 30 households included 18 landowning farming families and 10 landowning non-farming families. The population was 79, with 62% over 65 years old. Depopulation and aging have progressed rapidly in the last few decades. In the past 30 years, over 60 households lived in this hamlet. There were farmlands of 14 ha for rice farming, and all were very small plots of approximately 0.1 ha each. Large gaps and the steeply sloped area between plots required more manual labor to weed. Additionally, it took significant time for farmers to irrigate paddy fields using only mountain water. Although many farmers can support themselves without farming and by relying on their pensions, to maintain the farmland and the community, they are motivated to continue growing rice.

Under this condition, the community was committed to DPG since 2005 and received a grant of about thirty thousand dollars yearly. However, the support grant was insufficient for the farmers to continue rice production because of economic irrationality and drudgery. Therefore, it was difficult for them to envision how to continue rice production. This situation suddenly changed when the enterprise entered the hamlet as a new farmer in 2015. The community sought collaborating with the enterprise to continue rice production. Eventually, the community officially designated the enterprise as the main target farmer in 2020 to accumulate farmland in the "Plan for Human resource and Farmland" (PHF), which is usually made by a community and authorized by the local and national government [46]. It must outline the strategy for allocating and balancing farmland and human resources in order to keep farming in the hamlet. Depending on the PHF, the enterprise can accumulate farmland preferentially. In addition, many community members agreed to cooperate with the enterprise as not only a lender of farmland but also an outsourced worker for farming. They believed that cooperation with the enterprise was the best way to extend rice production for a long period in the hamlet. Therefore, in 2020, the enterprise cosigned a contract to outsource the irrigation work and farming activities to the community. Contrary to some of the other field works, the HM area currently has few SFT instruments to ease irrigation work.

### 6.3. Evaluation and Business Performance Analysis of the Enterprise

The theoretical framework of the farm business model was proved by analyzing the business data of the enterprise. Three scenarios of the model included combinations of conventional machines (CON), intermediate SFT (SFT1), and advanced SFT (SFT2). To simulate these scenarios, CON and SFT1 were assumed based on the real data on SFT2. The model with SFT2 had three kinds of SFT machines: tractor, transplanter, and drone. The drone for spreading fertilizer and chemicals was equipped with SFT1, but the tractor and transplanter were not. The model with CON operated conventional machines, but not any SFT machine. Labor and operating costs of SFT2 were comparable with SFT1 and CON, simulated based on machine performance data, as shown in Table 2.

**Table 2.** Labor and operating costs of the three scenarios.

| Machines and Other Fixed Assets | Scenario | Machine | Work Efficiency [1] (h/ha) | Work Efficiency Ratio (SFT/CON) | Machine Price (1000 yen) | Depreciation Cost [2,3] (1000 yen) |
|---|---|---|---|---|---|---|
| Tractor | CON | Normal | 12.2 | 66% | 6281 | 897 |
| | SFT2 | With GPS to assist precise cultivation | 8 | | 7810 | 1116 |
| Transplanter | CON | Normal | 7 | 106% | 2321 | 332 |
| | SFT2 | With GPS to assist straight planting | 7.4 | | 2574 | 368 |
| Chemical sprayer | CON | Knapsack sprayer for chemicals | 4.2 | 21% | 176 | 25 |
| | CON | Fertilizer applicator | 1.9 | 45% | 125 | 18 |
| | SFT1, SFT2 | Drone | 0.9 | | 3250 | 464 |
| Others | CON and SFT1, SFT2 | | | | 50,545 | 6751 |

[1] Total working hour included preparation, working on the field, maintenance, etc. [2] Depreciation cost used straight-line method. [3] Legal durable years for tractor, transplanter, and chemical sprayer was 7 years and for others were 6–15 years. Source: Ministry of Agriculture, Forestry and Fisheries [42].

Several conditions were necessary to simulate the business results of SFT1 and CON.

1. The three scenarios have common sales and variable costs in RFD but different labor costs depending on the calculation with machine performance data;
2. The three scenarios have common labor constraint as 3600 h a year for the whole business. Labor hours for each business comprising OBD are based on SFT2 data;
3. Depreciation costs are only captured by machines of RFD;
4. OBD's sales and variable costs are simulated using labor hours for running OBD, which includes food processing, contracting farm work, and dealing crops.

Table 3 shows the simulated business performances of each scenario: CON, SFT1, and SFT2. Depreciation costs of SFT machines were corrected to simulate the economic performance of SFT machines under the three scenarios. Fixed costs were accounted for RFD, not divided between RFD and OBD, to evaluate the effectiveness of developing OBD. Annual DFG and other supports (e.g., single fiscal-year subsidy for COVID-19) were subsidized to the enterprise in 2020 and presented in the simulation analysis as a part of the subsidies.

**Table 3.** Simulated business performance of three scenarios (1000 yen).

| Scenarios | Business Performances | RFD | OBD | Total |
|---|---|---|---|---|
| CON | Sales | 11,168 | 11,898 | 23,067 |
| | Total cost [1] | 21,511 | 12,492 | 34,003 |
| | Fixed cost | 9418 | 221 | 9639 |
| | Depreciation | 7801 | 221 | 8023 |
| | Variable cost | 6740 | 7230 | 13,971 |
| | Labor cost | 5352 | 5041 | 10,393 |
| | Gross income [2] | −10,343 | −594 | −10,936 |
| | Subsidies (DPG and others) | 8938 | | 8938 |
| | Ordinary profit [3] | −1405 | −594 | −1998 |
| SFT1 | Sales | 11,168 | 12,614 | 23,782 |
| | Total cost [1] | 21,629 | 13,230 | 34,859 |
| | Fixed cost | 9839 | 221 | 10,060 |
| | Depreciation | 8223 | 221 | 8444 |
| | Variable cost | 6740 | 7665 | 14,406 |
| | Labor cost | 5049 | 5344 | 10,393 |
| | Gross income [2] | −10,461 | −616 | −11,077 |
| | Subsidies (DPG and others) | 8938 | | 8938 |
| | Ordinary profit [3] | −1523 | −616 | −2139 |
| SFT2 | Sales | 11,168 | 13,629 | 24,798 |
| | Total cost [1] | 21,453 | 14,277 | 35,731 |
| | Fixed cost | 10,094 | 221 | 10,315 |
| | Depreciation | 8477 | 221 | 8698 |
| | Variable cost | 6740 | 8282 | 15,023 |
| | Labor cost | 4619 | 5774 | 10,393 |
| | Gross income [2] | −10,285 | −648 | −10,933 |
| | Subsidies (DPG and others) | 8938 | | 8938 |
| | Ordinary profit [3] | −1347 | −648 | −1995 |

[1] Total cost was calculated by adding fixed, variable, and labor costs. (See more detail on fixed cost and variable cost in Table S1.) [2] Gross income was calculated by sales minus total cost. [3] Ordinary profit was calculated by the sum of gross income and subsidies. Source: Author's calculation based on accounting record of the farm business enterprise.

Table 3 reveals that the SFT2 scenario showed the best business performance, followed by the CON and SFT1 scenarios. These differences in business performances were attributed to the results of RFD, especially labor costs. Given that the use of SFT2 improved labor allocation in RFD and more labor allocation to OBD, enabling the sales from OBD to continue to increase, the enterprise under SFT2 generated the highest annual sales of 24,798 thousand yen with the lowest total cost of RFD (see more details on OBD in Table S1).

When comparing SFT2 to CON, less labor was required on RFD under SFT2, but the scenario produced a similar level of ordinary profit, which benefited older farmers and the community more. The subsidy nearly eliminated the deficit that resulted in the ordinary profit at −1995 thousand yen (SFT2), −1998 thousand yen (CON), and −2139 thousand yen (SFT1), despite the fact that all scenarios faced a loss of 10 million yen. Although the enterprise had a deficit in 2020, RFD would utilize SFT more efficiently, and OBD is expected to become a profitable division in the future. In reality, the majority of the deficit is eventually covered by annual subsidies and financial support for the introduction of SFT machines. Even though SFT2 has the highest depreciation cost, SFT machines economize the labor force enough to offset the higher depreciation cost. Simultaneously, the results of the SFT1 scenario revealed insufficient SFT machines to operate the farm business in the HM area. Therefore, the three machine combinations scenarios provide evidence on how to utilize SFT for sustainable farmland in the HM areas.

*6.4. Comparison of the Financial Performances Analysis*

The financial performance analysis of three scenarios, CON, SFT1, and SFT2, were evaluated to compare the economic efficiency and effectiveness of SFT in HM areas. Financial indicators and ratio analysis [43] were useful for this study, especially fixed assets, fixed cost, and labor productivity employed to relate with utilizing SFT. Table 4 shows the results of financial performance analysis that evaluated the changes and differentiation among scenarios. First, sales of business, fixed assets, and fixed cost increased from CON to SFT1 and SFT2, respectively. The enterprise reduced the labor force for RFD and allocated more labor into OBD (SFT1: 1851 h per year, SFT2: 2000 h per year) with utilizing SFT machines. As the result, the enterprise with SFT2 generated 7.5% higher sales than that with CON.

**Table 4.** Financial performance analysis results.

| Financial Indicators | CON | SFT1 | SFT2 |
|---|---|---|---|
| 1. Sales (1000 yen) | 23,067<br>100.0% | 23,782<br>103.1% | 24,798<br>107.5% |
| 2. Ordinary deficit (1000 yen) | (1998)<br>100.0% | (2139)<br>107.0% | (1995)<br>99.8% |
| 3. Fixed assets (1000 yen) | 59,448<br>100.0% | 62,397<br>105.0% | 64,178<br>108.0% |
| 4. Fixed assets turnover [1] | 38.8% | 38.1% | 38.6% |
| 5. Fixed cost (1000 yen) | 9639<br>100.0% | 10,060<br>104.4% | 10,315<br>107.0% |
| 6. Fixed cost ratio [2] | 41.8% | 42.3% | 41.6% |
| 7. Labor productivity in total business [3] (yen/h) | 6407 | 6606 | 6888 |
| 8. Elasticity of labor productivity on total fixed cost [4] | | 0.63 | 0.94 |
| 9. Labor productivity (yen/h) in RFD | 6024 | 6385 | 6980 |
| 10. Elasticity of labor productivity in RFD on fixed cost [5] | | 1.21 | 2.00 |
| Labor hour [6] | | | |
| RFD (h/year)<br>OBD (h/year) | 1854<br>1746 | 1749<br>1851 | 1600<br>2000 |

[1] Fixed assets turnover was sales divided by fixed assets. [2] Fixed cost ratio was fixed costs divided by fixed assets. [3] Labor productivity was sales of business divided by labor hour. [4] Elasticity of labor productivity on total fixed costs was the change in labor productivity in total divided by the change in fixed costs. [5] Elasticity of labor productivity in RFD on fixed costs the change in labor productivity (yen/hour) in RFD divided by the change in fixed costs. [6] Total annual labor hour was 3600 h for three scenarios. Source: author's calculation based on accounting record of the farm business enterprise.

Second, the enterprise can improve labor productivity by introducing SFT. Labor productivity was calculated using two indicators: total business (both RFD and OBD) and RFD. The larger labor productivity is, the more productive the economic output per labor force becomes. To measure the sensitivity of labor productivity to a change in fixed asset rate, elasticity of labor productivity with respect to fixed assets of SFT2 (total: 0.94, RFD: 2.00) was more elastic than SFT1 (total: 0.63, RFD: 1.21).

Third, the enterprise faced a loss for all scenarios, where SFT2 had the lowest ordinary deficit (99.8%) compared to CON (100%) and SFT1 (107%). Simultaneously, the changes of fixed assets turnover (CON: 38.8%, SFT1: 38.1%, SFT2: 38.6%) and fixed cost ratio (CON: 41.8%, SFT1: 42.3%, SFT2: 41.6%) indicate that financial security was improved at SFT2.

We identified that as SFT machines were introduced to the HM areas, larger sales of business from OBD were conducted. These changes were attributed to the labor-saving function of SFT machines. However, it is worth noting that high costs of SFT machines do not allow the enterprise to improve its profitability until introducing enough SFT machines to cover depreciation costs and reach the optimal payoff as discussed in Figure 3. In other words, a small number of SFT machines can worsen the profitability of the whole business. This was evidenced in the outcome of SFT1, which did not generate sufficient effectiveness to impact the business. On the other hand, as the total amount of SFT machines exceeds an optimal level, the payoff could change from increasing to losing profit. In addition, not enough investment in SFT causes reduced financial security of a farming entity through decreasing fixed assets turnover [47] and increasing fixed cost ratio. This means that scale of investment to SFT should be considered from the viewpoint of financial security of the enterprise.

### *6.5. Key Drivers of the Enterprise Operating SFT on Farmland in the HM Areas*

First, the subsidies and support by national and local governments drive the connection between the enterprise and farmers in the HM areas. Second, employing SFT could improve the low productivity of rice in comparison to fixed costs and lower the use of labor forces. Third, the improvement of the farm business enterprise's financial structure makes the development of OBD more important. OBD also contributes to revitalizing the local community by improving sales and creating new value in the business [40,48]. For example, selling processed food and crop trading can boost farm business sales by acquiring customers and enhancing the value of the business. Machine contracting businesses can support farmers who have trouble continuing farming by providing the service. As a result, these services can support farming and livelihoods in the community.

The last driver is collaboration in farming activities between the enterprise and people who distribute additional income to the community [48,49]. In this context, the variable costs of RFD included payment for commissioned work for irrigation and weeding by community members. This cost occupied 18.6% of variable costs in RFD. The payment can be applied to the employees' additional 730 h of work, which was insufficient to cover the needs of two different types of work. Irrigation and weeding in HM areas are labor-intensive. Irrigation, in particular, necessitates three to four hours of light work per day, several days per week. Therefore, it is not efficient for employees to handle the two kinds of work, but it is suitable for the older people living in the community. Actually, the enterprise reduced costs and labor by commissioning the works to community members. Simultaneously, the payment amount has significance for the community members, especially the older residents. The opportunity to earn money through the commission work is extremely valuable to them. Furthermore, they can feel as though their participation in the job helps to maintain farming in the community. For the older residents, this is something worth living for.

## 7. Discussion

This study introduced the farm business model on diversifying farming business in HM areas to cover the additional costs of utilizing SFT and sustaining farmland. The survey results and financial performance analysis on the enterprise highlighted two challenges to maintaining farming in the HM areas while implementing SFT. First, without altering the business structure, the cost of implementing SFT was too high to cover the depreciation cost. In order to cover costs, new businesses must be created by operating SFT, which can economically minimize costs and labor hours. That is, operating SFT generates capital resources to invest in new businesses and supplies, as well as enabling a surplus labor force for existing ones. This is supported by [14], who revealed that SFT could reduce working hours, allowing farmers to expand cultivation land and allocate labor to additional businesses. The conditions to introduce SFT into paddy fields in flat areas with profitability required economies of scale and the expansion of land for rice cultivation [14]. If costs on cultivation land expansion is too high, as it is in HM areas, SFT is not economically worthwhile to the farm business model. In addition, expanding similar cultivation land in HM areas is not feasible to implement SFT, but other non-farming business units generated by SFT's labor allocation could possibly operate a profitable farm business.

Second, SFT alone is insufficient for maintaining family farming and farmlands in HM areas because rice farming in HM areas is not conducive to advanced mechanization, particularly regarding weeding and irrigation and requires human labor. As a result, community stakeholders must work together to take action. The farm business model for introducing SFT to sustainable farmland is shown in Figure 4.

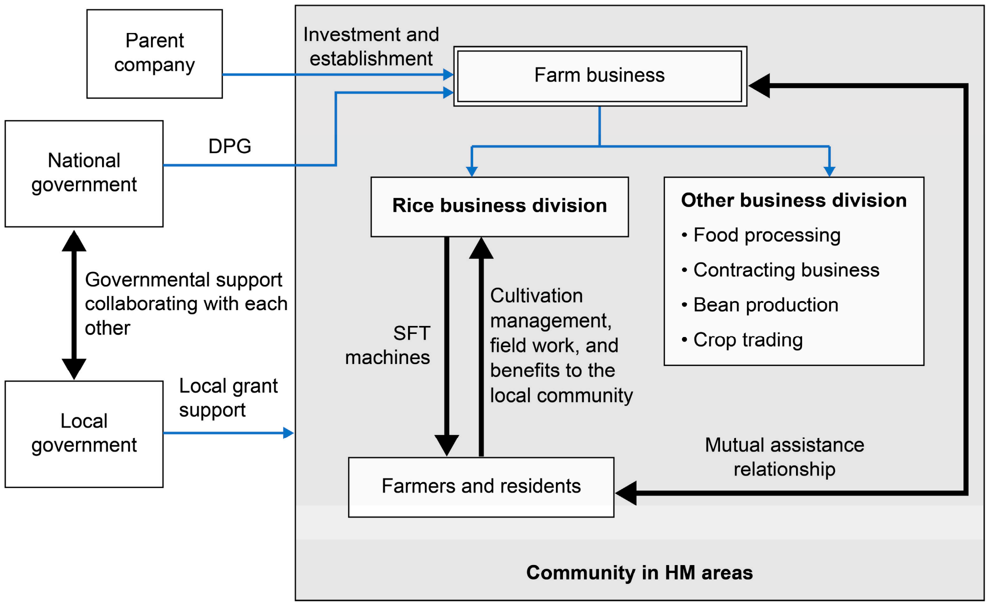


**Figure 4.** Diagram of the farm business model on introducing SFT to sustainable farmland.

Addressing the first issue, the development of diversified businesses alleviates some challenges on introducing SFT in HM areas. The sixth industrialization was applied to the farm business model, enabling farms to operate diversified businesses and improve farm incomes [34,36]. However, the sixth industrialization is diversified into various businesses and each business required specific conditions and management to become successful [36]. In general, farmers who embarked on business diversification typically need to procure additional resources for the business development. Some resources and facilities are not able to be procured under the farm business; thus, many farmers build networks with various actors both internally and externally in the community. Building networks with farming industries not only procures new resources but also creates business partners and market opportunities [38,39]. Figure 4 shows that the enterprise operates diversifying business units efficiently based on a network involving various actors. However, this management skill can be explained as an ability to adopt social factors and individual characteristics [30,31]. Furthermore, creating job opportunities for the residents in the community is another factor to make the sixth industrialization successful [34]. Revitalizing a community can drive and maintain farming in HM areas. One suggestion is to make efficient use of labor and equipment, including SFT machines. In other words, new businesses can maximize benefits by limiting additional operating costs [6,40]. Furthermore, for businesses operating in a labor-force constrained environment, collaboration with other firms is effective. For instance, the enterprise operates other business divisions with machines and labor rather than making sizable new investments. One example is the enterprise that makes the rice cake "Mame Mochi", which continues to hire regular staff throughout the year. The processed food businesses can be operated throughout the year, unlike rice farming. An essential goal for running an enterprise is to create opportunities to earn an income throughout the year. For some products requiring advanced machines, the enterprise acts as the original equipment manufacturer (OEM), supplying raw materials (such as rice) to an associate food processing company and selling the processed rice product (such as sake). In other words, to maintain farming in the HM area, the enterprise must ensure economic prudence rather than focusing on maximizing its short-term profit.

For the second issue, SFT makes rice farming work efficiently to an extent and stimulates agricultural structural changes in a region. That is, SFT opens up the possibility of extending the limitation of the economy of scale in HM areas, causing larger farms to realize greater profits. However, there are some inefficient tasks associated with rice farming, such as weeding or irrigation, which require significant manual labor and cannot be easily mechanized. This indicates that a farm seeking to expand must forge new ties with the community in order to produce rice. In concrete terms, the community is expected to assume responsibility for some fieldwork as contracted work. For example, the enterprise consigned the farm works (i.e., irrigation and weeding) to the community in 2020 and paid 2107 thousand yen (see more detail on commissioned work in Table S1). The development of relationships of mutual support for rice farming between the enterprise and the community is necessary and useful to make farming sustainable. The development of diversified businesses and collaboration between the entities requires a mutual assistance relationship. Another prominent driver is government support (such as DPG and SFT investment grants). Finally, finding the right enterprise that works with the community will create sustainable farmland in the HM areas and motivate community residents to stay in the disadvantageous area and maintain a vibrant environment.

## 8. Conclusions

This study investigated a farm business model that made use of SFT for farming in the HM areas in Japan. By analyzing the business performance and financial analysis in the case study of a hamlet in a HM area, three scenarios of SFT machine combinations: CON, SFT1, and SFT2, were analyzed. The theoretical framework of the farm business model was developed and tested. The farm business model for applying SFT had three stakeholders: collective activity by the farmer organization, farm operations by the enterprise, and a government subsidy. The model also conceptualized diversifying the farm business into rice farming and other business divisions. The findings from financial analysis of the case study were consistent with the theoretical framework of the farm business model. Scenarios SFT1 and SFT2 could increase sales of the farm business (SFT1: 100.3% and SFT2: 107%) by reducing annual labor force in RFD (SFT1: 105 h and SFT2: 254 h) and allocating these labor forces to OBD, leading to an improvement in labor productivity. Therefore, diversifying the farm business, key partners, and collective actions are prominent drivers in utilizing SFT to sustain rice farmland in the HM areas.

However, without suitable SFT machines, some financial indicators can become inefficient. For example, SFT1 (107%) generated higher deficit than SFT2 (99.8%), and the fixed costs ratio of SFT1 (42.3%) was higher than SFT2 at 41.6%. The elasticity of labor productivity to fixed assets explains these changes sufficiently, where the elasticity of SFT2 (0.94) was greater than the elasticity of SFT1 (0.63). This indicated that the change in fixed assets of SFT2 was more productive than that of SFT1, giving the potential of utilizing SFT to sustain farmland in HM areas.

There were two main difficulties with introducing and continuously utilizing SFT to maintain farming in the HM areas, which serve as a conclusion to this study. First, farms must create a successful business division structure using the idle resources produced by SFT in order to offset the depreciation cost of SFT machines. Second, even in the HM areas, SFT works to make farming operationally efficient. However, to maintain the business, it must secure its profitability. Hence, creating a profitable business division structure is essential to pay for maintaining the farmland in the HM areas and ensuring farming continuity using SFT.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12030592/s1, Table S1: Business performance of each business in SFT2 scenario.

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# Spin-Offs, Innovation Spillover and the Formation of Agricultural Clusters: The Case of the Vegetable Cluster in Shouguang City, Shandong Province, China

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**Abstract:** Agricultural clusters play a powerful role in promoting the agricultural transformation and rejuvenation of rural areas. However, no in-depth exploration has been made on how agricultural clusters form and evolve, especially in the context of China's long-term small-scale rural economy. The purpose of this article is to reveal the formation process and evolution mechanism of agricultural clusters by case study research. With the knowledge flow as the starting point, this article takes the Vegetable Cluster in Shouguang City of Shandong Province, China as an example to construct a theoretical framework in the three dimensions of points (spin-offs of enterprises or farmers), lines (network-spillovers of various innovation) and planes (the formation of new regional industry spaces) and put forward theoretical hypotheses. It is shown that: (1) The local spin-off of seed farmers is the main path in the transformation of traditional farmers into enterprises. (2) The network-spillover and adoption of innovative knowledge promote the derivation of specialized farmers or enterprises and realize regional agricultural specialization and spatial agglomeration. (3) The formation of the agricultural cluster resulted from the joint effects of spin-off derived from the entrepreneurial spirit of the farmers, network-spillover of various agricultural innovations and spatial integration of the agricultural landscape. The formation of local agricultural innovation systems marks the maturity of an agricultural cluster. This article contribute to the field by studying one source of Alfred Marshall's knowledge of external economy from the perspective of spin-offs and innovative spillovers, analyzing the agricultural increasing returns to scale neglected by Krugman, and exploring the micro mechanism of farmers' enterprise-oriented evolution and the formation of agricultural clusters in underdeveloped rural areas. The research results are of profound referential significance for the cultivation of agricultural clusters in developing countries.

**Keywords:** spin-offs; innovation spillover; agricultural cluster; vegetable cluster in Shouguang City; Shandong Province; China

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## 1. Introduction

Cluster initiatives are starting to be seen as a key approach to help advance all sectors of many countries [1–7]. As global agriculture has continuously demonstrated a clustering trend, agricultural clusters have increasingly attracted the attention of the academic world and have become a strategic tool for many developing countries to increase their agricultural international competitiveness [2,8].

In recent years, such bottlenecks as land, capital, and technology in China's agricultural development have become increasingly prominent. As a new agricultural organization mode, agricultural clusters have become an effective carrier for China to solve these problems and carry out a joint development of primary, secondary, and tertiary industries. In the economic development of China's rural areas, the emergence of specialized villages and agricultural clusters plays an important role [9], especially in recent years, and the country's policies on such issues as moderate scale management (1997), land circulation (2004), cultivation of new business entities (2014) and separation of the three rights (2016) have accelerated the formation of agricultural clusters.

Agricultural clusters promote agricultural transformation, industrial spatial reconstruction, and the economic and social development of rural areas with their unique advantages. With a large scale and specialization, they not only make up for Chinese rural economic shortcomings, including small-scale farmland, decentralized operation, and low organization levels, but also promote the industrialization and urbanization of rural areas, absorb surplus rural labor, and increase farmers' income. The integration of small-scale farmers achieves the connection between small-scale production and large markets, thus promoting the transformation of China's agricultural and agricultural development modes.

How are agricultural clusters formed? How have they evolved? During our survey, we found that traditional farmers in China's small-scale farmers' economy have evolved into enterprise-type farmers or agricultural enterprises by accepting and adopting new knowledge. There have also been spillovers of the innovative technology and new knowledge through spin-off networks, thus forming a development path that deviates from the original. Creation is a key to the formation of agricultural clusters and the industrial spatial reconstruction of rural areas is the result of agricultural clusters. Then, in rural communities, how is new knowledge generated and how does it spread through network spillovers? How is it widely adopted by farmers to form agricultural clusters? The answers to these questions are of great significance to further cultivate agricultural clusters and modern agriculture development in developing countries.

*Literature Review*

Industrial clustering has always been a core topic in the research of economic geography. Since the 1980s, with scholars' rediscovery of Marshall's 'industrial districts' in the context of globalization, 'industrial clusters' have quickly become a research hotspot in geography, economics, and management. They have dominated international mainstream research in economic geography. A large domestic and foreign literature has provided in-depth explorations of the source of industrial clusters' competitive advantages, conditions for their production, regional growth effects, network organization, technological innovation, etc. [10–19].

As for the formation mechanism of industrial clusters, as early as over 100 years ago, the industrial district theory pioneered by Marshall focused on the clustering of many similar small enterprises with the division of labor in specific regions [20]. Based on the assumption that the returns to scale of neoclassical economics remain unchanged, the theory attributes the advantages of enterprise clustering to the external economy of enterprises, but does not delve into where these external economies might come from.

The New Industrial District School [21] emphasized the influence of local socio-cultural factors on the learning mechanism of industrial clusters. It focused on the rooting of enterprises in the local community environment and the continuous emergence of labor division and professionalization, but did not explain how an enterprise is rooted in local culture and how it works.

The Competitive Strategy School of Porter (1990) [11] emphasized the 'Diamond Model' which identifies national competitive advantages based on industrial clusters, which include groups of interconnected companies, suppliers, related industries, and organizations in specific regions. This model has become a new approach for enterprises and governments to assess regional competitive advantages, but it weakens the spatial dimensions of clusters.

Krugman's New Economic Geography School [22] described the forward and backward connections of industries and industrial clustering caused by labor flows. However, it ignored the importance of technological spillovers and held that agriculture involves constant returns to scale, which is inconsistent with the reality of the growth and clustering of agriculture.

It can be seen that most of the existing literature focuses on industrial clusters in the high-tech, manufacturing, service, and creative industries [10,12–14,16,19,23]. Remarkably, little attention has been paid to clusters in the agricultural sector [2,7,19]. Although some international literature does use cases in the agricultural sector [11,15], they focus on the manufacturing industry due to the high industrialization degree and advanced agricultural product processing in the case areas.

Existing literature seldom separates agricultural clusters from manufacturing clusters, which means that it ignores the differences between agriculture and manufacturing in terms of cluster formation, evolution, and development. Agriculture has different characteristics from other industries in many key elements of cluster formation such as the actor, product type, industrial chain, and local rooting. For example, the basic actor of agricultural clusters is a farmer (or family farm) with characteristics such as enterprise operation, natural geographical clustering, local rooting, and the reproduction and dissemination capabilities of rural communities. The hierarchy between farmers and actors (such as leading enterprises) is more obvious; the agricultural chain is long and complicated (Stringer C. and Heron R, 2008), and involves more plans and government promotions (compared with manufacturing clusters). Therefore, the formation and evolution of agricultural clusters certainly have their own laws and uniqueness.

In the context of the small-scale rural economy, China's agricultural clusters are formed involving a large number of farmers. In this regard, the evolution of farmer organizations into enterprises is the key (first step) to the formation of agricultural clusters. Previous research into cluster evolution mainly focused on the cluster and network levels, paying little attention to the evolution of enterprise (or farmer) organizations in clusters. Existing research on cluster evolution also did not consider the heterogeneity of enterprises (or farmers) capacity (including scale, rights, and absorption capacity). In other words, the 'black box' of enterprises (or farmers) has not been opened. The status of industrial development in China's rural areas is characterized by a large number of specialized village clusters and few mature agricultural clusters, so specialized villages should be upgraded into industrial clusters through the organization and integration of industrial networks. This issue has not yet attracted enough attention from scholars.

Agricultural clusters are often spontaneous spin-off clusters. Existing research into spin-offs focuses on how enterprises in a cluster or industry are spun off. That is to say, clusters or industries are regarded as established. However, it should be noted that there is little research into how spin-offs form new clusters or industries through knowledge spillovers. To this end, with spin-offs and innovative spillovers as a conceptual breakthrough, this article takes the Vegetable Cluster of Shouguang City, Shandong Province as an example and delves into the formation process and evolution mechanism of agricultural clusters by case study research based on data gathered from field interviews and statistical yearbooks.

The field interviews attempted to answer key questions:

1. How do traditional farmers transform into enterprises in rural areas?
2. How do traditional farmers engage in new industries through knowledge spillovers and spin-offs from innovative farmers?
3. How do farmers and agricultural enterprises promote the formation and evolution of agricultural clusters through spin-offs and innovation spillovers?

By answering these questions, an in-depth analysis can be made of the enterprise-oriented evolution of farmer organizations, the formation of industrial networks and the spatial reconstruction process of the cluster industry, and a theoretical basis and practical references can be provided for the formation of agricultural clusters in other agriculture-based developing countries.

## 2. Theoretical Framework and Research Hypotheses

### 2.1. Connotations and Characteristics of Agricultural Clusters

An industrial cluster is a geographic concentration of inter-connected companies and institutions in a particular field [2,11]. Agricultural clusters are an extension and application of the industrial cluster theory in the agricultural sector. It has the essential characteristics of industrial clusters, including geographical proximity and industrial correlation [23]. Specifically, industrial cluster = industrial agglomeration + network [24]. First, the geographic agglomeration of interdependent small and medium-sized enterprises and institutions is a precondition; second, highly specialized labor division and cross-industry development are distinguishing features; and third, the local social network provides a deep foundation [17,25]. Thus, an agricultural cluster is simply a concentration of producers, agribusinesses, and institutions that are engaged in the same agricultural or agro-industrial subsector, and interconnect and build value networks when addressing common challenges and pursuing common opportunities [2]. Agricultural clusters include enterprises (or farmers and family farms operating as enterprise) that produce and process agro-products, related agricultural distribution enterprises, sales service enterprises, raw material and equipment suppliers, R&D centers, testing centers, universities, vocational training providers, suppliers of specialized inputs (such as components, machinery, and services), and providers of specialized infrastructure, governmental, and other institutions [2].

Different from traditional agriculture, agricultural clusters have such characteristics as the specialization of agricultural production, enterprise-orientation of agricultural production and operation actors, commercialization of agricultural products (similar to the commercial agriculture in western literature), and integration of agricultural operations.

Different from the industrial clusters of other sectors, agricultural clusters integrate the characteristics of the primary, secondary, and tertiary industries, namely agricultural product cultivation or the breeding industry, agricultural product processing, and related services before and after production. Therefore, there is a longer network industrial chain in the agricultural cluster. As the upstream products of agricultural clusters are characteristic agricultural products, farmers operating as enterprises are the basic production actors and agricultural clusters are easily affected by natural disasters; the differences in climate, market, technological innovation conditions, etc. in different regions shape the strong regional and localized characteristics of agricultural clusters.

It can thus be seen that the formation and evolution of agricultural clusters include the transformation of farmers into enterprises, the extension of industrial chain and the formation of network based on the agglomeration of enterprises (or farmers), and the co-evolution with cluster regions in technology, institution, and space [19]. The advantages of agricultural clusters come not only from the advantages of the geographical clustering of small and medium-sized enterprises and farmers), but also from the networking and interaction of various entities within the cluster; namely, agricultural cluster = agricultural agglomeration + industrial network [24]. Agricultural clusters are closely related to, and share the same goals as, the rural policies that China currently advocates. These policies include promoting integrated development of primary, secondary, and tertiary industries in rural areas, the reconstruction of the entire industry chain, and rural rejuvenation.

### 2.2. Spin-Offs

The attention to spin-offs in industrial cluster research began with research into the spin-offs of high-tech industrial clusters in America's Silicon Valley [26–28]. It emphasized that companies with leading roles (such as the first semiconductor lab founded by 1955 Nobel Laureate in Physics Shockley in Silicon Valley) are seeds from which myriad new semiconductor companies had spun off; they were interconnected and continuously clustered together to form the Silicon Valley cluster.

Spin-offs in agricultural clusters comprise the process by which the entities in the cluster breed and produce sub-entities (including farmers, agricultural enterprises, logistics companies, institutions, and organizations) which engage in industrial activities similar or related to theirs in various forms. Traditional farmers only produce traditional crops at the beginning. Once seed farmers playing a leading role in bringing new knowledge of an agricultural product (such as strawberries) to a certain place, such innovative knowledge would spread through social, administrative, technical, and management channels (or relations). The spread of the new knowledge that is imitated and adopted by the farmers diffuses through the aforementioned channels. Farmers who adopt such new knowledge from seed farmers and other channels, change their production mode from self-sufficient production to commercial production of a particular agricultural product. In this manner, the organizational form of agricultural production becomes enterprise-oriented, realizing organizational innovation and product innovation.

Therefore, hypothesis 1 is proposed:

**Hypothesis 1.** *The local derivation of seed farmers is the main way of the transformation of traditional farmers into enterprises. In the process of knowledge flow, the dissemination and diffusion of knowledge are manifestations of economic externality; the adoption of knowledge is the essential process in which new industrial actors are spun off from the original actors [19]. As such, the acceptability of new knowledge and the difficulty in farmers' adoption of new knowledge are the keys to the emergence of spin-offs.*

### *2.3. Innovative Spillovers*

The spillover effect of innovation plays a vital role in the development of an economy, as recognized and stressed by the endogenous growth models [29]. 'Innovative spillovers' mainly refers to the process in which innovative knowledge and success in such aspects as information, technology, management, and organizational forms related to production and operation activities are shared, spread, and imitated rapidly. Grossman and Helpman (1991) believed that innovation spillovers were an enterprise's free access to other enterprises' information without market transactions [30].

The process of spillovers mainly includes the knowledge spillover of the 'source' and the learning and absorption by the 'receiver'. When the knowledge is received and adopted by the receiver to form a new organization, the spin-off process begins, and the utility of spillovers is maximized. It is more effective if innovative knowledge spills through the spin-off channels.

Knowledge spillovers are not limited to the high-tech industry [31] or cities, and are common in traditional rural communities. In China's traditional agricultural areas, the proximity among households within a village or town often affects how well knowledge travels among households to facilitate innovation. Whether via the Marshall–Arrow–Romer (MAR) spillover, which focuses on the spillover from different firms in a common industry, or the Jacobs spillover, which focuses on the spillover from different individuals in different industries [31], innovative knowledge can travel in the air and spread among farmers in a barrier-free way. It would first be adopted by a few farmers and then gradually adopted by more [19]. Since farmers live in the same rural community for a long time and have natural agglomeration characteristics, innovation spillover leads to the spatial agglomeration of farmers who adopt innovative knowledge and produce similar products.

Therefore, hypothesis 2 is proposed:

**Hypothesis 2.** *The network-spillover and adoption of innovative knowledge promote the derivation of specialized farmers or enterprises and realize regional agricultural specialization and spatial agglomeration.*

### 2.4. Interaction among Spin-Offs, Innovative Spillovers, and the Formation of Agricultural Clusters

In rural areas, the enterprise-oriented evolution of farmers is the first step in the formation of agricultural clusters. Spin-offs turn traditional farmers into agricultural entrepreneurs, or collectively into institutions, which increase the number of local actors (points) (Figure 1).

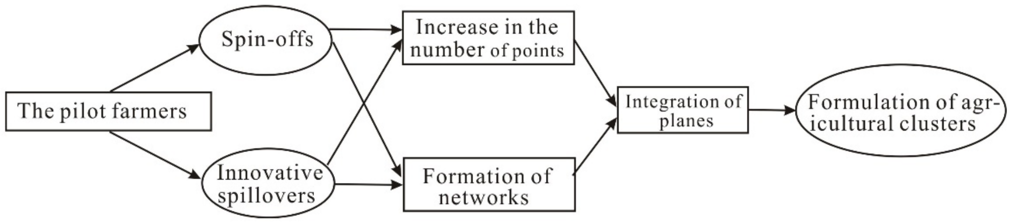


**Figure 1.** Interaction among spin-offs, innovative spillovers, and the formation of agricultural clusters.

Due to the complexity of new knowledge and the receptivity of farmers with different knowledge levels, spin-offs are hierarchical. Farmers with a high absorption capacity can adopt highly complex new knowledge and are spun off into high-level actors [32]. As such, the hierarchy of spin-offs increases the types of start-up actors and forms related diversification [33]. This is the key to the increase in the number and types of companies or institutions (i.e., points) in agricultural clusters. On the basis of spin-off networks, diversified actors further develop into cooperative networks and innovative networks (i.e., lines), which are the basic framework for the formation of agricultural clusters [19].

Compared with other industries, agricultural clusters are site-driven. Agricultural products are produced on farmers' contracted land and are sometimes processed in their own yards. Farmers transforming into entrepreneurs or institutions on the basis of rural clusters are naturally characterized by clustering. Agricultural production has explicit knowledge characteristics. The tightly netted rural communities provide the convenience for the spread and spillover of innovative knowledge. As a node in clusters, the government accelerates the maturing of agricultural clusters by promoting a regional innovation environment, constructing agricultural innovation systems, and integrating the industrial space.

Therefore, the formation of the agricultural cluster resulted from the joint effects of spin-off derived from the entrepreneurial spirit of the farmers, network-spillover of various agricultural innovations, and spatial integration of the agricultural landscape. From the perspective of knowledge flows, the innovation of original farmers (or pilot farmers) is a process of knowledge creation and recreation. The innovative spillover is a process of diffusing innovative knowledge, while the spin-off is a process of adopting innovative knowledge. Spin-offs are the effective results of innovative spillovers, while innovation spillovers are an important guarantee for the formation of spin-off networks and innovative networks. Pilot farmers increase the number of new actors (points) through spin-offs, and promote the formation of networks (lines) through innovative spillovers. The expansion of the scale of industry causes the government to integrate industrial spaces (planes). As illustrated in Figure 1, they interact to jointly promote the formation of agricultural clusters and the construction of local agricultural innovation systems.

Therefore, hypothesis 3 is proposed:

**Hypothesis 3.** *The formation of local agricultural innovation system marks the maturity of agricultural clusters.*

## 3. Methodology, Data Source, and Formation of the Case Cluster

### 3.1. Methodology

Case study research is a set of predefined procedures, steps, the study of a particular experience, and demonstration projects [34]. Agricultural cluster development process is divided into four phases using time series analysis technology. In order to verify the hypotheses of this article, the contribution of spin-off and innovation spillover to the formation of agricultural clusters in each stage was analyzed.

### *3.2. Data Source*

The data of this research came from five field surveys and follow-up interviews conducted by the author and students at the Vegetable Cluster of Shouguang, Shandong from November 2012, to December 2019. A total of 16 enterprises, 35 farmer households, and 12 managers from the Bureau of Agriculture, Science and Technology Bureau, and village governments were surveyed. The specific objects investigated include vegetable growers, farmer specialized cooperatives, seedling cultivation enterprises, agricultural materials distribution enterprises, vegetable trading markets, industry associations, Agriculture Bureau, Science and Technology Bureau, township/street office government, village committees, and other administrative staffs. Questions related to spin-off, innovation spillover, and industrial cluster development are designed in the questionnaire. For example, which farmers have influenced you to get involved in the vegetable industry? Which farmers were influenced by you to go into the vegetable industry? What are your sources of technology? In addition, the statistical data used came from *Shouguang Statistical Yearbook*, Shouguang Statistical Bulletin of National Economic and Social Development and the official website of the local government from 2005 to 2019.

### *3.3. Stages of Formation of Shouguang Vegetable Cluster*

Shandong Shouguang Vegetable Cluster is adjacent to Bohai Bay in the north central area of the Shandong Peninsula in China (Figure 2). Shouguang has a long history of vegetable cultivation. Jia Sixie, a native of Shouguang and agronomist of the Northern Wei Dynasty, penned scientific and detailed discussions on vegetable cultivation in his agricultural masterpiece Qimin Yaoshu. In the Ming and Qing Dynasties, the early-spring leek was a tribute to the imperial court. By the middle of the Qing Dynasty, scallions, Malian leeks, carrots, melons, celery, and tomatoes had become important agricultural products of Shouguang. In the long-term practice of production, the vegetable growers accumulated rich experience in vegetable cultivation. After 1949, although the vegetable cultivation in Shouguang continued in its historical tradition, under the influence of the planned economy, fewer varieties of vegetables were planted, including mainly scallions, cabbages, and radishes. After 1978, the land contracting responsibility system was implemented in rural areas and farmers had the right to decide which varieties to plant; the Shouguang Government decided to vigorously develop the vegetable industry using the traditional techniques of local vegetable cultivation. The dissemination of technical knowledge was promoted in the area by training seed-household models (such as the 'Five Kings', i.e., the King of Leeks, King of Celery, King of Tomatoes, King of Lotus Roots, and King of Watermelons) and organizing inspection and learning activities for farmers. In this way, many vegetable farmers and enterprises were derived locally, forming a division of labor and cooperation network between villages. Shouguang City is one of the areas in China where agricultural industrialization, standardization, commercialization, and internationalization started the earliest. In 2019, Shouguang City had a permanent population of 1,109,200 and arable land of 133,440 $hm^2$ (1 $hm^2$ = 10,000 $m^2$). The distribution characteristics of agricultural resources and the traditional planting habits of farmers in Shouguang have formed a hierarchical structure of 'vegetables in the south; grains in the center; salt and cotton in the north'.

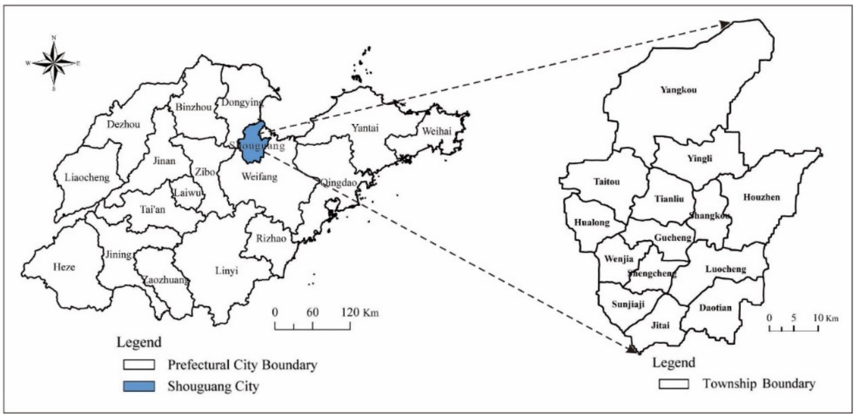


**Figure 2.** Location of the Shouguang Vegetable Cluster in Shandong Province.

According to the turning points of production technology in the development of the vegetable industry and the change of vegetable planting area and output value (Table 1, Figure 3), the development of the Shouguang Vegetable Cluster after 1978 could be divided into four stages. The first stage (1979–1988) was characterized by the planting agglomeration of big field vegetables, in the second stage (1989–1995), specialized villages (SV [1]) emerged with the development of facility agriculture, the third stage (1996–2012) witnessed the formation of agricultural cluster, and the fourth stage (2013–present) saw the formation of agricultural innovative systems and spatial integration in the cluster. It can be seen from Table 1 and Figure 3 that the sown area and output of vegetables increased from 5850 $hm^2$ and 126,000 t in 1980 to 413,500 $hm^2$ and 3,572,600 t in 2019, respectively, in Shouguang city. Over a dozen vegetable production bases have been built, including Wanmu (about 1672 acres) Pepper, Wanmu Leek and Wanmu Celery, formed vegetable industry agglomeration area. There are a total of 587 specialized villages and towns such as 'China's First Town of Leeks', 'China's First Town of Radishes', and 'China's First Town of Cantaloupes'; there are over 410 leading agricultural enterprises and 2569 farmers' specialized cooperatives, leading more than 80% of farmers to enter the vegetable production system in the form of 'company (cooperative) + base + farmer' and driving the development of such related industries as the local seed industry, pesticides, food processing, agricultural implement machinery, and logistics, thus forming a closely-connected industrial network and a famous vegetable cluster.

**Table 1.** Profile of the primary industry and vegetable outputs in Shouguang city.

| Year | GDP (100 Million Yuan RMB) | The Primary Industry (100 Million Yuan RMB) | Sown Area of Vegetables ($khm^2$) | Vegetable Outputs (Million kg) | Rural Per Capita Net Income (Yuan RMB) |
|---|---|---|---|---|---|
| 1986 | 8.8 | 4.3 | 12.6 | 600.0 | 515 |
| 1989 | 16.3 | 5.8 | 15.0 | 1200.0 | 809 |
| 1992 | 30.1 | 11.0 | 19.3 | 1250.0 | 1256 |
| 1995 | 53.0 | 17.2 | 32.5 | 2050.0 | 2826 |
| 1998 | 81.0 | 25.1 | 37.7 | 2384.0 | 3650 |
| 2001 | 116.1 | 28.6 | 57.0 | 3688.0 | 4256 |
| 2004 | 182.4 | 36.4 | 54.5 | 3660.0 | 5016 |
| 2007 | 316.1 | 46.9 | 50.6 | 3500.0 | 6619 |
| 2010 | 470.3 | 67.0 | 51.8 | 4154.1 | 9495 |
| 2013 | 701.2 | 86.4 | 52.1 | 4244.6 | 14,408 |
| 2016 | 856.8 | 97.3 | 44.8 | 3911.5 | 17,652 |
| 2019 | 768.1 | 101.2 | 41.4 | 3572.6 | 22,484 |

Data source: Shouguang Statistical Yearbook in1987–2020.

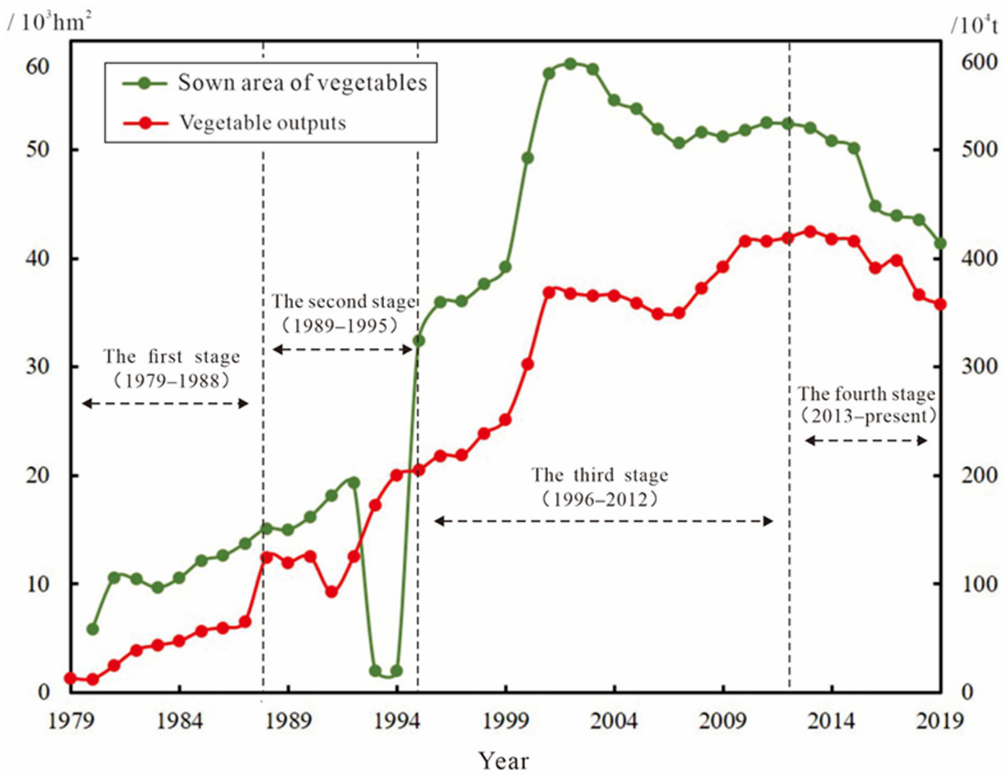


**Figure 3.** Formation and development stage division of vegetable industrial cluster in Shouguang city.

In the formation of the Shouguang Vegetable Cluster, the accumulation of technological experience, spillovers of innovative knowledge, and spin-offs of farmers (or companies) have played key roles. In particular, Shouguang City took the lead in successfully testing winter-warm greenhouse vegetable planting technology under the leadership of Wang Leyi of Sanyuan Village, starting a vegetable greenhouse revolution in China. It is a typical representative of facility agricultural clusters and green agricultural clusters. See Table 1 for the basic information of the primary industry and vegetable production values in Shouguang.

## 4. Results

### *4.1. Spin-Offs and Innovation Spillover in the Stage of Planting Agglomeration (1979–1988)*

In this period, although the household contract responsibility system of China's arable land greatly liberated the productivity of rural areas, most rural households were still self-sufficient in cultivating traditional food crops for food and clothing. At the end of the 1980s, advocated by the local government, some transformed from planting traditional food crops to vegetable cultivation. Such practices spilled their cultivating technology through such social relations channels as kinship, friendship, and relationships among farmers in the same area, resulting in similar plantations. In this way, they realized the clustering plantation of the vegetable industry. With the increase in the farmers' capabilities, the pilot or pioneer farmers achieved organizational innovation and transformed into enterprises. On the one hand, spin-offs (or derivation) through social relations channels could reduce the risks of information acquisition and the difficulty of technology acquisition. On the other, financial support could be obtained through more intimate social relations.

From a conversation about carrot cultivation in Peiling Village, Mr. Pei, who had always cultivated traditional crops, heard that the carrots in other places were better than the local carrots. This prompted him to introduce carrot seeds from Tai'an County in Liaoning Province and try to cultivate them. When he made a profit, his younger brother and cousin who live in the same village began to imitate him, and asked him to buy some seeds for them. After a year, the profits from carrot cultivation outstripped those of other food crops. Although this news spread quickly, many rural households still hesitated and chose to wait and see out of uneasiness. At this time, Mr. Pei introduced three or four more barrels of seeds and divided them among five family members and friends for free, in the hopes that they would encourage their relatives and neighbors to plant carrots. In this way, the third batch of carrot farmers was formed. After 2 years, more and more rural households started to plant carrots in large areas. With continuous planting practice and problem-solving by both friends and relatives, Mr. Pei accumulated experience and formed and spread new knowledge, making him the 'King of Carrots' and 'Planting Consultant' trusted by government personnel and rural people alike.

In this process, Mr. Pei and his relatives and friends achieved resource innovation, product innovation and technological innovation, as well as encouraging many new carrot farmers (Figure 4), which stimulated a huge market demand for carrot seeds. At this point, Mr. Pei abandoned his own carrot planting and innovatively established a seed supply and marketing company, thereby obtaining higher added value and achieving organizational innovation and enterprise transformation. He also created more carrot farming rural households through selling seeds and disseminating his own planting experience and technology free of charge within the village through the spread of kinship and geographic relations, helping local carrot farming to achieve industrial agglomeration in Peiling Village and its surroundings.

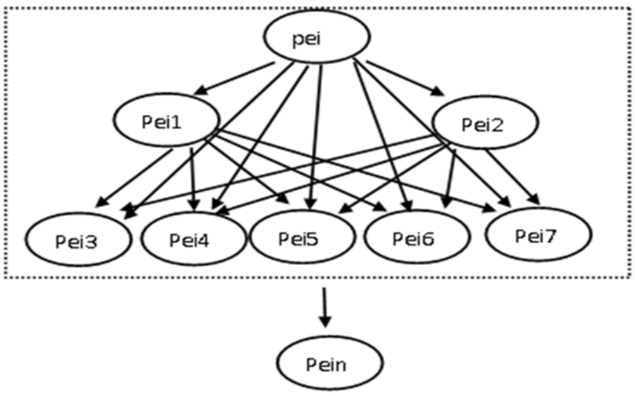


**Figure 4.** The spinoff process of carrot planting in Peiling village.

Similarly, the pilot farmers (seed-households, for instance the "five Kings" stated above) or enterprises had such spin-off and innovation overflow processes. By 1985, the number of vegetable varieties planted in the city had increased to more than 30. However, since such climate conditions as temperature had a huge impact on vegetable cultivation, vegetable market transactions were seasonal, and the development of the vegetable industry was limited. By 1988, big field vegetables were planted on about 3333 $hm^2$ of arable land in the city, and the scale and efficiency of clustering were not high.

*4.2. Spin-Offs and Innovation Spillover in the Formation of a Specialized Village (1989–1995)*

After experiencing the development period of industry agglomeration, specialized agricultural products had grown to a larger scale than before in the village area and were able to obtain higher profits than traditional agriculture, attracting more rural households in the area to derive the same kind of farmers or family farms. However, this process can easily make an area become locked into that single practice or cause different kinds of negative influence. If local farmers with an entrepreneurial spirit can break from their dependence on the original path, they can carry out agricultural innovation and create new paths. For example, when pilot farmers with an entrepreneurial spirit seize upon new technology that is suitable for the area, they will transform and utilize it in the local area, and update their own cultivated products and production methods. They would become leading farmers in opening up local windows of opportunity (innovative planting projects). As a result, a large number of rural households would be derived based on social relations channels, administration channels (i.e., the derived farmers have administrative subordination relations with the pilot farmers), technological channels (i.e., the derived farmers have mentoring relationship with the pilot farmers), or market channels (Figure 5). Innovative technologies would spill over through these derivative channels to the derived farmers.

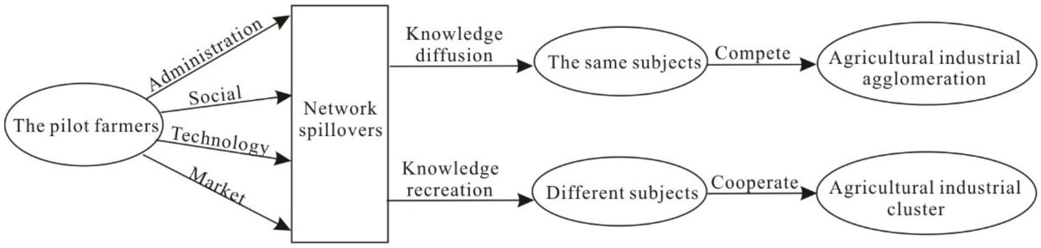


**Figure 5.** Spinoffs of different type of actors: related diversification.

In the formation of a specialized village, because agricultural production requires specialized but overt knowledge, and as the source of innovative knowledge, the innovation in the pilot farmers would first spread among same-level households within the village. This is because the greater the knowledge gap between the innovation subjects and the receptor, the more difficult the innovation spillover would be. However, if there exists geographical proximity, socio-cultural proximity, and institutional environment proximity, as well as cognitive proximity among the farmers in the same village, the innovation spillover would be more convenient. In this way, the leading farmers can influence more same-type planting households or family farms, and they would naturally gather in the same rural community. In this way, an industrial agglomeration that produces a specific product would be formed. The trust and identity of local culture strengthens the local buzz and industrial atmosphere, and more neighbors join in the new planting project, forming a specialized village.

Shouguang vegetable industry became famous in 1989 when Wang Leyi, secretary of Sanyuan Village, Sunjiji Town, Shouguang City, introduced greenhouse vegetables. In last month of 1988, Wang Leyi saw the local business opportunity of developing out-of-season vegetables from fresh cucumbers bought by his cousin, and hired Han Yongshan, a vegetable grower from Wafangdian City of Liaoning Province, to guide the village in building 17 winter-warm vegetable greenhouses, thereby setting off the first technological revolution in anti-season vegetable cultivation. Such technology of greenhouse construction rapidly spilled over to others within the village and even to those outside the village. In 1990, the government invested RMB 1 million in establishing a scientific and technological service hall integrating R&D promotion, commodity services and popular science training, as well as inviting experts to visit the local area to provide technological guidance, and supporting the promotion of greenhouse construction technology and the creation of large-scale greenhouses. From 1992 to 1993, guided by professional technical personnel, Wang Leyi successfully cultivated pollution-free vegetables and such new species as large cherries, grapes, and spirulina, sparking the second revolution of Shouguang's vegetables: the 'green revolution'. In 1996, Wang Leyi led the people to successfully test a new generation of high-standard greenhouses integrating irrigation, formwork retaining walls, electric roller blinds, steel frame support, and computer control. This technological innovation prompted Wang Leyi to establish a roller shutter factory and forge the vegetable trademark of 'Leyi'. Thus, Wang Leyi realized the transformation from a farmer to an entrepreneur. During this period, the villagers of other villages continue to imitate Wang Leyi and develop their own greenhouse vegetable planting. Thus, derived by administrative and technical channels, the number of vegetable greenhouses grew from the original 17 to 5000 in 1990, and to nearly 200,000 in 1995, and more than 4000 traditional farmers have been spun off and transformed into business organizations by absorbing and adopting innovative technologies from seed farmers, which verifies hypothesis 1 of this paper, that is, the local derivation of seed farmers is the main way of the transformation of traditional farmers into enterprises. The greenhouse vegetable planting areas increased to over 33,333 hm$^2$ in 1995, and the number of specialized villages increased from 23 in 1990 to 58 in 1995. During that period, Shouguang vigorously promoted the 'ten pollution-free vegetable production technologies' (the first in China); the area grew from 2000 $hm^2$ in 1991 to 18,667 $hm^2$ in 1995, with an annual output of over 1 billion kg; and more than 10,000 tons of pollution-free vegetables were processed and exported every year, selling well in Japan, South Korea, Hong Kong, Taiwan, Southeast Asia, and the United States. It follows that the seasonal open-air cultivation of vegetables subsequently developed into four-season greenhouse cultivation in Shouguang. The spatial pattern of scale production, regionalization distribution of vegetable planting formed rapidly in the surrounding area of Sunjiaji Town; meanwhile, influenced by farmer spin-offs and knowledge spillovers, a large number of specialized villages formed.

### *4.3. Spin-Offs and Innovation Spillover in the Formation Stage of the Agricultural Cluster (1996–2012)*

The formation process of an industrial cluster is also the process of the upgrading and integration of industries in specialized villages. The success of the pilot farmers and their followers will have an overflow and transmission effect on other farmers in the same village or surrounding villages, realizing the situation of 'one farmer helps a village and villages help a town' in the rural area.

Farmers at different levels developed in a local atmosphere of innovation. They gradually evolved into an enterprise or institution. In particular, driven by the entrepreneurial spirit, the pilot farmers often became leading enterprises in their localities.

Upon winning over other farmers by the pilot farmers as followers, if the farmers receiving new knowledge only adopted the innovative knowledge of the pilot farmers, they would practice the same production processes as those by the pilot farmers and would become competitors. However, they simply geographically gather together to share the external economy, and no form a cluster. If the farmers accepted the knowledge spillover and conducted other but relevant production processes, organization, technology, or market innovation on that basis, they would become complementary to the pilot farmers. Competition and cooperation between them, inspired the idea of constant innovation, and a cluster is formed. The complexity of the innovative knowledge is correlated to the competence of the farmers who adopted it. Innovation subjects of different types of planting, processing, services, or intermediary agency are derived, and the related diversification (Boschma and, Iammarino, 2009) of the cluster is formed (Figure 5).

As market scale promotes the division of labor (Smith, 1776), common product markets are formed by many farmers, enterprises, or institutions. More industrial chains link split-offs. The scope of the industry spreads to cover a greater rural area. It would form division and cooperation between specialized villages.

In the face of a common market and technical challenges, governments and scientific research institutions have participated in the joint solution and promotion of further innovation production and innovative network formation. The local innovation atmosphere helped every participant to do their best to innovate. They cooperated with each other to form an industrial network and a rural industrial cluster.

In this stage, by relying on green technology innovation, the Shouguang vegetable industry promoted the second revolution in vegetable technology, namely the 'green revolution', actively explored the cultivation techniques of green vegetables and organic vegetables, and realized transformation from a quantitative expansion to a quality improvement. The number of specialized villages reached 199 and clear industrial divisions arose among specialized villages. New-type production enterprises in such related fields as pesticides, seeds, fertilizers, and agricultural plastics were spun off and established. There were more than 400 vegetable and agricultural enterprises. Taking enterprises derived from the originals as an example, during the formation of an industrial cluster, the innovative behavior of individual entrepreneurs would inspire imitation in entrepreneurial communities. According to the recollections of Mr. Pei (Chairman of Hongshen Foods

Co., Ltd. in Shouguang City of Shandong Province, in 1997), while working in a public service unit, discovered that many villagers were growing carrots on a massive scale. Upon learning this, he resigned resolutely. After conducting research in other cities, he returned and established a small-scale carrot processing plant. With the increase in demand, in 2003, Mr. Pei set up a second branch for his business in the local village; in 2004, his operation secured rights to export processed carrots. In 2005, in order to lower import–export costs, he comprehensively exploited the international market and entered into trade relations with many countries. In this process, he continuously improved his machinery equipment. From 1997 to 2000, he helped his friends to start six carrot processing plants with the same level of education and knowledge as his own, forming the Peiling Vegetable Group, Longyuan Food Co., Ltd., Bilong Food Co., Ltd., Sifang Food Co., Ltd., Keshengda Vegetable Products Co., Ltd. and Fuhong Vegetable Food Co., Ltd. All six became leading enterprises developed under the mode of 'company + base + farmer'. In 2000, the success of the First Vegetable Expo in Shouguang City opened a window of external communication for the Shouguang Vegetable Cluster. A professional vegetable trading market was established and later expanded. The Vegetable Industry Association became increasingly standard. After 2000, even more carrot plants were built locally (Figure 6). In addition, scientific research institutes and intermediary service agencies joined and formed a close and open innovation cooperation network with the government and enterprises. At this point, the Shouguang Vegetable Cluster had formed. It can be seen that the pilot farmers (or enterprises) and their derived farmers (or enterprises) specialize in the same or different links of the industrial chain through knowledge dissemination, knowledge adoption and knowledge re-innovation, and jointly realize local industrial specialization and spatial agglomeration. The network-spillover and adoption of innovative knowledge promote the derivation of specialized farmers or enterprises and realize regional agricultural specialization and spatial agglomeration, which verifies hypothesis 2.

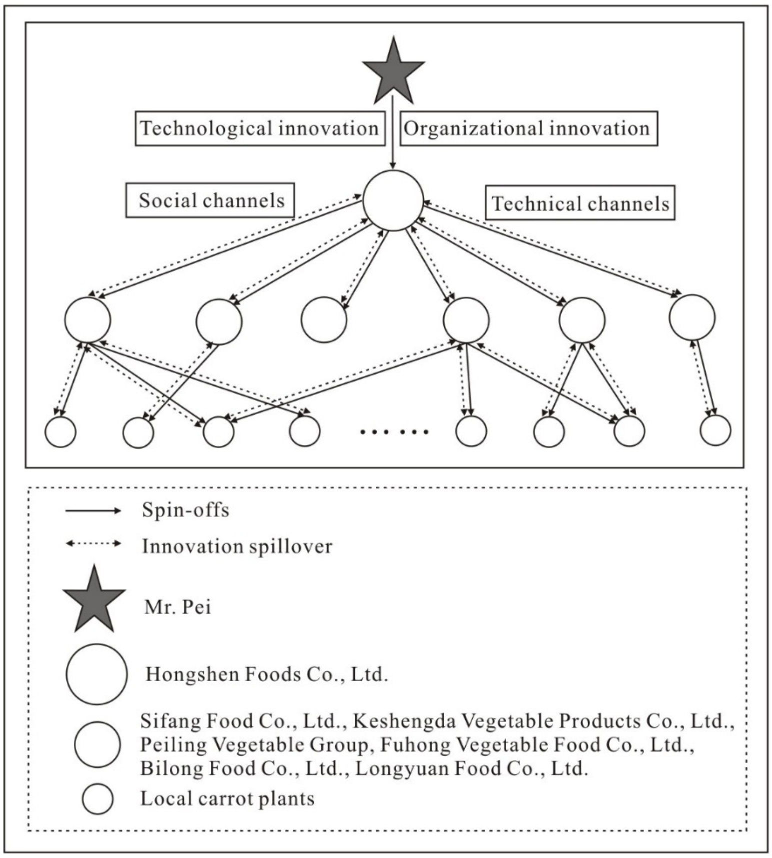


**Figure 6.** Spinoffs and innovation of carrot processing enterprise.

### *4.4. Innovation System Formation and Spatial Integration Stage (from 2013 to Present)*

Innovation is the driving force of sustainable development of industrial cluster. However, innovation is a systematic engineering, and innovation of one link must be coordinated with other links in order to play an effective role. Therefore, the formation of local agricultural innovation system marks the maturity of industrial clusters. The agricultural innovation system is an agricultural organization and system arrangement composed of diversified innovation subjects, networked innovation process, regional innovation environment, and integrated innovation objectives. The pilot farmers with entrepreneurial spirit in a region, triggered by a certain opportunity, acquire new knowledge or new technology for the development of a new industry, adopt the new knowledge, and successfully establish a start-up enterprise, and their new knowledge flows quickly in the neighboring rural communities and is imitated and adopted. A large number of similar and supporting enterprises or supporting service institutions have been derived [19], which have formed an innovation network together with government departments, university, research institutions and intermediary institutions. The Government has put forward a series of policy arrangements to promote the development of local industries and improve local innovation environment. It can be seen that spin-off and innovation spillover promote the formation of local agricultural innovation system and realize local product innovation, organizational innovation, institutional innovation, technological innovation, and spatial restructuring (Figure 7).

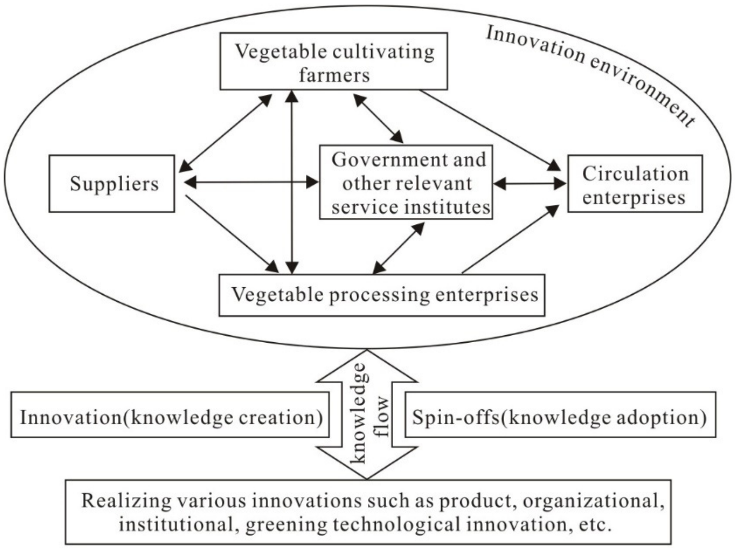


**Figure 7.** Formation of agricultural innovation system in the cluster area.

After a long period of practice, the technological innovation, product innovation and organizational innovation in the Shouguang Vegetable Cluster were increasing. For example, the vegetable ridge cultivation technique and cultivation techniques of large and small ridges were developed; the construction technology of winter-warm greenhouses was updated from the third generation in 1996 to the seventh generation; and highly practical and popular equipment was invented such as roller shutters, vegetable greenhouse films, greenhouse snow removers, smart storm lamps, plant growth lamps, and water-fertilizer integrated machines. Sci-tech, precise and creative agriculture projects were introduced, including automated computer management, comprehensive biogas utilization, Dutch intelligent mode, solar photovoltaic greenhouses, biological bacterial fertilization, and soilless cultivation, accelerating the development of the vegetable industry towards scientific, ecological and tourism agriculture.

To improve the situation of the decrease in soil fertility and increase in plant diseases and insect pests of perennial planting vegetables, Shouguang City implemented the 'Fertile Vegetable Soil Facilities Project', 'Root Knot Nematode Disease Prevention and Treatment Project', and 'Green Plant Protection project'. By the end of 2015, the whole city had created

552 'three-quality' (pollution-free, green, and organic) agricultural products (Table 2) and six national geographical indication products. A total of 80% of the vegetables of the park entered Beijing, Shanghai, Qingdao and more than 17 other large and medium-sized cities.

**Table 2.** Part enterprises and products certified "green food" certification in Shouguang vegetable industrial cluster in recent years.

| Certified Enterprises | Certified Products | Certified Time |
|---|---|---|
| Minlong Vegetable Professional Cooperative | Zucchini, Tomato, Towel gourd, Eggplant | 2017-10 |
| Hanxing Vegetable Professional Cooperative | Cherry tomato, Towel gourd | 2018-11 |
| Leyi Vegetable Technology Development Co., Ltd. | Long eggplant, Beans, Round eggplant, Pepper, Cherry tomato, Thorn free cucumber, Zucchini, Kidney bean, Balsam pear, Tomato, Cucumber, Round pepper | 2018-11 |
| Zhendu Vegetable Professional Cooperative | Colorful pepper | 2018-12 |
| Hengshuwujiang Agricultural Development Group Co. Ltd. | Pepper, Sweet pepper, Tomato, Cucumber, Eggplant | 2019-01 |
| Qingshuipo Agricultural Products Co. Ltd. | Pepper, Strawberry tomato, Tomato | 2019-07 |
| Lusheng Agricultural Science and Technology Development Co. Ltd. | Pumpkin, Tomato, Bell pepper, Watermelon, Thick-skinned melon | 2019-07 |
| Aijia Agricultural Development Co. Ltd. | Yam, Pumpkin, Turnip, Carrot, Kidney bean, Tomato, Colorful pepper, Towel gourd, Eggplant, Cucumber, Pepper | 2019-12 |
| Shouguang Vegetable Industry Group Co. Ltd. | Celery, Eggplant, Pumpkin, Radish, White gourd, Colorful pepper, Towel gourd, Round pepper, Tomato, Garlic moss, Green pepper, Balsam pear, Cucumber | 2019-12 |

Note: The above products are all vegetables (including melons and fruits).

In this stage, in responding to the changes in the market and technology, the government must constantly improve the local investment and innovation environment. For example, the government conducts spatial integration for the purpose of improving the efficiency of land utilization and industry innovation. After 2013, spatial integration was conducted in the Shouguang Vegetable Cluster on the principles of 'concentration, scale operation, and green and organic', thus accelerating the construction of a modern agricultural park covering 2333 $hm^2$ with Yangqing Road, Yangtian Road, and Changda Road as the 'Three Ecological Agricultural Corridors'. New technology and products were applied in standardized production, such as the integration of water and fertilizer and soilless culture, and were popularized vigorously in the park in order to accelerate the realization of standardized production. Through spatial integration, the number of specialized villages in Shouguang City was reduced to 109 in 2014, and the spatial pattern of specialized planting, large-scale production and regionalized development was formed at the township level.

Thus, it can be seen that cluster formation accelerates innovation spillover among institutions of government–industry–university–research–users [35], and the formation of the innovative network. These institutions coordinate with each other on the division of labor and jointly innovate. Finally, in a certain scope of the rural area, an agricultural innovation system focused on a specific agricultural product and featuring the integration of the primary, secondary, and third industries is formed, symbolizing the maturity of the agricultural cluster (Figure 7), and hypothesis 3 is tested.

## 5. Discussion

Marshall's original works were concern with an explanation of the competitive advantages of industrial clusters with knowledge spillover, the shared labor market, and the shared intermediate input products. In other words, he concluded that the external economy existed inside the industrial district, but what was the source of the external economy? Romer (1986) quantitatively studied the contribution of the innovation knowledge spillover, that is, external economy of knowledge to economic growth [36]. The Shouguang Vegetable

Cluster case qualitatively shows that one source of the spatial external economy, i.e., spatial increasing returns to scale, is that the innovative knowledge of the original subjects is adopted by other subjects locally through network spillover, deriving more similar subjects and sharing the knowledge brought by the original cost. If the new behavioral subjects were not derived and the external economy was hidden, the external economy would become clarified and enlarged by the newly derived subjects. This case study also shows that agricultural agglomeration can also bring spatial increasing returns to scale, rather than constant returns to scale.

The innovative ideas of the original subjects in traditional rural areas are spread by the genetic, academic, and geographic relationships, so entrepreneurs are rooted in the original social network and local culture via the derivative network. Because of the natural geographic, social, and cultural proximity that are similar to a knowledge base, successful innovative knowledge has its fastest spillover and adoption locally, thereby promoting the increase in agricultural agglomeration in the spatial returns to scale. In particular, the chain of agricultural industries has become longer, the market division space is now larger, and the technical threshold is now relatively lower than before. Under the circumstances of a sufficiently large produce market capacity, this division is continuously refined, the industrial chain links continuously increase, contact between subjects becomes closer, network nodes become further diversified, cooperation, and innovation emerge continuously, and the agricultural industrial cluster becomes mature.

The formation of an agricultural industrial cluster is an effective method for the promotion of traditional agricultural transformation and rural revitalization. For the cultivation of agricultural clusters in developing countries, especially Shandong Province, China, the following suggestions are put forward according to the results of this article and the knowledge and experience from the functioning of agricultural clusters from other provinces of China and abroad: (1) The entrepreneurial spirit of farmers should be encouraged in order to secure innovative opportunities suitable for the local conditions; (2) the quantification, simplification, circulation, and mobility of knowledge should be improved; (3) the quality and knowledge adoption capacity of farmers should be enhanced through professional training; (4) various types of entrepreneurship should be encouraged so as to promote the farmers' enterprise evolution; (5) different channels of innovation spillover shall be dredged in order to establish the innovative network; (6) the innovation environment of the area shall be constructed to allow the establishment of the local agricultural innovation system. The selection of different types of agricultural cluster cases for the quantitative analysis of the microcosmic mechanisms of agricultural clusters should be the orientation for subsequent research.

## 6. Conclusions

Based on a case study of the formation process and mechanism of Shouguang vegetable industrial cluster in Shandong Province, three hypotheses proposed in this article are verified. It can be seen that:

(1) The local derivation of seed farmers is the main path in the transformation of traditional farmers into enterprises. Derivation and innovation spillover during the formation of an agricultural cluster would produce the scale effect, economic effect, social effect, and spatial effect. Matching knowledge of different complexity with adoption subjects of different levels of ability is the key to the occurrence of beginning and the spread of innovation spillover. Levels of such spread were often in-line with social stratification form the relevant diversity of behavioral subjects.

(2) The network-spillover and adoption of innovative knowledge promote the derivation of specialized farmers or enterprises and realize regional agricultural specialization and spatial agglomeration. Path dependence resulting from entrepreneurial spirit delivery and related technology inheritance will trigger the self-reinforcing mechanisms of industrial cluster formation, thus leading to the reconstruction of the spatial structure of rural industry.

(3) The formation of the agricultural cluster was the result of joint effects of spin-off derived from the entrepreneurial spirit of the farmers, network-spillover of different agricultural innovations, and spatial integration of the agricultural landscape. This can be illustrated as pilot farmers with entrepreneurial spirits introduced or pursued innovative knowledge (knowledge production or introduction) → innovation spillover (knowledge diffusion) → derivation (adopted knowledge) → new subject entrepreneurship → industrial agglomeration → secondary innovation (complementary knowledge, reproduction and recreation) → derivation again (knowledge adopted again) → agricultural cluster formation → acceleration of agricultural innovation system perfection and industrial spatial integration. The formation of local agricultural innovation system marks the maturity of agricultural clusters.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Notes

[1] An SV is a rural settlement in which households engage in production or some interrelated commodities or service activities. Such activities constitute the main body of the social and economic values of this village (Li et al., 2010). For each SV, at least 50 percent of the entire village's output was produced by one or just a few particular leading industries, offering unique, marketable products by using certain scientific and technological processes; revenue from the leading industries or products dominated the village's total income and was the main source of household incomes; a majority of farmers were employed by the leading industries or participated in the production of the specialized products and corresponding business activities [9].

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# Is Land Expropriation to Keep Agricultural Use an Effective Strategy for the Conservation of an Urban Agricultural Heritage System? Evidence from China

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**Abstract:** Urbanization is one of the major threats to the dynamic inheritance of the agricultural heritage system (AHS). The ability to achieve sustainable development in intra-urban areas is an essential proposition related to the innovation of AHS conservation principles. The Haizhu high bed-low ditch agroecosystem (HHBLDA), a China-Nationally Important Agricultural Heritage System site located at the center of Guangzhou City, is taken as an example in this study. The effect of implementing the Land Acquisition to Keep Agricultural Use (LAKAU) on intra-urban AHS conservation is assessed through literature collection and review, field survey, and in-depth interviews. The results show that the LAKAU was implemented because of a three-decades-long struggle between ecological conservation and urban sprawl. Because of the important functions of ecosystem services, the AHS can coexist with urban land use in the course of rapid urbanization. The LAKAU mode can ensure that the nature of farmland remains unchanged, which is an effective strategy for the conservation of an urban AHS. The resulting problems, such as high operating costs, insufficient agricultural outputs, and insufficient local farmers in the AHS site because of off-farm opportunities, should be addressed by establishing an effective self-sustaining mechanism. Realizing the compatibility of management concepts between the AHS and nature reserves, adapting to the changing role of farmers, and strengthening the acceptance of the AHS by urban managers should attract the attention of decision-makers.

**Keywords:** urban agricultural heritage system; high bed-low ditch agroecosystem; farmland; land acquisition; wetland; nature reserve

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## 1. Introduction

Since 2002, the Globally Important Agricultural Heritage Systems (GIAHS) program of the Food and Agriculture Organization (FAO) of the United Nations and nationally Important Agricultural Heritage Systems (IAHS) in China, South Korea, Japan, Italy, Brazil, and other countries have been developed to safeguard traditional agricultural systems of global or national importance [1,2]. Given that the AHS cannot be separated from the participation of farmers, the main distinction between it and the World Cultural and Natural Heritage (World Heritage Convention) is its dynamic situation [3]. The AHS is a way of living in harmony with nature and emphasizes the comprehensive conservation of agricultural biodiversity, traditional agricultural knowledge, technology, and landscape.

Accordingly, the closed-off management mode, which is the common method of conserving historical sites and natural resources, is undesirable for the AHS. Previous studies have confirmed that agro-products, sustainable tourism, industrial integration, ecomuseums, and ecological compensation are ideal approaches for the dynamic conservation of the AHS [4–9]. The AHS and its conservation research conform to the logical framework of "driving force–pressure–state–impact–response" in which every segment is a scientific problem worth studying. However, the existing studies on some segments have only begun, and neither the research methods nor the theoretical depth are sufficient to date. For a long time in the future, sustainable mechanism, dynamic conservation, and adaptive management will still be the core research contents of AHS conservation [8].

### *1.1. Dilemmas Faced by the Urban IAHS*

Urbanization is one of the major threats to the dynamic inheritance of the AHS because city development may result in the loss of farmland, changes in farmers' careers, changes in agricultural landscape patterns, and increase environmental pollution, which have serious effects on AHS sustainability and expression of its value [10–12]. The threat of urbanization to AHS sustainability is a global problem. The chinampas system in Mexico, which is an urban farming mode, was designated as a GIAHS site in 2018 [13]. Urban expansion and pollution have resulted in displacement of farmland for urban uses and substantial deterioration of the environment of the chinampas system in recent decades. To address decreasing farmland and yield loss, farmers have adapted through developing new production strategies, which have contributed to the disappearance of the traditional system and changes in chinampa's structure [14,15]. Although the "chinampa-refuge model" (CRM) conducted by research groups has strengthened traditional agroecological practices and ecological restoration, some of the main challenges clearly out of reach of farmers' actions and the CRM need be addressed by urgent and participatory government action [16]. China's urbanization process has been in a rapid development stage since the 1980s. Land resources in peri-urban and suburban areas are increasingly scarce. This is an extremely challenging scenario for AHS conservation. The Xuanhua Grape Garden and the Jingxi Rice Cultivation System (Jingxi Rice Reserve located in Haidian District, Beijing) are two AHS sites located in intra-urban areas. The traditional vineyard area in Xuanhua City has been reduced to less than a quarter of its peak area due to rapid urbanization. Even after being designated as a GIAHS site in 2013, the increased government support and public awareness have not alleviated the conflict between conservation and development. Many vineyards have been expropriated to construct high-speed railways and buildings, which is supported by most farmers who are more inclined to obtain land acquisition compensation than plant grapes [17–20]. Jingxi rice refers to rice planted around the imperial gardens of the Qing Dynasty in the western suburb of Beijing City, with a planting area of 67 km$^2$ in the 1970s. Since the 1990s, the planting area in Haidian District has rapidly shrunk for regional gardening and greening and is now less than 0.67 km$^2$, of which only 0.53 km$^2$ is assigned within a permanent basic farmland zone (a type of farmland area that cannot be used for non-agricultural purposes under any circumstances) delineated by the government [21,22].

Based on the above-mentioned cases, the government, as a regulatory organ of market failure, can play a decisive role in AHS conservation under the demands of accountability and political interest incentives [23]. Only when the local government strongly intervenes in intra-urban AHS conservation can irreversible, huge heritage losses be prevented. AHS conservation must be incorporated into the urban planning strategy [24]. Notably, the issues confronting the urban AHS in different areas are not identical. A case study of GIAHS in Japan has shown that sustainable development may be easier to attain if AHS sites in urban areas do not involve farmland issues. In Ayu of the Nagara River System, people reap the river's bounty and, in turn, strive to preserve it for future generations. Despite flowing through urban and residential areas, the pristine Nagara River that runs through the site's center boasts an abundance of clear, high-quality water. Although famers account for only 1% of the total population, the total revenue from Ayu (*Plecoglossus altivelis*) across the entire prefecture is 18.3 million USD per year [25]. At present, the majority of IAHS sites worldwide are in rural areas. Although China is one of the countries with great achievements in AHS conservation in the world, only three of the 138 IAHS sites are within urban areas. Accordingly, the attention of researchers has not yet been drawn to the conservation of the intra-urban AHS. Previous studies are insufficient to guide the practices of urban AHS conservation, and further research is needed [26].

### *1.2. Research Objectives*

Only 28% of the European population lives in the countryside, and a projected 60% of the world's population is expected to reside in urban areas by 2030 [27,28]. The AHS is gaining increasing importance as a repository of lessons to be learned for more sustainable agriculture in the future [29]. Although only a few cases are discussed at present, scientific solutions to future common problems should be explored in the context of rapid urbanization to study how to scientifically and rationally conserve the intra-urban AHS. In this study, the authors developed an analytical framework to assess the sustainability of the urban AHS. The Haizhu high bed-low ditch agroecosystem (HHBLDA) is in the center of Guangzhou City, Guangdong Province, China. The government adopted the Land Acquisition to Keep Agricultural Use (LAKAU) in 2012 to permanently conserve the majority of farmlands in this region. An article in *Farmers Daily*, the state media of the Ministry of Agriculture and Rural Affairs of China, evaluated this method as a valuable mode for peri-urban AHS conservation [30]. Whether the AHS can achieve sustainable development in intra-urban areas is an important proposition related to the innovation of AHS conservation concepts. This study took the HHBLDA as a case study to achieve the following key goals: (1) to explore the dilemmas faced by AHS sites in the process of rapid urbanization; (2) to summarize the government's attention shift and policy change under the strategy of ecological priority; (3) to evaluate the effectiveness of the LAKAU mode for conserving the urban AHS; (4) to explore ways to deal with problems due to LAKAU implementation; and (5) to discuss the universality of the LAKAU mode in other urban AHS sites.

The marginal contributions of this study include the following three aspects. First, in terms of research direction, this study focuses on a rare case of the coexistence of a traditional agricultural system and urban land use in a metropolitan area, where the food and livelihood of farmers relied on land in the past, which is regarded as the first remarkable characteristics of GIAHS by the FAO, but has switched to other opportunities at present. It provides both a new theoretical theme and new practical field for future urban AHS research. Second, in terms of research method, this research provides a framework for assessing both natural and societal sustainability through multidisciplinary methods. Third, in terms of research results, it provides possible ways to achieve the survival and sustainable development of AHS sites in intra- or peri-urban areas by combining vertical (from government to farmer) and horizontal (food chain stakeholders) methods.

## 2. Study Area and Methodology

### *2.1. Study Area*

The high bed-low ditch agroecosystem, also called the raised and sunken bed system, is widely distributed in southern China, northern and eastern India, Indonesia, Bangladesh, Thailand's Chao Phraya Delta, and other lowland areas with dense water networks in the tropics and subtropics [31–33]. The scale of the high bed-low ditch agroecosystem reached its historical peak in the early 1990s in the Pearl River Delta in southern China, with an area of more than 5000 hm$^2$, accounting for approximately 7.5% of the farmland area of the Pearl River Delta [34,35].

The HHBLDA was successfully selected into the sixth list of the China-NIAHS in November 2021. Haizhu District, located at 23°3′–23°16′ N, 113°14′–113°23′ E, is the only island district among the 11 municipal districts of Guangzhou City. The entire Haizhu district, with a total area of 90.40 km$^2$, is situated at Haizhu, Guanzhou, and Yajisha islands and they are all surrounded by the Pearl River. Haizhu means "sea pearl" in Chinese. According to statistics, the permanent population of Haizhu District was 1.82 million and the urbanization rate was 100% in 2020. The spatial scope of the AHS site includes Areas Nos. 1 to 8 of the Haizhu Wetland (HW), which are managed by the Wetland Conservation and Management Office (WCMO), and four villages, including Luntou, Tuhua, Xiaozhou, and Longtan. The HHBLDA covers a total area of approximately 1100 $hm^2$, of which 30% is delineated as a permanent basic farmland zone (Figure 1). As the ecological conservation or ecological restoration areas, Areas Nos. 1-5 are not open to the public, but the orchards are managed by local farmers employed by the WCMO. The population within the HHBLDA site was 137,000 in 2020, among whom 109,000 were recent migrants.

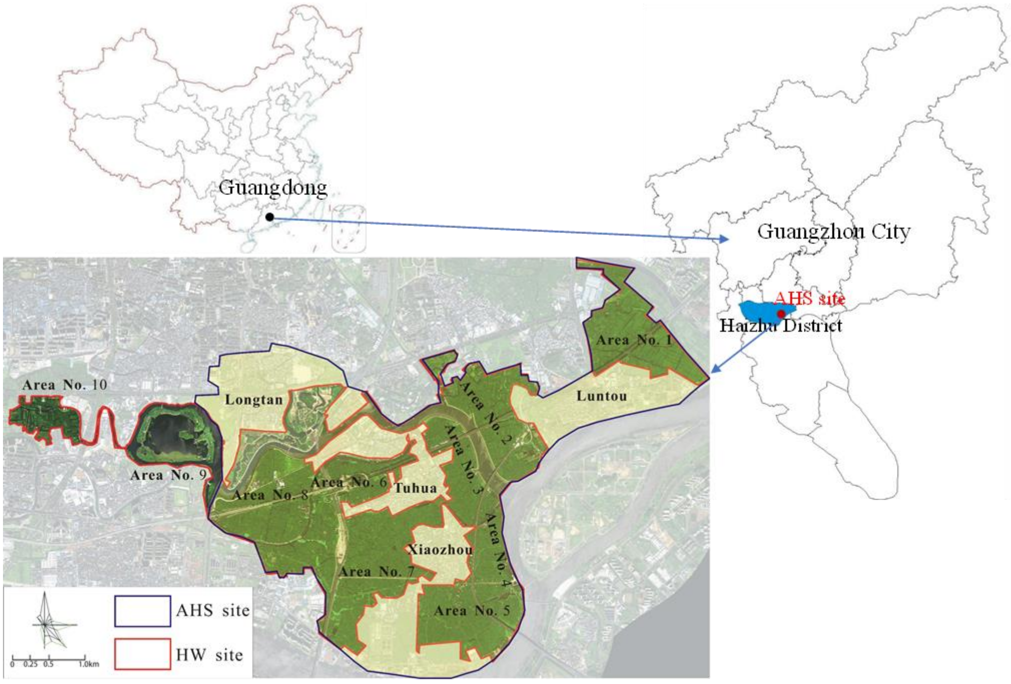



**Figure 1.** Location of the study area.

The HHBLDA has been used for more than 2000 years by local Haizhu people. Because Haizhu District is close to the old city of Guangzhou, in order to develop commercial agricultures dominated by dryland crop cultivation, ancestors fully utilized the local natural conditions of marine subtropical monsoon climate and dense water network to create and develop a high bed-low ditch agroecosystem with diverse forms of water and soil resource utilization. The typical traditional agricultural landscapes of HHBLDA include dike, artificial canal, water gate, high bed and low ditch, crop planting, livestock and poultry breeding, and aquiculture (Figure 2). More than a hundred years ago, Franklin H. King, an American agronomist, and George W. Groff, an American horticulturist, recorded the high bed-low ditch system of Haizhu District in pictures and text [36,37]. At present, the HHBLDA is the only IAHS site in China, which is located within a megalopolis as a whole.

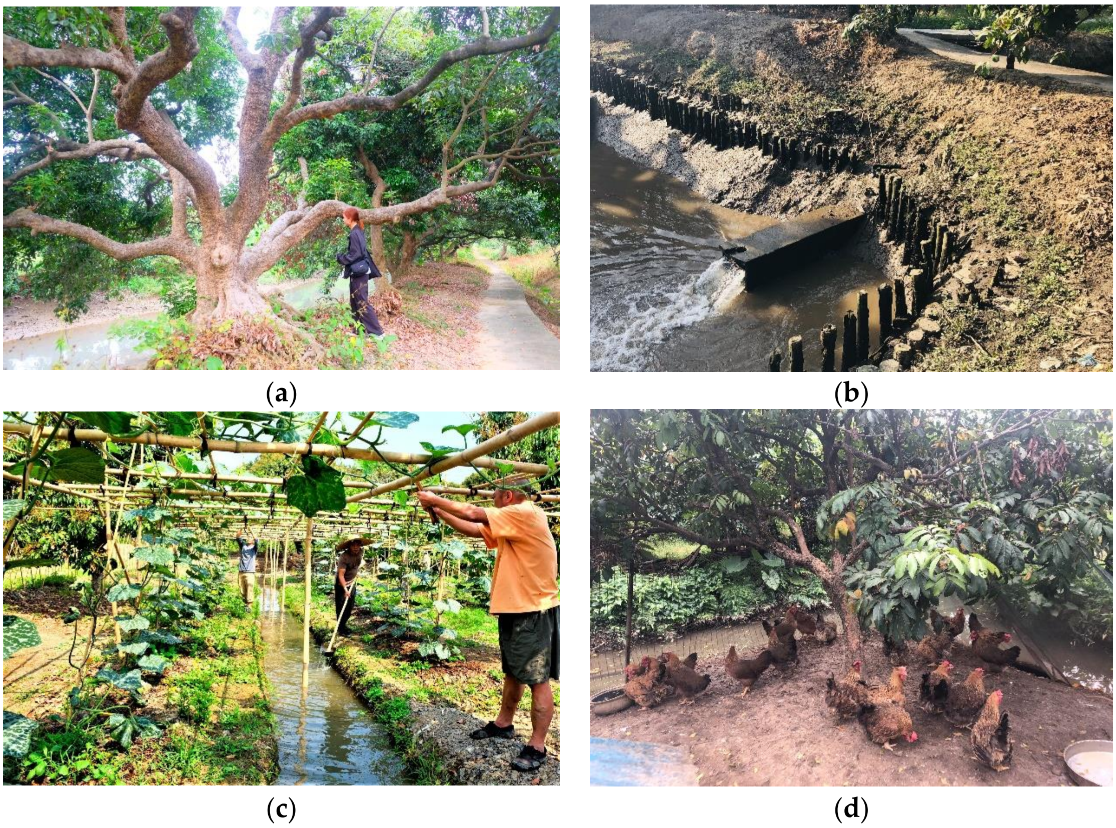


**Figure 2.** Photos of the HHBLDA: (**a**) Dike, ancient litchi trees, and artificial canal; (**b**) Wooden water gate; (**c**) High bed and low ditch; (**d**) Raising chickens under the fruit tree.

*2.2. Study Methods and Analytical Framework*

The authors were entrusted by the Haizhu District Government to undertake a comprehensive investigation and research on the AHS site in HW and nearby villages from September 2020 to October 2021 and completed the proposal and action plan for China-NIAHS. During this period, we travelled to the HHBLDA site to conduct this research and stayed for 42 days. Some of us repeatedly observed the traditional agricultural landscape, agricultural production, ancient trees, folk customs, historical buildings, and wetland park in the HHBLDA site. Meanwhile, various literature and materials related to the Haizhu District were collected and systematically collated, and semi-structured interviews were conducted with 28 villagers, eight government staffs, and three experts (Table 1). These interviews lasted between 30 min to 2 h. All interviews were recorded with respondents' permission and later transcribed. Through the above work, we had a comprehensive understanding of the conservation status of the HHBLDA and the management status of HW.

The effectiveness of a conservation strategy is decided by how well the strategy contributes to the AHS sustainability. This work established an analytical framework for assessing intra-urban AHS sustainability (Figure 3). The AHS has lasted for thousands of years because of its internal, stable, sustainable mechanism. Ecological and societal sustainability are the internal bases of the AHS, which ensure that the AHS has a sustainable agricultural production function [38,39]. Ecological sustainability includes natural and agricultural eco-environments. The premise for the existence of an urban agricultural system is its good maintenance of natural elements, such as water, soil, air, and biodiversity. Despite some vulnerabilities that occurred mainly due to socio-economic reasons, the intra-urban AHS still provides different ecosystem services to local communities, including food and byproduct supplies, soil erosion protection, prevention of hydrogeological risk and deforestation, agro-biodiversity and natural biodiversity conservation, cultural landscape preservation, benefits for agro-tourism, and traditional knowledge inheritance [40]. Previous studies have shown that the guidelines for AHS conservation mainly involve societal sustainability, including dynamic conservation, adaptive management, and economic support [3,6]. A balance between conservation, adaptation, and socio-economic development is emphasized for the urban AHS's dynamic conservation. The dynamic conservation and adaptive management of the AHS are inseparable. Different dynamic conservation approaches and dynamic management measures should be considered according to the local conditions. Generating income and adding economic value to goods and services of the AHS site in a sustainable fashion is one of the main objectives of AHS sustainable development [3,41]. The growing tourism interest in the AHS is witness to the importance of traditional livelihoods as heritage products [42,43]. Actions of ecological compensation and agri-food labeling system also prove that the use of economic support means can help to achieve the goal of AHS conservation [44–46].

**Table 1.** Basic information of interview samples.

| Category | No. | Main Interview Contents | Remarks |
|---|---|---|---|
| Villagers | A 1–28 | Traditional agricultural production knowledge<br>Livelihood transition after farmland loss<br>Evaluation on farmland status | Twenty-four villagers are regular or temporary farmers employed by WCMO |
| Officials of WCMO | B 1–4 | Implementation process of LAKAU<br>Farmland management system | One official is the leader, the remaining staff are responsible for wetland maintenance |
| Officials of the Bureau of Agriculture and Rural Affairs | C 1–4 | AHS conservation actions already completed and planned | One official is the leader |
| AHS experts | D 1–3 | Evaluation of AHS conservation status | All experts are members of China's Advisory Committee on IAHS |

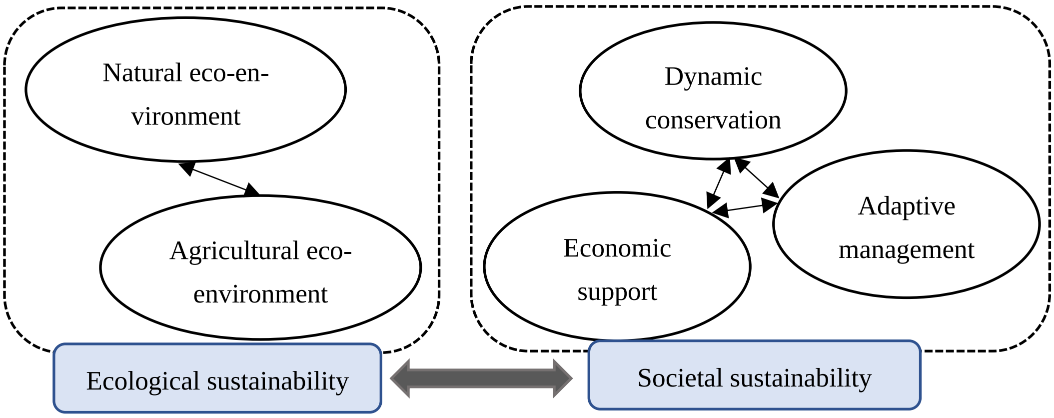



**Figure 3.** Framework for assessing intra-urban AHS sustainability.

## 3. Historical Background of the LAKAU Mode: Government's Attention Shift and Policy Change

### *3.1. Peri-Urban Period*

In ancient times, Henan Island (old name of Haizhu District) was separated from the Guangzhou urban area by the Pearl River. Henan Island has a history of peri-urban agriculture dating back more than 1000 years, making it one of the important fruit-, vegetable-, flower-, and tea-producing areas in Guangzhou. By the 1980s, the fruit cultivation was dominated at the AHS site. The area of farmland continued to diminish due to urban construction and industrial pollution. During the same period, the Guangzhou Municipal Government changed the functional orientation of the AHS site from an agricultural zone to an ecological zone, regarding it as the "southern lung" of Guangzhou for its important role on $CO_2$ fixation, $O_2$ release, and air flow. In 1991, the *Haizhu District Zoning Plan (1990–2010)*, adopted by Guangzhou Municipal Government, stipulated that Haizhu District is a vegetable garden and orchard reserve and the farmlands in this area must not be arbitrarily encroached upon or used for other purposes [47]. However, farmers were willing to build houses rather than continue to plant traditional fruit trees in order to obtain more economic benefits. During the rapid urbanization and industrialization in the surrounding areas, the relative economic benefits of fruit trees continued to decline and villagers' livelihood no longer depended on them. "In Tuhua Village, the annual longan fruit yield was 800,000 kg in the 1980s, but by the middle and late 1990s, it was only 10,000 kg, with an average of only 3–4 kg per household" (B2). The villagers transformed part of the orchard into factory buildings, shops for rent or for self-operation, or developed animal husbandry to compensate for the economic losses caused by the deterioration of fruit growing conditions due to environment pollution. This resulted in the gradual reduction of the orchard area and increased soil pollution [48]. A 72-year-old man in Luntou (A27) noted that: "At that time, many farmers destroyed fruit trees and built illegal buildings to make a living. Village collective not only acquiesced, but even provided temporary loans to farmers who were short of money to build house". The *Guangzhou Urban Comprehensive Plan* proposed the establishment of the Haizhu District Orchard Reserve in 1996 to prevent the "southern lung" from becoming a "southern waste land" [47]. According to the *General Plan for the Orchard Reserve* completed in 1998, the household contract responsibility system with small scale farmers, an effective agricultural management mode used elsewhere at that time, had limitations for orchard conservation in this region. The correct way to preserve orchards was by changing the decentralized contract mode of fruit tree management to an intensive and large-scale operation [49].

### *3.2. Intra-Urban Period*

With the rapid eastward and southward expansion of the Guangzhou urban area, especially affected by the construction of Xiaoguwei Island University Town, the AHS site has been surrounded in the center of the city since 2004. According to statistics, the area of the orchard was 2700 $hm^2$ in 1986, 1300 $hm^2$ in 1998, and only 1100 $hm^2$ in 2005. From 1990 to 2005, the land for urban development approved by the government within the orchard reserve reached 51.816 $hm^2$, and another 134 $hm^2$ of land was illegally used for construction. Tourism was considered by the government to balance development and conservation. Some orchards in the reserve, leased by the government at 15,000 RMB per hectare, were built into the Yingzhou Ecological Park, Longtan Fruit Park, and Shangchong Fruit Park between 1998 and 2010. However, their role in improving the incomes of local villagers remained very limited. The problems of low economic benefits of fruit trees and reductions in orchard area have not been effectively solved [50].

The Guangzhou Tower, Haixinsha Park, Flower City Square, and other major municipal projects were completed one after another, then forming the Central Axis of Guangzhou New City before the opening of 2010 Guangzhou Asian Games. The AHS site is located at the southern end of the central axis, with a straight-line distance of only 3 km from Guangzhou Tower. With the substantial growth of land value, the contradiction between the "lung" (environment) of the city and the "stomach" (livelihood) of the villagers further intensified. Guangdong Provincial Government accelerated the protection and utilization of the orchard reserve in early 2011 to thoroughly solve the problem and improve the image of the city. On 16 March 2012, the Ministry of Land and Resources approved Guangzhou to use the LAKAU mode for overall farmland acquisition. This was the first case in China to use the LAKAU mode. Subsequently, land acquisition was conducted smoothly and completed on 23 April 2012. A total of 790 $hm^2$ of farmland was acquired, involving eight villages, 11,382 households, and 34,146 people. This land acquisition was the largest project in the history of Haizhu District. Government departments effectively protected the interests of village residents through measures such as a high compensation standard, which reached 4.9 million RMB per hectare, implementation of social security for all villagers, deployment of land reserved for economic development according to 10% of the land acquisition area, and a priority to provide jobs for villagers [51]. In summary, the implementation of the LAKAU was a result of a three-decades-long struggle between ecological conservation and urban sprawl, which resolved the contradiction between the "lung" of the city and the "stomach" of the villagers to a certain extent.

## 4. Evaluation of the LAKAU Mode: An AHS Perspective

### *4.1. Ecological Sustainability*

#### 4.1.1. Natural Eco-environment

In 2012, the Haizhu District declared the core area of the orchard reserve as the pilot construction unit of the National Wetland Park. After a decade of construction, HW has become an important ecological space accessible to Guangzhou citizens and a regulator and stabilizer for the urban ecological environment. Continuous monitoring data in recent years show that the ecosystem of HW has been fully restored. The related monitoring indicators, such as water quality and air quality, have shown a stable and positive trend each year, and biodiversity has steadily improved. At present, the main water quality conditions in the wetland range from Class IV to Class III water standards, and the water quality in certain areas can reach Class I and II water standards. Villagers understand very well the improvement of the eco-environment. A resident of Xiaozhou (A22) noted that: "The most serious water pollution was during the period of 1990s. The water was smelly and dirty, and even those native fruit trees would easily die. Now the recovery is quite ideal. There are more fish, shrimp, and crabs now". According to statistics in March 2022, the number of bird species in HW has increased from 72 to 183, that of vascular plants has raised from 294 to 835, the number of insect species has promoted from 66 to 536, and the number of fish species has grown from 36 to 60 since the establishment of the automatic monitoring station in 2015.

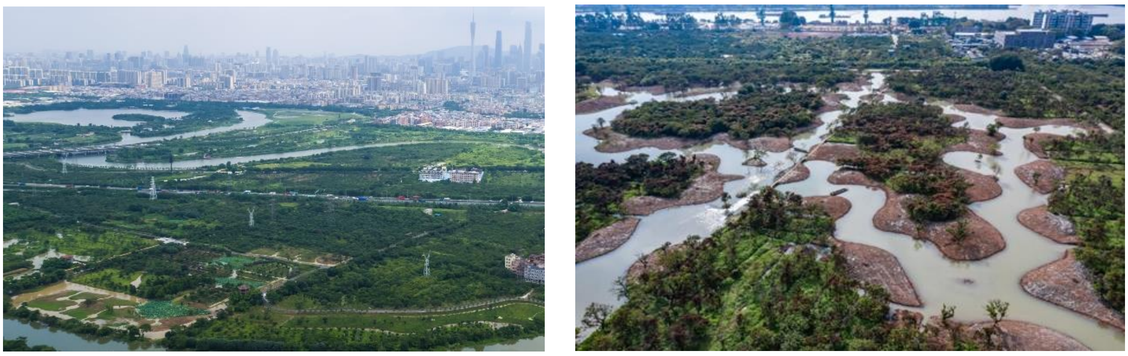
At present, HW is the only national key construction wetland in Guangdong Province. It occupies a pivotal position in the tourism industry of Haizhu District. It is the "ecotourism core" and "eco-cultural tourism zone" in the spatial layout of regional tourism development. With convenient transportation and abundant resources, the WCMO has established a nature school and an agricultural education base to conduct various forms of natural education, farming culture popularization, and popular science activities. In recent years, the WCMO has won some national level awards, such as the National Model Prize for Residential Environment, the National Wetland Protection Demonstration Award, the National Forest and Grass Science Popularization Base, the National Primary and Secondary School Environmental Education Social Practice Base, and the National Nature Education School Base.

#### 4.1.2. Agricultural Eco-environment

Identifying and listing the core AHS elements are essential prerequisites for IAHS scientific conservation, which has been valued by the Ministry of Agriculture and Rural Affairs of China since 2020 [52]. The core elements of the HHBLDA mainly include the land use mode of the high bed-low ditch, the landscape of the dike paddy field biodiversity, traditional agricultural species, Pearl River culture, and traditional waterside villages. Government departments at all levels have continuously attached importance to and strictly protected the ecological function of the AHS site in the past 30 years. Specifically, after the construction of the wetland in 2012, most farmlands in this region have been permanently protected. This allows the traditional agricultural landscapes in HW to avoid the influence of urban sprawl and the area is "refrigerated". This initiative has realized the good retention of preserving the traditional landscapes of the high bed-low ditch system and dike paddy field. In particular, the dikes, old trees, water gates, foot bridges, and other AHS elements are rare in the Pearl River Delta region today.

In addition to the farmers in the AHS site, the WCMO has played an important role in promoting local farming culture through multiple channels by setting up the Haizhu

Wetland Natural School and Agricultural Education Base and organizing tourism festivals, such as the Dragon Boat Festival and the Shixia (name of a longan cultivar) Longan Festival. The flat bed and straight ditch are typical landscape features of high bed-low ditch systems. However, the high bed-low ditch landscape and fruit trees in the open area of HW have been lost to varying degrees and replaced by park landscapes dominated by artificial lakes, ornamental trees, ornamental flower fields, and hardened roads due to the creation and implementation of a series of tourism landscapes and infrastructure projects (Figure 4a). In 2018, the WCMO commissioned a team of experts to select approximately 20 hm$^2$ of orchard in Area No. 5 to implement an ecological restoration project. This project aimed to optimize ecosystem services by widening the furrow and making it meander. Borders were piled high, the fruit forest was thinned, and tall trees were sparsely planted to form a vegetation layer of tree, shrub, and grass (Figure 4b) [53]. Transforming the high bed-low ditch landscape may have been beneficial from the perspective of biodiversity and landscape aesthetics, but this task was destructive from the perspective of AHS conservation because the structure and function of the traditional high bed-low ditch system were deformed or lost. For example, boats were often needed for transportation from one bed surface to another bed because of the widened ditches, which made it difficult to manage fruit trees daily. Some bed surfaces were uneven and stacked, which easily caused water and soil erosion. The flourishing of other plants inevitably resulted in the inhibition of fruit trees. Although the Bureau of Agriculture and Rural Affairs of the Haizhu District hoped that the fruit trees could be well managed, they couldn't do much because the farmlands were assigned to be managed by the WCMO. A staff member from this bureau (C2) noted that: "Although we can apply for some government funds, WCMO does not always have enough enthusiasm to cooperate with us. WCMO is a subordinate unit of the Forestry Bureau, it seems to be inevitable for them to take agriculture less important".



(**a**) (**b**)

**Figure 4.** Loss of traditional agricultural landscape: (**a**) Haizhu Lake with an area of 53 hm$^2$ constructed in 2011 (Credit: Huiqiang Xie); (**b**) Landscape after implementing an ecological restoration project (Credit: Huiqiang Xie).

### *4.2. Societal Sustainability*

#### 4.2.1. Dynamic Conservation

In addition to government financial support, the main source of economic income in HW is tourism. The Haizhu Wetland Park (Areas Nos. 6 and 8) is now a tourist attraction with great influence. From 2013 to 2019, the number of tourists has exceeded 40 million. In 2013, more than 3.75 million people bought tickets to enter the park. In 2019, this value rose to 8.43 million, and the ticket revenue reached 5.02 million RMB. The living state of the HHBLDA in an intra-urban area is not as good as other IAHS sites in rural areas. The main duty of the WCMO is ecological conservation. This inevitably results in not paying enough attention to fruit tree production. The management and protection measures for fruit trees were mostly equivalent to those of ornamental trees in parks. Constrained by the financial system, the fruit produced by orchard trees cannot be sold on the market and are only given to tourists, welfare institutions, and schools. This results in the lack of important economic benefits for heritage activation. "As a government department, WCMO has no power to sell agricultural products. All financial revenues and expenditures should be audited. So if these fruits are sold, this will be against the rules" (B3). Approximately 10–30 farmers are employed in each area of HW. A certain number of temporary workers are also hired during the busy season, and they are responsible for the management of thousands of fruit trees. Existing farmers have a difficult time completing the workload required for the normal production of fruit trees. Farmers must also be responsible for the removal of invasive plants, such as *Mikania micrantha*, and the dredging of rivers and ditches. A head farmer working in Area No. 3 (A15) noted that: "Although it saddens me to see some trees dead, the area of orchard is too large to manage. All we can do is just to keep all fruit trees to survive, we don't care whether they bear fruit". According to the existing staffing, carefully managing the fruit trees to reproduce the vibrant appearance of orchards before the 1980s is impossible. At present, Areas Nos. 2 to 5 of HW have a total of more than 300 $hm^2$ of orchards for ecological conservation, which have not yet been opened to the village residents and the public. The surrounding residents in Xiaozhou and Tuhua expressed their frustration. The three AHS experts interviewed did not agree with the current management mode of farmlands. One expert (D1) noted that: "Since HW is a constructed wetland evolved from agricultural production, its management mode cannot be equivalent to the natural wetland. At present, the natural eco-environment has been well restored. It is time to resume agricultural production and let the public participate in management".

#### 4.2.2. Adaptive Management

Different AHS sites exist in distinct environments, hence protection and management methods should also vary. Establishing a sustainable adaptive management mechanism and avoiding the misunderstanding of closed-off conservation are important for intra-urban AHS sites. After the enclosure management of the wetland, the WCMO paid attention to strengthening cooperation with the village community. A co-construction agreement with Longtan Village promised to give priority to hiring village residents for wetland management and to set up a team of local farmers in charge of orchard management. Most farmers who lost their farms did not have enough skills to get a job in the urban sector [11]. When the villagers saw that the land cultivated by their elder generations was protected, some were also inspired and actively participated in the ecological restoration, management, and maintenance of HW. A villager of Luntou (A4), the head of the Agricultural Education Base, noted: "I was also extremely opposed to land acquisition at the time because I was afraid that the government would use the precious farmland left by our ancestors to build high buildings. After the land acquisition, I felt that the government had not reneged on its promise, and I just came across the recruitment of the wetland, so I agreed to work here". Statistics provided by the WCMO confirmed that 379 employed farmers were all from villages near HW (Figure 5). The view of a Tuhua farmer (A11) was representative: "I'm not old enough to retire. I do not like playing mahjong, nor do I have any other hobbies. Keeping fit is my goal. You know that the salary 2800 RMB per month, is only enough for breakfast and cigarettes. Our elder generations have been planting fruit trees, and I have a lot of affection for this. Working for WCMO is also quite decent". The survey also found that interpersonal communication was one of the reasons for female interviewees who chose to work there. According to the survey, most farmers were between 50 and 60 years old, and their self-occupied housing area was approximately 2000 $m^2$. Thus, house rental was the main source of income for most families. The job was still unattractive to most migrant workers due to the low salary. A leader of the WCMO (B1) noted that: "These farmers are basically over 50 years old now. After a few years, once they retire, there will be no suitable residents. We do not know how to resolve this problem". In view of the adaptive management of HHBLDA, an expert (D2) noted that: "A multi-stakeholder system should be established involving communities, farmers, governments, scientists, and business enterprises as well as social organizations".

**Figure 5.** Farmers employed by the WCMO: (**a**) Fruit tree cultivation (Credit: Huiqiang Xie); (**b**) Vegetable cultivation; (**c**) Dredging ditch mud (Credit: Huiqiang Xie); (**d**) Farming culture education (Credit: Huiqiang Xie).

4.2.3. Economic Support

In recent years, the ecological effect of HW has brought great economic benefits to the surrounding areas, and it has become a signature for attracting top enterprises and talents. According to a study in 2014, the space scope impact of HW on the appreciation of the surrounding real estate prices was expected to reach 1400 m, within which the real estate appreciation was 6.7% [54]. Nowadays, the Guangzhou Artificial Intelligence and Digital Economy Pilot Zone adjacent to the wetland have successfully attracted several leading companies. In contrast, in the four villages in the core area of the HHBLDA site, the WCMO cannot make overall use of the surrounding construction land due to multiple land ownership issues, resulting in difficulty of implementing key projects. However, the spillover effect of park ecology and tourism value is relatively limited, and no strong positive feedback relationship exists between wetland investment and land appreciation [55]. According to the survey, the current income sources of villagers mainly included rental income from factory buildings and houses, wage income, commercial operation, and dividends from the village collective economy. Longtan, which has many industrial lands but no farmland, gains a considerably higher annual income per capita than the other villages, which was 3.0, 5.3, and 13.5 times that of Tuhua, Luntou, and Xiaozhou villages, respectively in 2019. The construction and maintenance of the constructed wetland ecosystem require a large investment of capital and manpower, and the management and protection of more than 200,000 fruit trees. The security investment is also great due to the large and scattered area. According to a leader of the WCMO (B1), the operating cost is considerably higher in the intra-urban area than in a wetland park far from an urban area. It was estimated that the operating cost of HW is 30 times higher than that of Nansha Wetland of Guangzhou, which is approximately 60% of the HW area. Commercial operation projects of the park are limited due to the needs of wetland conservation, and the lack of sufficient profit channels makes the operation of the park unable to support daily management. Moreover, the operation investment mainly depends on government financial support. In view of the limited economic benefits, an expert (D3) noted that: "The integration of tourism and AHS may never be sufficient to generate enough economic benefits comparable to the rise in land value caused by urbanization. It is inappropriate to overemphasize the economic benefit of intra-urban AHS". In 2019, the *Haizhu Wetland Quality Improvement Work Plan* issued by the Bureau of Forestry and Landscaping of Guangzhou Municipality proposed utilizing farmlands to develop a diversified economy and planned to explore social marketing and other channels to participate in wetland operation. In 2020, the Haizhu Wetland Ecological Development Co., Ltd., responsible for wetland revenue business, was established. The revenue capacity and social and economic benefits of HW are expected to soon be greatly improved and may be able to provide economic support for the sustainable development of the HHBLDA.

## 5. Discussion

### *5.1. Option on Land Acquisition or Not*

The current reform of China's agricultural land system involves three modes: Land Acquisition to Keep Agricultural Use (LAKAU), No Land Acquisition to Keep Agricultural Use (NLAKAU), and No Land Acquisition to Transfer Agricultural Use (NLATAU). As far as the AHS is concerned, preserving farmland for agricultural use is a prerequisite. The NLAKAU mode is an option for intra-urban AHS conservation and is even the most acceptable method according to mainstream concepts. However, previous case studies of intra-urban AHS sites have shown that the NLAKAU mode cannot drastically solve the dilemmas caused by urbanization. Considering that the main source of income for households is no longer from agriculture, many farmers either actively give up agricultural production because the income from agriculture is relatively limited and bearing the high cost of living in urban areas is difficult, or they passively give up agricultural production because of water and air pollution. Government departments constructed scenic spots by leasing orchards. However, the tourist attraction effect and economic return were quite limited because the construction of supporting facilities had many restrictions. If an area is contracted by enterprises, obtaining sufficient economic benefits is difficult without changing land properties due to the high renting rate in an intra-urban area. In the Xuanhua Grape Garden site, the vineyards are in the courtyards of the residents. Only a small proportion of farmers in Xuanhua support grape planting, and many farmers welcome real estate developers to expropriate their land [19]. In urban areas where land resources are scarce, the current NLAKAU mode is eventually likely to evolve into expropriation in the interests of all parties. Practices of intra-urban IAHS in China have proven that regulating permanent basic farmland zones has an important impact on the choice of AHS conservation strategies. Permanent basic farmland, as the strictest manifestation of China's farmland protection system, is a decisive factor in safeguarding sustainable farmland utilization in urban areas, and its existence ensures that urban managers take measures to protect farmlands [56]. So for the urban AHS, the LAKAU mode is an effective measure to protect against its extinction risk and provides a choice for urban managers in China.

### *5.2. Challenges Brought by the LAKAU Mode*

Although the LAKAU mode is one good option, its universally adoptability and whether the policy obstacle can be removed remain unclear.

First, can the incongruity of conservation principles between the AHS and nature reserves be solved? The coexistence of the IAHS and nature reserves is common in China, but the two protection systems are managed by different government departments which usually have different resource management concepts and focuses. For example, the AHS requires the continuity of the agricultural production function, which is often ignored by nature reserves. The organic integration of conservation concepts and the integration and unification of management levels between the two can help in accurately and comprehensively understanding the scientific mechanism of the AHS, thereby improving the depth and breadth of AHS conservation and realizing rational heritage protection and utilization. The AHS advocates the development of agricultural production in an ecological manner, which should complement with ecological conservation projects. The positioning and management of IAHS sites in the natural reserve system are worthy of consideration by decision-making departments [57].

Second, can the dominant role of farmers in AHS sites be changed? IAHS conservation has always advocated for respecting the dominant role of farmers, which is fully applicable in rural areas. However, the livelihoods dominated by agricultural production are unsustainable in many peri- and intra-urban areas, and farmers have gradually engaged in non-agricultural occupations. Practices of GIAHS in Japan have shown that multi-stakeholders from rural and urban communities can equally provide important contributions toward sustaining food security and continuity of traditional agricultural systems [58,59]. Therefore, AHS managers should look at the new practices of multi-stakeholders according to local conditions, not stick to outdated regulations, and actively take flexible countermeasures that allow citizens to participate in production through farmland lease and maximize the enthusiasm of local farmers and public for AHS conservation [60].

Third, can urban managers better accept the AHS? The first LAKAU mode was approved and implemented in Haizhu District, which has its particularity in China. This policy was effective not only because of the urgent need to protect the urban ecological environment and solve the livelihood problems of villagers, but also because of the high attention and strong promotion of government departments at all levels. Farmlands are not a necessary landscape in intra-urban areas, and they will be difficult to preserve if they are not delineated as permanent basic farmland zones. Owing to their ecological functions, farmlands should coexist with urban land uses in the process of urbanization [61,62]. Agriculture can become an integral part of the urban ecological environment, and the innovative development of cities in the future should be able to better accept the AHS. The integration of animal raising and crop planting can realize the recycling of material and reduce the risk of crop diseases and pests in a non-chemical manner, which is a classic practice of traditional ecological agriculture. The basic prohibition of livestock, poultry, and aquaculture in current urban areas causes great challenges for the integrity and value of the AHS. Whether intra-urban AHS sites can be delimited as a restricted animal raising area is worthy of further discussion.

### *5.3. Suggestions for Improving Intra-Urban AHS Vitality*

One of the most serious difficulties that the intra-urban AHS faces is the lack of vitality due to the separation of farmland from farmers caused by changes in farmers' livelihood or by land acquisition. From the perspective of HHBLDA conservation, the construction of a wetland park through the LAKAU mode was one of the best options available in 2012. This initiative preserved core AHS elements to the greatest extent and reserved the opportunity for future value exploration, protection, and utilization. At present, some difficulties and problems still remain, such as insufficient agricultural production function, separation of farmland and local community, shortage of local farmers, high operating cost of HW, and low public participation in some areas. To this end, the following strategies are recommended for adoption in the future: (1) straightening out the management mechanism of the coexistence of National Wetland Park and China-IAHS, maximizing the unity of management concepts, and improving the function of agricultural production without damaging the ecological environment; (2) selecting an area of HW to build a demonstration area for AHS protection and utilization, and exploring an AHS co-management system with multiple stakeholders; (3) establishing an eco-compensation mechanism to make up for villagers' contribution for ecological protection; (4) enlarging the open area of HW in an orderly manner and expanding the tourism economic radiation effect on surrounding villages; and (5) increasing financial support and popular science propaganda, fostering so called "bellwethers", including high bed-low ditch agricultural technology inheritors and local intangible cultural heritage successors, and letting them lead the growth of a group of "new farmers" in villages by opening training classes or recruiting apprentices.

Due to the implementation of the LAKAU, the relationship between community residents and farmlands has fundamentally changed, so it is particularly important to establish an adaptive co-management system for the HHBLDA's sustainable development. This co-management system could be formed both vertically and horizontally. The vertical management system includes coordination among government authorities, implementation institutions (such as the agricultural bureau, natural protection bureau, financial bureau, and institutions for research and education), local community organizations (such as village organizations), and cooperation among individual farmers. The horizontal management system includes combined efforts from multi-stakeholders along the food chain from field to table, including people and enterprises for production, storage, marketing, processing, selling, and consumption. The financial support for the LAKAU and annual subsidy, the *Haizhu Wetland Quality Improvement Work Plan* (2019), and the formation of Haizhu Wetland Ecological Development Co., Ltd. (2020) are parts of the efforts for the formation of this co-management system.

## 6. Conclusions

The development and prosperity of the HHBLDA are the result of the unique natural conditions of the site as an island and the advancement of commercial agriculture in the suburbs of Guangzhou during the historical period. Because government departments at all levels have attached great importance to the ecological function of Guangzhou's "south lung" for a long time, this AHS site was fortunately not swallowed up by urban construction when it entered the central part of the metropolis, finally realizing permanent protection through the implementation of the LAKAU. The following achievements are worthy of recognition in the field of AHS conservation through the construction of the National Wetland Park in the past decade. First, the ecological function of the AHS has been effectively protected and improved through continuous ecological conservation, making it one of the symbols of ecotourism in Guangzhou. Second, the traditional high bed-low ditch landscape, traditional fruit tree species, rivers, water gates, ancient trees, and other AHS elements have been preserved due to the overall conservation of farmlands. Third, traditional farming culture has been promoted through multiple channels by hosting activities of natural and agricultural education and agricultural festivals such as the Longan Festival and the Dragon Boat Festival. Fourth, optimization of the eco-environment has encouraged the surrounding villages and communities to change from "urban value depression" to "ecological value highland", thus gradually and effectively alleviating the contradiction between the city's "lung" (ecological effect) and the villagers' "stomach" (economic effect). Lastly, hundreds of villagers have been employed in posts for agricultural technology, personnel management, commercial operation, cultural popularization, security, and others. They have taken new responsibilities in the conservation and inheritance of the AHS. In the process of rapid urban sprawl, time is the worst "enemy" for saving local traditional agroecosystems. This case study proves that permanent extinction of the urban AHS can be avoided and opportunities for subsequent dynamic development can be retained through the implementation of the LAKAU in a short time.

Different agricultural types have varying circumstances in the face of the urbanization process. As an essential cultural component of cites, the AHS should be more accepted by urban managers [11,26]. Facing the various dilemmas of urban AHS, the LAKAU is undoubtedly an effective conservation strategy. However, this mode can only resolve some specific problems faced by urban AHS sites, meanwhile, new challenges inevitably arise. So only by continuously improving management and operation mechanisms can AHS inheritance and protection be effectively guaranteed. In China, land resources are owned by the state and the government plays a key role in decision-making and implementation, thus the government can effectively intervene in alleviating human-land conflicts during the urbanization process of AHS sites. However, types of land ownership are quite varied in different countries. Whether the LAKAU mode is applicable to urban AHS conservation in other countries should be explored through further case studies and related practices. As large areas of the countryside are being swallowed up by towns, the conservation of the urban AHS deserves more attention from researchers, governments, and the public.

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# Household Livelihood Strategy Changes and Agricultural Diversification: A Correlation and Mechanism Analysis Based on Data from the China Family Panel

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**Abstract:** Social and economic transformations have a profound impact on farmers' livelihood strategies, and changes in these strategies, in turn, deeply impact the agricultural system. Based on four waves of China Family Panel Studies (CFPS) tracking data, this paper uses a Markov transfer probability matrix to explore changes in farmers' livelihood strategies and builds multiple logit and fixed-effect models to empirically analyze the impact and lag effect of these changes on agricultural diversification. The results show that (1) farmers who choose not to shift away from an agricultural livelihood show no significant change in agricultural diversification. Compared with households showing an increase in the agricultural diversification index, households showing a decrease in this index are more inclined to diversify if they choose to maintain an agricultural livelihood either part-time or full-time. For households with an unchanged agricultural diversification index, their index value is more likely to remain unchanged if they choose to maintain a part-time or full-time agriculture-oriented livelihood. Moreover, (2) the impact of livelihood strategy changes on agricultural diversification displays regional heterogeneity. The index value of farmers in the central region shows no statistically significant change over the sample period, while the index value of farmers in the eastern region increases. Farmers in the eastern and central regions with unchanged index values are more inclined to show persistent index values. (3) Changes in farmers' livelihood strategies have a lag effect on agricultural diversification that becomes significant at two lag periods.

**Keywords:** household livelihood strategy; agricultural diversification; heterogeneity; lag effect; China

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## 1. Introduction

Throughout the development history of the world, agricultural decline in the process of rapid industrialization and urbanization has become a global trend. Since the 1950s, the United States, Sweden, Japan, South Korea and other countries have seen a decline in agricultural economic benefits and a widening of the income gap between urban and rural residents. To improve their income levels, increasing numbers of farmers have left farming to make a living in other sectors. Many farmers have gradually changed from an agriculture-oriented to a diversified livelihood, with the number of agricultural employees rapidly decreasing on a large scale. According to World Bank statistics, the proportion of agricultural workers in the world's total employed population decreased from 64.43% in 1960 to 26.75% in 2019, a decrease of 37.68 percentage points. Taking the BRICS countries (Brazil, Russia, India, China and South Africa) as representatives of the world's emerging markets, during 1960–2019, the employment proportion of Russian agriculture practitioners in the total population fell by 27.19%, and those of their South African and Indian counterparts by 15.11% and 44.16%, respectively, while the proportion of Chinese agricultural professionals in the total population decreased even more, reaching 57.40% (data source website: https://data.wordbank.org/ (accessed on 12 April 2021)). With the decrease in the number of agricultural employees and the transformation of farmers' livelihoods, farmers must carefully consider how to manage limited land resources to maximize the benefits and diversify their agricultural production structure and nonagricultural management.

Regarding the framework of sustainable livelihood analysis, the UK Department for International Development (DFID) proposed that the household livelihood strategy comprises a combination of related activities taken by farmers to achieve certain livelihood goals based on their livelihood capital in the context of fragile livelihoods [1]. In this framework, livelihood capital can be divided into five categories: natural, social, human, material and financial. Livelihood capital reflects the livelihood resources available to farmers in a multidimensional way and more comprehensively highlights farmers' ability to resist risks by using family endowments. Farmers' choice of livelihood strategies depends on their livelihood capital status and the mode in which this capital is combined and utilized. Compared with other factors, livelihood capital has a more direct and obvious influence on the livelihood strategies of farmers. The natural environment, socioeconomic conditions, assets and other factors constrain farmers' livelihood strategy choices. Scholars in China and abroad have used the sustainable livelihood analysis framework. The peasant household model vividly explains the influencing mechanisms associated with livelihood capital strategies among peasant households, with farmers' social and human capital playing a decisive role in allowing farmers to participate in nonagricultural activities [2–4]. Farmers with higher natural and material capital tend to choose agriculture or agriculture-oriented livelihood strategies, while farmers with higher social capital and financial capital tend to adopt part-time agricultural or nonagricultural livelihood strategies [5,6]. Due to the enduring nature of natural capital and material capital of farmers, the impact of internal and external shocks is relatively small; farmers with greater natural and physical capital tend to choose the more traditional livelihood strategy of agriculture, while farmers richer in human, social and financial capital tend to select livelihood combinations featuring a greater, more diverse range of livelihood modes [7,8]. When internal and external conditions, especially livelihood capital levels, change, farmers often adjust their livelihood strategies by evaluating family endowments and the expected effects of a livelihood change to adapt to new production relations. Relevant studies show that (1) natural capital plays a role in promoting side businesses, (2) farmers with higher human capital tend more towards nonagricultural strategies, (3) material capital promotes agricultural industrialization and (4) financial capital inhibits agricultural industrialization [9]. In addition, farmers' choices of livelihood strategies depend significantly on their previous livelihood strategies. The accumulation of natural, human, social and financial capital promotes an orientation of farmers' livelihood strategies towards high returns, while the binding effect of sunk costs in the form of agricultural fixed assets in physical capital hinders the diversification of farmers' livelihoods [10].

Agricultural diversification is generally regarded as an effective strategy to improve risk management, reduce poverty [11,12] and increase food security. It can reduce the risks caused by internal and external shocks such as natural disturbances, economic crises and poverty and can increase rural income. The core idea of diversification is to maximize utility from available resources. On the one hand, agricultural diversification leads to planting structure diversification, which enables farmers to carry out diversified agriculture in different agricultural ecological environments, which is beneficial for different crops to match different soil environments and climate conditions and is also beneficial for the labor force as it makes full use of the spatial distribution of crop species, which allows for more reasonable time allocation and improves the efficiency of resource allocation. Ultimately, farmers' income and agricultural output will be improved [13,14]. Different crops demand different soil nutrients, so farmers can use different fertilizers to meet crop planting and growth needs, effectively improving soil fertility and agricultural production efficiency. On the other hand, while diversified planting exposes farmers to different types of risks, it disperses the risks in the planting and production processes and helps avoid or mitigate some sudden natural and market shocks that lead to reduced outputs or fluctuating incomes [15]. For example, Guvele [16] and Niroula and Thapa [17] argue that planting diversification is conducive to reducing natural and market risks in agricultural production and income fluctuations, especially in agricultural areas with labor shortages and frequent natural disasters. Van Hung et al. [18] argue that, based on the current scale of farm operations in China, planting diversification in high value-added agricultural products such as vegetables is conducive to maintaining a relatively reasonable income level for farms. Some scholars have discussed the influencing factors of agricultural diversification and believe that farmers with higher human and social capital tend to diversify away from agriculture [19], which may hinder agricultural diversification. Akpan et al. [20] identify several positive and negative driving factors of agricultural diversification through their research in Nigeria. Anderzen et al. [21] show that access to credit and technical assistance has a positive impact on agricultural diversification. The continuous increase in farmers' off-farm livelihood is in competition with agricultural production, which results in farmers reducing their input in agricultural production to obtain a higher off-farm income. Holden et al. [22] find that an increase in farmers' nonagricultural income reduced their enthusiasm for investment in agricultural production activities, resulting in low agricultural productivity. The decrease in agricultural productivity also affected agricultural production.

Related studies often focus on analyzing a certain aspect of changes in farmers' livelihood strategies and the diversity of farmers' operations but fail to analyze the impact of such livelihood strategy changes on agricultural diversification. In the process of rapid urbanization and urban rural social and economic transformation, farmers' livelihood strategies have undergone fundamental changes. The dependence of the agricultural labor force on subsistence farming has weakened, and changes in livelihood strategies have promoted agricultural diversification. This difference is reflected in the livelihood endowments of different families; farmers' agricultural production decisions have a direct, fundamental impact on agricultural diversification, while family livelihood assets, as the most critical factor affecting rural economic activities [23], directly or indirectly determine family agricultural production. In view of this, the impact of livelihood strategy changes on the agricultural diversification of Chinese farmers is analyzed here. Over the past 40 years of reform and opening, China has experienced rapid industrialization and urbanization, gradually transforming from a rural to an urban society and from an agricultural to a nonagricultural economy. In this process, the livelihood strategy of farmers has changed accordingly, manifesting through the diversification of livelihoods. How can we scientifically characterize these changes in farmers' livelihood strategies? How do such changes affect agricultural diversification? The relevant issues have not been thoroughly studied. In this paper, based on four waves of China Family Panel Studies (CFPS) tracking data, farmers' livelihood strategies are divided according to the proportion of wage income in total household income. A multiple logit regression method is used to analyze the influence of changes in farmers' livelihood strategies on agricultural diversification and discusses the lagging effect of changes in farmers' livelihood strategies on agricultural diversification. This work provides empirical support for promoting the diversification of farmers' income and agricultural development.

## 2. Theoretical Analysis Framework

Based on the proportion of household wage income in total household income, household livelihoods are divided into the following three types: if household wage income is less than 20% of total household income, the livelihood strategy is agricultural; if wage income is between 20% and 80%, the livelihood strategy is part-time agricultural; and if wage income is more than 80%, the livelihood strategy is nonagricultural. Different types and directions of livelihood strategy change have different effects on agricultural diversification. The changing types of farmer livelihood strategies can be divided into maintenance livelihoods and variable livelihoods. In this paper, maintenance livelihoods are divided into agricultural maintenance, part-time agricultural maintenance and nonagricultural maintenance, and the variation in household livelihoods are divided into two types: changes towards an agricultural livelihood and changes toward an off-farm livelihood (Table 1). In the following, we analyze the impact of household livelihood strategy changes on agricultural diversification based on the characteristics of the type of change.

**Table 1.** Changes in household livelihood strategies.

| **Types of Farmer Livelihood Strategies** | | **Current Period** | | |
|---|---|---|---|---|
| | | **Off-Farm Livelihood** | **Part-Time Agricultural Livelihood** | **Agricultural Livelihoods** |
| Base period | Off-farm livelihood | No change in nonagricultural livelihood | Transition towards agricultural livelihood | Transition towards agricultural livelihood |
| | Part-time agricultural livelihood | Transition towards off-farm livelihoods | No change in part-time livelihood | Transition towards agricultural livelihood |
| | Agricultural livelihoods | Transition towards off-farm livelihoods | Transition towards off-farm livelihoods | No change in agricultural livelihood |

*2.1. Impact of Subsistence Livelihoods on Agricultural Diversification*

The livelihood system of farmers has a self-organized character [24]. Farmers will make intuitive comparisons based on family endowments and livelihood outcomes, measure the opportunity cost of family endowments and measure the advantages and disadvantages of livelihood outcomes [25,26]. If the results of this assessment are consistent with expectations, the livelihood strategies of farmers in the previous phase will persist in the current period. This is because if farmers repeatedly adjust or constantly change their livelihood strategies, they cannot accumulate enough practical experience in their livelihood development in the corresponding field, and they find it difficult to correctly predict the external risks of the industry. In addition, frequent replacement of livelihood development strategies causes unnecessary loss and waste of livelihood capital for poor families [27], and the best choice for farmers is to maintain their original livelihood strategies at this stage. For maintenance farmers, maintaining the current agricultural planting structure offers results relatively consistent with expectations. The diversity index of maintenance farmers is different due to different agricultural planting structures. Therefore, maintaining the necessary large-scale professional planting is the main way for a farmer to sustain an agricultural livelihood. However, large-scale professional planting may decrease the agricultural diversification index. Farmers who maintain a part-time agricultural livelihood, engaging in both agricultural and nonagricultural production, may maintain a specific farming scale only temporarily or may diversify their agricultural planting structure to meet the family's diversification. As the agricultural planting structure remains unchanged or increases, the agricultural diversity index generally remains unchanged or increases. For farmers who maintain nonagricultural livelihoods, agricultural production has little impact on their livelihood. Therefore, their attitude toward agriculture may be more flexible or emphasize large-scale and specialized planting by other farmers in the form of land transfers, corresponding to no change or to a decrease in the agricultural diversification index (Figure 1).

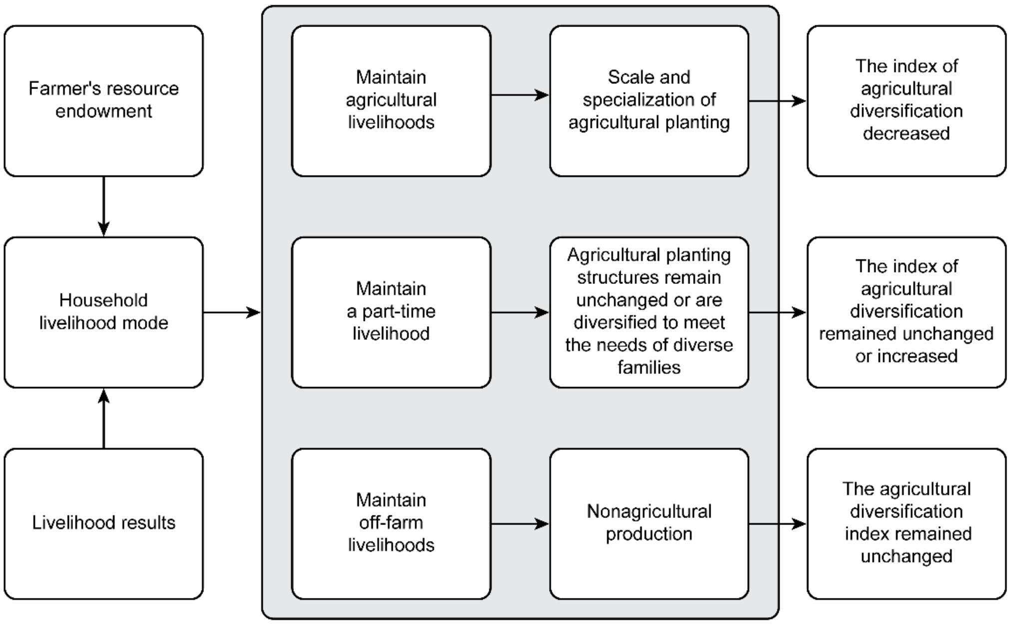


**Figure 1.** Impact of maintenance livelihood on agricultural diversification.

*2.2. Impact of Farmers' Variable Livelihoods on Agricultural Diversification*

Given the coordination of household endowments and livelihood results, when certain external factors are injected into farmers' self-organized livelihood systems, rational farmers will react quickly to these factors and take action on livelihood strategies, thereby driving other farmers to change their livelihood strategies through demonstration effects [28]. For example, the government may attach great importance to agriculture, rural areas and farmers and may have offered a series of preferential policies for farmers. Some farmers have realized that land capital can create more value and have begun to lease more land to operate high-value-added cash crops, changing the original planting structure. These farmers' demonstrations of success drive other farmers to follow suit due to a herding effect. This type of livelihood strategy change is agriculture-oriented. Farmer livelihoods oriented towards agriculture on the premise of expanding land capital can achieve certain livelihood objectives through large-scale and specialized agricultural production, but doing so may hinder agricultural diversification. However, some farmers may diversify their production to disperse risks, which promotes diversified agricultural production.

Farmers' livelihood has the dual objectives of income growth and income stability [29]. The choice of livelihood strategy involves not only the pursuit of higher family income but also the control of risks; however, the agricultural industry has a long production cycle and management issues. Changes to the agricultural planting structure may produce yields that are lower than ideal with respect to the farmers' livelihood goals. Limited land resources in rural areas and the livelihood demands of the increasing surplus rural labor force gradually drive family members to work out of town and seek new outlets, leading to a relatively weakened role of natural capital and an increasingly prominent role of human capital [30,31]. The income of such households comes mainly from nonagricultural labor. These farmers are not completely divorced from agricultural production, as they raise poultry and plant vegetables to meet their basic living needs. Their livelihood strategy changes veer towards off-farm activities. Farmers who prefer nonagricultural livelihoods cannot meet their needs to improve their lives by changing the method of land use, so they pay more attention to nonagricultural livelihoods when making production decisions. Agricultural production may shift from diversified cultivation to monoculture, or the scale of monoculture may be reduced. The uncertainty surrounding agricultural production may lead to transfers of household land [32,33], which are not conducive to the diversification of the household's own agriculture [34]. Through land transfers, large agricultural farmers may accumulate more natural and material capital [35,36], which makes them more inclined to choose agriculture-oriented livelihood strategies and to plant crops with higher economic value added in combination with more diversified utilization, such that the agricultural diversification index increases (Figure 2).

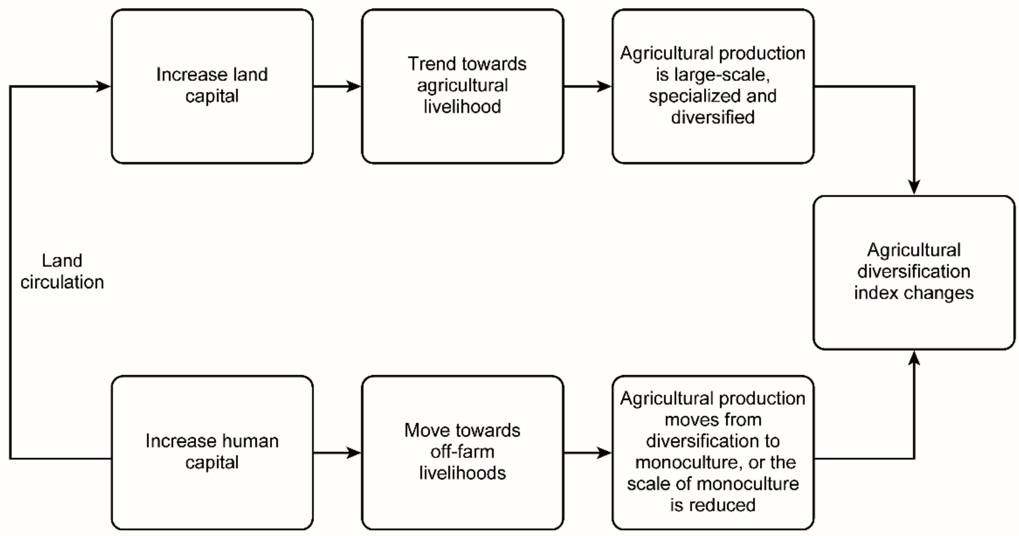


**Figure 2.** Impact of farmers' variable livelihoods on agricultural diversification.

## 3. Index Selection, Research Methods and Data Sources

### *3.1. Index Selection*

The agricultural diversification index is the key dependent variable in this paper. O'Donoghue et al. [37] observed that there are five commonly used indicators to measure agricultural diversification, namely, the maximization index, Herfindahl index (HI), global total entropy index (TE), correlation entropy index (RE) and independent entropy index (UE). Based on the availability of CFPS data, the HI is used to measure agricultural diversification, with products represented by agricultural, forestry, livestock and aquatic products. The formula is as follows.

$$HI = \sum \left(\frac{A_{it}}{\sum A_{it}}\right)^2 \tag{1}$$

$$D_{rt} = 1 - HI \tag{2}$$

$A_{it}$ represents the value of product $i$ at time $t$, $\sum A_{it}$ represents the sum of the values of all products at time $t$, and $HI$ is the Herfindahl index, calculated by the sum of squares of the total product value. To make the expression of agricultural diversification more intuitive, we use the inverted Herfindahl index to represent agricultural diversification, namely, Equation (2), where $D_{rt}$ is the diversification level of household $r$ at time $t$; the value of the agricultural diversification index $D_{rt}$ is between 0~1, where the larger the value is, the higher the degree of agricultural diversification. A smaller value indicates a higher degree of agricultural specialization.

To study changes in farmers' livelihood strategies and their impact on agricultural diversification, we code the difference between the current and base period values of the agricultural diversification index as reduced, unchanged or increased, corresponding to values 1, 2 and 3, respectively.

The independent variable considered in this paper is the change in farmer livelihood strategy, coded with values 1, 2, 3, 4 and 5.

Since changes in farmers' livelihood strategies may have heterogeneous effects on agricultural diversification in different regions, this paper divides the study regions into the eastern, central and western regions, with assigned values of 1, 2 and 3, respectively. The specific variable assignments are shown in Table 2.

**Table 2.** Variable definitions and settings.

| Variable Type | Variable Name and Code | Variable Setting |
|---|---|---|
| Dependent variable | Agricultural diversity index (Y) | A decrease in the agricultural diversification index is assigned value 1 |
| | | No change in the agricultural diversification index is assigned value 2 |
| | | An increase in the agricultural diversification index is assigned value 3 |
| Independent variables | Types of changes in household livelihood strategies (SJCL) | No change in agricultural livelihood is assigned value 1 |
| | | No change in part-time agricultural livelihood is assigned value 2 |
| | | No change in a nonagricultural livelihood is assigned value 3 |
| | | A change to an agricultural livelihood is assigned value 4 |
| | | A change to an off-farm livelihood is assigned value 5 |
| | Regional types (AR) | The eastern region is assigned value 1 |
| | | The central region is assigned value 2 |
| | | The western region is assigned value 3 |

### *3.2. Research Methods*

#### 3.2.1. Markov Chain

A Markov chain is an important method for analyzing changes in farmers' livelihood strategies from the perspective of structural changes. Its principle is as follows: if the livelihood strategies of the farmers studied in each year are of a possible type, then the probability distribution of the livelihood strategies of the farmers in year $t$ can be represented by a state probability vector of $1 \times k$, and the probability of transfer between the livelihood strategies of farmers in different years can be expressed as a $k \times k$ matrix $P$, which is expressed as follows.

$$P = \begin{bmatrix} P_{11}(d) & P_{12}(d)\ldots & P_{1j}(d) & \ldots & P_{1k}(d) \\ P_{21}(d) & P_{22}(d)\ldots & P_{2j}(d) & \ldots & P_{2k}(d) \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ P_{k1}(d) & P_{k2}(d)\ldots & P_{kj}(d) & \ldots & P_{kk}(d) \end{bmatrix} \tag{3}$$

$$P_{ij}(d) = \frac{n_{ij}(d)}{n_i} \tag{4}$$

$$0 \le P_{ij}(d) \le 1 \tag{5}$$

$$\sum_{j=1}^{k} P_{ij}(d) = 1 \tag{6}$$

In Equations (3) and (4), $P_{ij}(d)$ represents the probability that the livelihood strategy of a peasant household is $i$ at a certain time and transitions to $j$ after time $d$, and $n_{ij}(d)$ represents the sum of the number of peasant households whose livelihood strategy is $i$ at a certain time but transitions to $j$ after time $d$. $n_i$ represents the sum of the number of rural families relying on livelihood strategy $i$ in the four years of the whole research period. At the same time, the matrix meets the two criteria associated with Equations (5) and (6); that is, the probability of a change in one livelihood strategy to another livelihood strategy is between 0 and 1, and the sum of the probabilities of a change in livelihood strategy for all livelihood strategies is 1. For example, if a peasant household's livelihood strategy in 2012 is agriculture-oriented, the sum of probabilities of choosing an agriculture-oriented part-time agricultural or nonagricultural strategy in 2014 is equal to 1.

3.2.2. Model Setting

(1) Multiple logit model

According to the data type, the dependent variable, agricultural diversification, is an ordered multiclass classification variable. We first consider using the ordered logit model to explore the impact of farmers' livelihood strategy changes on agricultural diversification. In a parallel trends test of the original data, it is found that the *p*-value is less than 0.05, and the null hypothesis of no correlation is rejected, so the model is invalid. Therefore, this paper uses multiple logit regression models for empirical analysis. The general expression of the multiple logit model is as follows: for *j* = 1, 2 … *J*, if the option of class *J* is set as the reference group, the probability ratio of the occurrence of the remaining class $J-1$ can be expressed in the logit form of Equation (7) as follows:

$$ln\left(\frac{p(y=j\text{x})}{p(y=J\text{x})}\right)=\alpha_j+\sum_{j=1}^{k}\beta_{ij}X_i \quad (7)$$

$$i\in[1,k],\ j\in[1,J-1]$$

where *j* indicates a decrease, no change or an increase, and the reference term *J* = increase. *k* is the number of explanatory variables, $1\le k\le 5$, and $x_i$ is the explanatory variable, *i* = 1, 2, 3, … 8.

(2) Fixed effect model

To explore the lagged effect of farmers' livelihood strategy changes on agricultural diversification, this paper constructed the following panel data model:

$$Y_t=\alpha+\beta_1 SJCL1_{t-i}+\beta_2 SJCL2_{t-i}+\beta_3 SJCL3_{t-i}+\beta_4 SJCL4_{t-i}+\beta_5 SJCL5_{t-i}+\varepsilon \quad (8)$$

where *t* represents the number of periods (four tracking periods from 2012 to 2018), and *i* represents the number of periods (*i* = 0, 1, 2) in which the independent variable lags behind. SJCL1–5 represents five types of livelihood strategy change. This model examines the correlation between agricultural diversification in phase *t* and changes in livelihood strategies of farmers in the current period, the later period and two other periods. In panel data analysis, there are two main methods: the fixed effect model and the random effect model. According to the Hausman test, the *p*-value of 0.000 indicates that the null hypothesis of the random effect model is not valid. Therefore, this paper adopts the fixed effect model to analyze the lag effect.

(3) Quantile regression

Quantile regression is an extension of OLS and was first proposed by Koenke and Bassett [38]. It can fully reflect the relevant information of independent variables by estimating different conditional quantiles of dependent variables. Regression parameters change with different loci of dependent variables, which is conducive to a more detailed and comprehensive analysis of the regression relationship between variables and is relatively robust [18]. In this paper, the quantile regression method was used to test the robustness. Five loci, 0.1, 0.25, 0.5, 0.75 and 0.9, were selected to establish the quantile regression model as follows:

$$Q_q(Y)=\lambda+\sum\beta_i X_{it}+\varepsilon_{it} \quad (9)$$

where $Q_q(Y)$ is the number of score values corresponding to the *q* location, $X_{it}$ is the value of each variable in period *t*, $\beta_i$ is the quantile regression coefficient, *i* is 1 to 8, $\lambda$ is the constant term and $\varepsilon_{it}$ is the random disturbance term.

*3.3. Data Sources*

The data in this paper are from the four CFPS waves conducted by the Chinese Institute for Social Science Surveys (ISSS) of Peking University from 2012 to 2018. This project adopts the tracking survey method to collect data at three levels: from individuals, families and communities. The CFPS sample is a multistage equal probability sample extracted by the implicit stratification method that covers 25 provinces/cities/autonomous regions, with the population of the sampled provinces accounting for approximately 95% of the total population of China (excluding Hong Kong, Macao and Taiwan). Based on research needs, Stata 15.0 software was used to clean the tracking data for the 2012, 2014, 2016 and 2018 waves. On the basis of family FID matching, urban families were eliminated, and only rural families were retained; then, observations with missing variable information and discontinuous data across years were eliminated. When the remaining observations were combined into a balanced panel database containing the four waves of tracking data, the final result was a sample of 3659 rural households with four phases of tracking data each. Considering the influence of regional factors on agriculture, we divide the sample into eastern, central and western macro-regions based on the level of economic and social development. The eastern region covers nine provinces and cities: Fujian, Guangdong, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang. The central region covers eight provinces: Anhui, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi and Shanxi. The western region covers eight provinces and autonomous regions: Gansu, Guizhou, Shaanxi, Sichuan, Yunnan, Chongqing, Guangxi and Xinjiang.

## 4. Analysis of Empirical Results

### *4.1. Changes in Household Livelihood Strategies*

From the perspective of the direction of change in farmers' livelihood strategies, most farmers choose to maintain their original livelihood strategies. From 2012 to 2014, 2014 to 2016 and 2016 to 2018, the proportions of households that did not change their livelihood strategies were 52.50%, 58.80% and 56.40%, respectively (Table 3). From 2012 to 2018, the number of agricultural farmers first decreased, then increased and finally decreased again; the number of nonagricultural farmers increased and then decreased before returning to an increasing trend; and the number of part-time farmers initially rose and then declined continuously in the latter waves. On the whole, farmers' livelihood strategies change frequently. In 2014, the number of agricultural farmers increased significantly, while the number of nonagricultural farmers decreased significantly. In 2018, the number of nonagricultural farmers increased significantly, while the number of agricultural and part-time farmers decreased. These trends may be related to the implementation of a targeted poverty alleviation strategy in 2014. The Ministry of Agriculture and Rural Affairs, the Poverty Alleviation Office of The State Council and other departments launched a series of rural industry poverty alleviation projects, enabling some farmers to return to the countryside to start their own businesses, thus significantly increasing the number of agriculture-oriented farmers. However, the entrepreneurial effect brought about by the policy may not have met the expectations of farmers, resulting in a new round of migrant workers and an increasing number of nonagricultural farmers. From the perspective of the speed of change in farmers' livelihood strategies, the adjustment is slow in the short term, which may be due to the strong persistence of livelihood strategies and the accumulation of livelihood results over time, such that the effects associated with the transformation of farmers' livelihood strategies manifest with a certain lag.

To facilitate further research on farmers' livelihood strategies and their relationship with agricultural diversification, based on changes in farmers' livelihood strategy types from the beginning to the end (from 2012 to 2018), we generate a livelihood strategy transition probability matrix and present the changing trend over the five defined types of changes. Table 4 shows the change types (namely, no change from agriculture, no change from part-time agriculture, no change from a nonagricultural strategy, a transition to agriculture and a transition to a nonagricultural strategy) and the proportions of each over time.

**Table 3.** Transition probability matrix of household livelihood strategy changes (2012–2018).

| Time | Livelihood Strategy | Off-Farm Livelihood | | Part-Time Agricultural Livelihood | | Agricultural Livelihood | | Sum | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number | Percentage (%) | Number | Percentage (%) | Number | Percentage (%) | Number | Percentage (%) |
| 2012–2014 | Off-farm livelihood | 735 | 66.34 | 232 | 20.94 | 141 | 12.73 | 1108 | 30.28 |
| | Part-time agricultural livelihood | 336 | 39.72 | 335 | 39.60 | 175 | 20.69 | 846 | 23.12 |
| | Agricultural livelihood | 434 | 25.45 | 419 | 24.57 | 852 | 49.97 | 1705 | 46.60 |
| | Sum | 1505 | 41.13 | 986 | 26.95 | 1168 | 31.92 | 3659 | 100.00 |
| 2014–2016 | Off-farm livelihood | 984 | 65.38 | 311 | 20.66 | 210 | 13.95 | 1505 | 41.13 |
| | Part-time agricultural livelihood | 298 | 30.22 | 433 | 43.91 | 255 | 25.86 | 986 | 26.95 |
| | Agricultural livelihoods | 203 | 17.38 | 230 | 19.69 | 735 | 62.93 | 1168 | 31.92 |
| | Sum | 1485 | 40.58 | 974 | 26.62 | 1200 | 32.80 | 3659 | 100.00 |
| 2016–2018 | Off-farm livelihood | 1082 | 72.86 | 220 | 14.81 | 183 | 12.32 | 1485 | 40.58 |
| | Part-time agricultural livelihood | 476 | 48.87 | 301 | 30.90 | 197 | 20.23 | 974 | 26.62 |
| | Agricultural livelihoods | 315 | 26.25 | 203 | 16.92 | 682 | 56.83 | 1200 | 32.80 |
| | Sum | 1873 | 51.19 | 724 | 19.79 | 1062 | 29.02 | 3659 | 100.00 |

**Table 4.** Types and statistical description of changes in household livelihood strategies.

| Types of Livelihood Strategies | | 2018 | | |
|---|---|---|---|---|
| | | Off-Farm Livelihood | Part-Time Agricultural Livelihood | Agricultural Livelihood |
| 2012 | Off-farm livelihood | 759 | 173 | 176 |
| | | No change in nonagricultural livelihood | Transition towards agricultural livelihood | Transition towards agricultural livelihood |
| | Part-time agricultural livelihood | 463 | 208 | 175 |
| | | Transition towards off-farm livelihoods | No change in part-time agricultural livelihood | Transition towards agricultural livelihood |
| | Agricultural livelihoods | 651 | 3432 | 711 |
| | | Transition towards off-farm livelihoods | Transition towards off-farm livelihoods | No change in agricultural livelihoods |
| Types of change in livelihood strategies | | No change in agricultural livelihood | 711 | 19.43% |
| | | No change in part-time agricultural livelihood | 208 | 5.68% |
| | | No change in nonagricultural livelihood | 759 | 20.74% |
| | | Transition towards agricultural livelihood | 524 | 14.32% |
| | | Transition towards off-farm livelihoods | 1457 | 39.82% |

### *4.2. Impacts of Changes in Household Livelihood Strategies on Agricultural Diversification*

According to Table 5, changes in farmers' livelihood strategies and regional heterogeneity can be explained as follows:

**Table 5.** Parameter estimation of the model.

| Agricultural Diversification Index | Decrease | | | No Change | | |
|---|---|---|---|---|---|---|
| | B | Standard Error | Exp(B) | B | Standard Error | Exp(B) |
| No change in agricultural livelihood | 0.216 | 0.118 | 1.241 | 0.092 | 0.110 | 1.097 |
| No change in part-time agricultural livelihood | 0.622 *** | 0.192 | 1.862 | 0.643 *** | 0.177 | 1.902 |
| No changes in nonagricultural livelihood | −0.262 ** | 0.131 | 0.770 | 0.337 *** | 0.102 | 1.401 |
| Transition towards agricultural livelihood | 0.492 *** | 0.130 | 1.636 | 0.365 *** | 0.121 | 1.441 |
| Transition towards off-farm livelihoods | —— | —— | —— | —— | —— | —— |
| Eastern region | −0.376 *** | 0.107 | 0.686 | 1.115 *** | 0.099 | 3.050 |
| Central region | −0.007 | 0.106 | 0.993 | 1.187 *** | 0.103 | 3.277 |
| Western region | —— | —— | —— | —— | —— | —— |
| Intercept | −0.854 *** | 0.083 | | −1.400 *** | 0.091 | |
| Chi squared | 304.250 | Pseudo $R^2$ | 0.179 | Nagelkerke | 0.191 | |

Note: The *p*-value corresponding to the independent variable is less than 0.05, indicating that the independent variable has an impact on the dependent variable (relative to the comparison term), which indicates that the model is significant. ** and *** in the table represent significance at the levels of 5% and 1%, respectively.

(1) Heterogeneity of household livelihood strategies

There was no significant difference in the agricultural diversification index among farmers who chose to maintain their agricultural livelihood. Compared with those showing an increase in the agricultural diversification index, farmers with a decrease in their agricultural diversification index were more inclined to display a persistent index decrease if they maintained either a part-time or an agriculture-oriented, full-time agricultural livelihood strategy, with these groups 1.862 and 1.636 times more likely to show such a decrease as farmers with nonagricultural-oriented livelihoods, respectively. If the livelihood strategy changes to maintain nonagricultural livelihoods, the agricultural diversification index is more inclined to increase, with this possibility being 0.77 times that of farmers with nonagricultural-oriented livelihoods. Compared with those showing an increase in their agricultural diversification index, farmers with a decrease in their index values are more inclined to see this decrease persist if their livelihood strategies change to part-time agricultural livelihoods or if they maintain a nonagricultural livelihood or an agro-oriented livelihood, with this probability being 1.902, 1.401 and 1.441 times that of the farmers moving towards off-farm livelihoods, respectively.

(2) Regional heterogeneity

With respect to the three regions, the agricultural diversification index in the central region did not statistically significantly differ over time, but that in the eastern region was 0.686 times more likely to increase than that in the western region. Farmers in the eastern and central regions with the same agricultural diversification indices were more likely (by 3.050 times and 3.277 times, respectively) to see their index values persist than farmers in the western regions. This is consistent with the result from Han and Lin's [39] study that China's agricultural diversification index has been relatively stable. Regional differences in agricultural development are one of the important reasons for changes in regional agricultural diversification index values. As agricultural production in the eastern region shifts from traditional subsistence crops to modern high value-added cash crops, the share of these crops in total agricultural output increases and with it the region index of agricultural diversification. However, traditional agriculture continues to occupy a dominant position in the rural western region. To seek higher economic returns, traditional agricultural cultivation in this region has shifted from single to mixed crops. Therefore, the agricultural diversification index in western China is also expected to increase. In addition, the central region has an agricultural resource advantage and development on the basis of large-scale specialized production, with the leading commercial production industry; this leads to both greater agricultural production in the central region and increases in farmers' incomes and improves the competitiveness of regional agricultural products. Thus, the central region is more inclined to see its agricultural diversity index reduced.

### 4.3. The Lag Effect of Household Livelihood Strategy Changes on Agricultural Diversification

Generally, the impact of the independent variable on the dependent variable often manifests with a time lag, and the dependent variable itself is also defined by the dependency of the change in the current period on the selection of the past period. This phenomenon of the dependent variable being affected by past values of itself or of the independent variable is called the hysteresis effect. In line with the above analysis, we further processed the panel data by using the fixed-effect model and Stata's lag function to obtain the first and second lags of the explanatory variables, thus forming three sample sets. The independent variable values from the early stage of each sample set were regressed on the dependent variable values for the current period. Based on the results of multiple rounds of regression, the impacts of changes in farmers' livelihood strategies on agricultural diversification in the current and later periods were obtained (Table 6).

**Table 6.** The lag effect of household livelihood strategy changes on agricultural diversification.

| Variable | No Change in Agricultural Livelihoods | No Change in Part-Time Agricultural Livelihood | No Change in Nonagricultural Livelihood | Transition towards Agricultural Livelihood | Transition towards Off-Farm Livelihoods |
|---|---|---|---|---|---|
| Current period | 0.078 ***<br>(2.63) | 0.161 ***<br>(3.40) | 0.154 ***<br>(4.41) | −0.111 ***<br>(−4.90) | 0.287 ***<br>(22.70) |
| $R^2$ | 0.003 | 0.018 | 0.009 | 0.015 | 0.106 |
| *F* test | 3.26 | 3.28 | 3.59 | 3.07 | 3.39 |
| Number of observations | 2844 | 832 | 3036 | 2096 | 5828 |
| One-period lag | −0.027<br>(−0.87) | −0.099 *<br>(−1.86) | −0.098 ***<br>(−2.77) | −0.068 **<br>(−2.15) | 0.015<br>(0.91) |
| $R^2$ | 0.001 | 0.008 | 0.005 | 0.004 | 0.003 |
| *F* test | 3.52 | 3.58 | 4.15 | 2.88 | 3.21 |
| Number of observations | 2133 | 624 | 2277 | 1572 | 4371 |
| Two-period lag | 0.097 **<br>(2.29) | 0.020<br>(0.25) | −0.142 **<br>(−2.51) | −0.134 ***<br>(−2.73) | 0.139 ***<br>(6.07) |
| $R^2$ | 0.007 | 0.003 | 0.008 | 0.014 | 0.025 |
| *F* test | 2.73 | 3.58 | 2.73 | 2.11 | 2.35 |
| Number of observations | 1422 | 416 | 1518 | 1048 | 2194 |

Note: The numbers in parentheses are *t* values; *, ** and *** represent significance at the levels of 10%, 5% and 1%, respectively.

First, this paper observed the impact of changes in farmers' livelihood strategies on agricultural diversification in the current period. All five types of livelihood strategy changes showed significant effects at the 1% level. In general, livelihood strategy changes had a significant impact on agricultural diversification in the current period, with four of the five types of changes having significant positive effects. Second, this paper observed the impact of livelihood strategy changes on agricultural diversification in the first lagged period. Only three of the five variables were significant, displaying a negative correlation and a decreased significance level relative to that of the baseline results. In general, changes in farmers' livelihood strategies reduced agricultural diversification in this lagged phase to some extent. Finally, we observed the impact of changes in farmers' livelihood strategies at two lag periods. Compared with the results at one lag period, the significance of the explanatory variables increased, and the coefficients of more variables became positive. This indicated that when there was a lag of two periods, the impact of changes in farmers' livelihood strategies on agricultural diversification was enhanced. In general, livelihood strategy changes had a significant impact on agricultural diversification in this period.

In conclusion, changes in household livelihood strategies have a lag effect on agricultural diversification. Specifically, the effect at the first lag is reduced, while the effect at the second lag is significant. From the perspective of impact magnitude, the lagged effect of livelihood strategy changes on agricultural diversification first decreases and then increases. In terms of the direction of influence, the significant positive correlation in the current period changes to a negative correlation in the first lag period but becomes positive again in the second lag period. The main reason for this result may be that most rational farmers choose livelihood strategies based on the livelihood capital they have at present and then diversify their agricultural planting, such that the livelihood strategy decisions of farmers in the current period have a significant contemporaneous impact on agricultural diversification. However, there is strong persistence in farmers' livelihood strategies, and an incomplete or delayed understanding of the livelihood capital available or of agricultural policies prolongs or hinders the process of information transmission, which weakens the positive effect of livelihood strategy changes on agricultural diversification in the first lag period. Over time, this information problem is gradually ameliorated, and farmers' choices on the basis of family endowments and livelihood results become better informed, which tends to increase the positive effect of farmers' livelihood strategy changes on agricultural diversification.

**5. Robustness Test**

Our estimates may be subject to errors from the measurement of the agricultural diversification index with classification variables [40]. For example, from 2012 to 2018, if the agricultural diversification index of one peasant household changed from 0.1 to 0.9 and that of another peasant household changed from 0.1 to 0.2, both households were classified as showing an increase in their index values, but there were significant differences in the agricultural diversification structures of these two peasant households. Therefore, this paper takes the specific value of change in the agricultural diversification index as an independent variable to conduct the regression analysis again.

According to Table 7, the impact on the agricultural diversification index of the same explanatory variable at different quantiles varies greatly. Using farmers who chose a nonagricultural livelihood as the reference group, farmers who chose to maintain an agricultural or a part-time agricultural livelihood had a negative impact on diversification at all quantiles. Quantiles 0.75 and 0.9 showed a significant negative impact, but the impact at quantiles 0.1, 0.25 and 0.5 did not pass the significance test. For farmers who chose to maintain nonagricultural livelihoods, the impact was significant at 0.01 at quantiles 0.1 and 0.9, with the coefficient first decreasing, then increasing, and again decreasing, indicating that when the variation range of the agricultural diversification index reached 0.1, the impact of choosing to maintain a nonagricultural livelihood on the agricultural diversification index reached its maximum. Transitioning towards an agricultural livelihood showed significant negative effects at quantiles 0.1, 0.75 and 0.9 but failed to pass the significance test at quantiles 0.25 and 0.5. Using the western region as the reference item, the eastern region showed a significant effect at the 0.01 level at quantiles 0.1, 0.5, 0.75 and 0.9, with positive effects at quantiles 0.1, 0.75 and 0.9 and a negative effect at quantile 0.5. The central region showed a significant effect at the 0.01 level at quantiles 0.1, 0.5 and 0.9, with positive effects at quantiles 0.1 and 0.9 and a negative effect at quantile 0.5. Therefore, the types of changes in farmers' livelihood strategies and regional factors affected farmers' agricultural diversification levels, with the quantile regression verifying the robustness of the multiple logit model results.

**Table 7.** Quantile regression of the agricultural diversification index on changes in household livelihood strategies.

| Types of Household Livelihood Strategy Changes | *q* = 0.1 Coefficient | *q* = 0.25 Coefficient | *q* = 0.5 Coefficient | *q* = 0.75 Coefficient | *q* = 0.9 Coefficient |
|---|---|---|---|---|---|
| No change in agricultural livelihood | −0.024 (0.029) | −0.000 (0.004) | −0.000 (0.025) | −0.127 *** (0.042) | −0.000 *** (0.000) |
| No change in part-time agricultural livelihood | −0.054 (0.047) | −0.010 (0.006) | −0.000 (0.041) | −0.519 *** (0.067) | −0.055 *** (0.000) |
| No change in nonagricultural livelihood | 0.122 *** (0.029) | 0.000 (0.004) | −0.000 (0.025) | 0.067 (0.041) | 0.000 *** (0.000) |
| Transition towards agricultural livelihood | −0.089 *** (0.033) | −0.000 (0.004) | −0.000 (0.028) | −0.180 *** (0.046) | −0.000 *** (0.000) |
| Transition towards off-farm livelihood | —— | —— | —— | —— | —— |
| Eastern region | 0.164 *** (0.025) | 0.005 (0.003) | −0.106 *** (0.022) | 0.184 *** (0.036) | 0.000 *** (0.000) |
| Central region | 0.077 *** (0.026) | 0.005 (0.004) | −0.106 *** (0.023) | 0.042 (0.037) | 0.000 *** (0.000) |
| Western region | —— | —— | —— | —— | —— |
| Mean absolute error (MAE) | 0.521 | 0.381 | 0.377 | 0.559 | 0.746 |

Note: Robust standard errors in parentheses; *** represent significance at the levels of 1%.

## 6. Discussion

Although different types of livelihood strategy changes have different impacts on agricultural diversification, it is worth further considering whether agricultural diversification truly meets farmers' expectations and improves farmers' production efficiency. Existing studies have found that China's agricultural production has an obvious labor-saving tendency [41] and that agricultural diversification is not conducive to the improvement of farmers' livelihoods. Chinese agriculture is trending towards large-scale and specialized development; however, if farmers' management ability is deficient, a strategy of agricultural diversification will inevitably lead to deviation from optimal factor allocation, resulting in losses of production efficiency. This means that when the diversification of planting is at a low level, farmers can neither improve the production efficiency of a single crop through specialized production nor leverage the economic advantages of a range of crops through mixed management, giving rise to a dilemma between specialization and diversification and leading to an overall efficiency loss. Under rationalized management, agricultural diversification positively impacts agricultural technical efficiency, agricultural resource use and environmental outcomes [42]. Agricultural policy departments should try their best to provide farmers with agricultural information and credit support and actively assist those who choose to maintain nonagricultural livelihoods in carrying out crop diversification.

The development of world agriculture has tended towards greater intensiveness, specialization, scale and mechanization [43,44]. China's agricultural development is no exception, and it is necessary to encourage the development of intermediate-scale agricultural operations on the premise of maintaining an appropriate level of diversification [45]. To develop agricultural operations at this scale, farmers' livelihood strategies must be correspondingly adjusted, investment in the agricultural industry in rural areas should be increased, agricultural industry projects should be invigorated, agricultural industrialization should be promoted, the quality and stock of rural capital should be strengthened and farmers should be guided in adjusting their livelihoods in an orderly way. Second, farmers should be encouraged to participate in land circulation by shifting peasant household land management rights toward large circulation cultivation, expanding new agricultural management bodies, promoting mechanization and agricultural production and operation at a moderate scale, liberating farmers from small-scale peasant production and encouraging farmers to transition towards nonagricultural livelihoods that can improve their livelihood results. Finally, farmers' ability to shift to a nonagricultural livelihood strategy should be enhanced. Vocational skills training should be strengthened for farmers, livelihood skills should be improved and diversified employment opportunities should be increased.

The influence of livelihood strategy changes on agricultural diversification in China can be used as a reference for developing countries. First, the pull effect of industrialization and urbanization on the rural surplus labor force is the premise of the change in farmers' livelihood strategies [46]. Therefore, developing countries should also focus on coordinating industrial restructuring and urbanization and making the forward guidance on changes in livelihood strategies in the process of farmers' transfer. Second, land circulation is one type of natural capital used to realize farmers' livelihood. By encouraging land operation and circulation, natural capital can be optimized and the land circulation system can be improved to provide land policy guarantees for farmers' livelihood transformations. Third, the government should promote the development of rural finance, increase the support of financial institutions for farmers through formal channels, encourage financial institutions to conduct innovative research on rural mortgage products and improve the financing capacity of farmers. Only when the livelihood problems of farmers are solved can the livelihood strategies of farmers be transformed. The transformations of farmers' livelihood strategies enable moderate-scale operations in agricultural development, which can improve the specialization and mechanization of agriculture.

The farmers who earn CNY 3676~10,000 per year from agricultural enterprise are defined as "moderate scale" in this study. According to the case study of Henan province in China, the moderate scale of grain planting is 2.85~4.44 ha. If agricultural workers are hired, the size can be up to 8.87 ha [47]. Other studies have proposed moderate-scale standards, such as 1.34~3.35 ha [48], 3.35~4.69 ha [49], 0.67~6.7 ha [50]. It is about 2.01~4.02 ha in the south and 4.02~8.04 ha in the north [51], 6.7 ha [52] and 9.65 ha [53]. Therefore, moderate scale is a relative concept.

Based on data from the China Household Tracking Survey, the Herfindahl index was adopted to measure agricultural diversification. However, in this paper, agricultural diversification products were divided into the categories of agricultural and forestry products, as well as livestock and aquatic products. Data limitations may have caused relatively large internal differences in the values of the agricultural diversification index, affecting the classification of agricultural diversification in later periods and further improvements to the index are thus needed in future studies. In addition, both farmers' livelihood strategy changes and agricultural development are affected by agricultural policies, but in this study, given restricted data availability, the model did not consider how agricultural policies in different periods and regions shaped changes in farmers' livelihood strategies and affected agricultural diversification, which should be considered in future studies. The choice between macro-data and micro-data was a dilemma. Although macro-data were relatively easy to obtain, they could not deeply explain the internal mechanism of the impacts on agricultural diversification resulting from changes in farmers' livelihood strategies; additionally, the impacts on agricultural planting resulting from changes in farmers' livelihood strategies should be studied with more micro-data. CFPS is a national, large-scale and multidisciplinary social micro-tracking survey with a sample size of 16,000 households, including the livelihood change module of farmers and their agricultural operation conditions, which thoroughly meet the needs of this study.

## 7. Conclusions

Based on four waves of CFPS tracking data, a Markov transition probability matrix was used to explore farmers' livelihood strategy changes, and a multivariate logit model and a fixed-effect model were built. The impact of farmer livelihood strategy changes on agricultural diversification and the hysteresis effect were examined in the empirical analysis. The results showed that (1) farmers' livelihood strategy decisions were strongly persistent. Regarding the speed of change, the adjustment of livelihood strategies was slow, with most farmers choosing to maintain their original livelihood strategy in the short term. (2) Different types of livelihood strategy changes had different impacts on agricultural diversification. Compared with households showing an increase in their agricultural diversification index, households showing a decrease in the index were more inclined to show a persistent decrease if they chose to maintain a part-time or full-time agriculture-oriented livelihood. If households chose to maintain nonagricultural livelihoods, the agricultural diversification index tended to increase. Households with unchanged agricultural diversification index values were more inclined to remain persistently unchanged in these values if they chose to maintain a part-time, agro-oriented livelihood or nonagricultural livelihood. (3) The impact of livelihood strategy changes on agricultural diversification showed regional heterogeneity. Compared with households showing an increase in their agricultural diversification index, farmers in the central region with a decreased agricultural diversification index showed no statistically significant change, but that of farmers in the eastern region tended to increase. Farmers in the eastern and central regions with an unchanged agricultural diversification index were more inclined to show persistent stasis. (4) The effect of household livelihood strategy changes on agricultural diversification manifested with a lag. This impact decreased at a lag of one period but significantly increased at a lag of two periods. From the perspective of impact magnitude, the lagged effect of livelihood strategy changes on agricultural diversification first decreased and then increased. In terms of the direction of influence, the significant positive correlation in the current period changed to a negative correlation in the lag period but again became positive in the second lag period.

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# Maintaining Agricultural Production by Building Local Distribution Systems in the Northern Area of Japan

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**Abstract:** In the field of vegetable farming, it has become a common approach for farmers to advance into the secondary and tertiary industries to increase their income, an initiative known as the sixth industrialization. Under these circumstances, a growing trend is to outsource a part of the sixth industrialization activities in order to improve consumer satisfaction, strengthen market competitiveness, and avoid investment risks. However, owing to a mismatch between farmers and processors, there are few cases that result in collaboration. Under such circumstances, a new distribution channel called local distribution systems have been born, and its importance is increasing in Japan. This paper demonstrates how a local distribution system for farmers living in rural areas could address this distortion. The concept of local distribution systems has been used since the 1990s, and yet, its significance and importance are still increasing in relevancy in today's Japanese agriculture. In this study, the subject is an intermediary (Company A) that originated from farmers, so it was able to understand the behavioral principles of farmers and to identify businesses that could not be covered by the management resources of farmers themselves. Through the entrustment of the business, company A could support the production and sales activities of the farmers. The following conclusions were drawn: (1) the company does not directly involve members in the decision-making of sales methods but instead provides a number of options for decision-making, and (2) the needs on the production side will match those on the consumer side and play the role of communication. By building such a collaboration system, the company succeeded in establishing a local distribution system. In the distribution of vegetables, which is characterized as perishable items, it is essential to pursue efficiency and rationality through a wholesale market system to distribute the products from producers to a large number of consumers. However, constraints in the wholes system limit the extent to which this local distribution functions. This paper demonstrates how a local distribution system for farmers living in rural areas could address this distortion. The concept of local distribution systems has been used since the 1990s, yet its significance and importance are still increasing in relevancy in today's Japanese agriculture.

**Keywords:** local food system; vegetable production; commitment; cooperative relationship

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## 1. Introduction

### 1.1. The State of Japanese Agricultural Production

Agriculture in Japan has been facing increasing difficulties due to demographic changes in the farmer population and also general changes in the agricultural system. First, the number of agricultural producers is declining. According to statistics reported by the Ministry of Agriculture, Forestry, and Fisheries of Japan (JMAFF), the percentage of farmers aged 65 years or older clearly shows a steadily increasing trend (Table 1); the Japanese farming population shrank by 51.9 percent from 5.4 million in 1985 to 2.6 million in 2010, and over this 25-year period, the number of "senior" farmers (65 years old or older) increased from 1.4 million to 1.6 million. This indicates a dire situation that the agricultural industry is facing compared with other industries. For example, the number of industrial workers has increased by 270,000 in the 10 years since 2012 due to the return from overseas expansion following the depreciation of the yen. However, Japan, as a whole, has been coping with the declining birthrate and progressive population aging, leading to the prospect that food demand will shrink significantly in the future.

**Table 1.** Numbers of all farmers and older farmers aged ≥65 years.

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|
| All farmers (Unit: 1000) | 4819 | 4140 | 3891 | 3353 | 2606 | 1757 | 1404 |
| Older farmers aged ≥65 years (Unit: 1000) | 1597 | 1800 | 2058 | 1951 | 1605 | 1140 | 979 |
| (Unit: %) | 33.1% | 43.5% | 52.9% | 58.2% | 61.6% | 64.8% | 69.7% |

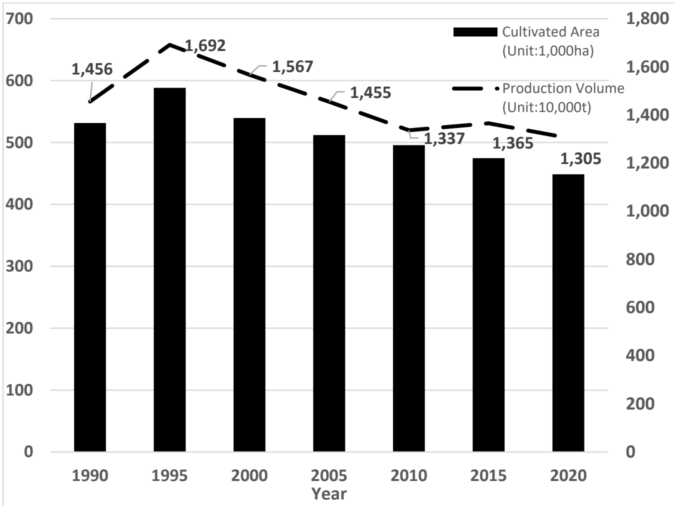
Source: JMAFF Statistics. Note: "Farmers" refers to individuals who are engaged mainly in farming.

Secondly, technological innovations such as storage and transportation systems have promoted the globalization of food markets. Along with this, the import of inexpensive agricultural products from overseas has grown, whereas the prices of domestic agricultural products have remained sluggish over the long term. Thirdly, a deterioration of the production environment has been observed. The influence of abnormal weather, such as torrential rainfall and long-term drought, as well as damage caused by wildlife including monkeys and wild boars, is expanding and having detrimental effects on producers.

### *1.2. The Current State of Vegetable Production in Japan*

Regarding the production of vegetables, there has been a long-term declining trend in Japan, characterized by increased import volumes from overseas. The structure of vegetable production has, over the years, undergone some changes driven largely by several factors: (1) domestic consumption of vegetables is decreasing, especially among young people; (2) domestic productivity has declined with the aging of vegetable producers and a decrease in arable land area. In addition, the prices of imported products are lowered because of the appreciation of the yen against the dollar and transportation technology innovation such as aviation and maritime transport.

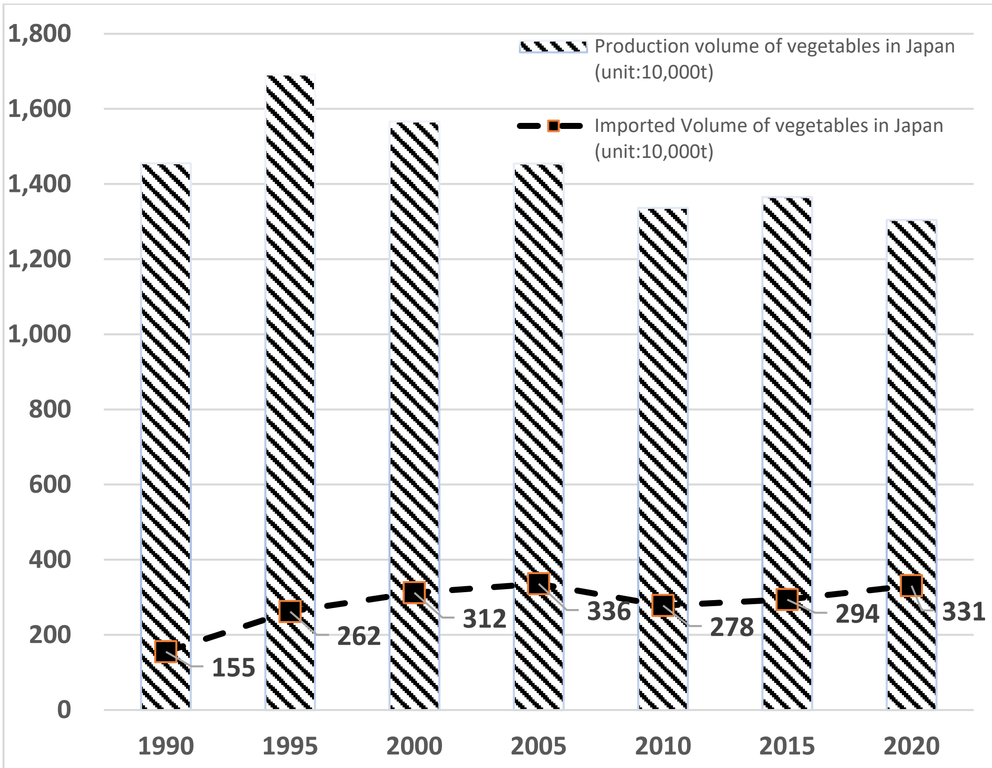
Japan has been witnessing a steady decline in the area under cultivation for vegetables. Figure 1 shows the trends in the cultivated area and the production volume of vegetables from 1990 to 2020. The cultivated area has shown a consistently decreasing trend since 1995 (approximately 500,000 ha) but has remained flat in recent years (approximately 430,000 ha in 2020). The production volume decreased from 14.5 million tons in 1990 to 13.0 million tons in 2020, showing a decrease of nearly 10% over the past 30 years.




Source: JMAFF Statistics.

**Figure 1.** Trends in cultivated area and production volume of vegetables in Japan.

Figure 2 shows the trends in the import volume of vegetables including processed goods. In 1980, the volume of vegetables imported to Japan from overseas was 280,000 tons; it increased to 1,550,000 tons in 1990, 2,620,000 tons in 1995, and 3,310,000 tons in 2020.




Source: Agriculture and Livestock Industries Corporation of Japan (JALIC) Statistics.

**Figure 2.** Trends in import volume of vegetables including processed goods.

China had been steadily expanding its vegetable export volume to Japan up until 2007 when a poisoning incident involving frozen dumplings occurred and slowed the rate of vegetable export from China. This incident led to distrust and doubt among Japanese consumers regarding the wholesomeness and safety of Chinese food products. The influence was apparent; the import volume of vegetables from China decreased by 40%

in February 2008 compared to 25% in the same period in the preceding year and by 25% in the entire year, 2008.

Figure 3 shows an outline of the main vegetable distribution routes. The thickest arrows represent the flow of distribution from vegetable producers to shipping associations (e.g., agricultural cooperatives) and wholesale markets, where trading is done. Currently, the flow through wholesale markets is on a long-term downward trend. Nonetheless, the flow through wholesale markets accounts for approximately 70% of all distributions, suggesting that the main distribution routes of vegetables still pass through wholesale markets. The reason why wholesale markets play such a prominent role in vegetable distribution is because they have a collection function (i.e., various products are gathered from all over the country and distributed to customers) as well as a settlement function for fee collection.

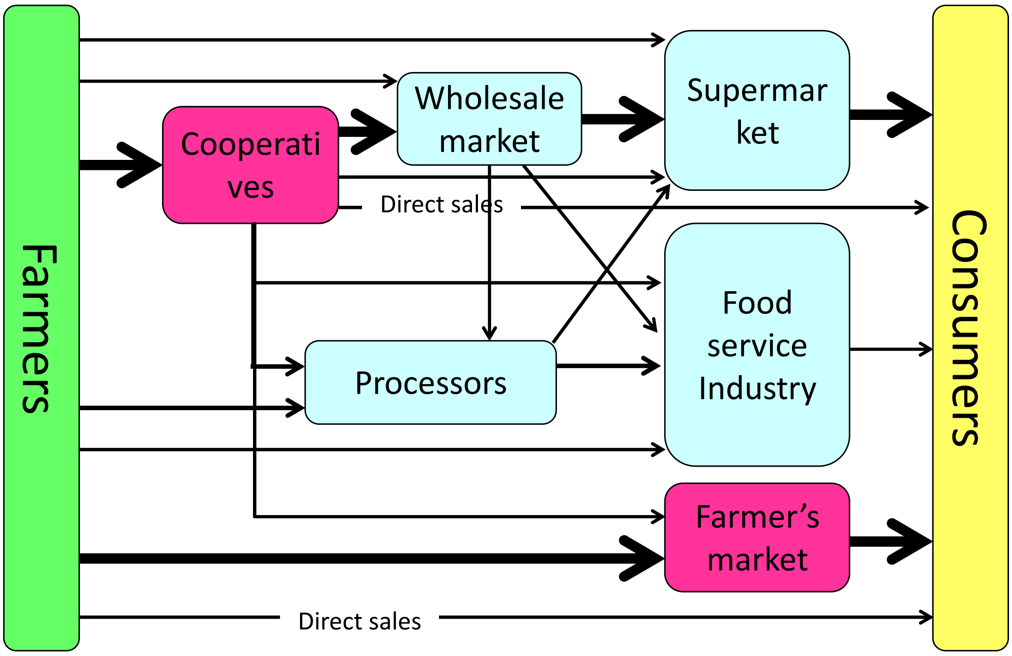



**Figure 3.** Main vegetable distribution routes in Japan. Source: JALIC Statistics.

The number of vegetable producers who do not go through wholesale mostly ship their products directly to processors or to end-users in the food service industry. In addition, a more recent trend is for vegetable producers to bring in and sell their products directly to direct sellers in farmers' markets.

There is also an indirect path via mediating agricultural cooperatives and processors. They seek producers who can supply the products as long as possible in order to ensure the annual supply of vegetables. Because an annual supply system is difficult to establish for vegetables, they adopt measures such as inter-production systems that take advantage of their own network. In addition, if there are missing products as a result of various conditions such as natural phenomena, they will depend on vegetables purchased from wholesale markets or imports from overseas.

Agriculture in the Tohoku region is centered on paddy field agriculture; arable crops such as wheat and soybean are now being promoted. In 2019, the area of paddy fields in the Tohoku region was approximately 600,000 ha, accounting for about a quarter of the total area of paddy fields in Japan. In addition, the Tohoku region has approximately 830,000 ha of arable land, of which approximately three-fourths are used as paddy fields. There were roughly 250,000 agricultural companies in 2015, showing a 21% decrease over a 5-year period from 2010. Rice was the main crop. It is known that the proportion of farmers who cultivate only rice is particularly high in the region (59% in the Tohoku region, 77% in

Akita Prefecture). There are approximately 10,000 companies with 10 ha of land or more (an increase of 18.9% over 5 years from 2010), accounting for roughly 5% of the total.

For vegetable producers contracting with processors and the food service industry, one of the benefits is that their cultivation is not restricted by weight-based transaction standards [1]. Rather, it is transformed into weight-oriented cultivation. Moreover, transaction prices are usually determined every half a year, so they are less susceptible to price fluctuations due to unseasonable weather conditions.

On the other hand, contract cultivation can be difficult in situations where the shortage of items is not allowed. Because the needs of customers must be met by ensuring the supply of products at a "fixed time, fixed amount, fixed price, and fixed quality," the correspondence becomes important. The producer side is required to provide the ordered quantity at the price predetermined according to the quantity within the delivery date. However, agricultural production is unstable because it is affected by natural phenomena and climate change. Therefore, as a way to deal with the shortage of products, producers cultivate approximately 1.5 times more than the usual amount to avoid risks. Even so, if a shortage occurs, the producers must resort to purchasing the products at a wholesale market for shipment.

*1.3. The Current State of Agricultural Production in the Northern Part of Japan*

Located in the northeastern part of Japan, the Tohoku region consists of six prefectures: Aomori, Iwate, Miyagi, Akita, Yamagata, and Fukushima (Figure 4). These six prefectures take up roughly 30% of the country's land area, and their combined population accounts for about 7% of the entire country's population. In addition, many of these prefectures are located around the 40th parallel north, have an annual average temperature approximately five degrees lower than that in Tokyo, and have characteristically heavy snowfall in winter.

**Figure 4.** Location of the Tohoku region in Japan.

In the Tohoku region, the past 10 years has seen a growing gap between the east and west sides. The eastern part of Tohoku, which was severely damaged by the 2011 Great East Japan Earthquake and subsequent tsunami and nuclear disaster, has undergone a major transformation in the reconstruction process. Specifically, agricultural companies with more than 100 ha of paddy farming fields have emerged; these companies have achieved stable management by introducing various innovative advanced technologies and expanded their scale of operation.

On the other hand, having suffered little damage from the disaster, the agricultural structure in the western region has remained highly dependent on rice cultivation, of which the growing season is from spring to autumn. Despite attempts to move away from rice-dependent agriculture since the 1980s, farmers in the area have not been able to transition away from the monoculture/part-time rice farming structure [2].

As the demand for rice in Japan continues to decline, the impact of falling prices has become a major opportunity to break away from rice-dependent agriculture. Demand for rice in Japan in 2019/20 was 7.14 million tons; five years ago, in 2015/16, it was 7.66 million tons. The rate of decline was 100,000 tons per year, showing an increase from 80,000 tons per year in the first half of the 2010s.

A decline in rice prices directly leads to a decline in income for those with a rice cultivation-dependent production structure. The selling price of rice in Japan has been on a long-term downward trend, averaging 17,171 yen per 60 kg in 2001, 15,215 yen in 2011, and 14,963 yen in 2021. The rate of decline in rice prices has slowed in recent years, but there is no sign of a turnaround.

This decline in rice demand and price, however, is a trend that has been observed in Japan since the 1980s. In particular, the liberalization of rice distribution in the latter half of the 1980s has led to a significant decline in agricultural income due to declined rice prices. Yet, opportunities for side jobs are unstable, and wage levels remain low compared with other regions. Moreover, in recent years, significant reductions in public work projects continue, decreasing further the opportunities for farmers to work outside the agricultural sector.

In the western part of the Tohoku region, where agriculture has been maintained by monoculture (rice) farming, not only the number of farmers but also the population in the region continues to decrease. This has raised concerns about the increasing burden of maintaining and managing the infrastructure in daily life and community functions. In addition, there also arise problems related to the fragility of conservation and management of local resources such as farm roads and drainage channels, which have traditionally been maintained through unpaid labor mainly provided by farmers. A decrease in the number of farmers means a decrease in the number of people responsible for these maintenance activities, and reduced local resources related to this particular agricultural production will lead to a further decline in agricultural income, resulting in a negative spiral.

The predominance of rice cultivation in agriculture has continued to decline. The food law enacted in 1995 and the revision of the law in 2004 further liberalized the distribution of rice, while demand for rice declined at a pace of more than 80,000 tons per year; rice prices continued to follow the downward trend in tandem with this. Under such circumstances, some farmers have begun to grow away from rice farming and start working on vegetable production. The farmers that have been linked to agricultural cooperatives are trying to shift their management styles towards local direct sales via farmers' markets, and the direct sales are equipped with functions to support this conversion.

The guidance and technical development led by the government and JA on the production, shipment, and coordination of new core vegetables in the region are often targeted at large-scale, full-time farmers and agricultural companies that are premised on mechanization. Therefore, vegetable producers such as female and elderly farmers who grow a variety of vegetables in small amounts cannot enter this business model and are thus required to explore their own sales channel. There are cases in which small-lot, multi-item vegetable farmers build new distribution channels in order to sell agricultural products to local consumers, going beyond the framework of conventional local distribution systems such as farmers' markets.

## 2. Theoretical Framework and Research Question

### *2.1. Research Area*

Many researchers have focused on the rice cultivation-dependent agricultural structure since the 1970s. In particular, the promotion of vegetable production as a response to the rice acreage reduction policy introduced in the 1970s has attracted much attention. Later, with the establishment of agricultural machinery cooperatives in the Tohoku region, the introduction of vegetable farming was promoted as a measure to utilize the surplus labor force resulting from the widespread use of machinery. However, until 2000, rice prices remained relatively high, and due to constraints, such as being far away from high consumption areas (e.g., Tokyo, Osaka), the promotion of vegetable production did not appear to be effective.

Since 2000, with a continuous downward trend in rice prices, the following changes in the distribution environment surrounding vegetables have been observed.

(1) The sophistication of logistics technology and progress in freshness preservation technology. It has become possible to produce vegetables even in areas far from Tokyo and Osaka, for example, in the Kyushu and Hokkaido regions.

(2) Farmers' markets have become an important sales channel for vegetables. Agricultural direct sales stores, where producers themselves determine prices and sell their products, have undergone a unique evolution in Japan.

(3) The predominance of rice cultivation in agriculture has continued to decline. The food law enacted in 1995 and the revision of the law in 2004 further liberalized the distribution of rice, while demand for rice declined at a pace of more than 80,000 tons per year; rice prices continued to follow the downward trend in tandem with this.

### *2.2. Research Question*

The market distribution rate of domestic vegetables remains over 70% (in 2018: 79.2%), and wholesale markets are still the main distribution channel today, although the distribution rate is decreasing year by year. It has long been pointed out that the price-setting function of wholesale markets has weakened.

Against this backdrop, the following two points have become clear. First, agricultural companies need to make management decisions such as "where and how to sell agricultural products"; mass retailers including supermarkets want to procure domestic raw materials and ingredients in a stable manner [3]. Secondly, the presence of local distribution systems, such as farmers' markets, has become a key component among many options for selling agricultural products [4]. In particular, traditional agricultural companies that have been linked to agricultural cooperatives are trying to shift their management styles towards local direct sales via farmers' markets, and the direct sales are equipped with functions to support this conversion.

In addition, female and elderly farmers who cultivate a wide variety of products in small quantities need a sales channel in place of the market distribution channel that has stringent standards and requires a stable supply. Under such circumstances, new sales channels are being constructed through which local farmers can sell agricultural products to local consumers. In the current distribution system, agricultural products produced in rural areas are collected in urban areas, returned to the rural areas again, and sold at local retail stores. However, with the aim of maintaining agriculture in local areas, some local farmers managed to build new collection systems and sales channels to bring back various profits that flow out to urban areas.

In this paper, "local distribution areas" refer to regions where agricultural products cultivated by farmers in the fields can be delivered to consumers within one day through distribution channels, which are defined as "local distribution systems." These systems may be built by farmers themselves to help maintain small-scale production and part-time farmers who cultivate a wide variety of vegetables in small quantities.

In response to this situation, there are cases where farmers in the Tohoku region themselves construct new local distribution systems, return various profits that flow out to Tokyo, and aim to maintain regional agriculture. Our research question is to clarify the role of the local distribution system built by farmers and contributing to the maintenance of production by small, elderly, and part-time farmers who produce a large variety of vegetables in small quantities, as well as the securing of sales channels for large-scale full-time farmers.

### *2.3. Research Methods*

In the local distribution system, the main path comprises sales at farmers' markets and shop-in-shop sales at local supermarkets. The system promotes new value, such as local production for local consumption, and facilitates face-to-face relationships among farmers. On the other hand, several problems inherent to the local distribution system have been pointed out. For example, farmers may cancel their contracts with local mass retailers if wholesale market prices rise even for a short period of time, and mass retailers cannot conclude contracts because they cannot convey the merits of contracts to the farmers [5]. In addition, farmers are required to plant in amounts that exceed the amount specified in the contract in order to avoid production fluctuation risk.

To address these issues, the operators of farmers' markets and shop-in-shops at local supermarkets should play a role in building and maintaining continuous relationships with farmers, mass retailers (e.g., supermarkets), and consumers [6]. The continuation of relationships and actions between organizations (including individuals) is explained by the concept of "commitment" in organizational theory, especially micro-organization theory.

The data used for analysis were obtained from multiple interview surveys conducted with Mr. and Mrs. B from July 2021 to November 2022. In particular, through interview surveys, how they gain the trust of members and other questions were analyzed through qualitative data using micro-organization theory. There are almost no farmers working on such local distribution, not only in the Tohoku region but also in Japan as a whole. Therefore, this research is not a comparative study between cases but an analysis of rare cases and an extraction of necessary elements for future benchmarks.

In micro-organization theory, "commitment" is interpreted as "being continuously involved in responsible events and things" [7]. Elucidating the process by which members of an organization and stakeholders "understand" the meaning of events and continue to do so is the most important aspect according to this theory.

This "commitment" process can be divided into three stages. The first stage is "sensing." When a new environmental change is brought about by an individual or an organization's actions, we "sense" the change and move on to the second stage of "interpretation," that is, we "interpret" the change on the basis of objective information and accurate analysis. The method differs depending on the individual or organization, and, therefore, it is extremely important to align interpretations with farmers. In other words, an organization is required to select a specific interpretation from a variety of interpretations. By doing so, the third stage, "action," will be continuously performed.

In Akita Prefecture, farmer's income from side jobs was low because of the unstable nature of these jobs, whereas income from agriculture, especially rice farming, was high. Projects such as Akita Prefecture's vegetable mega-complex development project, which aims to develop highly market-competitive vegetable production areas with a market distribution system, have been promoted under the leadership of the government, agricultural cooperatives of Japan (JA), and commerce associations.

However, the guidance and technical development led by the government and JA on the production, shipment, and coordination of new core vegetables in the region are often targeted at large-scale, full-time farmers and agricultural companies that are premised on mechanization. Therefore, vegetable producers such as female and elderly farmers who grow a variety of vegetables in small amounts cannot enter this business model and are thus required to explore their own sales channel. There are cases in which small-lot, multi-item vegetable farmers build new distribution channels in order to sell agricultural products to local consumers, going beyond the framework of conventional local distribution systems such as farmers' markets.

In Section 3, we organize the relationships between vegetable farmers and a company that has been working to build new distribution channels in Akita Prefecture. Based on the commitment theory, our analysis will focus on how the stakeholders' understanding has been enhanced and the continuity of the relationships has been achieved.

*2.4. Emerging Innovative Companies in Agriculture in Japan*

Recently in Japan, farming companies demonstrating a dramatic breakthrough in their development have emerged. Such companies often extend their business activities beyond farming, engaging in other entrepreneurial endeavors including the distribution (i.e., collecting and marketing) of agricultural products, transportation services, food processing, and mail-order and internet sales.

Until recently, research on farm business development in Japan has tended to center on the managerial ability of farm executives (owners or managers). While entrepreneurship with innovation as its central element has been considered the primary engine of economic development, it has distinct meanings for a diverse range of researchers, the establishment of a market, and the creation and management of a business.

In Europe, for instance, researchers have articulated agricultural entrepreneurship with competence of farm managers, organizational capability, policy measures and institutional frameworks. In Japan, where private financing, consulting services, and human resource providers are far less developed than most European countries, farm managers face many challenges and understand the need to figure out alternatives, such as networking with partners. Despite the dearth in research on entrepreneurship, researchers on farm management should delve into agricultural entrepreneurship to better support rising entrepreneurial farm companies.

*2.5. Rokuji-sangyo-ka and Japan's Agricultural Cooperatives (JA)*

*Rokuji-sangyo-ka* means, if translated literally, sixth or hexadic industry/industrialization. The sixth industry is all industries combined or multiplied, i.e., 1 (primary) + 2 (secondary) + 3 (tertiary) = 6, or $1 \times 2 \times 3 = 6$.

Let us first introduce the backdrop against which *Rokuji-sangyo-ka* has emerged in Japan's farming and food sectors. One of many dire problems facing Japanese farming and rural communities is the decline in income and in the rural economy. As consumer demands have diversified, retail sectors are eager to respond by developing new products. This results in increased influence and control over the upstream side of value change, or the primary sector, resulting in lowered prices of products. While the downstream sector may gain more added value, the most critical problem is that primary sector producers, such as farmers, tend to be left out from such benefits. Global competition can exaggerate the pressure to lower product prices. Aging and depopulation of rural communities also contribute to the loss of economic vitality.

In response to this situation, the *Rokuji-sangyo-ka* movement intends to help primary sector producers, i.e., farmers, increase their income by integrating pluri-sectorial business activities. By doing so, farmers are expected to be able to market their products, control prices, gain profits from added value that would otherwise belong to downstream players, increase their income, and contribute to reviving the local economy. *Rokuji-sangyo-ka* business can be instigated in different ways, with one of the most straightforward examples being the initiative of farmers who wish to do processing of their products on their own and market and sell them directly to consumers. With this business model, the farmers could gain more from added value. Another pattern is to start a joint venture with players of other sectors such as processing and retail.

In our previous study, we identified diverse patterns of *Rokuji-sangyo-ka* business development. The first one, which is an ideal and typical pattern of farmer initiatives, demonstrates that *Rokuji-sangyo-ka* can be done by outsourcing processing. The second pattern is a more comprehensive pattern in which farmers incorporate processing and direct sales to retailers and consumers into their business practices. As their businesses grow and sales increase, oftentimes more ingredients are needed. Thus, some farmers doing processing and marketing would build a network of collaborating growers who supply ingredients. Finally, the third pattern demonstrates a more complex business endeavor that incorporates more service-sector oriented businesses, e.g., a vineyard with a restaurant, café, or wedding services.

In the agri-food value chain in Japan, JA Group has been playing vital roles in connecting products of predominantly small-scale farmers to downstream sectors; however, JA Group is now faced with the same problem of lowered product prices.

## 3. Results

Company A, located in Akita Prefecture, cultivates rice and vegetables, which are sold to local supermarkets along with those cultivated by neighboring farmers. This company has five divisions that handle (1) rice production, (2) vegetable production, (3) vegetable processing, (4) vegetable and processed food sales, and (5) consumer cooking experiences.

Based on the concept "a new farmer group that can survive in the 21st century," Company A uses a small distribution system, conducting everything from production to sales and consumption within the region and connecting farmers, supermarkets, and consumers to improve the agricultural income of its members. The company also strives to contribute to the promotion and revitalization of agriculture in the local area and the securing and training of farmers.

### *3.1. Overview of Company A*

In this section, an overview of Company A is provided, which engages in diversified management of paddy rice, vegetables, pickles processing, and sales through husband-and-wife cooperation in response to the needs of local residents in a single rice-cropping area. In particular, how to build a local distribution system is provided for agricultural products and processed products operated shop-in-shop in partnership with a local supermarket.

In 1986, Mr. and Mrs. B, who established Company A, took over the management. At the time, the rice sales environment was deteriorating, and there were many inquiries from neighboring residents about the sale of their paddy fields. In addition, vegetables such as green soybeans, pokeweed, and pumpkin were being introduced as crops for rotation to improve yields and reduce costs. After 1986, they started to cultivate new vegetables (spinach, Japanese mustard spinach, other leafy vegetables, tomatoes, and melons) to strengthen the company's vegetable division. In 1997, Mrs. B participated in an overseas training program for female agricultural creators in Germany, where she learned about green tourism initiatives and efforts to set up a direct sales store to carry out sales activities. This training gave her a hint, and after completing the training, she built the foundation for her current sales method, starting with home delivery and direct sales and then moving on to order sales from nearby hotels.

In 1998, she established an organization for selling vegetables with six female farmers in the area. Until then, she had been selling vegetables directly in a "hand selling" style using light trucks in an attempt to improve and establish door-to-door and home delivery sales. This also involved directly delivering vegetables every Wednesday to elderly people's homes. In order to supply customers with a sufficient assortment of products, she adjusted the types and quantities of vegetables to be delivered each time and reflected those in their planting plans. As a result, the sales volume increased year after year.

In 2005, when opening a local supermarket of vegetables and fruits for local consumers, she proposed and adopted the shop-in-shop method (Figure 5). She initiated the method with 12 female members. In addition to expanding the variety of fresh vegetables used for pickles (10 types of pickles including light pickles and smoked pickles) and boxed lunches, in 2008, she signed a partnership agreement with seven direct marketing companies in the prefecture, aiming to expand the membership inside and outside the region and handling volume of the stores. The number of stores in the prefecture has increased to 16 in 2022.


**Figure 5.** How vegetables and fruits are sold in a supermarket run by Company A.

With increases in the handling volume and number of transactions, opportunities for negotiations with supermarkets also increased. Thus, in 2013, the company was converted into a joint-stock company, which involved a rebuilding of its business management system. In 2017, a food and agriculture educational facility was established, its theme being to create a space where people of all ages can enjoy cooking together while being surrounded by nature in the mountainous areas.

*3.2. Establishment of Local Distribution Systems by Building Cooperative Relationships*

Company A expanded the direct sales networks and home delivery of fruits and vegetables. It also developed a sales network made up of local female farmers, increasing its name recognition mainly among elderly people and consumers. Taking advantage of the local supermarket it had opened, the company started introducing shop-in-shops. Today, it operates 21 shop-in-shops not only in the local area but also in neighboring municipalities, and these shops have been highly evaluated by consumers. The number of members also increased to 185 in 2022 from 12 at the time of its launch.

The sales system of Company A is characterized by the following three points.

1. Development of various shop-in-shop methods. The generally used shop-in-shop method by Company A is to create a purchase plan on the basis of the annual shipping plan submitted by the members (farmers) and matching it with the needs of the store.

Following this, the company delivers vegetables to the store, displays them, and collects consignment fees from the members. Company A customizes shipping, display, and sales methods for each farmer. Specifically, farmers can choose between container shipment and bag-packed shipment methods and select stores to which they sell their products. There are also traditional shop-in-shop consignment sales, and Company A purchases and sells the entire volume to supermarkets. There are many different ways of doing business with farmers.

2. Meticulous sales management and systems to address shortages. Company A has adopted a system in which items that are shipped in large quantities from farmers are purchased and delivered to all stores. In addition, it has devised ways to minimize unsold items, such as transferring products between supermarkets while monitoring sales. Moreover, by analyzing POS data, advice on shipping volumes is provided to each member to prevent food loss and reduce the shortage of hot-selling products. Furthermore, by ensuring the traceability of agricultural products such as the use of fertilizers and pesticides, the cropping situation can be grasped in a centralized manner.
3. Handling of the processed food sector, such as pickles and boxed lunches. Traditional in-store shops have strengths in small-lot, multi-item sales. Company A expanded its pickle and boxed lunch processing divisions. The processing business not only adds value to non-standard products but also allows the company to accurately grasp the needs of consumers who prefer traditional pickles.

By deploying this sales system, the members' sales channels expanded, and their incomes increased. This, in turn, helped the company secure more farmers and diversify production items.

Once a month, Company A holds regular meetings with all members at four venues in the prefecture. During the regular meetings, the secretariat communicates sales data as well as complaints and requests from supermarkets to improve members' sales motivation and foster their sense of responsibility and provides feedback on production and sales. In addition, seminars are held on the latest production/sales techniques and labeling methods to improve cultivation techniques and knowledge. Moreover, all employees conduct voluntary inspections of hygiene management and labeling of processed foods twice a year.

In collaboration with local supermarkets, the company composts food waste and provides the composted materials to create soil in farm fields to support the ecosystem. This initiative has been certified by the government on the basis of the Law Concerning the Promotion of Food Resources, and nine farmers are involved in this initiative.

Finally, in collaboration with consumers, the company actively seeks to utilize local resources, such as by holding tasting events every year. The company has established a food and agriculture education facility in Akita City, where food and agriculture education is offered (e.g., hands-on sausage and dry-cured ham making classes in the winter). In addition to supplying ingredients for school lunches and traditional rice cakes, it regularly holds farm workshops, handmade cooking classes, and sales experience classes for students.

The company provides a place for elderly people and women to play an active role in the community. For example, the above-mentioned food education activities are led by female members who have skills to make traditional local sweets. Such active efforts to create a place for food education is highly evaluated by educators.

## 4. Discussion

In this section, we analyze the relationships of Company A with farmers in light of the commitment theory. As described in the previous section, the basis of a wide variety of business relationships between Company A and farmers is the regular monthly meetings attended by all members. New information, such as sales data, and complaints and requests from supermarkets are shared during these meetings; this generates the driving force for changes in the production and sales environments.

Each farmer “senses” new changes in the information provided on a monthly basis. They move onto the process of “interpretation,” for which an important role is to exchange the information between members and to establish a forum for interaction among farmers of different generations. In addition to the regular meetings, Company A holds events that combine seasonal events, etc., to provide opportunities for the members to exchange information and interact across generations. These events also provide opportunities for veteran farmers to convey the joy and charm of farming to young farmers, and for male and female members of all ages to interact with each other.

Mr. B, the owner of the company, said, “Many farmers are sometimes selfish. We are creating various methods and mechanisms with the motto of being flexible and natural every day.” Occasionally, excessive demands are made by consumers and supermarkets, but in such cases, Mr. and Mrs. B stand at the supermarket and directly appeal to consumers and supermarket staff. They accept and respond to requests from supermarkets and consumers, adhering to the management philosophy, “a new farmer group that can survive in the 21st century.” Moreover, they provide sales destinations that “farmers can choose for themselves.” These activities lead to compatible contributions to the “understanding” of farmers.

The customization of a wide variety of sales methods that cater to individual farmers functions to promote the "understanding" of farmers. For large-scale farmers who produce a limited variety of vegetables in large quantities, Company A purchases products from the collection center and delivers them to each store. For farmers who produce multiple items, the company offers an option to adopt the traditional shop-in-shop style sales method. New farmers who wish to expand their sales channels will be provided an opportunity to negotiate directly with supermarket buyers to select a sales method. These are just a few examples, and each farmer can take a different sales approach. This gives “satisfaction” to each farmer and leads to “action,” the third process of continuous trading.

The local distribution system centered on farmers’ markets is generally faced with the problem of a chronic shortage of sales volume and product lineup due to the aging of the population and the lack of new members. Owing to the efforts of Company A to build a robust organizational structure, the number of young members, both male and female, is increasing, even though they do not specifically engage in recruitment. This initiative by Company A serves as a signpost for intermediaries responsible for agricultural product sales in the system regarding the roles they should play, as agricultural production is carried out by various companies that work hard to maintain agricultural productivity in local areas in Japan.

## 5. Conclusions

In the field of vegetable farming, it has become a common approach for farmers to advance into the secondary and tertiary industries to increase their income, an initiative known as the sixth industrialization. Under these circumstances, a growing trend is to outsource a part of sixth industrialization activities in order to improve consumer satisfaction, strengthen market competitiveness, and avoid investment risks. However, owing to a mismatch between farmers and processors, there are a few cases that end up in collaboration. In this study, it is an intermediary (Company A) that originated from farmers, so it was able to quickly identify businesses that could not be covered by the management resources of farmers themselves, and through the entrustment of the business, company A could support the production and sales activities of the farmers. The following conclusions were drawn: (1) the company does not directly involve members in the decision-making of sales methods but instead provides a number of options for decision-making, and (2) the needs on the production side well match those on the consumer side and play a role in communication.

By building such a collaboration system, the company succeeded in establishing a local distribution system. In the distribution of vegetables, which are characterized as perishable items, it is essential to pursue efficiency and rationality through a wholesale market system to distribute the products from producers to a large number of consumers. However, the limits of the wholesale market system are actually occurring. The case presented in this paper demonstrates how a local distribution system for farmers living in rural areas could address this distortion. The concept of local distribution systems has been used since the 1990s, and yet, its significance and importance are still increasing in relevancy in today's Japanese agriculture.

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Article

# The Transformation of Fishermen's Livelihoods in the Context of a Comprehensive Fishing Ban: A Case Study of Datang Village at the Poyang Lake Region, China

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**Abstract:** How fishermen produce and live has been a hot topic of academic concern in recent years. However, existing research has focused excessively on marine fishermen. Inland fisheries make a significant but often overlooked contribution to rural livelihoods in developing countries. In this paper, we constructed a framework for fishermen's livelihood strategies and used questionnaires and in-depth interviews to study 275 households of inland fishermen in a professional fishing village at Poyang Lake. The results show that (1) the impact of the comprehensive fishing ban has led to significant changes in the livelihood capital of inland fishermen, leading to fishermen being forced to change their livelihood strategies. (2) The current livelihood strategies can be divided into four categories, which are non-fishing employment, self-employment, public welfare positions and retirement respectively. (3) Livelihood capital such as age, education, social interaction and fishing rights influence their choice of livelihood strategies. (4) The fishing ban proposal generally meets the interests of fishermen, but there is some capacity for improvement in terms of implementation details and policy flexibility. Based on these findings, we recommend that the government conducts further in-depth research and adjusts and improves its policy options in good time. To the satisfaction of all parties, the current policy protects the environment and achieves sustainable human development, making Chinese contributions and proposing Chinese plans to address global environmental change.

**Keywords:** livelihood strategies; policy change; inland fishermen; employment conditions

## 1. Introduction

Global environmental change deeply affects marine and terrestrial biodiversity [1] and changes in fisheries policy are shaped by the environment [2–5]. China is the world's largest fishing nation in terms of fishing fleets, the number of people working in the fishing industry and the production of marine fish [6,7]. However, approximately 57% of China's marine fish resources are overexploited. The rapid growth of coastal cities has put enormous pressure on marine ecosystems, resulting in the loss of 80% of coral reefs, 57% of mangroves and over 50% of coastal wetlands, most of which are important spawning, nursing or feeding grounds for fish [8]. To conserve fishery resources, in 1987, the Fisheries Bureau of the Chinese Ministry of Agriculture proposed a "double control" system, which is to control the total number of fishing vessels powered by marine engines and their total engine power [9]. Then, the Chinese government issued policies (vessel buy-back schemes, fuel subsidy reductions, employment assistance funds, etc.) to support fishermen to transfer to other industries, in 2003 and 2015 [10]. The implementation of these policies is a positive response to global environmental change.

As marine fisheries policies continue to be explored and improved, the Chinese government is gradually turning its attention to inland rivers and large lakes. The Yangtze River is one of the richest rivers in the world in terms of aquatic biodiversity and has an important role to play in maintaining China's ecological security. For a long time, the living environment of aquatic organisms in the Yangtze River has been deteriorating due to the impact of overfishing, sand and gravel dredging and beach dredging; the biodiversity index has continued to decline, and the resources of rare and endemic species are in overall decline [11–13]. In recent years, the average annual catch of fishery resources in the Yangtze River has been less than 100,000 tonnes, accounting for only 0.15% of China's total aquatic product production [14].

Against this background, the Chinese government has issued the Opinions on Strengthening the Protection of Aquatic Life in the Yangtze River. It is proposed to promote a ban on fishing in key waters and to scientifically delineate areas where fishing is prohibited and restricted, to accelerate the establishment of a compensation system for fishing bans in key waters of the Yangtze River basin, to guide fishermen in the Yangtze River basin to accelerate their withdrawal from fishing and switch to production, and to provide leadership in achieving a complete ban on fishing in aquatic life reserves. The rest and recuperation system for rivers and lakes should be improved, and a system of closed fishing periods of reasonable duration should be gradually implemented in key waters such as the main streams and important tributaries of the Yangtze River. As of 2020, fishing is to be banned in all of the Yangtze River Basin [15].

China is one of the world's most important fishing nations, but little is known about its inland fisheries. Most of the existing research on fishermen has been focused on marine fishermen [6,16–19]. Fishermen in this study refer to workers living in inland lakes and riverine areas who are engaged in fish production as their main occupation, excluding marine fishermen who work part-time or engage in distant-water fishing [20]. Studies have been conducted on the make-up, classification and management of inland fishers and fishing rights. Any fishery is made up of three components: the environment, the fish and the human [21]. Fishermen can be divided into broad groups depending on their purpose and how they use the resource, such as food fishermen, recreational fishermen and other stakeholders [22]. The fisherman is situated in a complex network of social, financial, ecological and administrative influences that govern his life [23]. The most discussed issue is management and legislation. They address but are not limited to policies supporting Agenda 21, the Convention on Biological Diversity, FAO Code of Conduct for Responsible Fisheries, UNESCO Convention and Ramsar Convention [22]. In the past, the restrictions on fishing were mainly seasonal cultivation, and the 10-year comprehensive fishing ban has now been introduced for the first time in China. In this context, a phased ban on fishing in key waters of the Yangtze River basin was introduced on 1 January 2020 [24]. As an important inland lake in the Yangtze River basin, more than 300 fishing villages and over 100,000 fishermen in the Poyang Lake area have ended their centuries-old way of livelihood [25]. How fishermen produce and live after going ashore has become a hot topic of concern for the community. It is essential and urgent to clarify the livelihood strategies and attitudes of fishermen towards policies in the wake of the fishing ban. However, to date, such studies have been scarce.

The overall objective of this study is to better understand how a comprehensive fishing ban changes the livelihood strategies and human-fishery relations of inland fishers. This target can be further broken down into the following specific questions. (1) What are the characteristics of inland fishermen? What are the impacts of the complete fishing ban on the livelihood capital of fishermen? (2) What are the types of livelihood strategies available after comprehensive fishing bans? (3) What are the main factors affecting the transformation of inland fishermen's livelihoods? (4) What are the attitudes of different livelihood types towards the no-fishing policy?

## 2. Literature Review and Theoretical Framework

### *2.1. Fisheries, Fishermen, and Fishing Villages*

Fishing in inland waters is one of the oldest human practices, and fishing tools have been found among the earliest human remains [22]. Inland fisheries are largely governed by the social and geographical context in which they are located and respond to demographic, economic and policy changes. Accompanying that is the evolving management of fisheries. Attempts at managing inland fisheries are very ancient. They can be traced back to medieval Europe when fishermen were grouped into guilds to manage the exploitation of fishing resources [26]. In France, inland fisheries are managed by controlling landings [27]. In other parts of the world, inland fisheries are largely regulated by local traditional religions. Modern governments have attempted to control inland fisheries by restricting seasons, locations or gear types, and implementing centralized management at the national level [28]. For example, China has had a closed season system in place for many years and a comprehensive fishing ban on the Yangtze River that has been implemented in recent years [29,30].

There have been numerous studies on the Three Rural Issues [1] [31], but little attention has been paid to the special group of fishers, and they are invisible in the shadow of the "three rural" issues [20]. Fishers are people who fish for a livelihood and can be divided into marine fishermen and inland fishers, depending on where they fish. In this study, fishermen mainly refers to inland fishermen. Funge-Smith [32] considers that inland fisheries play an important role in livelihoods and food security. However, whether in Europe or Asia, the problems faced by fishermen are much the same. For example, there is a surplus of labor and difficulties in changing jobs; income growth is slow; fishermen's economic interests and equal rights are not effectively safeguarded and social security is inadequate; and unemployment is an increasingly serious problem due to natural conditions and human policies [33–36].

Fishing villages refer to villages where fishermen live together. The social structure and division of labor in fishing villages are relatively simple, with a low population density and a strong native culture [37]. Compared with urban areas, the contradictions between economic development and resources and environment are more obvious in fishing villages; the construction of infrastructure such as transportation, communication and energy is backward; education, health care and other social security undertakings are relatively lagging behind [38]. These conditions have a significant impact on the livelihood assets of fishermen. This in turn affects the solution to the Three Fisheries Issues [2]. Yu et al. [39] proposed that the Three Fisheries Issues should be adjusted by public policies, and argued that there is a similarity to the Three Rural Issues, reflecting the Three Fisheries Issues characteristics of depleted fishery resources, difficult livelihood of fishermen and the weak economy of fishing villages. From the perspective of subjectivity, the topic of the Three Fisheries Issues is a special subject, which is in reality concerns the transformation of fishermen, i.e., how to conduct transformation of their industrial affiliation, livelihood and identity [20].

### *2.2. Fishermen Livelihood Strategy Framework*

Much research has been done on livelihood strategies and the analytical framework is well developed. The UK Department for International Development's (DFID) sustainable livelihoods framework is the most commonly used for livelihood analysis [40]. This framework has been used by many scholars to study the livelihood strategies of various groups. Mazzone [41] examines the impact of energy use on the diversification of livelihoods in the Brazilian Amazon from two decentralized systems of renewable and non-renewable sources. Su et al. [42] discussed livelihood strategies for tea farmers, and called for building partnerships between tea farmers and tourists to enhance the integration of tea and tourism, promote the participation of local tea farmers and increase incomes, especially for those with low livelihood assets. Based on existing research, Winters et al. [43] developed a framework for analyzing households' livelihood strategies to measure their livelihood assets, activities and outcomes. For this study, the details of these frameworks need to be revised to suit the specific context of fisheries, fishers and fishing villages. However, whether it is the fishermen, the fishing industry or the fishing village, it is not an about individuals but a socio-ecological system [44]. The subsystems of fisheries resources, fisheries management, and fisheries fishing interact with each other in the broad social, political and economic context of the external environment [9]. Most importantly, these mentioned theoretical frameworks provide the knowledge base for the development of a framework for fishermen's livelihood strategies.

Based on the characteristics of fishermen, fisheries and fishing villages, we have developed a framework (Figure 1) for analyzing fishermen's livelihood strategies by combining the sustainable livelihoods framework, the household livelihood strategies and the socio-ecological systems framework [40,43–46]. The framework deliberately highlights policy change factors. Our key goal is to understand the impact of policy change on fishers' transition and livelihood capital.

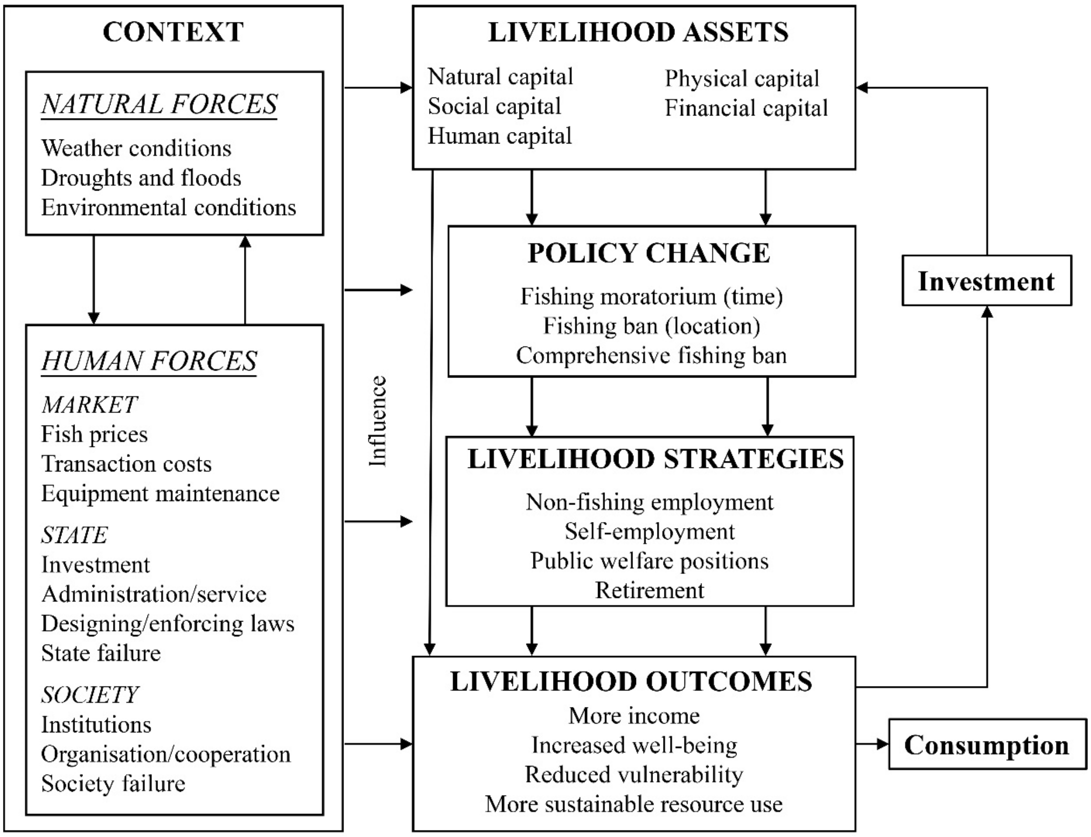


**Figure 1.** Fishermen's livelihood strategy framework (adapted from [40,43–46]).

This framework consists of five sections: context, livelihood capital, policy change, livelihood strategies, and livelihood outcomes. Context refers to the external environment of fishers' livelihoods, which has a direct impact on policies, livelihood capital, strategies, and outcomes. Market prices affect fishermen's willingness to fish and income; government agencies manage fishermen's rights to fish in the waters. Livelihood assets are the resource base of people and include natural, social, human, physical and financial capital. For example, fishermen need fishing boats, nets and shrimp cages to catch fish, etc. The policy changes for inland fishermen refer mainly to the three policy types of a fishing moratorium, fishing ban and comprehensive fishing ban. The two former are mainly about fishing bans at specific times and places, such as fish spawning periods and nature reserves [9]. The comprehensive band does is not allow fishing at any time or location. Livelihood strategies refer to how people choose the best way to achieve their livelihood outcomes in a certain natural and human context, in the face of policy changes, using the livelihood capital they possess, and in their production and business activities, to adapt to the external environment and to improve their livelihood situation [46]. For inland fishermen affected by bans, there are four categories of strategies to choose from, and they are non-fishing employment, self-employment, public welfare positions and retirement [18]. Livelihood outcomes generally are the goals that people achieve through livelihood strategies, such as increased income, increased well-being, more sustainable use of natural resources and reduced vulnerability [47]. Part of these outputs are used for consumption and the rest are further transformed into livelihood assets through investment.

## 3. Materials and Methods

### *3.1. Study Area*

Poyang Lake is a seasonally important lake in the Yangtze River basin, located on the south bank of the middle and lower reaches of the Yangtze River, north of Jiangxi Province [48]. It is the largest freshwater lake in China, with a maximum area of about 4000 square kilometres during periods of high water [49]. According to statistics, there are more than 300 traditional fishing villages in the lake area. More than 20,000 households and over 100,000 people have been fishing for a living for generations.

Datang Village is the largest fishing village in the Poyang Lake area in northern Jiangxi (Figure 2). It is a typical suburban inland fishing village, backed by Lushan Mountain and facing Poyang Lake. Datang Village is a key village in terms of the implementation of the fishing ban in Jiangxi Province, with a land area of 0.3 square kilometres. There are 3 groups of villagers in the village, with 388 households and 1528 people; approximately 90% of the village population make their living by fishing. Of these, 275 households have fishing licenses and support a total of 1218 family members. In addition, there are more than 100 fishermen who fish without a licence.

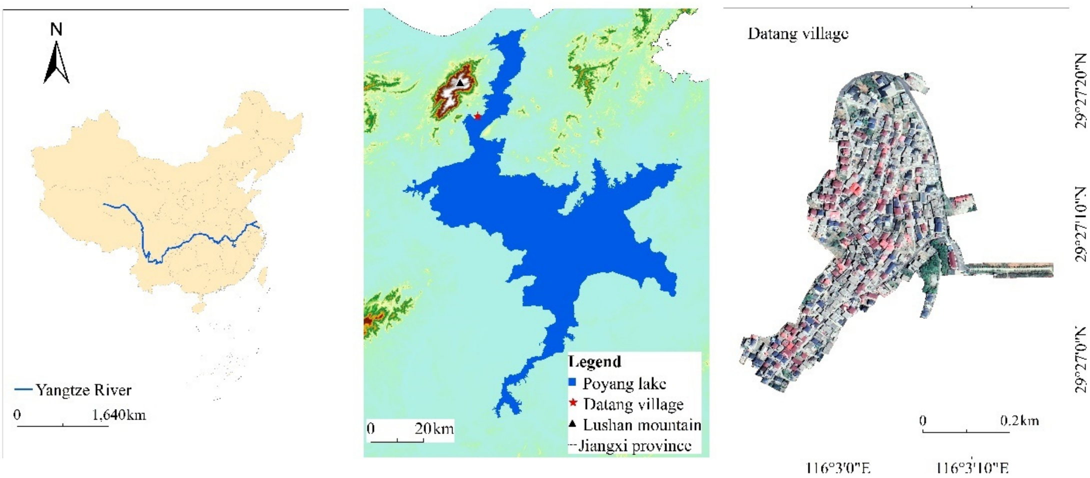


**Figure 2.** Location Map of Datang Village (Source: collated by the author).

### *3.2. Data Collection*

In order to systematically understand the policy background and specific measures of the comprehensive fishing ban, we collected 12 relevant documents and circulars by means of a desktop survey. These documents are mainly issued by governments at both national and local levels. Their main contents cover various aspects such as aquatic life protection, fishing ban notices, compensation schemes, boat and net recovery, retirement protection and employment guidance. Meanwhile, we have also collected several reports and interview articles on the comprehensive fishing ban from authoritative media. These documents allow us to better understand China's policies and regulations on inland fisheries management, as well as the detailed provisions of the comprehensive fishing ban in the Yangtze River basin.

The fieldwork was carried out from March 2020 to July 2022. To explore the changes of fishermen's livelihood strategies and their influencing factors before and after the fishing ban, we conducted field surveys in the Poyang Lake area on three occasions in March 2020, December 2021 and June 2022. The first two of these were pre-studies in which we visited three traditional fishing villages in the Poyang Lake area. During this period, the research questionnaire was designed through participant observation, and typical interviews. In the final study, 275 questionnaires were collected and semi-structured interviews were conducted with eight fishermen who had changed jobs. One household is surveyed per questionnaire and the head of the household is selected for the survey. The questionnaire included information on household demographics, housing, household income and expenditure before and after the fishing ban, social security, boat and net tools, and employment placement. The interviews covered fishermen's attitudes towards the fishing ban policy, difficulties in transitioning their livelihoods, their sense of identity after the transition, and their demands for policy adjustments. Each interview lasted approximately 30 to 60 min and was recorded throughout.

## 4. Result

### *4.1. Statistical Characteristics*

Although fishermen are seen as a part of the farmer category in the context of the larger agricultural concept, there are important differences between fishermen and farmers in terms of production and livelihood [50]. Fishermen and farmers differ in many ways, notably in the lack of the necessary security of means of production and in the clear retirement age; at the same time, fishermen have a high cost of production tools and face a greater crisis of unemployment; In addition, the consequences of disasters are severe [51,52]. According to our surveys, there are 275 licensed fishermen in Datang village (Table 1), with an average age of 45.53. Under the latest fishing ban, fishermen over the age of 60 have the option to retire. A total of 202 fishermen own fishing boats, including 166 steel boats and 36 wooden boats. The average length is 11.78 m, width 2.04 m, load capacity 2.46 tonnes and power 23.88 kilowatts. Based on our interviews, it costs around 50 to 80 thousand RMB to build one of these fishing boats. Compared to other fishing villages, the living conditions of fishermen in Datang Village are relatively good. The average household dwelling area is 239 square metres, with 53.96 square metres per capita, which is higher than the national average [53].

**Table 1.** Statistics on the basic characteristics of fishermen.

| Types | Indicators | Mean | Standard Deviation |
|---|---|---|---|
| Demography | Age | 45.53 | 10.30 |
| | Years of education | 8.19 | 2.43 |
| | Family size | 4.43 | 1.76 |
| | Number of dependents | 0.48 | 0.79 |
| | Number of people raised | 1.26 | 1.10 |
| Boats and gear | Steel boats | 166.00 | / |
| | Wooden boats | 36.00 | / |
| | Length of boat (m) | 11.78 | 1.62 |
| | Width of boat (m) | 2.04 | 0.59 |
| | Power of boat (kw) | 23.88 | 11.79 |
| | Tonnage of boat (t) | 2.46 | 1.30 |
| | Age at disassembly | 5.87 | 2.27 |
| Compensation for fishing ban | Valuation of boat (RMB: thousand yuan) | 26,950.50 | 13,209.80 |
| | Valuation of gear (RMB: thousand yuan) | 6903.61 | 5.67 |
| | Fishing license buyback (RMB: thousand yuan) | 1000.00 | 0 |
| | Transitional Living Allowance (RMB: thousand yuan) | 12,000.00 | 0 |
| | Total compensation for fishing ban (RMB: thousand yuan) | 27,789.07 | 13,697.41 |
| Income and expenses | Household income before the fishing ban (RMB: thousand yuan) | 80,000.00 | 3997.85 |
| | Of which, fishing income (RMB: thousand yuan) | 50,000.00 | 3308.91 |
| | Household expenses before the fishing ban (RMB: thousand yuan) | 40,000.00 | 3742.13 |
| | Household income after the fishing ban (RMB: thousand yuan) | 31,432.73 | 10,375.60 |
| Housing | Size of family housing ($m^2$) | 239.00 | 112.46 |
| | Size of individual housing ($m^2$) | 53.96 | / |
| | Age of housing | 17.99 | 6.57 |

Source: collated by the author.

*4.2. Transformation of Livelihood Strategies*

Of the 275 fishermen households we surveyed, 253 had achieved a livelihood transition (92%). Fishermen in the study area identified four livelihood strategies such as non-fishing employment (LS1), Self-employment (LS2), Public welfare (LS3) and retirement (LS4), respectively.

Figure 3 shows that the largest number of fishermen chose LS1. In terms of age, the majority of them are between 30 and 60 years old (89%); in terms of employment direction, they are mainly working in the tertiary sector (79%); and in terms of education level, most of them were categorized as primary and middle school (92%). One of the most interesting observations is the group of 82 fishermen in livelihood category LS2. Their areas of business are mainly in the tertiary industry too. However, the average level of education of this group of fishermen is higher than that of people who chose LS1. Only eight fishermen chose to take up public welfare positions (LS3); this is because such positions are funded by the village council and their primary purpose is to protect the livelihood of low-income and disabled groups. A group of 10 fishermen have chosen to retire (LS4). They are all over 60 years old, in poor health and with low levels of education, making it difficult to find suitable positions for them in the job market. Therefore, retirement is a good option for them, after a lifetime of hard work.

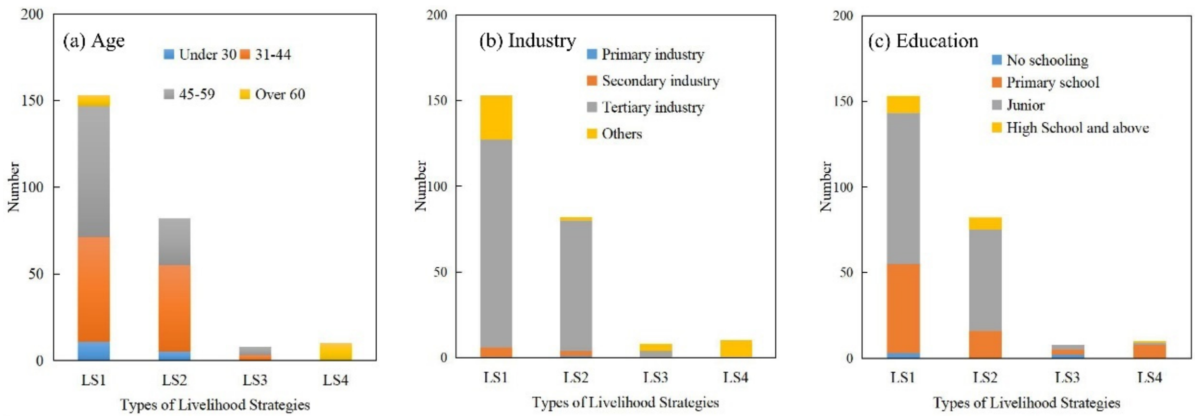


**Figure 3.** Analysis of fishermen's livelihood in relation to (**a**) age, (**b**) industry, and (**c**) education.

*4.3. Factors Influencing the Transformation of Livelihood Strategies*

According to the Fishermen's Livelihood Framework, livelihood capital is the main factor influencing fishermen's livelihood strategies.

Natural capital. The overall natural capital of the fishermen in the Datang village is extremely scarce. Due to its location on the outskirts of the city and facing Poyang Lake, there is almost no available land. After the government issued a fishing ban, fishermen lost their right to fish in Poyang Lake. However, the village is small and there are no freshwater ponds inside it to raise plants and animal resources such as fish, shrimps and shellfish. Fishermen who lost their fishing rights in lake waters, like farmers who lose their land, have particularly few livelihood strategies to choose from, constrained by several factors.

> *We are a professional fishing village, our ancestors have been fishing for generations, and our education level is relatively low. Now that fishing is not allowed, we have no skills, so we have to go out to do odd jobs, work as security guards or something like that, and some of the women have gone to garment factories.* (Interview number: DT01)

Human capital. The fishermen of Datang village are suffering from schistosomiasis (100%) and are in poor health due to the long hours of production and living on the lake. The health of fishermen may be eased and restored when they retire from the lake and are removed from life on the water. However, on a cultural level, the majority of fishermen are educated at the primary or lower secondary level (92%), with only a small number having a high school education or above (7%), and some have not even attended school at all (1%), so overall the level of education is low. Meanwhile, because of their year-round livelihood as fishermen, they have had less contact with the outside world and society, and when they leave their original environment, they easily show fear and anxiety in their psychological condition.

> *I am very grateful to the village committee for giving me a public service position as a cultural manager, as I only have a junior high school education and am not well enough to know what I can do after the fishing ban.* (Interview number: DT03)

Social capital. The social capital held by fishermen in Datang village can be broadly divided into policy capital and family kinship and karma. Policy capital refers to the government's purchase of pension and medical insurance for all men over 60 and women fishermen over 55 years of age. This will allow them to retire with a certain amount of money (under 1000 yuan RMB) per month to make ends meet, just like city workers. Furthermore, all fishermen have medical insurance and if they fall ill, the hospital can reimburse most of their medical bills. Family kinship and karma, on the other hand, play essentially the same role as social capital, giving help to fishermen in need when their livelihoods break down. However, fishermen have relatively simple social networks and therefore social capital is scarce.

> *Our relatives, friends and neighbours are all fishermen and there are no social resources to rely on. Now that fishing is banned, jobs are not so easy to find. But I'm sure I can do it if I work hard, I'm still quite young after all.* (Interview number: DT08)

Financial capital. The main element of financial capital owned by fishermen is expressed in terms of household income. These incomes are mainly derived from stable fishing operations, employment in business, etc. Investment income is largely absent as fishermen are not good at financial investment due to their literacy level limitations. As the market was better in previous years, many fishermen had some family savings, so after the ban, some families chose to start their businesses, but mostly concentrated in the restaurant, accommodation and water transport industries.

> *My family has a boat, and except for the fish spawning period and bad weather, we spend most of the time fishing in the lake, and we can sell fish for money every day when we dock, and we have saved more than 100,000 yuan over the years. Now I have a restaurant, and many tourists come to my house to eat, so business is quite good.* (Interview number: DT06)

Physical capital. For the fishermen of Datang village, their physical capital is mainly their fishing boats, nets and houses. When the fishing was withdrawn, the boat and nets were bought back and dismantled by the government, which gave a certain allowance, but it was much less than the cost of the boat. Previously, the price of fish was relatively high and part of the money earned each year was used to upgrade equipment; most of the rest was used to build houses with 53.96 square metres of housing per person. From the outside, therefore, the houses in the village of Datang are quite wide and beautiful. Now, without boats and nets, sources of income are cut off and livelihoods become unsustainable.

> *Most of the young people have gone out to work, while some women have chosen to work in the clothing factories in and around the village; Working in the garment factory, they can earn more than 2000 yuan a month to supplement their household.* (Interview number: DT01)

*4.4. Emotions, Attitudes and Fishing Bans*

From media reports and our deep interviews, it is possible to identify the emotions experienced by fishermen and their attitudes towards the fishing ban.

By reviewing media reports, we find that fishermen have a deep attachment to their boats, which in their hearts are not just a means of making money, but also their homes. For example, a report from The Paper News reads: The day before signing the withdrawal agreement with the county government, on 29 December 2019, Zhang Qirong (a fisherman) was preoccupied and kept thinking about her fishing boat, after the relevant recovery program had been issued to fishermen, and she estimated that all her fishing gear together was probably worth only about 10,000 yuan. She was a bit upset, saying that it was all she had. *"I have almost nothing but these (boats and nets)"* (News report number: MR200107). This feeling was also deeply felt during our fieldwork, when a fisherman in his 50s said: *Watching my boat being dismantled, I knew it was time to say goodbye to my old life. Life will be better with the help of the government and just regard fishing as a good memory* (Interview number: DT03).

However, are the media reports always true? One news report reads: *I work as a sailor in the park, responsible for visitor safety, and my wife works as a cleaning lady. The two of us together earn 4000 yuan a month, which is similar to, but easier than, fishing in the past!* (News report number: MR200113). In fact, we found in our survey that income after switching jobs was not as much as fishing and varied considerably. For example, when asked about his current income, an employee of a water transport company said: *It's not even close to what fishing used to be, it's just a way to make a living. In the past, if you went fishing, you could earn 1000 to 2000 yuan a day, or a few hundred yuan at worst; Although there indeed is less of it now, I believe it is all temporary, the reform needs a process and the days will get better* (Interview number: DT05).

Human emotions are complicated. As regards Poyang Lake, this water has fed generations of fishermen, and many people have lost their lives here for livelihood, some are grateful for it, some have hated it, but no matter what, they can never leave it.

The fishing ban not only affected the fishermen's emotions but also changed their attitude towards the government to some extent. In the process of retiring the fishermen, the government has given them a certain amount of money for the transition period, some money for buying back their boats and nets, and they have been given insurance. However, one of the fishermen said: *I am 55 years old and will not receive my pension for another five years, and I am still confused about how to spend this period* (Interview number: DT02). *We have always thought that the central government's policy is very good, but it may be that the explanation was not clear enough when it was implemented at the bottom and caused us some misunderstanding* (Interview number: DT07). At a derelict fish processing plant, several fishermen told us that *although he cannot fish in Poyang Lake, he can still raise fish in his fish pond, only with less income. But he believes this is all temporary* (Interview number: DT04).

Regarding plans, many fishermen say they hope the government will build a factory nearby so that they can work without fear; or introduce some jobs that match their skills. The previous employment assistance policy did not work well because the skills needed for the jobs did not match theirs.

## 5. Discussion

*5.1. Characteristics of Inland Fishermen*

Previous studies [39,54] suggested that fisheries, fishermen and fishing villages mainly face problems such as resource depletion, livelihood difficulties and economic weakness. However, in this study, we found that before the fishing ban, the fishing industry in Datang village was economically active, with fishermen earning significant incomes and making a good living. Most of them have used the income from fishing to build bright and spacious houses for their families, with the remaining funds being able to be invested in upgrading their fishing equipment. Consequently, the ban has led to a reduction in the quality of life of the region's fishermen and an increase in their economic vulnerability, upsetting the original balance of life. Therefore, we have to think that it is good to protect the environment, but we face difficulties in formulating and applying policies to ensure that people's living standards do not decline in the process.

We found low levels of educational attainment and poor social mobility among fishers in Datang village, which is largely consistent with the findings of existing research on fisher characteristics [52]. However, it is worth noting that the average age of fishermen in the region is younger and the ageing population is fewer than in other types of agriculture, particularly rice farming [46]. At the same time, before the fishing ban, everyone had almost the same natural capital—the right to fish. The rapid development and changes in the community of Datang village after the fishing ban may lead to an increasing problem of disparity between the rich and the poor.

### *5.2. Main Transfer Paths*

Livelihood strategies of inland fishers differ from those of marine fishers. According to Schultz's [55] labour transfer theory, for marine fishermen, labour transfer pathways can be divided into internal and external industrial transfers. Internal industry transfer refers to the transfer of marine fishermen to related fisheries industries, such as mariculture, fish processing and part-time fishing. External industry transfer refers to the transfer of marine fishermen to industries unrelated to marine fisheries, such as migrant labour and commerce [18]. In this study, however, we found that the industrial transfer paths of inland fishermen were very limited, mainly into secondary and tertiary employment and self-employment. A few fishermen have also chosen to take up public service jobs offered by the village, for example, cultural wardens and road cleaners.

We found that in the traditional professional fishing villages in the Poyang Lake basin, the current ban on fishing has forced them to give up fishing altogether, and even recreational fishing is not allowed. As a result, local fishermen turn to employment in areas not related to the fishing industry. In contrast, this is not the same in other parts of the world. In Brazil, in the Amazon basin, the management of fisheries is limited to specific species. There are also restrictions on the size of fishing boats and nets, which regulate fishing to a certain extent, but do not have much impact on the choice of livelihood strategies of fishermen [56,57]. In the Great Lakes region of the United States, for example, commercial fishing was once the main industry of the lakes. With the decline in biodiversity, only a small amount of commercial fishing still takes place, but the focus of the fishery has shifted to sport fishing. Moreover, for local people, fishing is a way of life that has been passed down from generation to generation, and commercial fishing and subsistence are allowed to preserve their right to livelihood [58].

### *5.3. Shortcomings of the Current Policy*

Every policy has its positives and negatives [59]. In the case of the comprehensive fishing ban policy in the Yangtze River basin, on the one hand, it contributes to the reduction of pollution, the protection of the environment and the enhancement of biodiversity. On the other hand, it has affected the production, life and livelihood of local fishermen. In this study, we found that the policy is not yet adequate and many aspects could be further improved. First, in terms of fishing rights, its legal basis is not sufficient; there is no clear legal regulation on whether the fishing rights of Poyang Lake belong to the state, locality or residents. Furthermore, although the government carried out certain employment assistance activities, such as special job fairs, employment training sessions, job search subsidies and business start-up incentives, their outcomes are not obvious, mainly due to the poor match between the jobs offered by enterprises and the education, skills and needs of retired fishermen. Finally, the medical guarantee for fishermen who have retired from fishing needs some fine tuning. During the survey, we found that all fishermen in the area suffer from schistosomiasis, a chronic disease, but there are no details on the medical subsidies and reimbursement policies for this disease. In general, we found that the majority of fishermen were receptive to the new policies, with only a small percentage expressing an opinion. Through our research, we consider that it will take some time to test the effectiveness of the implementation of the various policy measures.

## 6. Conclusions and Recommendations

This paper is the first qualitative study to examine the transformation of fishers' livelihood strategies, the factors influencing them and their response to policy change scenarios from the perspective of inland fishers' livelihoods after the implementation of a comprehensive fishing ban in the Yangtze River Basin. Based on the findings of the study, we believe that some recommendations can be made in the following areas to help people in the region to choose better livelihoods.

It involves, firstly, enhancing education and training to enhance the human capital of fishermen. For fishermen of various occupations and levels of education, we may provide aquaculture technology training, production skills, vocational skills, management and service levels, and green fisheries development concepts. For fishermen wanting to go out for employment, priority should be given to providing basic vocational skills training and guiding them to move to economically developed areas such as the Yangtze River Delta and the Pearl River Delta for employment.

Moreover, there is potential to develop tourism and other industries based on the state of local resources. A leisure fishing industry may be developed which integrates ornamental, leisure fishing, fishing experience, and fishing culture tourism; several fishing villages may be created with characteristics that connect industry, culture, tourism, production, life, and ecology. For fishermen ready, willing, and able to work across sectors and fields, priority goes to guiding them to re-employment in aquaculture, aquatic product processing, and other related familiar jobs.

Finally, the government should provide good policy protection. For example, financial support may be increased for the diversified development of the fishing industry, supporting the extension of the fishing industry chain, and developing new fishing models. In addition, it is necessary to implement tax incentives to encourage employers to hire many retired fishermen. These policies can include tax exemptions, capital subsidies, and guaranteed loans. Furthermore, a system of support and protection may be establishedfocusing on vulnerable groups of fishermen such as the poor, the elderly, the sick, and those who are "boat-bound" and have no re-employment capacity.

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## Notes

[1] The Three Rural Issues are three issues relating to rural development in mainland China: agriculture, rural areas and farmers. The name "Three Rural Issues" was first coined by economist Wen Tiejun in 1996, and were highlighted by China's top leaders as areas of rural development in China that need work.

[2] Three Fisheries Issues refers to an overall term for the three issues of fisheries, fishermen and fishing villages.

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# Social Capital, Crop Specialization and Rural Industry Development—Taking the Grape Industry in Ningling County of China as an Example

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**Abstract:** Village-level social capital is an important factor to promote rural revitalization, but it is often ignored by existing researches. Based on the field investigation on 357 grape industry villages in Ningling County of Henan Province, decomposed village social capital into three dimensions (social network, social norm and social trust), this paper aims to discuss how village social capital influences rural industry development by promoting crop specialization. Results showed that the social network affects the transmission of grape planting information and technology. The richer the social network, the faster the diffusion of grape planting and the faster the realization of crop specialization. However, different types of social network play different roles. Social norms affect whether villages participate in grape production decisions. Proper risk awareness and efficient and reliable social organization services can help village farmers participate in grape planting and improve the level of crop specialization. Social trust affects the scale and duration of grape planting in a village; that is, the higher the level of social trusts, the higher the degree of crop specialization. In short, social capital can effectively promote the rapid cultivation of superior crops, enhance the specialization level of agricultural production and drive the coordinated development of upstream and downstream industries, thereby promoting the development of rural industries. This study emphasizes that, in the process of rural revitalization, developing countries should consider the social environments of different regions, fully mobilize the power of local social capital and develop reasonable and feasible technology popularization, adoption and implementation programs.

**Keywords:** social capital; rural revitalization; crop specialization; China

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## 1. Introduction

Many villages in many countries around the world are facing recessions [1], low standards of living, natural conditions unsuited to farming, limited income earned from agricultural activity and poor outfitting in social and technical infrastructure, which lead to a large number of farmers' migration away from rural areas [2,3], leaving abandoned or declining settlements [3,4], and the trend of recession in the rural areas of China is particularly obvious [5,6]. Similarly to the "rural renaissance" proposed by many countries [7–9], the Chinese government has put forward a rural revitalization strategy in response to the massive loss of the rural population and the sluggish rural economy, aiming to achieve the goals of "advanced production, a comfortable living standard, a civilized lifestyle, clear and tidy villages, and effective governance". Research and practice have proved that economic factors play a crucial role in rural vitalization [10]. Thus, a prospering rural economy is considered to be the premise of rural revitalization. However, we how to implement this?

Agriculture is the basic industry of rural economy; it can not only provide raw materials such as grain, fruits and vegetables but also provide diversified food and agro-tourism ecological products. Studies have confirmed that specialization contributes to agricultural economic growth significantly [11,12], on account of which the Chinese government is implementing a new urbanization strategy and a series of land system reforms to promote large-scale, specialized, clustered and modern agriculture. However, China's existing household management mode and ultra-small-scale agricultural production caused by farmland fragmentation restrict the upgrading of agricultural industries [13]. According to the research, it is a fait accompli that China's small-scale peasant economy has existed for a long time [14]. Therefore, the Chinese government has introduced a series of policies to promote the development of the regionalization and agglomeration of agricultural production in some regions [15]: for example, changing the business model and implementing the separation of ownership, management rights and contract rights and so on. However, this phenomenon only appears in a few regions and has not yet been widely spread. Small farmers still form the main body of China's agricultural production [16], and fragmentation and decentralization are still the main business models of China's agriculture [17]. In the context of "small farmers in a big country", how can we further promote the regionalization and large-scale expansion of agricultural production and form regional crop specialization so as to promote the improvement of agricultural production efficiency and the development of modern agriculture? Currently, from such perspectives as economics and management, scholars believe that we should devote ourselves to transforming the scattered product market into a centralized large-scale market [18], government subsidies [19], integration into large-scale agricultural organizations [20], improvement of the mechanization level [21], land consolidation [22], but the implementation effect is not satisfactory [22–24]. According to the endogenous growth theory, the fundamental motivation of regional development lies in the region itself. Some scholars believe that farmers are both the main body of rural industry development and the beneficiaries of rural revitalization [25]. If hundreds of millions of farmers' enthusiasm, initiative and creativity are mobilized to participate in the same agricultural production project consciously and actively, the implementation effect will be more guaranteed [25]. However, how to make large-scale dispersed farmers actively participate in the same type of crop planting to form regional specialization patterns still requires in-depth discussion.

Studies have shown that social capital promotes farmers' adoption of the same production technology and production models by strengthening communication and cooperation among farmers, transforming professional knowledge into easy-to-understand language and overcoming the limitations of promotion times, distance, culture and knowledge level [26,27]. By promoting rural land transfer [28], social capital promotes the cluster development of regional industries [29,30] and changes the forms of rural land use. However, previous studies have focused on the role of social networks in farmers' participation in agricultural projects and the adoption of production technologies and ignored other dimensions in the composition of social capital, such as social norms and social trust. Previous studies have focused on farmers, while ignoring the formation of social capital at the village level, thus underestimating the role of village governments in crop specialization and rural revitalization. In fact, in China, a village is the smallest administrative unit that constitutes a village area, and the village collectively owns the ownership of land in the village area [31] and has the principal competence in external affairs, and information sharing and action direction among the villagers are highly consistent. It can be seen that most of the existing studies on social capital focus on farmer or region level, while there are few studies on small-scale village level. However, village-level social capital plays a leading role in crop specialization and industrial revitalization in Chinese villages. Then, how do we define village-level social capital? What role do its different dimensions play in crop specialization? How does social capital promote the development of rural industries by influencing crop specialization? The solution of these problems is of great significance to the formation of regional agricultural specialization and rural revitalization in China.

To this end, taking the grape industry in Ningling County of China as an example, based on the field survey data of 357 villages and adopting the Logit regression model and least square regression model, this paper offers comprehensive analysis on how village-level social capital affects crop specialization in traditional Chinese agricultural areas and further affects the development of rural industries.

## 2. Theoretical Hypotheses and Indicator Selection

### 2.1. Theoretical Hypotheses

The study of social capital was first undertaken in the field of sociology where the focus was on the importance of relationships between individuals based on the premise of "trust" and "cooperation", and within groups with the organization's accumulative actions as the core [32]. In the late 1970s, "social capital" began to be widely applied in academic research after being put forward as a clear concept. However, the multi-dimensional nature of social capital makes its measurement methods diverse. For example, the World Bank proposed cohesive social capital, bridging social capital and connected social capital [33]. Collier divided social capital into government social capital, which is dominated by rules, and civil social capital, which is dominated by beliefs and organizations [34]. Krishna believed that social capital included formal institutional capital and informal relational capital [35]. Nahapiet et al. classified social capital by using external social relations, trust among internal members and members' understanding of the organization's collective goals [36]. Uphoff divided social capital into structural social capital and cognitive social capital from the perspective of performance [37]; the former consists of specific elements such as norms and rules in social organizations, while the latter is embodied in abstract concepts such as trust and values. Onyx et al. mainly focused on three dimensions: community participation, community organization and trust [38]. Narayan's measurement classification added living in harmony, daily interaction, general rules, etc., based on the work of Onyx [39]. Chinese scholar Liu Guoliang divided social capital into the social capital network, network difference, social participation and trust [40]. Pei Zhijun in his research further divided it into six aspects: universal trust, normative trust, formal network, informal network, shared vision and social support [41]. Lu Huiling et al. studied the impact of rural social capital on farmer income in three dimensions: trust, norms and social network [42]. Wang Tianqi and Huang Yinghui added reciprocity, participation and social capital cultivation [43]. Some scholars divided social capital into homogeneous social capital and heterogeneous social capital according to the nature of relations. In conclusion, in the process of measuring social capital, the measurement index system is often not fixed due to the limitations of research purpose and content, but the indexes of different measurement dimensions are essentially similar and fuzzy, and the measurement is mainly carried out in three aspects: social network, social norms and social trust. As such, village social capital is defined as the sum of social connections formed by villagers in a village based on the common perception and trust of other social individuals under the constraints of local social norms. It can be decomposed into three dimensions, social network, social norm and social trust, and proposes research hypotheses regarding its impact on crop specialization.

The first dimension is the social network, which mainly refers to the relationships among actors in a group [44]. In this paper, it refers to the degree of contact between farmers and different actors in the village before participating in grape planting. It mainly contains two elements: the "connection relationships" among different nodes, such as connection subject, connection frequency, etc.; and the "infective material" that flows along the connection relationships, such as information, ideas, emotions, culture, etc. [45]. Through the connection mechanism, the social network transmits information, technology and knowledge to different nodes; provides farmers with job opportunities; finances channels; and provides access to information for assistance, such as an informal system to provide security for households and reduce the sensitivity of households relative to risk so smallholders can share risk through social networks to mitigate the inhibitory effect of risk on households' planting [46], ultimately affecting the overall behavior and choice of the region [47]. Most Chinese villages are "acquaintance societies" formed by generations of families, and the farmers have established a complex and stable relationship network with each other through geography, kinship and industry. When a village changes its land use mode, selects a certain crop and obtains considerable economic benefits, it plays the central role of a node, which transmits and spreads that land use mode to other villages [48] and then influences the land use behavior of other farmers in the region influences the change in crop specialization degree [49]. Research studies confirm that households with more connections were more likely to adopt a range of new technologies, such as ploughs, varieties, inputs, orchards, afforestation, grazing land rehabilitation and so on [50]. Therefore, to some extent, the social network is the spatial diffusion network of the crop planting information and provides a signal for crop planting structure adjustment. On this basis, Hypothesis 1 is proposed:

**H1.** *The denser the social network, the higher the crop specialization degree*.

The second dimension is social norms, which refers to the standards of behavior that members constituting a specific society should follow together. Under the restrictions of such standards, people form specific behavior patterns [51], which are various, including customs, religious beliefs, moral norms, business air, social trust, laws, regulations, etc. [52]. Some scholars divide social norms into descriptive social norms, imperative social norms and individual norms [53,54]. They describe how individual actions are influenced by the behavior or opinions of others in the same social group. Under the social relations structure of China's rural areas, the production activities of farmers are mostly carried out on the basis of geographical relationships, and their behaviors are inevitably affected by the social norms in the village. Empirical studies have shown that a farmer's decision is influenced by what other farmers think of the scheme, farmers are more likely to join planting when they are informed that a large number of farmers performed planting likewise in their social group. For example, social norms have a direct impact on farmers' behavior of organic fertilizer application and crop variety adoption [52], and social norms can stimulate farmers to adopt cultivated land protection behaviors by affecting their related value cognition, risk confidence and skills [55]. When new crop planting technology spreads to a village, the common value orientation of the villagers will become the decision-making basis of whether the village "follows the trend". Particularly in the case of limited knowledge, farmers'planting structure adjustment is more likely to be affected by local culture and production habits. On this basis, Hypothesis 2 is proposed:

**H2.** *Social norms have an important impact on the decisions of farmers in villages regarding crop specialization*.

The third dimension is social trust, which is the product of the social culture and social system, and it can help people avoid inefficient non-cooperative traps and reduce free-riding problems by increasing communication and facilitating social exchange [56] and then effectively reducing transaction costs and facilitating cooperation among people [57]. Scholars have attempted to classify it in two dimensions: One dimension is interpersonal trust; it refers to the trust between people. Another dimension is institutional trust, such as the government and the legal system [58]. In this paper, it refers to the trust of villagers in various policies and different actors. The farmers' social trust determines the extent to which they are willing to give credit or act on the advice of others [59]. Whether the farmers in the same area persist in the same land production mode may have a great impact on the recipients themselves and their surrounding environment [60]. Therefore, a high level of social trust among villagers is conducive to the establishment of a cooperative environment of mutual trust and more frequent communication in the village, and this can in turn promote crop specialization through social exchanges such as the sharing of information and technical experience. On this basis, Hypothesis 3 is proposed:

**H3.** *The higher the level of social trust, the more conducive it is to the improvement of crop specialization*.

Social capital, including social network, social trust and social norms, is gradually formed in the long-term co-production and living process of rural households in China. Villagers abide by social norms, cherish the collective reputation of their village and interact with each other through complex networks of social relations. Once a certain crop is planted by the villager of a village and appears in the farmland, its planting technology, market benefits and other information will be transmitted to other farmers in the village and other surrounding villages through social networks. When the first farmer who produces the crop succeeds, other farmers will select the planting time and scale based on local social norms and their trust in the first farmer's experimental results. As the number of households and villages participating in that crop's planting increased, the number of follow-up households and villages increased. Thus, repeatedly, the planting scale and scope of that crop planting continue to expand. The large-scale planting of primary agricultural products stimulates the industrial division of labor; thus, its related upstream and downstream industries gradually appear in the region, and the industrialization development will be formed. However, social capital has the characteristics of geographical embeddedness and uneven spatial distribution [61,62]. As the Chinese saying goes, "habits differ from those within 100 li, customs differ from those within 10 li", which shows that there are differences in the social network structure, content of social norms, level of trust, etc., in different regions. Therefore, with the increase in the distance from the initial planting place, information decays, social trust decreases, social norms change, and the number of villages and planting scale both decrease until zero. Thus far, the phenomenon of regional crop specialization and industrialization with fuzzy boundaries has been formed under the influence of social capital (Figure 1). Hypothesis 4 is proposed:

**H4.** *Social capital in specific regions promotes industrial prosperity through crop specialization.*

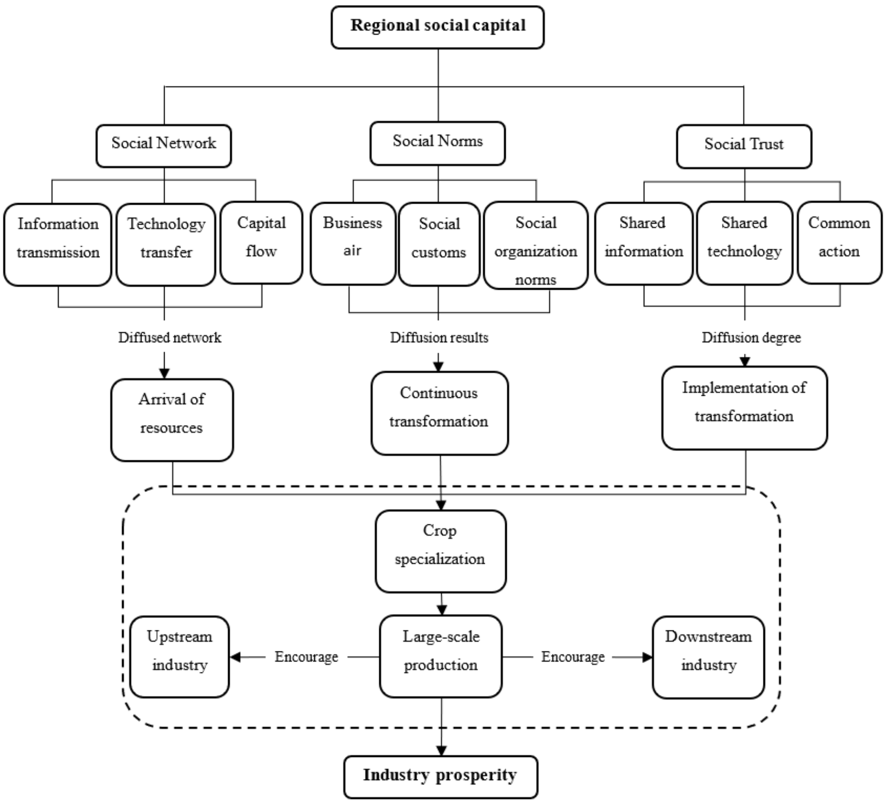



**Figure 1.** Logical relationships among village social capital, crop specialization and industrial revitalization.

### 2.2. Indicator Selection

According to the above analysis, social capital measurement indexes were selected in the following three aspects (Table 1):

(1) Measurement index of social network. The social network has multi-dimensional characteristics such as kinship relationships, geographical relationships and industry relationships. The indexes used by different scholars differ greatly, such as the frequency of going out [63], number of friends and relatives [64], amount of gift spending [65], etc. By referring to previous studies and combining the survey's data, the communication frequencies among all the farmers in the village and among ordinary farmers, relatives and friends, merchants, scientific research institutions, cooperatives, leading enterprises and government organizations before planting a crop were selected to measure the social network index level of the village (the assignment method is shown in Table 1).

(2) Measurement index of social norms. Affected by cultural customs, planting habits, social structure, etc., the farmers in different villages take different main factors into consideration in selecting a crop type to plant, thus forming unique social norms. The degrees to which a village household be affected by different factors when making the decision to plant a different crop, such as business air (e.g., risk culture, laborious traditions, thrifty habits, efficiency consciousness, innovation milieu and market environment), social customs (e.g., thrifty habits, farming habits and farming taboos) and social organization norms (e.g., service mode of technical associations, service level of cooperatives and cooperation of leading enterprises) were taken as the measurement index of social norms. According to the respondents' perception, scoring and assignment can be made using the Likert 5-grade scale with reference to previous studies [66].

(3) Measurement index of social trust. Social trust is generally divided into two broad categories: generalized trust and particularized trust [67]. However, according to the division of trust objects, social trust includes interpersonal trust and institutional trust [68]. In view of the great role of the Chinese government in rural economic development, this paper adopts the classification standard of the latter. The interpersonal trust measurement index in this paper mainly includes the trust of neighbors, highly skilled personnel, entrepreneurs, highly educated people, family members, etc., while the institutional trust mainly refers to the trust of all the farmers in the village towards the industrial policy, agricultural technology extension policy, etc.

**Table 1.** Determinants of village social capital.

| First-Level Index | Second-Level Index | Third-Level Index | Explanation * |
|---|---|---|---|
| Social network | Homogeneous social network | Frequency of communication with farmers in other counties | For the degree of contact intimacy of farmers in village and different behavior subjects before participating in crop planting, 1 represents very low contact frequency and 5 represents very high contact frequency based on the Likert scale method. For planting villages, the score is their social network value of the year before participating in crop planting; for non planting villages, the score is their current social network value. |
| | | Frequency of communication with non-village farmers in the county | |
| | | Frequency of communication with farmers in village | |
| | Heterogeneous social network | Frequency of communication with vendors | |
| | | Frequency of communication with customers | |
| | | Frequency of communication with research institutions | |
| | | Frequency of communication with cooperatives | |
| | | Frequency of communication with leading enterprises | |
| | | Frequency of communication with county government | |

**Table 1.** *Cont.*

| First-Level Index | Second-Level Index | Third-Level Index | Explanation * |
|---|---|---|---|
| Social norms | Business air | Risk culture | For the level of farmers affected by local business air, social customs and social organization norms when considering whether to plant new crops, planting scale and planting duration. According to Likert scale, 1 means very low influence and 5 means very high influence |
| | | Laborious traditions | |
| | | Profit-oriented concept | |
| | | Efficiency consciousness | |
| | | Innovation Milieu | |
| | | Market environment | |
| | Social customs | Thrifty habits | |
| | | Farming habits | |
| | | Farming taboos | |
| | Social organization norms | Service mode of technical associations | |
| | | Service capabilities of farmer cooperatives | |
| | | Cooperation mode of leading enterprise and farmer | |
| Social trust | Institutional trust | Industrial policy | For the trust of villagers in various policies, 0 means complete distrust and 10 means complete trust. |
| | | Agricultural technology extension policy | |
| | | Information sharing policy | |
| | | Rural financial policies | |
| | | Infrastructure construction capability of government | |
| | | External publicity capability of government | |
| | Interpersonal trust | neighbors | For the farmers' perception and trust in different behavior subjects, 0 is lowest and 10 is highest. |
| | | Highly skilled personnel | |
| | | Entrepreneurs | |
| | | Well-educated people | |
| | | Family relatives | |
| | | Managers | |
| | | surrounding villages' households | |

* Scoring is determined according to the perception of cadres staying in the village long-term.

## 3. Materials and Methods

### *3.1. Study Area*

Ningling County is located in the east of Henan Province, China, with convenient transportation conditions, flat terrain and a mild climate (Figure 2). Ningling County is an "agricultural county",most of its population is dependent upon agricultural economy, and its producers of agricultural are mainly smallholders. Fruit crops such as grapes and pears except traditional food crops such as wheat and corn are planted in Ningling County. In 2016, the garden fruit output reached 282,200 tons. The grape planting industry began in the 1980s. In 1990, there were only two planting villages, but after 2010, the number of planting villages increased rapidly and the planting scale continued to expand. At present, the total number of villages that have planted and are planting grapes is 111, accounting for about 1/3 of all villages in the entire county. In addition, grape retail and wholesale individual businesses, grape planting cooperatives and grape deep-processing enterprises surrounding the grape planting industry have appeared. Since 2010, the number of various subjects has increased rapidly, the pattern of grape specialization has been further highlighted and the industrialization's development momentum has been strong. It is important to note that the smallholders in Ningling County are constrained by local asset stock and access to external resources; moreover, their livelihood capital, such as natural, human, physical and financial capital, is limited. Social capital is a relatively controllable resource for farmers because it can be enhanced with increasing social connectedness, and it may also be diminished through the expansion of individualism and conflict [69]. Therefore, it is typical and representative to take the grape industry in Ningling County as an example in this study.

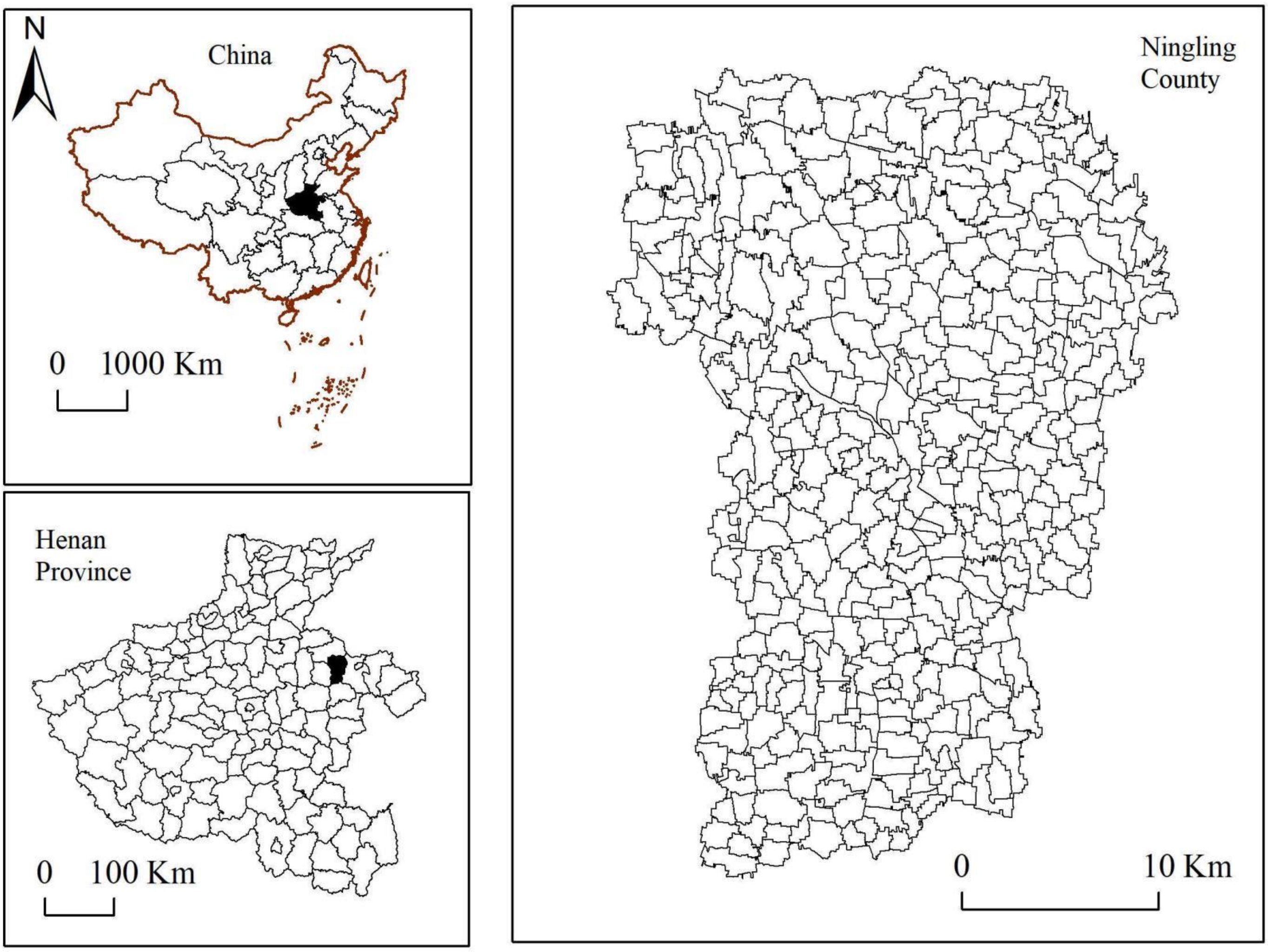



**Figure 2.** Location of Ningling County.

## *3.2. Data Acquisition*

There were two main data sources. The first was official data, which mainly includes the following contents: (1) *Statistical Yearbook of Henan Province (2017)* and vector graph of the administrative divisions of the province; (2) population scale, arable land area, land use structure, township boundaries and village range of each village in Ningling County; (3) individual households, cooperatives and enterprises in Ningling County, and their time of establishment, scale, distribution location, scale of grape planting in the village and its changes over the years; (4) name change and village amalgamation of administrative villages in Ningling County. The second source was field survey data. With the assistance of the Ningling County government, the survey team carried out questionnaire interviews with local long-term cadres staying in 364 villages (there was a total of 364 villages in the entire county, of which 7 were zoned as development zones; thus, no statistics were acquired) of 14 townships in the county. The respondents are the elderly, veteran cadres, current leaders of the village committee, etc., who are very familiar with the village's situation. Some questionnaires are filled out by one person, if he or she knows all the information very well; some questionnaires are filled in by more than one individual to ensure the accuracy of the data or to meet the perception of most people. The questions included population size and structure, natural resource, industrial structure (planting structure), social capital at the year before grape planting, etc. All data are collected by taking the village as the unit. After verification and modification by telephone, 357 valid questionnaires were obtained with an efficiency rate of 98.1%. Before the analysis, the above data were processed as follows: (1) when there was a discrepancy between the official data and the actual survey data in population, the actual survey data prevailed in this study in view of the high variability of population number and the lag of the official data; (2) all data were subject to non-dimensional processing using the standardized method.

### *3.3. Data Processing*

With the exception of the social capital of social networks, social norms and social trust (Table 1), crop planting is also affected by the situation of village resources (such as human resources and land resources) and traffic location, the cultivated land area [33,70], administrative area and traffic land area of each village; the number of highly educated laborers and entrepreneurs at the year before grape planting was selected as the human resources; the Euclidean distances from each village to the diffusion source of grape planting (Yangyi Township) and the counties were selected as the traffic location. Land resources, human resources and traffic location were collectively referred to as the basic development conditions of the village area and included in the model as control variables with social capital variables as explanatory variable. For grape-growing villages, the index values were the conditions at the year before planting grapes; for non-grape-growing villages, the index values were the conditions at the time of the survey.

Social network, social norms and social trust with control variables (land resources, human resources and traffic location) constitute three sets of variables, and principal component analysis was used for dimensionality reduction. The results show that the KMO values were all greater than 0.80. Sigs were all 0.000 and the cumulative contribution rate was all greater than 60%, indicating that it was suitable for factor analysis and the effect was good. Finally, three groups of independent variables are constructed (Figure 3):

(1) Social network (includes two second-level indicators of homogeneous social network and heterogeneous social network) in combination with land resources, human resources and traffic location;
(2) Social norms (includes three second-level indicators of business air, social customs and social organization) in combination with land resources, human resources, traffic location;
(3) Social trust (includes two second-level indicators of institutional trust and interpersonal trust) in combination with land resources, human resources and traffic location.

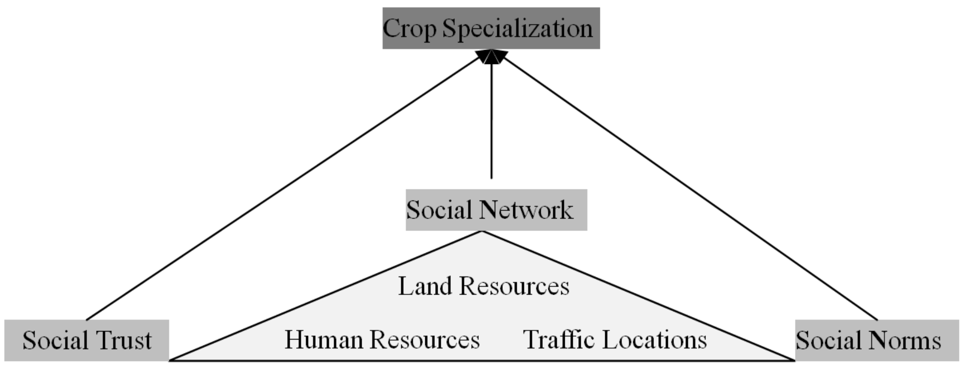



**Figure 3.** Village social capital and basic conditions for crop specialization.

It is interesting to note that, in the above three indicator systems, land resources all include the village road area, cultivated land area, traffic area, canal area and administrative area of villages; human resources all include the proportion of well-educated people and the number of entrepreneurs; traffic locations all include distance of village to the diffusion source of grape planting and county seat. In this study, the score after the rotation of the maximum variance of each group of variable is taken as the variable value.

### 3.4. Methods

Whether to plant, planting scale, planting duration and centrality were the specific indicators for measuring the development of crop specialization in a village, which reflect whether the crop structure of the village is transformed, degree of transformation, duration of transformation and demonstration–promotion ability, respectively. With the administrative village as the analysis unit, the model was constructed with whether to plant, planting scale, planting duration and centrality as dependent variables; the indicators of social network, social norms and social trust before participating in specialized crop production in the village as independent variables; and the basic development conditions of the village as the control variable.

Model 1: For whether to plant or not, the logistic bivariate regression model was selected. The formula is as follows:

$$O = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)} \quad (1)$$

where dependent variable O is the probability of whether grapes are planted in the village; $x_1$, $x_2$..., $x_n$ are the independent variables; and $\beta_1, \beta_2, \ldots, \beta_3$ are the undetermined coefficients of logistic regression. The above formula is transformed due to the following:

$$O = \frac{\exp(x'\beta)}{1 + \exp(x'\beta)},\ 1 - O = \frac{1}{1 + \exp(x'\beta)} \quad (2)$$

$$\text{Therefore}, \ln(O_i/1 - O_i) = \alpha + \sum_{k=1}^{k} \beta_k x_{ki} \quad (3)$$

where $O_i = O(y_i = (1 \mid x_{1i}, x_{2i}..., x_{ki}))$ is the change probability of planting in the village when the independent variables $x_{1i}$, $x_{2i}$..., $x_{ki}$ are a given value, in which $\alpha$ is the intercept term and $\beta$ is the slope.

Model 2: Stata15.0 was used to carry out OLS and OLS+ robust standard error regression on the data, and a White heteroscedasticity test was carried out on the regression results. For models with heteroscedasticity, the weighted least square method was used to revise them repeatedly until a better fitting effect was achieved.

The ordinary least square formula is described as follows:

$$y_i = \beta_{i1}x_{i1} + \beta_{i2}x_{i2} + \ldots + \beta_{in}x_{in} + \varepsilon \quad (4)$$

where $y_i$ is the *i*th dependent variable; $x_{i1}$, $x_{i2}$, ... $x_{in}$ are independent free variables affecting the ithdependent variable; $\beta_{i1}$, $\beta_{i2}$, ... $\beta_{in}$ are the undetermined coefficients of $x_{i1}, x_{i2}, \ldots, x_{in}$; and $\varepsilon$ is the residual.

The weight of the weighted least square method is $1/\sqrt{v_i}$ (reciprocal of standard deviation). For the *i*th observed value (duration and scale of grape planting in the village, etc.), the regression equation becomes the following.

$$\frac{y_i}{\sqrt{v_i}} = \beta_{i1}\frac{x_{i1}}{\sqrt{v_i}} + \beta_{i2}\frac{x_{i2}}{\sqrt{v_i}} + \ldots + \beta_{in}\frac{x_{in}}{\sqrt{v_i}} + \frac{\varepsilon}{\sqrt{v_i}} \quad (5)$$

## 4. Results

### 4.1. Impact of Social Network on Crop Specialization

From the perspective of space, crop specialization is the process of continuously increasing the scale of crop planting and expanding the spatial distribution. According to previous studies, the realization of this process was often present in the village that has succeeded in planting first, influencing surrounding villages to gradually participate through different network channels and then forming a regional specialized production pattern. According to the statistics, the average value of the original (the year before participating in grape planting) social network index of grape planting villages in Ningling

County was much higher than that of non-grape planting villages in current, and the heterogeneous and homogeneous social network indexes of the former were 0.17 and 0.30 larger than those of the latter, respectively. Among the grape planting villages, (1) the higher the social network index at the year before grape planting, the larger the planting scale. For example, for villages with average heterogeneous social network index values of 0.287, 0.287 and 0.471, the average plant scale values were 0.001 $hm^2$, 0.005 $hm^2$ and 0.039 $hm^2$, respectively, and the corresponding homogeneous social network index values were also higher at 0.197, 0.197 and 0.567; (2) the higher the original social network index, the greater the influencing ability of the village, and the more conducive it is to promoting crop specialization. For example, the heterogeneous and homogeneous social network index values of villages with a centricity greater than 0 before grape planting were 0.223 and 0.217, and those of villages with centricity equal to 0 were 0.202 and 0.078; (3) the more developed the original homogeneous social network, the longer the grape planting time. In villages with planting time of more than 10 years, 5–10 years and less than 5 years, the homogeneous social network value gradually decreased to 0.413, 0.089 and 0.047.

That results can also be seen from spatial distribution map (Figure 4), in which 4.7% of grape planting villages had a homogeneous social network score higher than 2, but this proportion of non grape planting villages only 1.9%; however, the proportion of grape planting villages with a homogeneity social network score lower than −1 is 7.5%, but the proportion of non grape planting is 17.6%. These phenomena also occur in heterogeneous social capitals.

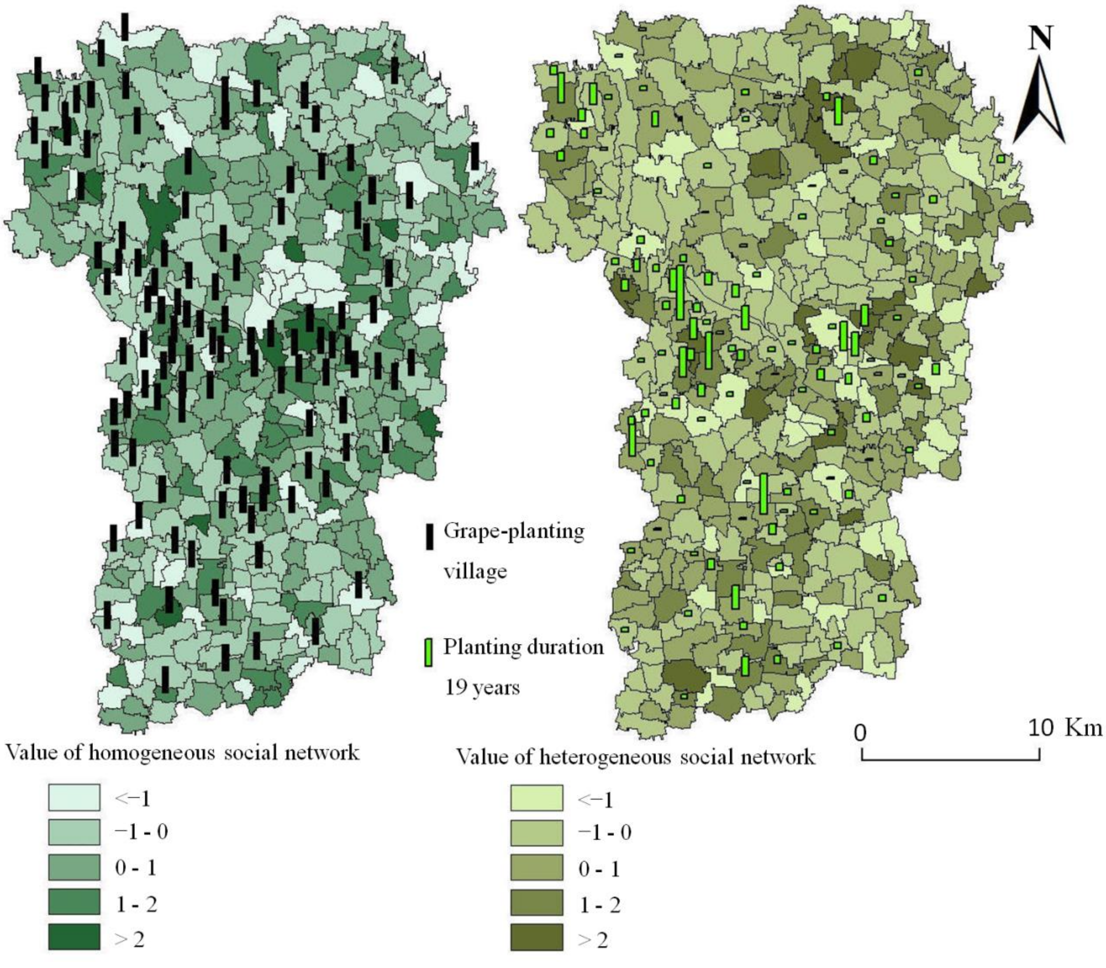



**Figure 4.** Spatial pattern of social network and crop specialization.

The regression (Tables 2 and 3) shows that the original homogeneous social network had significant influence on whether to plant grapes in the village in the future, planting scale, planting time, centrality level, etc. However, the original heterogeneous social network had no significant influence on whether to plant grapes in the village, planting duration and centrality level, but it had a profound influence on the future grape planting scale in the village. These results indicate that the social network established by the relations among family members and local farmers has a comprehensive influence on the agricultural production of the village and affects the speed, scale and future expansion trend of crop specialization. For villages with a more developed homogeneous network, the probability of participating in grape planting is greater, the planting scale is larger the planting time is longer and the influence on other villages is stronger. Moreover, for the villages with more frequent contacts with cooperatives, scientific research units, leading enterprises, etc., the probability of planting grapes on a large scale in the future is greater. Villages with rich heterogeneous social networks have close contacts with enterprises and scientific research institutions. Villagers' planting decisions may be less affected by villagers in surrounding villages, but they are more likely affected by enterprises and external market environments. Due to its good external contact network, once it participates in grape planting, its production scale is generally relatively large. In short, a rich social network provides a channel for villages to acquire and spread new planting information and technology. By influencing the type, scale and duration of crop planting, it changes the use of rural productive land and affects the pattern of crop specialization. This confirms Hypothesis 1.

**Table 2.** Impact of social capital on grape planting decisions in village.

| Variable Type | Independent Variable | Odds Ratio | Std. Err. | Z | P > \|z\| | Prob > chi2 | Pseudo $R^2$ |
|---|---|---|---|---|---|---|---|
| Social network | Homogeneous social network | 1.383 | 0.169 | 2.66 | 0.008 | 0.000 | 0.094 |
| | Heterogeneous social network | 1.205 | 0.142 | 1.58 | 0.113 | | |
| | Human resources | 1.380 | 0.163 | 2.73 | 0.006 | | |
| | Land resources | 1.300 | 0.155 | 2.2 | 0.028 | | |
| | Traffic location | 0.566 | 0.075 | −4.32 | 0.000 | | |
| | Constant | 0.365 | 0.046 | −7.94 | 0.000 | | |
| Social norms | Business air | 1.202 | 0.147 | 1.5 | 0.132 | 0.000 | 0.082 |
| | Social customs | 1.279 | 0.152 | 2.06 | 0.039 | | |
| | Social organization norms | 1.04 | 0.123 | 0.33 | 0.742 | | |
| | Human resources | 1.277 | 0.15 | 2.08 | 0.037 | | |
| | Land resources | 1.313 | 0.155 | 2.3 | 0.021 | | |
| | Traffic location | 0.568 | 0.074 | −4.35 | 0.000 | | |
| | Constant | 0.371 | 0.046 | −7.92 | 0 | | |
| Social trust | Institutional trust | 1.384 | 0.175 | 2.56 | 0.010 | 0.000 | 0.085 |
| | Interpersonal trust | 0.994 | 0.123 | −0.05 | 0.960 | | |
| | Human resources | 1.476 | 0.177 | 3.25 | 0.001 | | |
| | Land resources | 1.305 | 0.155 | 2.25 | 0.025 | | |
| | Traffic location | 0.608 | 0.08 | −3.79 | 0.000 | | |
| | Constant | 0.369 | 0.046 | −7.92 | 0.000 | | |

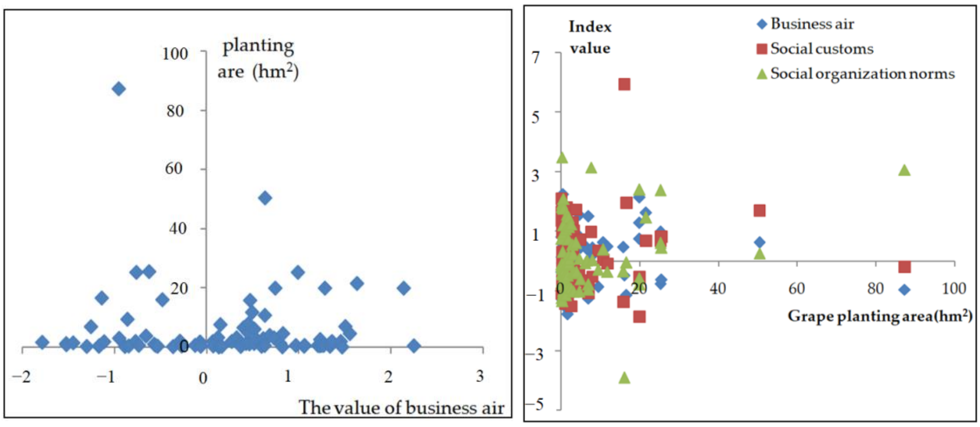
**Table 3.** Impact of social network on grape planting status in village.

| Dependent Variable | Social Network Indicators | Coef. | Std. Err | t | P > \|t\| | Prob > F | $R^2$ |
|---|---|---|---|---|---|---|---|
| Planting scale | Homogeneous social network | 0.589 ** | 0.241 | 2.45 | 0.015 | 0.000 | 0.051 |
| | Heterogeneous social network | 0.729 *** | 0.24 | 3.05 | 0.002 | | |
| | Land resources | 0.293 | 0.212 | 1.38 | 0.168 | | |
| | Human resources | 0.296 | 0.214 | 1.38 | 0.168 | | |
| | Traffic location | −0.500 ** | 0.194 | −2.56 | 0.011 | | |
| | Constant | 1.325 | 0.283 | 4.69 | 0.000 | | |
| Planting duration | Homogeneous social network | 0.722 *** | 0.211 | 3.42 | 0.001 | 0.0000 | 0.101 |
| | Heterogeneous social network | 0.404 * | 0.211 | 1.92 | 0.056 | | |
| | Land resources | 0.246 | 0.186 | 1.32 | 0.188 | | |
| | Human resources | 0.707 *** | 0.189 | 3.75 | 0.000 | | |
| | Traffic location | −0.583 *** | 0.17 | −3.42 | 0.001 | | |
| | Constant | 1.975 | 0.249 | 7.95 | 0.000 | | |
| Centrality | Homogeneous social network | 0.159 ** | 0.076 | 2.08 | 0.039 | 0.276 | 0.017 |
| | Heterogeneous social network | 0.064 | 0.077 | 0.84 | 0.403 | | |
| | Human resources | 0.041 | 0.069 | 0.59 | 0.552 | | |
| | Land resources | −0.001 | 0.685 | −0.02 | 0.983 | | |
| | Traffic location | −0.080 | 0.063 | −1.27 | 0.207 | | |
| | Constant | 0.213 | 0.088 | 2.43 | 0.016 | | |

Ps. Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

### 4.2. Impact of Social Norms on Crop Specialization

Social norms exist in people's minds, affect their behavior and are generally difficult to change (especially customs and habits). When the farmers of Ningling County make decisions on agricultural production, the villages that tend to change their planting structure generally believe that the impacts or roles of the business air, social customs and social organization norms are very important, while villages that are generally satisfied with the current situation believe that the above factors have little impact on their crop planting decisions. The factor rotation scores of the former were 0.170, 0.238 and 0.032 higher than those of the latter. Interestingly, with the increase in business air, that score is the value of the rotation of the maximum variance of risk culture, laborious traditions, profit-orieted concept, efficiency consciousness, innovation milieu and market environment; the scale of grape planting in the village first increased and then decreased, while the duration and centrality of grape planting in the village increased as a whole (Figure 5). This shows that villagers who do not care about risks or that are without any economic sense are not planning to plant grapes on a large scale, and excessive concern about risks or swaying by considerations of gain and loses are also not conducive to the regionalization of grape planting; on the other hand, villagers who plan to plant on a larger scale and for a longer period of time are generally more concerned about risk. In addition, the service quality of social organizations such as cooperatives, leading enterprises and governments has an obvious impact on the regional agricultural specialization level. They believe that efficient and reliable social organization services can stimulate their enthusiasm for production, which is conducive to crop specialization. Compared with social capital, the traffic location of village has a greater impact on the scale, duration and centrality of grape planting in the village (Table 4).




(**a**) (**b**)

**Figure 5.** Social norms and grape planting area of villages.

**Table 4.** Impact of social norms on grape planting in village.

| Dependent Variable | Social Norm Indicators | Coef. | Std. Err | t | P > \|t\| | Prob > F | $R^2$ |
|---|---|---|---|---|---|---|---|
| Planting scale | Business air | 0.185 | 0.325 | 0.57 | 0.570 | 0.0003 | 0.068 |
| | Social customs | 0.586 * | 0.332 | 1.77 | 0.078 | | |
| | Social organization norms | 1.141 *** | 0.344 | 3.32 | 0.001 | | |
| | Traffic location | −0.96 *** | 0.321 | −2.99 | 0.003 | | |
| | Human resources | 0.522 | 0.342 | 1.53 | 0.128 | | |
| | Land resources | 0.363 | 0.327 | 1.11 | 0.269 | | |
| | Constant | 1.375 | 0.345 | 3.98 | 0.000 | | |
| Planting duration | Business air | 0.400 * | 0.210 | 1.90 | 0.058 | 0.0000 | 0.078 |
| | Social customs | 0.515 ** | 0.214 | 2.41 | 0.016 | | |
| | Social organization norms | 0.344 | 0.221 | 1.55 | 0.121 | | |
| | Traffic location | −0.737 *** | 0.206 | −3.57 | 0.000 | | |
| | Human resources | 0.504 * | 0.220 | 2.29 | 0.022 | | |
| | Land resources | 0.292 | 0.211 | 1.39 | 0.166 | | |
| | Constant | 1.837 | 0.222 | 8.28 | 0.000 | | |
| Centrality | Business air | 0.146 | 0.116 | 1.26 | 0.207 | 0.0206 | 0.040 |
| | Social customs | 0.035 | 0.118 | 0.30 | 0.767 | | |
| | Social organization norms | 0.370 *** | 0.122 | 2.99 | 0.003 | | |
| | Traffic location | −0.217 * | 0.114 | −1.90 | 0.058 | | |
| | Human resources | 0.113 | 0.122 | 0.93 | 0.352 | | |
| | Land resources | −0.024 | 0.117 | −0.20 | 0.839 | | |
| | Constant | 0.255 | 0.123 | 2.07 | 0.039 | | |

Ps. Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In subfigure (a), The abscissa is the value of business air which is the score that after the rotation of the maximum variance of business air group of variable, the ordinate is the grape planting area of smallholders. However, the ordinate is the value of business air, social customs, social organization norms which are the scores that after the rotation of the maximum variance of each group of variable, the ordinate is the grape planting area of smallholdersin subfigure (b). We can clearly observe that the relationship between the planting area and each value is an inverted "U" shape. In other words, the planting area increases and then decreases as values change.

### *4.3. Impact of Social Trust on Crop Specialization*

Institutional trust has a significant impact on whether a village participates in planting, planting scale and planting duration. In other words, the more trust the village farmers have in the industrial policy, agricultural technology extension policy, information sharing policy, rural financial policies, infrastructure construction capability of government and external publicity capability of government, the more active they will be in participating in crop planting, the larger the planting scale and the longer the planting duration. Moreover, the influence of institutional trust on the scale and duration of grape planting in villagers is far greater than that of interpersonal trust. This result explains why strong leadership by a local committee or local government played an important role in rural revival; a strong leadership that motivates and leads the local farmers might be decisive in some cases [5]. The trust levels of farmers in technical personnel, entrepreneurs and well-educated people have a limited impact on their participation enthusiasm, planting scale and planting duration, but the interpersonal trust level has a significant impact on the spatial diffusion of crop planting in the village. The higher the interpersonal trust level, the stronger the external diffusion ability of villages (Table 5). That is to say that the participation in the decision making of villages may be affected by the surroundings, but the production scale and duration vary depending on the situation of each village.

**Table 5.** Impact of social trust on grape planting in village.

| Dependent Variable | Social Trust Indicators | Coef. | Std. Err | t | P > \|t\| | Prob > F | $R^2$ |
|---|---|---|---|---|---|---|---|
| Planting scale | Institutional trust | 0.636 ** | 0.275 | 2.31 | 0.021 | 0.002 | 0.051 |
| | Interpersonal trust | 0.512 * | 0.281 | 1.82 | 0.069 | | |
| | Human resources | 0.613 ** | 0.289 | 2.12 | 0.035 | | |
| | Land resources | 0.127 | 0.286 | 0.44 | 0.657 | | |
| | Traffic location | −0.777 *** | 0.261 | −2.98 | 0.003 | | |
| | Constant | 1.413 | 0.330 | 4.28 | 0.000 | | |
| Planting duration | Institutional trust | 0.604 *** | 0.192 | 3.14 | 0.002 | 0.000 | 0.097 |
| | Interpersonal trust | 0.341 * | 0.196 | 1.74 | 0.083 | | |
| | Human resources | 0.821 *** | 0.202 | 4.07 | 0.000 | | |
| | Land resources | 0.144 | 0.199 | 0.72 | 0.471 | | |
| | Traffic location | −0.616 *** | 0.182 | −3.38 | 0.001 | | |
| | Constant | 1.907 | 0.230 | 8.28 | 0.000 | | |
| Centrality | Institutional trust | 0.128 | 0.118 | 1.08 | 0.279 | 0.0181 | 0.037 |
| | Interpersonal trust | 0.347 *** | 0.120 | 2.89 | 0.004 | | |
| | Human resources | 0.162 | 0.124 | 1.31 | 0.192 | | |
| | Land resources | −0.051 | 0.122 | −0.41 | 0.679 | | |
| | Traffic location | −0.255 ** | 0.112 | −2.28 | 0.023 | | |
| | Constant | 0.288 | 0.141 | 2.03 | 0.043 | | |

Ps. Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

*4.4. Crop Specialization Promotes the Development of Rural Industries*

The geographic concentration and scale effect of agricultural production can promote the specialization of the upstream and downstream industries and the development of service industries, forming such advantages as increasing returns to scale, generating the agglomeration effect and accelerating the development of rural industries. In 2000, there were only nine villages engaging in grape planting in Ningling County, only one grape deep-processing enterprise and no individual industrial and commercial businesses or cooperatives engaging in grape sales and management. However, ordinary consignment points and cooperatives providing planting technology services have established. In 2005, the number of planting villages increased to 20, with the spatial distribution mainly in Yangyi Township and Luogang Town, showing a small agglomeration phenomenon. However, the number of grape enterprises, cooperatives and individual industrial and commercial businesses did not change. From 2005 to 2010, the grape planting industry grew rapidly. In 2010 alone, there were 17 new grape planting villages. At this time, the number of individual industrial and commercial businesses and grape processing enterprises increased to two. From 2011 to 2017, the regional specialization speed of the grape planting industry was rapid, and the number of villages that planted grapes in the county increased to 111 (Figure 6). After some planting villages withdrew, the number of grape planting villages in the entire county reached 84 in 2017. During this period, there were 109 fresh grape retailers, 16 wholesalers, 7 fruit seedling sellers and technical service providers, 27 grape planting cooperatives and 11 grape processing enterprises engaging in grape juice, canned grapes and wine, and different operators were distributed in each area of the county according to their own service market objects. For example, the retail industry was more distributed throughout counties, townships and other densely populated areas, the planting cooperatives were located near the grape planting villages, and the deep processing enterprises were largely located in the technical development zone (Figure 7), forming an industrialization development pattern integrating "planting–processing–sales".

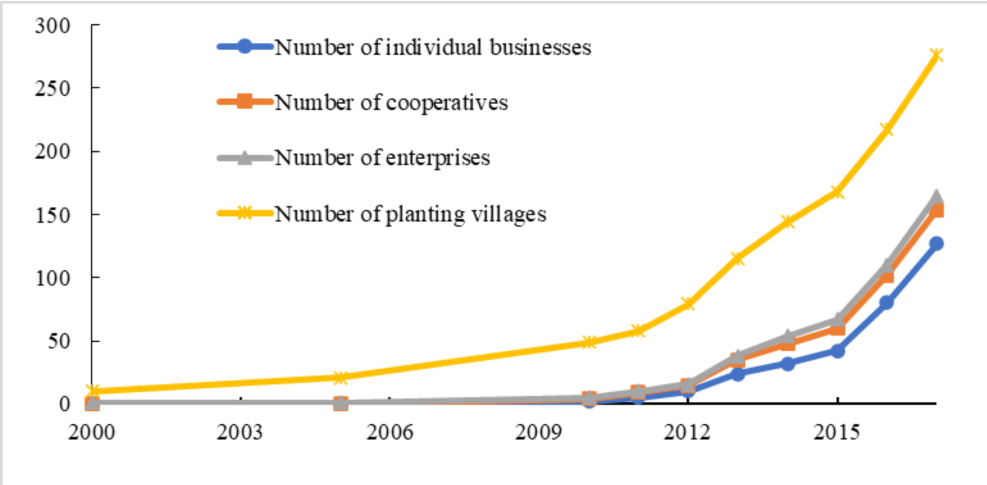



**Figure 6.** Numbers of different producers at different times.

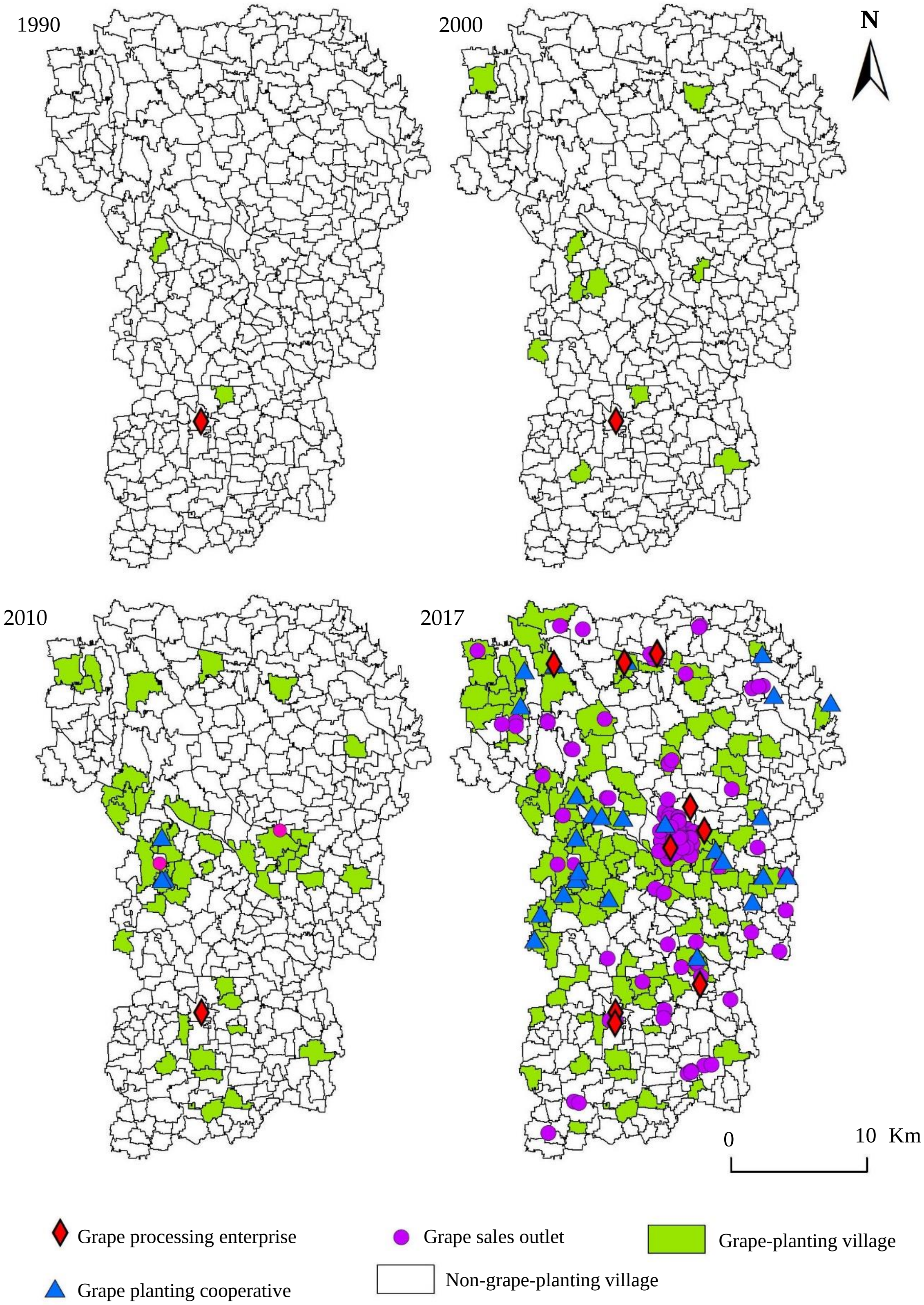



**Figure 7.** Locations of different producers.

## 5. Conclusions and Discussion

### *5.1. Conclusions*

Based on existing studies, this study proposes a theoretical hypothesis about the interaction among social capital, crop specialization and rural industrial development. With the development of the grape industry in Ningling County, Henan Province, China, this paper analyzes how the social capital drives the development of the grape industry by promoting crop specialization using actual survey data and official statistical data, and taking the villages as the analysis units. The results show that the following: (1) for villages with a richer social network, the realization of crop specialization is faster, but different types of social network have different directions. For villages with a more developed homogeneous network, the possibility of participating in grape planting is greater, the planting scale is larger, the planting time is longer and the influence on other villages is stronger. For villages with a more developed heterogeneous social network, the possibility of planting grapes on a large scale in the future is greater. (2) Social norms have a significant impact on crop specialization. Appropriate risk awareness and efficient and reliable social organization services are conducive to crop specialization. Not caring about risk or worrying too much about risk is not conducive to the expansion of grape growing areas, and efficient and reliable social organization services are conducive to crop specialization. (3) The higher the level of social trust, the faster the crop specialization. The more trust farmers have in the government's ability, the more enthusiasm they have to participate in characteristic planting the larger the planting scale and the longer the planting time. For villages with a higher level of interpersonal trust, the external diffusion ability is stronger. In short, social capital can effectively promote the rapid promotion of superior crops, enhance the scale and specialization level of crop planting, promote the coordinated development of upstream and downstream industries, and promote the prosperity of rural industries.

### *5.2. Discussion*

Extensive literature has a common denominator: The causes of Europe rural recessions are not natural but political and economic [2]. In view of this, Western European countries have introduced a series of policies to curb rural recession and believe that social economy institutions may be a key factor in the fight against rural recessions [71]. However, effective policies are usually built on a basis of endogenous potentials found in a region and participation of local population [72]. Policies should be designed in accordance with the local conditions, make local community feel like an essential and active part of the policy design and encourage them to be co-responsible for the challenge [73,74]. Otherwise, the role of policies will be limited [10]. In other words, Rural revitalization requires not only the support of policies and the assistance of exogenous resources but also the combination of endogenous and exogenous resources. To exapand on this, social capital will provide the greatest help for farmers to make full use of exogenous resources [75]. Although social capital is seen as an aspect of social inequality that hinders inclusive development [76], deceiving fellow villagers is not common in China because they have lived together for generations; thus, ordinary Chinese villagers generally trust their relatives and fellow villagers, regardless of whether or not the villagers are their neighbors [77]. In China, social capital plays a important role to fully ensure the participation of community members in the process of discussion and consultation and leading to a concern and joint action in land transfer and shared benefits [78].

It can be seen from this study that in the development of the grape industry in China's traditional agriculture, the social network affects grape planting information and technology transfer, social norms affect whether farmers participate in decisions about grape production, and social trust affects farmers' grape planting scale and duration, which all in turn affect the degree of crop specialization and the development trend of rural industries. However, reform and opening up and the market economy have had serious impacts on social norms, trust, integrity and social exchanges in rural China. It is also important for China's rural revitalization to figure out how to improve the degree of rural culture by retaining rurality, how to improve the effectiveness of farmers' social exchange by establishing an integrity system of rural society as a whole, and how to improve the prosperity of social capital in villages and competitive characteristic industries in the county. According to the results of this study, although the homogenous social network can improve the current degree of crop specialization, the heterogeneous network can better improve the degree of crop specialization in the future. In the context of China's land system and the restricted red line of 1.8 billion mu of arable land, no industrial land or construction land is allowed in the arable land of village areas. Therefore, the land use pattern in the future will evolve towards a land use division of labor in which "industrial land or commercial land is concentrated in towns and villages, while villages are specialized in certain crops". Crop specialization enables the rural planting industry to obtain the benefits of the scale economy and specialization economy. The expansion of industries promotes the further strengthening of cooperation and communication among farmers, thereby increasing their social capital and further optimizing and reconstructing their crop specialization. Social capital, crop specialization and industrial prosperity promote each other and form a positive feedback mechanism. Therefore, in the rural revitalization process, competitive industry projects should be selected according to the local conditions; the social customs and institutional norms of different regions should also be considered in the process of project promotion; full play should be given to the power of regional social capital; feasible technical promotion, adoption and implementation plans should be developed. This will start a positive cycle and promote coordinated development among local social capital, division of labor, crop specialization and industrial prosperity.

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# Smallholders' Livelihood Resilience in the Dryland Area of the Yellow River Basin in China from the Perspective of the Family Life Cycle: Based on GeoDetector and LMG Metric Model

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**Abstract:** Farm households' sustainable livelihoods in the dryland area of the Yellow River basin is an important guarantee of ecological protection and high-quality development for the Yellow River basin. However, farm households in this region have been facing frequent droughts, water resource shortages, severe soil erosion and other problems; their livelihood security has been seriously threatened. This study used a livelihood resilience framework to evaluate farm households' livelihood resilience in dryland areas through the field survey data and identified the influencing factors of livelihood resilience using the GeoDetector and the Lindeman, Merenda and Gold method (LMG) from the family life cycle perspective. The results revealed the following points: (1) there were significant differences in livelihood resilience, adaptive capacity and anticipatory capacity at each stage of the family life cycle at a 5% significant level. (2) The top two variables of livelihood resilience were preparedness and planning, and substitutable assets, followed by household characteristics. With the evolution of the family life cycle, the impacts of family assets and basic service access on livelihood resilience showed a "U" trend. On the contrary, savings and safety nets showed an inverted "U" shape. (3) Both the GeoDetector and LMG metric models could identify the key influencing factors, but the variable importance rankings of the two models were different to some degree. Finally, based on the results of the analysis, this study proposed targeted policy recommendations for building livelihood resilience of farm households.

**Keywords:** livelihood resilience; family life cycle; GeoDetector; LMG metric model; dryland area; China

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## 1. Introduction

The concept of "sustainable livelihoods" was proposed during the 1980s to the early 1990s [1], which mainly comprises the following five components: capabilities, assets, activities, resilience and natural resources [2]. Among them, livelihood resilience in the face of stresses and shocks is central to both livelihood adaptation and coping [3]. Most scholars believed that this concept not only involved people's livelihood vulnerability but also their ability to resist external disturbances and their adaptability after a disturbance [4,5]. Livelihood resilience aims to sustainably manage resources for human development and well-being from the micro-level of smallholders [6], which has become a powerful tool to explore sustainable livelihoods [7,8]. Since resilience is characterized by stability, dynamics and steady-state transformation [9], integrating resilience into livelihoods is conducive to understanding how smallholders cope with adverse external disturbances and how they stabilize their livelihoods, as well as understanding livelihood system dynamic properties [10]. Building resilient livelihoods means that livelihood strategies of specific households are better able to cope with diverse impacts caused by adverse shocks and high uncertainties, manage livelihood risks and adapt to changing conditions [11] to promote sustainable livelihood development.

The notion of resilience was first introduced into ecosystem studies by Holling [12], which was defined as the ability of an ecosystem to absorb disturbances and maintain its function and state [9]. Afterwards, resilience was gradually applied to more complex system sciences, such as social-ecological systems. With the gradual deepening of research concerning resilience to the social-ecological system, scholars gradually focused on the concept and theoretical study of livelihood resilience [13], which broadens the research field of resilience [14].

Livelihood resilience research mainly includes the following three aspects: the theory research of livelihood resilience, livelihood resilience assessment and analysis based on several analytical frameworks and exploring influencing factors of livelihood resilience.

(1) Livelihood is identified as a way of making a living that individuals, families or groups depend on [8], which is composed of capabilities, assets and activities [2], focusing on the connection between assets owned by people and livelihood decisions, except for income [15]. Due to the vulnerability of their living environment, the livelihoods of highly poor and disadvantaged groups are hampered, which leads them to be unable to escape the development dilemma. The sustainable livelihood approach is a powerful livelihood tool, which takes livelihood capitals as the core and underscores transforming livelihood capitals and activities into livelihood outcomes. This method is expected to find the entry point to formulate future development strategies to strengthen the development capacity of these vulnerable groups and help them gradually remove livelihood obstacles to achieve livelihood sustainability [15]. The notion of livelihood resilience, proposed as a component of sustainable livelihoods [2], inherits the research paradigm of resilience to social-ecological systems and highlights the role of human agency and our individual and collective capacity to cope with stressors [13]. For example, people can use social networks to solve the issues of information asymmetry and resource shortages and improve the ability to cope with disasters. Resilience is an inherent attribute of a system based on the adaptive cycle theory of social-ecological systems [16]; thus, study on livelihood resilience is a further improvement of the study on livelihood system mechanisms. Livelihood resilience places people at the center to solve livelihood development needs and the limitations of livelihood activities of the poorest and most vulnerable groups with the resilience theory and provides opportunities for them to achieve sustainable livelihoods. In terms of the concept of livelihood resilience, some scholars proposed the concept of livelihood resilience by combining the concepts of livelihood and resilience, but there no consensus has been reached. The current concept that is widely applied was proposed by Tanner et al. [13], which emphasizes the capacity of all generations to maintain and improve livelihood opportunities and human well-being in the face of external disturbances.

(2) Livelihood resilience assessment is the primary task for managers to understand people's ability to cope with disturbance and formulate resilient management strategies. At present, the comprehensive evaluation method through the analysis framework is more popular. Therefore, it becomes important to build an appropriate analysis framework. Several researchers have put forward a variety of analytical frameworks according to their own research needs, but there is still no universal analytical framework. Currently, the popular analytical frameworks are the framework of buffering, self-organization and learning capacity proposed by Speranza et al. [17] and the resilience index measurement approach (RIMA), proposed by the Food and Agriculture Organization [18], respectively. In addition, Sina et al. [8] developed a measuring livelihood resilience framework, comprising individual livelihood coping capacity, individual well-being, access to livelihood resources and social-physical robustness of local community, applying thematic analysis based on a literature review. Bahadur et al. [14] developed a 3As (adaptive capacity, anticipatory capacity and absorptive capacity) framework in the project "Building resilience and adaptation to climate extremes and disasters project", funded by the Department for International Development (DFID), which constructed a comprehensive indicator system at household and community levels. The assessment facilitates the integration of liveli-

hood and resilience, as well as issues related to human agency and empowerment, which is in line with the notion of livelihood resilience proposed by Tanner et al. [13]. Because of this, this study used this framework to assess the livelihood resilience of smallholders.

Secondly, as livelihood resilience aims to solve the problem of sustainable livelihoods of the poorest and most vulnerable groups, vulnerable ecological areas, poverty-stricken areas and disaster-prone areas are the focus of scholars. The dryland area, lying in the south of the Yellow River basin, is one of the areas with a vulnerable ecological environment in China, where the agricultural production has been faced with frequent droughts, serious soil erosion, and water shortage for a long time [19,20]. Therefore, the livelihood security of smallholders in this area is seriously threatened. Meanwhile, smallholders' livelihoods in this region have been deeply affected by social and economic transformations. For example, due to the impact of COVID-19, farmers' agricultural production and off-farm activities have been severely restricted, and their incomes have significantly decreased, which increases the vulnerability of their livelihoods. Therefore, building resilient, sustainable livelihood needs to be paid enough attention by managers. In 2019, China's central government put forward a strategy for ecological protection and high-quality development in the Yellow River basin, taking the issue of people's livelihood sustainability in this region to a new height. However, studies on the livelihood resilience of smallholders in the dryland area of China are very limited. It is necessary to evaluate the livelihood resilience of farmers in the dry tableland area, which aims to provide a theoretical reference for relevant government departments and managers to understand the livelihood resilience level and establish a resilient management system for the study area.

(3) Identifying the key factors of livelihood resilience can help managers to integrate existing resources and formulate effective livelihood resilience improvement policies for vulnerable groups. Some scholars have attempted to explore the influencing factors of livelihood resilience. For instance, Ado et al. [21] studied influencing factors of farmers' resilience to food security in the Aguie district of Niger and showed that family size, agricultural production and agricultural experience were the most important determinants of farmers' resilience to food security. Li et al. [22] revealed that education investment, social network, family burden ratio, and family size were the major factors that influenced the livelihood resilience of relocated migrants in China. Wen et al. [23] revealed that savings, per capita income, educational investment, educational level of household head, as well as social networks, were the core factors that influenced the resilience of households on the Loess Plateau in China. These pieces of literature have directly or indirectly confirmed the significant impacts of household characteristics and related factors on livelihood resilience, which are closely related to the family life cycle. The concept of family life cycle (FLC) was first proposed by Rowntree [24], which refers to the process of birth, development and disappearance of a family [25]. At present, the impact of FLC on smallholders has attracted the extensive attention of scholars. The existing literature mainly focused on the relationships between FLC and farmland management scale [26–28], smallholders' farmland transfer behaviors [29], livelihood strategy [29,30], rural labor transfer [31], and multidimensional poverty [32,33]. They explicitly or implicitly reflected that there were differences in capital accumulation, family size, dependency burden, livelihood risks and livelihood strategies of a household as the evolution of FLC [28,34], which lead to different livelihood resilience levels. However, there are few related studies. Therefore, this study attempts to explore the influencing factors of smallholders' livelihood resilience from the perspective of the FLC, which helps stakeholders to understand the research mechanism of livelihood resilience, and provide references for local governments and managers to formulate targeted resilient livelihood measures.

Additionally, in terms of research techniques, statistical methods, such as the structural equation model [35] and regression model [36], are more popular. However, some important influencing factors will be excluded from the analysis because of some overlap between the influencing factors and indicators system, which is usually ignored in an estimation. Therefore, it is necessary to explore the relative importance of influencing factors to the evaluated index of livelihood resilience. In recent years, GeoDetector has been widely used to explore the influencing factors of spatial heterogeneity, but this method can also measure the explanatory powers of factors to dependent variables using statistical data [37]. Meanwhile, the Lindeman, Merenda and Gold (LMG) method is a method of relative importance assessment based on a linear regression model [38]. Therefore, both methods can be used to explore the important influencing factors of livelihood resilience.

Through the above literature review, this study mainly has three contributions to the existing literature, which are as follows: (1) we evaluated the livelihood resilience of smallholders in the dryland area of the Yellow River basin based on the 3As framework proposed by Bahadur et al. [14]. On the one hand, by combing the 3As framework and livelihood resilience concept accepted by most scholars, we believed that the 3As framework fully considered the role of human agency and empowerment, so it has certain advantages in livelihood resilience assessment. On the other hand, the dryland area has an important strategic position in the Yellow River basin of China; thus, building smallholders' livelihood resilience in this region is related to the implementation of a high-quality development strategy for the whole Yellow River basin. Considering this, we filled this gap to evaluate smallholders' livelihood resilience in the dryland area of the Yellow River basin in China. (2) Both GeoDetector and LMG metric models were used to identify the important factors that affect smallholders' livelihood resilience. The estimation of influencing factors of livelihood resilience is limited due to its widely inclusive indicator system. The above models can estimate the relative importance of the factors of livelihood resilience to identify crucial factors. (3) We provided a new perspective for analysis. FLC is a sociological concept, which this research introduced into the field of geography. Taking it as an entry point, we analyzed the differences in the livelihood resilience of smallholders in different stages of the FLC and their influencing factors, and aimed to help local governments formulate a targeted resilient livelihood management pathway to promote sustainable livelihood development in the dryland area of the Yellow River basin.

The remaining sections of this paper are organized as follows: the second section is the introduction of the study area. The third section is materials and methods, including data collection, theoretical framework and research methods. The fourth and the fifth parts are the results and discussions, respectively, which are the important contents of this study. The final part is divided into conclusions and suggestions.

## 2. Materials and Methods

### 2.1. Study Area

The dryland area is located in the south of the Yellow River basin in China (Figure 1), with a total population of about 18 million. The per capita of arable land in the study area is less than 0.133 ha. The dry land accounts for about 75% of the total arable land [39]. Therefore, the contradiction between the population and farmland is prominent in the study area. Topographically, a flat and open stretch slopes from north to south, with an altitude of 251~2779 m. The climate type of the study area can be described as a warm temperate, semi-arid continental and monsoon climate with four distinct seasons. Its average annual precipitation ranges from 400 mm to 650 mm, mainly concentrating in July to September every year. In addition, its annual average temperature is between 8.3 °C and 13.5 °C. The type of agriculture in the dryland area is rainfed agriculture that is identified as one of the important agricultural production areas in the Yellow River basin of China. Meanwhile, the study area is an important fruit and food production basis for the country, including high-quality grain, apple and pear [40]. Due to the vulnerable ecological environment and the climate-related impacts, the serious soil erosion, frequent flood and drought disasters, diseases and insect pests have been challenges for the sustainable agricultural development in the study area. In addition, with the continuous development of urbanization and industrialization, smallholders changed their farmland utilization and livelihood strategies. Meanwhile, they are faced with diverse pressures, such as children's education and enrollment and cash gifts, which aggravated the vulnerability of their livelihoods.

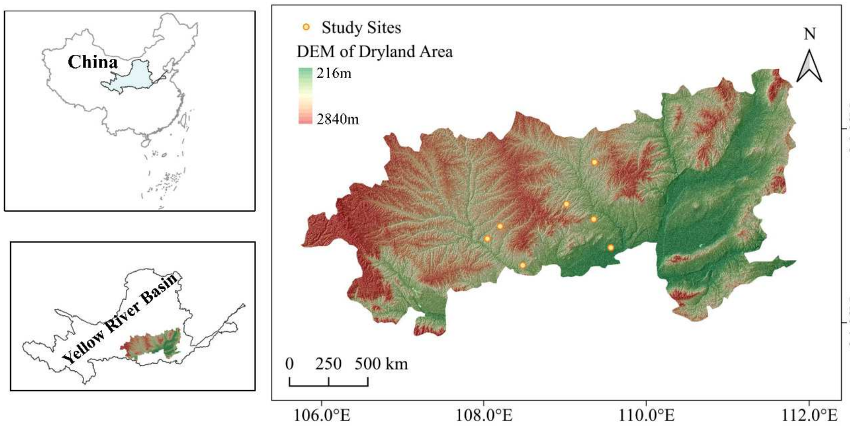


**Figure 1.** The study area location and the survey site distribution.

### 2.2. Data Collection

Data collection included the following two phases: pre-survey and formal survey. The presurvey was conducted in September 2019, which aimed to investigate the rural production and living conditions in the study area, such as farmers' livelihood types and strategies, and rural infrastructure construction. After obtaining the pre-survey results, finally, we revised and finalized the formal questionnaire. The formal survey was conducted in November 2019. The stratified random sampling method of "county-township-village-smallholders" was adopted in this phase to select the interviewed samples. Firstly, seven counties or cities were randomly selected from the study areas, which are shown in Figure 1. In the next step, we randomly chose one or two townships from each county or county-level county. Then, a total of eight administrative villages were determined. Finally, 40–45 smallholders were selected randomly from each administrative village as respondents. The face-to-face interviews to the household heads were implemented with structured questionnaires. Generally, the interviews lasted from 40 to 60 min. During the interview, the investigators introduced the investigation's purpose and explained any doubts for the respondents. Finally, a total of 353 questionnaires were distributed, of which there were 342 valid questionnaires, excluding the incomplete or error data, with an effective rate of 84.7%. Additionally, the focus group discussions for the village cadres were carried out to collect the agricultural production and rural basic situations.

The questionnaire involved a total of 43 questions, which were mainly divided into the following three parts: (1) basic information on a smallholder, such as household size, gender, ages, education levels and occupations of family members; (2) livelihood capital possessed by a smallholder, including natural capital, physical capital, financial capital, social capital and human capital; (3) livelihood strategies and stresses faced by a smallholder.

### 2.3. Theoretical Framework

The theoretical framework in the current study is shown in Figure 2. Livelihood resilience refers to "the ability of all people across generations to sustain and improve their livelihood opportunities and well-being despite environmental, economic, social and political disturbances" [13], which is mainly measured by the 3 As analysis framework in this study. The 3As analysis framework was proposed by Bahadur et al. [14] in the project "Building resilience and adaptation to climate extremes and disasters", funded by the Department for International Development (DFID), which initially aimed to help the communities in South and Southeast Asia, East Africa and the Sahel becoming more resilient to the climate-related shocks and stresses to ensure the vulnerable groups' well-being. Bahadur et al. [14] deconstructed resilience into three easily identifiable abilities, adaptive capacity, anticipatory capacity and absorptive capacity, which interlinked each other. In particular, adaptive capacity refers to the ability of a social system to cope with long-term, ongoing future risks, and to learn and adjust to the adverse consequences, such as salinity. Anticipatory capacity is the ability of a social system to avoid or reduce the negative climate-related effects and extreme events through preparation and planning before the shocks and stresses. In addition, absorptive capacity refers to the ability of a social system to use skills and resources to cope with and manage adverse statuses, emergencies or disasters, such as hurricanes. Campbell [41] adopted this analysis framework to estimate the livelihood resilience of coffee growers living in Cedar Valley of Jamaica. According to the indicator system constructed by Bahadur et al. [14] and Campbell [41] and the actual situation and data availability in our study area, we constructed 25 indicators and 8 dimensions to evaluate smallholders' livelihood resilience. The specific indicator system is shown in Table 1.

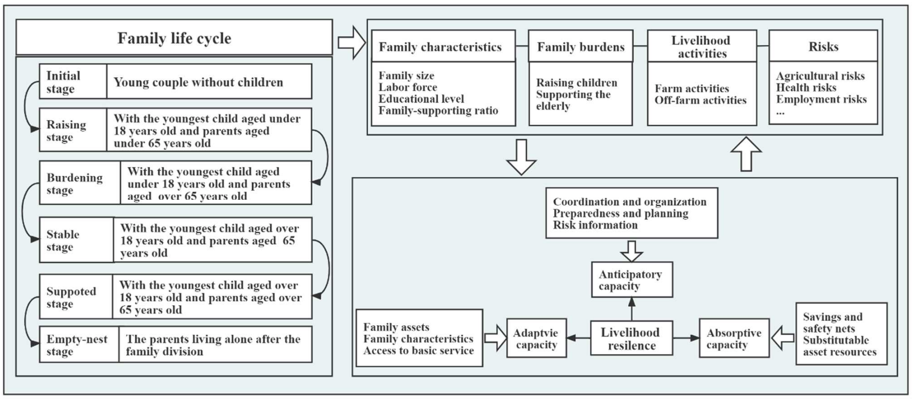


**Figure 2.** Theoretical framework of this study.

The concept of FLC was first proposed by Rowntree [24] to solve poverty issues, which refers to the repeated process from birth to the vanishing of a family [25]. Due to the cultural differences in different regions in the world, the criteria of the FLC division should fully consider family characteristics in the study areas. Given this, this study integrated the relevant studies on the Chinese FLC and referred to the work by Ye et al. [29]. Considering whether the children in a family were over 18 years old and whether the elderly were over 65 years old, the given smallholders in the dryland area of the Yellow River basin in China were divided into six types, which were the initial stage, raising stage, burdening stage, stable stage, supported stage and empty-nest stage, as shown in Figure 2.

FLC is a comprehensive reflection of human capital characteristics, which evolves with the changes in the household size and the quantity and quality of the labor force in a family [27,28]. The existing literature revealed the close relationships between the FLC and labor supply, household income, consumption and savings, and livelihood strategies [25,26,42,43]. For example, after the birth of a child in a family, the raising burdens of the family gradually increase. Then, the obligation to support the elderly appears as the FLC evolves, when the burdens of the family reach the maximum. As the children reach adulthood, the burden reduces, which reduces to the minimum when there are no people to support or raise. Some studies indicated that family income in different stages of the FLC was different, and the relationship between FLC and family income presented an inverted "U" shape. Furthermore, FLC had a significant impact on off-farm labor transfer. The research by Lin and Wang [44] revealed that the probability of off-farm labor transfer showed a trend of an inverted "U" shape with the evolution of the FLC. In addition, smallholders at different stages of the FLC faced different risks and shocks [34]. After reviewing the existing literature, it is found that not only the household characteristics and burdens, such as labor force and family size, but also the livelihood activities and risks faced by the smallholders, are closely related to their resilience to livelihood. Therefore, taking FLC as the entry point, it is crucial to explore the resilience of smallholders in different stages to external pressures and shocks for scholars and managers to dynamically understand the resilience of farmers' livelihoods.

**Table 1.** The indicator system and variable weights of livelihood resilience assessment.

| Components | Dimensions | Indicators | Descriptions of Indicators | Roles | Weights |
|---|---|---|---|---|---|
| Adaptive capacity | Family assets X1 | Farmland areas A1 | 1 = 5 mu and below, 2 = 5~10 mu, 3 = 10~15 mu, 4= 15~20 mu, 5 = 20 mu and above (1 mu is about 0.067 ha) | + | 0.120 |
| | | Durable goods A2 | Number of durable goods possessed by a household/piece | + | 0.060 |
| | | Housing area A3 | The total area of housing owned by a household/m$^2$ | + | 0.120 |
| | Family characteristics X2 | Education level A4 | The educational level of a household head, 1 = primary school and below, 2 = junior high school, 3 = senior high school, 4 = junior college, 5 = university and above | + | 0.134 |
| | | Health A5 | The general health of family members, 1 = very unhealthy, 5 = very healthy | + | 0.134 |
| | | Family-supporting ratio A6 | The ratio of non-labor population to total population in a family/% | - | 0.270 |
| | Access to basic services X3 | Traffic convenience A7 | The smallholders' distance from the nearest market /km | - | 0.066 |
| | | Medical facility A8 | Supporting facilities of hospital nearest to a family, 1 = very few, 5 = many | + | 0.066 |
| | | Irrigation water A9 | Whether farmland can be continuously irrigated, 1 = yes, 0 = no | + | 0.200 |
| Anticipatory capacity | Coordination and organization X4 | Skill training B1 | Whether family members participated in farm skill training, 1 = yes, 0 = no | + | 0.149 |
| | | Farmer-benefiting policies and projects B2 | Whether there were farmer-benefiting policies and projects, 1 = yes, 0 = no | + | 0.149 |
| | Preparedness and planning X5 | Strategies to coping with agricultural disaster risks B3 | Number of measures adopted to deal with agricultural disaster risks (such as increasing pesticides, irrigations, plastic mulching, soil moisture conservation techniques, changing crop varieties and cropping structures) | + | 0.216 |
| | | Diversity of livelihood activities B4 | Whether a family adopts off-farm measures to resist external disturbance, 1 = yes, 0 = no | + | 0.323 |
| | Risk information X6 | Disaster risk information B5 | Number of ways to obtain disaster risk information, 1 = very few, 5 = many | + | 0.082 |
| | | Weather forecast B6 | Whether you often follow the weather forecast, 1 = yes, 0 = no | + | 0.082 |
| Absorptive capacity | Savings and security nets X7 | Savings C1 | 1 = CNY 10,000 and below, 2 = CNY 10,000–40,000, 3 = CNY 40,000–70,000, 4= CNY 70,000–100,000, 5 = CNY 100,000 and above | + | 0.157 |
| | | Agricultural insurance C2 | Whether a smallholder buys agricultural insurance, 1 = yes, 0 = no | + | 0.054 |
| | | Assistance from kith and kin C3 | 1 = very little, 5 = very much | + | 0.090 |
| | | Government assistance C4 | Whether you get assistance from local government, 1 = yes, 0 = no | + | 0.032 |
| | Substitutable asset resources X8 | Credit services C5 | Whether farmers have access to credit services, 1 = yes, 0 = no | + | 0.166 |
| | | Off-farm income C6 | Whether the family has off-farm income, 1 = yes, 0 = no | + | 0.300 |
| | | Crop diversity C7 | Number of species of crops | + | 0.200 |

## *2.4. Methods*

### 2.4.1. Livelihood Resilience Measurement

In this paper, the analytic hierarchy process (AHP) and technique for order preference by similarity to an ideal solution (TOPSIS) were adopted to calculate adaptive capacity, absorptive capacity and anticipatory capacity. Before calculating, we used the range normalization method to standardize the data.

According to the methods of decomposition, comparative judgement and comprehensive thinking, AHP regards the study respondents as a hierarchical system to quantify the factors from each hierarchy. Compared with the expert scoring method, this method integrates the quantitative method into the qualitative method to make the subjective scoring more reasonable. In addition, the objective weighting method, such as the entropy evaluation method, assigns weights according to the dispersion degree of data distribution. Specifically, when the values change greatly, the weights of these indicators assigned are greater. Therefore, this method easily ignores the importance of indicators. Comparatively, AHP has the advantage of considering the importance of indicators to the objectives. Hence, AHP was selected in this study to assign weights to the indicators, which all passed the consistency tests. The weights of the indicator system are shown in Table 1.

The TOPSIS method is a common multi-objective decision analysis method, which aims to evaluate the relative merits according to the distances between the positive and negative ideal solutions. The computation procedure is shown as follows:

① Building a dimensionless data matrix

$$\left(Y_{ij}\right)_{m\times n} \tag{1}$$

② Computing the weight normalization matrix

$$\left(Z_j\right)_{m\times n} = \left(Y_{ij}\times w_j\right)_{m\times n} \tag{2}$$

③ Computing the positive ideal solution $Z^+$ and negative ideal solution $Z^-$

$$Z^+ = (Z_1^+,\ Z_2^+,\ldots,Z_n^+) = \left\{maxZ_{ij}\middle|j=1,\ 2,\ldots,n\right\} \tag{3}$$

$$Z^- = (Z_1^-,\ Z_2^-,\ldots,Z_n^-) = \left\{minZ_{ij}\middle|j=1,\ 2,\ldots,n\right\} \tag{4}$$

④ Computing the Euclidean distance between each identified indicator and positive and negative ideal solutions

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(Z_{ij}-Z_j^+\right)^2} \tag{5}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(Z_{ij}-Z_j^-\right)^2} \tag{6}$$

⑤ Computing the close-degree $C_i$ of the positive and negative ideal solutions and the surveyed respondents

$$C_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{7}$$

where the values of $C_i$ are between 0 and 1. $C_i$ with a high value indicates that the evaluated objective is larger.

⑥ Computing the livelihood resilience $LR$

$$LR_i = \frac{AC_i + ABC_i + ANC_i}{3} \tag{8}$$

where $AC_i$, $ABC_i$ and $ANC_i$ represent the adaptive capacity, absorptive capacity and anticipatory capacity of the *i*-th sample, respectively.

#### 2.4.2. The Specification of the GeoDetector Model

The GeoDetector is used to detect spatial heterogeneity of data and reveal its driving factors by a set of spatial variance analyses [38], which has been widely applied to study geography issues in recent years. It includes factor detector, interaction detector, risk detector and ecological detector. Among them, factor detection can measure the interpretation degree of the given indicators to livelihood resilience, which is measured by the q value [39], which is as follows:

$$q = 1 - \frac{1}{n\partial^2}\sum_{i=1}^{l} n_i \partial_i^2 \quad (9)$$

where $q$ indicates the explanatory power of the independent variable X to livelihood resilience, which ranges from 0 to 1. The larger the q value, the greater the power of X with regard to livelihood resilience. Furthermore, $n$ is the number of samples, $l$ is the number of involved indicators, $\partial^2$ and $\partial_i^2$ are the total variance and the variance in the $i$-th indicator, respectively.

2.4.3. The Specification of the LMG Metric Model

The Lindeman, Merenda and Gold method (LMG) decomposes $R^2$ into non-negative contribution based on the average orderings of explanatory variables from the multiple linear regression model [45], which is regarded as one of the parametric regression methods on the basis of variable decomposition. In this study, the LMG metric was conducted to measure the explanatory powers of the selected indicators to livelihood resilience. The specific calculation steps are shown as follows:

① Firstly, a multiple linear regression model (MLR) is established to calculate $R^2$, shown by the following equation:

$$R^2 = \frac{Model\ SS(model\ with\ variable\ in\ S)}{Total\ SS} \quad (10)$$

where *Model SS* represents the sum of squares of the model, and *Total SS* is the total sum of squares.

② When adding the regressors in a set $M$ to a model, the additional $R^2$ is defined as *seq* $R^2$, which is calculated by the following formula:

$$seqR^2\left(\frac{M}{S}\right) = R^2(M \cup S) - R^2(S) \quad (11)$$

③ The formula for $R^2$ allocated to the regressor $x_k$ in the order $r$ can be written as follows:

$$seqR^2(\{x_k\} \cup S_k(r)) = R^2(\{x_k\} \cup S_k(r)) - R^2(S_k(r)) \quad (12)$$

where $S_k(r)$ denotes a set of regressors entered into the model before regressors $x_k$ in the order $r$. The order of the regressors in any model is a permutation of the available regressors $x_1, \ldots, x_p$, which is expressed by the tuple of indicators $r = (r_1, \ldots, r_p)$.

④ The metric LMG for the regressors $x_k$ is calculated as follows:

$$LMG(x_k) = \frac{1}{p!}\sum_{r\ permutation} seqR^2(\{x_k\}|r) \quad (13)$$

The LMG metrics were conducted using the R package "Relaimpo" developed by Grömping [46].

## 3. Results

### *3.1. Description of Livelihood Resilience*

The AHP-TOPSIS method was applied to calculate the three components of livelihood resilience, and then Formula (8) was used to calculate the livelihood resilience of smallholders in the dryland area in China.

3.1.1. Adaptive, Anticipatory and Absorptive Capacity

The results of one-way ANOVA showed (Table 2) that the adaptive capacity and anticipatory capacity of smallholders at different stages of the FLC were significantly different at the 5% and 1% levels, respectively. Specifically, all the average values of the adaptive, anticipatory and absorptive capacities of smallholders in the empty-nest stage were at their minimum, while the average values of the adaptive and absorptive capacity at the supported stage were the largest, as was the case for the average values of the expected ability of the initial stage.

**Table 2.** Mean values and one-way ANOVA of livelihood resilience and its components.

| | Initial Stage | Raising Stage | Burdening Stage | Stable Stage | Supported Stage | Empty-Nest Stage | Mean Value | Homogeneity Variance | ANOVA |
|---|---|---|---|---|---|---|---|---|---|
| Adaptive capacity | 0.349 | 0.341 | 0.327 | 0.368 | 0.370 | 0.318 | 0.345 | 0.069 | 0.033 ** |
| Anticipatory capacity | 0.494 | 0.465 | 0.446 | 0.417 | 0.446 | 0.329 | 0.440 | 0.262 | 0.000 *** |
| Absorptive capacity | 0.298 | 0.284 | 0.286 | 0.280 | 0.320 | 0.262 | 0.287 | 0.687 | 0.597 |
| Livelihood resilience | 0.398 | 0.380 | 0.369 | 0.372 | 0.384 | 0.320 | 0.372 | 0.789 | 0.032 ** |

*** $p < 0.01$, ** $p < 0.05$.

Figure 3 shows the kernel density distribution of the adaptive, anticipatory and absorptive capacities. In terms of adaptive capacity, the curve of kernel density of the supported stage was relatively flat, indicating that data of that stage fluctuated greatly. The kernel density curves of the other stages were steep, especially in the initial stage, suggesting that the data distributions were concentrated. As for anticipatory capacity, the kernel density curve in the initial stage was flat, with values that largely fluctuated. The peak value in the empty-nest stage showed a left bias, which revealed that the anticipatory capacity of most families at this stage was small. In addition, the curve in the supported stage showed a steep trend, indicating that the anticipatory capacity of most families was concentrated in the mean value. As far as absorptive capacity was concerned, the kernel density curves of the supported stage and empty-nest stage showed a bimodal distribution, indicating that the absorptive capacity of farmers at this stage showed a polarization trend. The density curves of the other stages were steep with left-biased peaks, indicating that the absorptive capacity of most smallholders was small.

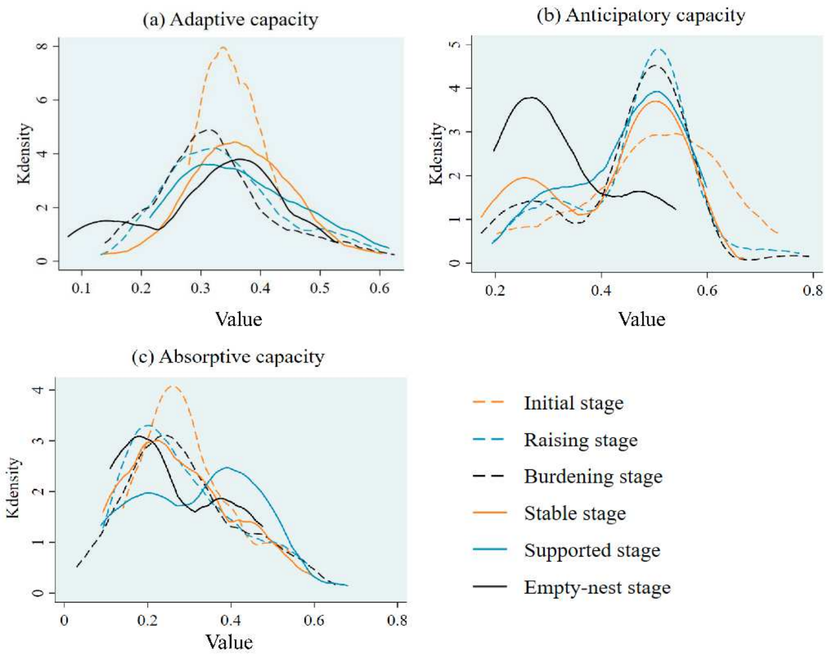


**Figure 3.** Kdensity of adaptive, anticipatory and absorptive capacity.

3.1.2. Livelihood Resilience

The results of one-way ANOVA also showed (Table 2) that the livelihood resilience of smallholders at different stages of the FLC was significantly different at the 5% level, which had an average value of 0.372, a maximum value in the initial stage and a minimum value in the empty-nest stage. Figure 4 showed the violin diagram of livelihood resilience in every stage. The box of livelihood resilience of farmers in the initial stage is close to the upper section, indicating that the livelihood resilience in this stage was high. The livelihood resilience in the empty-nest stage was narrow at the top and wide at the bottom, which revealed that the livelihood resilience in this stage showed low-value distribution. Livelihood resilience in the raising stage was close to the lower quartile, which showed a lower livelihood resilience in this stage. During the supported stage, on the contrary, the livelihood resilience was wide at the top and narrow at the bottom, indicating that the resilience of most farmers was high.

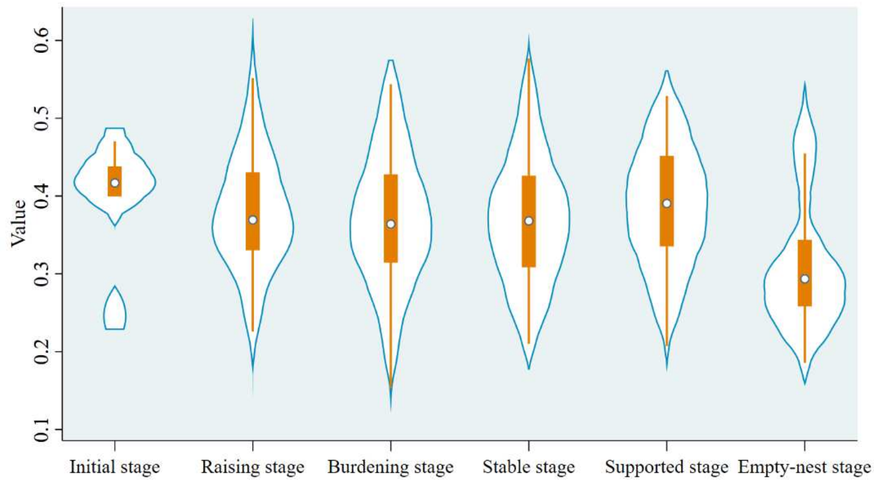


**Figure 4.** Violin plot of livelihood resilience in each stage of the family life cycle.

*3.2. Influencing Factors of Livelihood Resilience*

3.2.1. The Results of Factor Detection

This study regarded the computed livelihood resilience index at each stage of the FLC as the dependent variable and took the dimensions of livelihood resilience as the independent variables. Then, the explanatory powers of the dimensions of livelihood resilience were calculated through Formula (9). Considering the small sample size in the initial stage of the study area and the fact that families in the initial stage will enter the raising stage soon after they build a family, this study incorporated samples in the initial stage into the raising stage, referring to the research by Ye et al. [29]. After that, according to the requirement of the GeoDetector model, the continuous variables among the independent variables were converted into discrete variables by the natural breaks method.

Factor detection revealed the explanatory powers of the influencing factors with regard to livelihood resilience at the dimension level. Table 3 showed the q values of eight dimensions in each stage of the FLC, which reflected that both preparedness and planning and substitutable asset resources were that most important variables in any stage of FLC. Meanwhile, coordination and organization, risk information, and access to basic service were not very important, especially coordination and organization. Additionally, family characteristics and family assets were the important variables in the raising stage. Family characteristics, family assets and savings and safety nets were relatively important factors in the burdening stage. According to the q values, the variable importance ranking of savings and safety nets was the third in the stable stage and supported stage, followed by family characteristics, access to basic service and family assets. As for the empty-nest stage, family assets and family characteristics were relatively important influencing factors.

**Table 3.** Explanation powers of eight dimensions contributing to livelihood resilience.

| | Family Assets | Family Characteristics | Access to Basic Services | Coordination and Organization | Preparedness and Planning | Risk Information | Savings and Safety Nets | Substitutable Asset Resources |
|---|---|---|---|---|---|---|---|---|
| Raising stage | 0.134 | 0.252 | 0.094 | 0.005 | 0.388 | 0.100 | 0.092 | 0.337 |
| Burdening stage | 0.195 | 0.187 | 0.052 | 0.054 | 0.383 | 0.083 | 0.132 | 0.425 |
| Stable stage | 0.145 | 0.219 | 0.160 | 0.100 | 0.380 | 0.065 | 0.273 | 0.453 |
| Supported stage | 0.108 | 0.221 | 0.174 | 0.052 | 0.343 | 0.045 | 0.264 | 0.505 |
| Empty-nest stage | 0.423 | 0.350 | 0.237 | 0.202 | 0.435 | 0.154 | 0.223 | 0.661 |

#### 3.2.2. LMG Metric

To further explore the important factors of livelihood resilience, the LMG metric method was used to calculate the relative importance of eight dimensions. First, the variance inflation factor (VIF) analysis at the dimension level was conducted to test the identified regressors' multicollinearity. The results showed that the VIF of all regressors was less than 10 (Table 4), indicating that there was no multicollinearity between the regressors. Subsequently, multiple linear regression (MLR) was used to investigate the impacts of indicators on livelihood resilience from the perspective of the FLC. Finally, the LMG metrics of the factors in each stage were calculated based on the MLR model.

**Table 4.** The VIF analysis of eight dimensions contributing to livelihood resilience.

| | Family Assets | Family Characteristics | Access to Basic Services | Coordination and Organization | Preparedness and Planning | Risk Information | Savings and Safety Nets | Substitutable Asset Resources |
|---|---|---|---|---|---|---|---|---|
| VIF | 1.145 | 1.066 | 1.052 | 1.046 | 1.078 | 1.031 | 1.110 | 1.125 |

The variable importance rankings obtained by the LMG metrics are shown in Table 5. The results revealed that preparedness and planning, and substitutable asset resources were the most important influencing factors in all stages of FLC. Furthermore, both coordination and organization and risk information were not very important in any of the stages of FLC. As for the other dimensions, we found that family characteristics ranked third in the raising stage, followed by savings and safety nets, access to basic services and family assets. The q values of family assets and family characteristics were relatively large in the burdening stage. For the stable stage, the q value of family characteristics ranked third, followed by savings and safety nets, and family assets. In the supported stage, access to basic services, family assets, savings and safety nets, and family characteristics were relatively important variables to livelihood resilience. In the empty-nest stage, family assets, family characteristics and access to basic service were relatively important.

**Table 5.** The LMG metrics of eight dimensions' contribution to livelihood resilience.

| | Family Assets | Family Characteristics | Access to Basic Services | Coordination and Organization | Preparedness and Planning | Risk Information | Savings and Safety Nets | Substitutable Asset Resources |
|---|---|---|---|---|---|---|---|---|
| Raising stage | 0.076 | 0.134 | 0.078 | 0.004 | 0.335 | 0.003 | 0.079 | 0.291 |
| Burdening stage | 0.124 | 0.087 | 0.038 | 0.016 | 0.332 | 0.003 | 0.066 | 0.335 |
| Stable stage | 0.064 | 0.158 | 0.030 | 0.023 | 0.321 | 0.015 | 0.117 | 0.272 |
| Supported stage | 0.084 | 0.073 | 0.097 | 0.004 | 0.269 | 0.003 | 0.083 | 0.388 |
| Empty-nest stage | 0.192 | 0.141 | 0.074 | 0.012 | 0.249 | 0.054 | 0.049 | 0.229 |

### *3.3. Bivariate Correlations*

In order to compare and analyze the result consistency of the GeoDetector model and LMG metric, we took the data of smallholders in the stable stage as an example to draw the bivariate correlations between livelihood resilience and the eight dimensions (Figure 5). The results showed that smallholders' livelihood resilience was strongly correlated with family assets (X1), family characteristics (X2), preparedness and planning (X5), savings and safety nets (X7) and substitutable asset resources (X8).

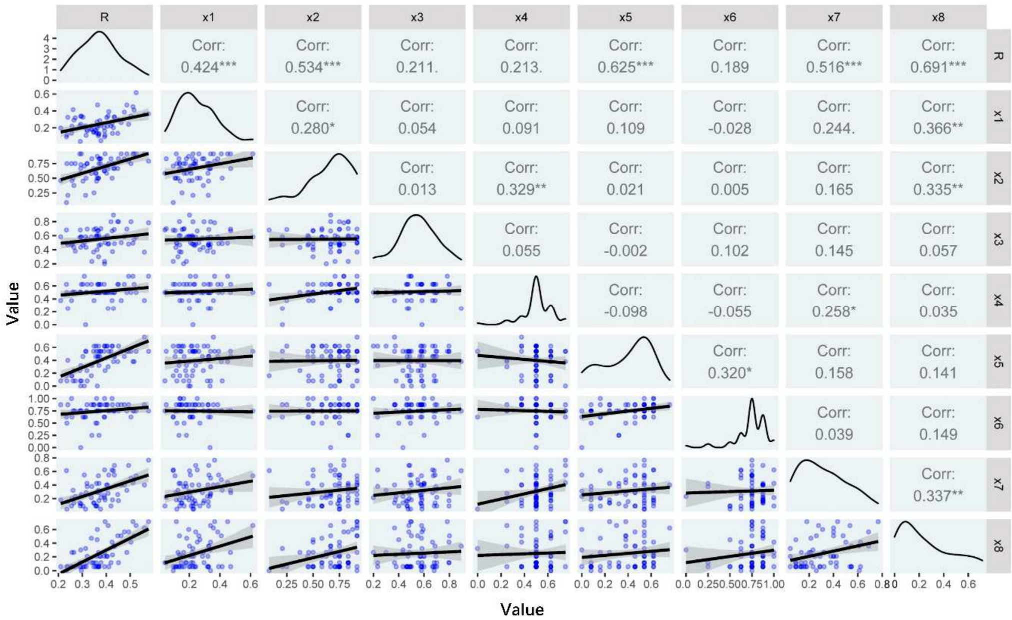


**Figure 5.** Bivariate correlations between livelihood resilience and eight dimensions in the stable stage. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

## 4. Discussion

### *4.1. Livelihood Resilience of Smallholders in Different Stages of the FLC*

Through the analysis of livelihood resilience of smallholders, it can be concluded that livelihood resilience did not present a monotonically increasing or decreasing trend with the evolution of the FLC. The mean values of livelihood resilience in the burdening stage and empty-nest stage were lower than the mean value of all samples, while they were higher in the initial, raising, stable and supported stages, which might be explained by the fact that the dependency and support burdens of a family did not increase or decrease gradually with the evolution of the FLC, but varied in different stages. Families either in the initial and stable stages have no dependency or support burdens, while smallholders in the raising and supported stages have a single dependency or support burden. Particularly, smallholders in the burdening stage have both dependency and support burdens. Therefore, it can be observed that the livelihood resilience of smallholders in different stages is different. According to the field survey in the dryland area of China, it was common for the elderly in rural areas to take care of their grandchildren and perform farming duties, which increased the effective labor force to a certain extent [47] and reduced dependency and support burdens of a family. Hence, we found that this could effectively enhance the livelihood resilience of smallholders in the burdening and supported stages. Secondly, there were differences in social capital accumulation and depreciation possessed by smallholders in different stages of the FLC, which made information acquiring channels and social networks different. All of these ultimately led to the different levels of livelihood resilience of smallholders in different stages of the FLC.

Additionally, smallholders select different livelihood activities according to their needs and goals in the different stages of the FLC, which also result in different levels of livelihood resilience of smallholders. Previous studies showed that smallholders in the middle stages of the FLC were more likely to choose off-farm strategies than those at either end [33]; thus, those families have greater livelihood resilience due to higher off-farm income. In addition, with the evolution of the FLC, farm income of smallholders increased [28], as well as the agricultural risks they faced. Hence, the livelihood resilience of smallholders decreases. Therefore, it is important to conduct targeted agricultural skills training for smallholders in the burden and supported stages to enhance their ability to cope with agricultural risks and family income, which can promote smallholders' livelihood resilience.

Generally, members from smallholders in the empty-nest stage are more than 65 years old, so it is difficult for them to migrant working. More importantly, influenced by their physical health, farmers in the empty-nest stage generally tend to choose farming or retirement, which results in limited agricultural income and the minimum non-agricultural income for them. In addition, medical expenses are burdens for smallholders in the empty-nest stage. Therefore, poor family income and heavy medical expenses lead the families in this stage to have a poor ability to resist risks and vulnerable livelihoods. In other words, smallholders in the empty-nest stage have lower livelihood resilience. Given this, relevant managers should pay attention to the ability to access the medical and health of smallholders in the empty-nest stage and improve the living conditions of the elderly, such as building an elderly community and providing a variety of basic services in the community for them. Moreover, land transfer and a safety network in the empty-nest stage should be encouraged and built.

### *4.2. Analyzing the Influencing Factors of Livelihood Resilience*

According to the factor detection results, preparedness and planning and substitutable asset resources had the greatest impacts on the livelihood resilience of smallholders at all stages of the FLC. Preparedness and planning were mainly measured by the farm strategies to deal with agricultural disasters and off-farm activities, which can reflect the ability of smallholders to cope with agricultural disasters and social shocks. Smallholders in the dryland area of China usually adopted soil moisture conservation technology, mulching, changing planting structure and crop varieties, increasing pesticides and irrigation to cope with agricultural disasters, as well as employing migrant workers and focusing on non-agricultural operation and other off-farm activities to resist climate change or social disturbances. Substitutable asset resources "can ensure that farmers can use other assets to stabilize their consumption and maintain health even if they suffer from a heavy asset loss caused by external disturbances" [14], which were measured by off-farm income and crop diversity. Secondly, family characteristics have a great impact on livelihood resilience. This may be because household characteristics (mainly including education levels, health status and family-supporting ratio) have a greater impact on the livelihood activities and capitals of smallholders in any stage of the FLC, which ultimately affects their livelihood resilience. Fan et al. [48] also confirmed that physical capital, human capital and social network have an important impact on farmers' livelihood vulnerability. Therefore, relevant managers should diversify farmers' livelihood strategies, and take targeted measures to improve their livelihood skills to improve income levels, such as agricultural and non-agricultural skill training in rural areas and the development of new agricultural management models.

This study also revealed that the explanatory power of family assets and access to basic services on livelihood resilience of smallholders showed a U-shaped trend, along with the evolution of the FLC. These were the crucial parts of adaptive capacity. On the contrary, the importance of savings and safety nets on the livelihood resilience of smallholders showed an inverted U-shaped trend with the evolution of the FLC. Specifically, family assets mainly involved farmland size, housing area and family durable goods, etc. Smallholders in the supported and burdening stages were built in the second round of the farmland contract period in China, so land consolidation and reallocation based on family member changes were not allowed, which resulted in these smallholders having limited farmland sizes [27]. However, this policy also made smallholders in these stages more likely to select off-farm employment, so that they generally possessed larger housing areas and more durable goods, and were more resilient to cope with the long-term livelihood pressures caused by external disturbances. In addition, they had fewer savings due to heavy dependency and support burdens. In order to improve the livelihood resilience of smallholders in this stage, relevant managers should conduct targeted off-farm employment skill training, encourage entrepreneurship, and provide policy support to smallholders. In addition, these families should be encouraged to transfer farmland to promote non-farm labor transfer. As for the smallholders in the supported stage, the importance of family assets to livelihood resilience was small, while the importance of savings and safety nets was large, indicating that the impact of family assets on the livelihood resilience gradually decreased with the evolution of the FLC. Since smallholders in the burden and support stages tended to focus on farming due to family responsibilities, age, health and other reasons, agricultural skills training should be carried out for them to improve their agricultural income.

In terms of smallholders in the empty-nest stage, the impact of savings and safety nets on livelihood resilience decreased due to their low importance ascribed to it. Risk information and coordination and organization had less impact on livelihood resilience. In this study, risk information was mainly measured by disaster risk information and weather forecast, which could effectively prevent the adverse impact of extreme events on agriculture and reduce agricultural losses. The low importance of risk information may be caused by various information channels and low agricultural dependency; thus, the impact of risk information was small. Coordination and organization were measured by agricultural skill training and benefiting-farmers policies and projects. Smallholders in the dryland area in China reported that they received less farming skill training and expressed a lack of understanding of benefiting-farmer policies and projects. Given this, village cadres should promote farmer-benefitting policies and projects to ensure locals can fully enjoy preferential treatment.

### *4.3. Comparative Analysis*

By comparing the results of the GeoDetector and the LMG metric, it was found that both methods could identify the important influencing factors of livelihood resilience. Specifically, the impacts of preparedness and planning and substitutable asset resources on livelihood resilience of smallholders in different stages of the FLC were similar in the two methods. Secondly, family characteristics had a great impact on livelihood resilience. Except in the burdening stage and empty-nest stage, the variable importance rankings of the two methods have poor consistency in the other stages. For instance, the bivariate scatter plots of smallholders' livelihood resilience and eight dimensions in the stable period proved that both the GeoDetector and LMG metric from the MLR model could identify the important influencing factors well, but there were differences in their variable importance rankings. This may be because the LMG metric based on the MLR model is a variance analysis method and decomposes $R^2$ into the regressors to calculate the relative importance of indicators, which can better identify the linear correlations between eight dimensions and livelihood resilience [38]. The GeoDetector, which uses a spatial variance analysis method, has no linear assumption on variables and is immune to multicollinearity among multiple independent variables [37], so it can also accurately identify linear correlations. To sum up, both methods can identify important influencing factors of livelihood resilience. However, the independent variables must be discrete in the GeoDetector model [37]. Therefore, according to the analysis requirement, we converted the independent variables into discrete variables before analysis. We think that this may be one of the reasons for the differences in the variable importance ranking of the two methods.

## 5. Conclusions

Sustainable livelihood development of smallholders in the dryland area is crucial for the implementation of the strategy of ecological protection and high-quality development in the Yellow River basin. For a long time, farmers in the dryland area of the Yellow River basin have suffered from natural and social shocks, which seriously threaten their sustainable livelihood development. Therefore, it is important to urgently analyze the resilience of farmers' livelihood in the dryland area. Given this, this study evaluated the livelihood resilience of smallholders in the dry land of the Yellow River basin based on the 3As framework, and then explored the relative importance of indicators of livelihood resilience from the perspective of the FLC. Finally, the target suggestions were put forward for local governments to build resilient livelihood management policies (Figure 6).

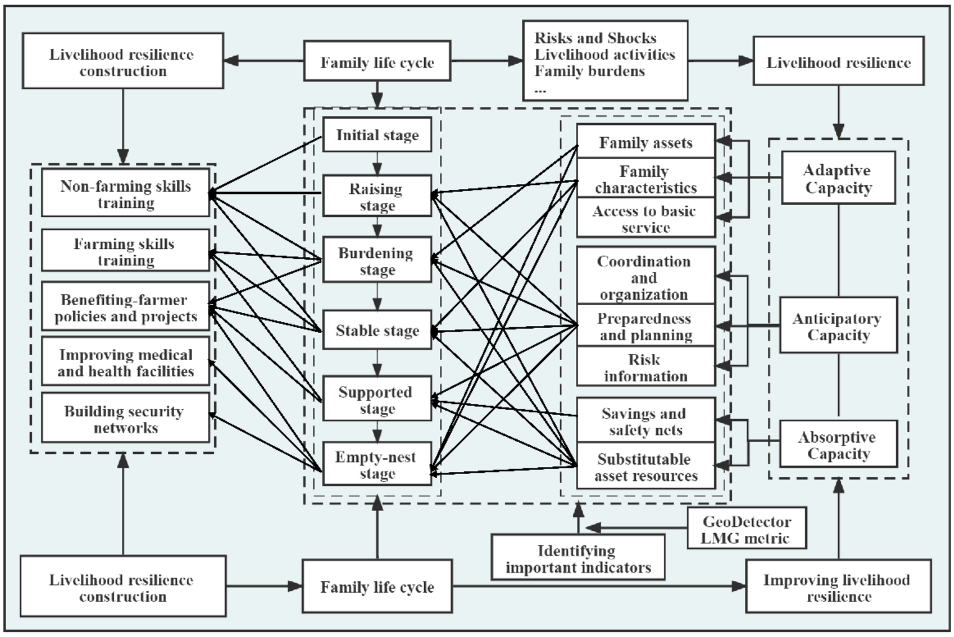


**Figure 6.** The mechanism of household livelihood resilience analysis and improvement from the family life cycle perspective.

According to the results and discussions, the conclusions were drawn as follows:

(1) There were significant differences in the livelihood resilience, adaptive capacity and anticipatory capacity of smallholders in each stage of the FLC at a 5% level. Livelihood resilience in the burdening stage and the empty-nest stage was lower than the population mean value, while the resilience of livelihood in the initial stage, raising stage, stable stage and supported stage was higher than or equal to the population mean value.

(2) Preparedness and planning and substitutable assets resources had the impacts on the livelihood resilience of smallholders at each stage of the FLC. And the factor of family characteristics also was an important determinant. Furthermore, the impact of family assets and access to basic services on the smallholders' livelihood resilience showed a U-shaped trend with the evolution of the FLC. On the contrary, the impact of savings and safety net on livelihood resilience presented an inverted U-shaped trend with the evolution of the FLC.

(3) Comparing the results of the GeoDetector and LMG metric models, it was found that the two models can better explore the key influencing factors of livelihood resilience, such as family characteristics, preparedness and income, and substitutable asset resources. However, there were differences in the relative importance rankings of the given regressors in each stage of the FLC between the two models, especially in the raising stage and supported stage. Through comparison and analysis, we found that the results obtained by the GeoDetector were more accurate to explore the relative importance of indicators to livelihood resilience in this study.

Based on the results of this study and field survey in dryland areas, it found that preparedness and planning, substitutable asset resources, and family characteristics were identified as the important factors affecting smallholders' livelihood resilience. In addition, several indicators had different impacts on livelihood resilience at different stages of the FLC. Given this, when formulating the policies to achieve the livelihood sustainability of the locals, the government should give full consideration to the key influencing factors and the stages of the FLC for a smallholder. Specifically, the local government should carry out vocational skill training for farmers and promote labor force transfer in the first few stages to diversify family income, with the aim of building a resilient livelihood.

Secondly, managers should pay attention to farming skill training and the improvement of disaster prevention and mitigation capabilities for farmers in the later stages of the FLC to improve their livelihood resilience. In addition, diversified farm-benefiting policies and projects should be put forward to reduce farmers' agricultural input costs and living costs. Moreover, the ability to access basic services for smallholders in the empty-nest stage should be improved by improving basic medical and health conditions in the rural regions and living conditions of the elderly, encouraging families in the empty-nest stage to conduct farmland transfers to maintain their living standards and strengthen their ability to resist risks. Finally, local managers should focus on the safety network construction of smallholders in the empty-nest stage.

The problem of "empty-nest" discussed in this study is a social problem that has been widely focused on in China but is not a global social problem. For the studies on family life cycles in other regions, different criteria need to be considered according to the actual situations, so the results obtained in this study have a certain limitation. Additionally, this study explored the differences in livelihood resilience and the relative importance of its influencing factors from the perspective of the FLC, because smallholders in different stages of the FLC have distinctive structure characteristics. Future works need to examine the moderator role of FLC to enrich livelihood resilience research and provide suggestions for livelihood resilience construction in rural areas in the Yellow River basin of China.

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**Institutional Review Board Statement:** Ethical review and approval were waived for this study because data and information collected through face-to-face interview. Moreover, personal opinions on the research topics were treated in an aggregated form.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

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

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**Research Involving Human Subjects:** This study was approved by the review board of Shaanxi Normal University and conducted in accordance with the approved relevant guidelines and regulations. All subjects gave their informed consent for inclusion before they participated in the study.

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# Impacts of Policy-Driven Transformation in the Livelihoods of Fishermen on Agricultural Landscape Patterns: A Case Study of a Fishing Village, Island of Poyang Lake

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**Abstract:** The agricultural landscape patterns of fishing village have undergone visible transformations in recent decades. Scholars pay less attention to fishermen with diverse livelihoods. Therefore, it is necessary to sort out the changing characteristics of fishermen' livelihoods and agricultural landscape patterns under different policy periods. We use in-depth interviews, remote sensing technology, and mathematical analysis to systematically study the changes in fishermen's livelihoods and in agricultural landscape patterns in a typical fishing village. The results show that policy have profoundly affected fishermen' livelihoods. Livelihood transformation have altered local land use practices, which had a direct impact on agricultural landscape patterns. The livelihood of fishermen has changed from diverse to single, and their cropping structure were gradually becoming simpler and more specialised. After grazing ban and comprehensive fishing ban, many fishermen migrated to towns and cities, it accelerated the loss of population in the fishing village, which caused the amount of abandoned land increasingly. Left-behind fishermen became rice farmers by contracting abandoned paddy fields. The expanses of abandoned land and bamboo woodland had increased, which caused agricultural landscape patterns gradually becoming fragmented, heterogeneous and complex.

**Keywords:** Poyang Lake; fishermen; policy; livelihoods; landscape patterns; transformation

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## 1. Introduction

With Reform and Opening-up being carried out in 1978, China has experienced rapid urbanization and industrialization. In addition, the departure of large numbers of labourers from the rural has led to the abandonment of large amounts of arable land, which made the agricultural landscape increasingly fragmented, heterogeneous and complex [1]. At the same time, changes in the livelihoods of farmers have led people to abandon arable land as they have stopped growing food. Human activities have profoundly impacted how agricultural landscape patterns have changed worldwide [2,3]. Socioeconomic development is a significant driver of change in land use and land cover and has had a substantial impact on the structure and function of landscapes [4–6]. Numerous studies have shown that socioeconomic factors determine landscape pattern change [7–10]. Moreover, socioeconomic development is usually driven by governmental policies and planning [11]. Such policies are important drivers of the evolution of natural and human factors, such as the natural environment, socioeconomic conditions, land use, landscape patterns, and farmers' livelihoods [12]. The development gap between rural and urban areas has resulted in a variety of issues related to land and livelihoods [13]. As powerful national macro-control instruments, governmental policies constitute viable solutions to these problems. Livelihoods entail a selective use of resources that is closely related to specific environmental, social, and cultural conditions [14]. Farmers' livelihoods can serve as an important lens through which to view the changes taking place in regional agricultural landscape patterns.

There is a close relationship between farm household types and changes in agricultural landscape patterns, and different types of farm household decisions can passively or actively influence the structure of agricultural landscapes [15,16]. Therefore, to realise the integrated value function of agricultural landscapes and to alleviate human-land conflicts, attention must be paid to the role played by farmers' livelihoods in landscape development [17]. Farmers' non-agricultural livelihoods fundamentally lead to the sustainable use of agricultural land [18,19], which affects the function and structure of agricultural landscapes as they adapt their livelihood strategies and land use decisions to reduce their vulnerability [20–22]. Indeed, policies play an important role in guiding farmers' livelihood strategies and land use practices [18,20]. Studies have shown that there is a strong correlation between changes in agricultural landscape patterns and farmers' incomes [23], that changes in incomes are caused largely by changes in agricultural livelihoods and that policy interventions play an important role in influencing the livelihood choices of farm households [24,25].

Research on the relationship between policy, livelihoods and agricultural landscapes has focused on traditional agricultural areas, poor areas and ecologically fragile areas and has mainly targeted farmers with a single livelihood [12,26–28]. In most parts of the world, inland fisheries have been shown to be critical for food security, environmental health and economic development [29], but scholars have paid little attention to the agricultural landscapes of inland freshwater fishing regions and fishing communities with diverse livelihoods. Therefore, to shed light on the human-land relationship in inland freshwater fishing regions, it is necessary to sort out the changing characteristics of fishers' livelihoods and agricultural landscape patterns in different policy periods.

Since the 1990s, Poyang Lake has been the most important fishing area in the Yangtze River basin [30]. It is the richest lake in China in terms of freshwater fish resources, and the lake islands have fertile marsh soil and sufficient water for irrigation. People living on the lake islands not only rely on fishing for their livelihood but also engage in farming activities. Thus, their livelihoods are diversified. The Chinese government has paid close attention to the depletion of fishery resources, environmental degradation and frequent floods in Poyang Lake in recent years [31]. With the continuous adjustment of national policies such as flood relocation policy, grazing ban and comprehensive fishing ban, fishermen have changed their traditional livelihoods. Many have migrated to towns and cities, large amounts of arable land have been abandoned, and the agricultural landscape has changed dramatically.

As Hexi village is located at an island in Poyang Lake, boats are the only means of travel here, and travel to the island is extremely inconvenient. Therefore, it is rarely disturbed by the outside world. The villagers have been fishing for a living for generations; thus, they all have an extremely similar way of life. Furthermore, the high degree of overlap between Hexi village's administrative boundaries and the actual extent of Hexi Island, as well as the large amount of arable land and the variety of agricultural land on the island, suggests that Hexi village is a great reflection of changes in land use and land cover on the other islands of Poyang Lake. This case study focuses on Hexi, a typical fishing village on Poyang Lake, and builds a scientific and rational research framework to investigate the transformation taking place in agricultural landscape patterns on the Poyang Lake islands. The aims of this study are (1) to analyse the transformation of agricultural landscapes by fishermen in different policy periods and the relationship between fishermen's livelihoods and agricultural landscapes, and (2) to reveal the dynamic changes and transformation of agricultural landscape patterns in fishing villages. These aims have theoretical and practical significance for gaining insight into changes in agricultural landscape patterns in inland freshwater fishing regions in order to develop and enrich land use transformation theory. Furthermore, this study provides a scientific basis for optimising the agricultural landscape patterns on the islands of the Poyang Lake, revealing the relationship between humans and the land in this unique geographical environment.

## 2. Policy Review and Research Framework

Policy has guided the livelihoods and productive activities of farmers. In 1952, private agriculture was banned and replaced by a collective agriculture system, which was the basis of economic and social life in rural China for a long time. Land in this period was owned by both the state and the collective [32]. Peasants could only work collectively in rural areas, and private profit-making activities and freedom of movement were severely restricted [33]. Agricultural cultivation and grain production flourished under the influence of the "grain as the key link" policy. In the early 1980s, with the introduction of the family contract responsibility system, Chinese farmers were granted long-term land tenure [34]. The decentralisation of land contributed to the rapid growth of agricultural production in the early stages of reform [35]. Farmers were given the right to make their own production decisions and to earn an income from farming. The "vegetable basket" project was proposed by the Chinese Ministry of Agriculture in 1988 to alleviate the short supply of agricultural and side-line products in China, with a focus on solving the market supply shortage [36]. Subsequently, in 2010, the Chinese State Council issued a circular on strengthening the "vegetable basket" project that emphasised advances in agricultural cultivation techniques, resulting in a significant increase in the area of vegetable greenhouses [37,38].

The uncontrolled reclamation of arable land and creation of fields around lakes over a long period led to the reduction of the reservoir capacity and flood storage function of many lakes, which in turn caused frequent floods [31]. In 1998, a huge flood in the middle and lower reaches of the Yangtze River caused enormous agricultural losses and destroyed many villages [39]. Subsequently, the government proposed a policy of migrant relocation and returning the fields to the lake, concentrating on relocating residents of low-lying areas and prohibiting them from reclaiming arable land in the wetlands of Poyang Lake in a disorderly manner. This policy was intended to reduce the impact of the livelihood behaviour of small farmers on the ecological environment. In addition, the capture fisheries of the Yangtze River provide an important source of food for many people in the basin [40,41]. During the long period of uncontrolled fishing, the fishery resources of the Yangtze River rapidly declined, and some fish species became functionally extinct. There were even times when there were no fish to be caught. For this reason, in 2003, the Chinese Ministry of Agriculture implemented a closed season policy for the Yangtze River, prohibiting fishing from April to June each year [42]. However, the implementation of the closed season did not allow the fishery resources of the Yangtze River basin to recover. Starting in 2021, the government imposed a 10-year comprehensive ban on fishing throughout the Yangtze River basin [30,43], and fishermen switched their productive activities to other industries.

Cattle breeding is also an important source of income for agricultural smallholders. Schistosomiasis has been virtually eliminated in China, but areas with infected snails and the number of afflicted animals are on the rise [44]. Domestic animals, mainly cattle, are the main infectious source of schistosomiasis, and more than 90% of schistosomiasis cases in the Poyang Lake grassland are in cattle [45]. To prevent and control schistosomiasis, the Jiangxi provincial government implemented the policy of closing the area to grazing in 2013 and stipulated that farmers cannot raise raw cattle in livestock pastures along Poyang Lake, which has made many farmers' incomes decrease.

Agricultural landscape patterns transformation refers to changes in the composition and structure of agricultural landscapes that accumulate over time and lead to fundamental changes in the form and function of agricultural landscapes and their evolution [46]. Indeed, government policy decisions, livelihood changes, and land use transformation all cause changes in the spatial and temporal distribution of agricultural landscape elements, ultimately leading to significant changes in agricultural landscape patterns [47,48].

Figure 1 illustrates the research framework for the transformation of agricultural landscape patterns, which demonstrates the gradual change from homogeneity and high agglomeration to fragmentation, heterogeneity and complexity. Policy contributes to changes in the livelihoods of fishermen and a massive migration of labour to urban areas.

Increased abandonment of arable land, as well as changes in agricultural cultivation behaviour, lead to changes in the structure and function of the agricultural landscape. Such change ultimately causes a transformation in agricultural landscape patterns.

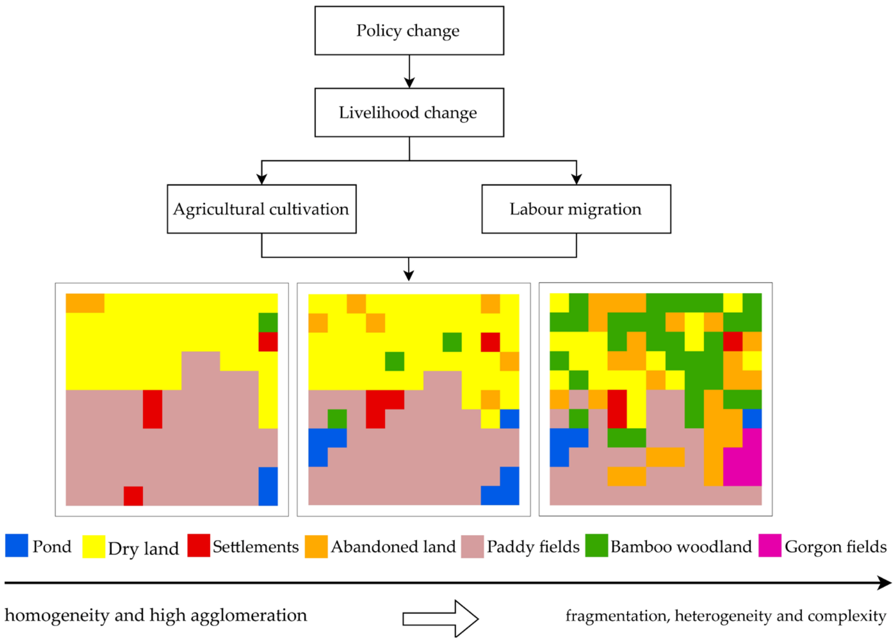


**Figure 1.** Sketch of the fishing village of transformation of agricultural landscape patterns.

## 3. Materials and Methods

### *3.1. Study Area*

Poyang Lake is located in the lower reaches of the Yangtze River in northern Jiangxi Province. It is the largest freshwater lake in China, with an area of approximately 3960 square kilometres. According to statistics, there are 41 islands in Poyang Lake, and the islands contain 50 administrative villages, which are all fishing villages.

Hexi village is located at Hexi Island, and the extent of the island is the actual extent of the village. Hexi is a typical fishing village of Poyang Lake (Figure 2). The topography is elevated in the north and low in the south. The village is rich in arable land, with dry land in the northern uplands and large expanses of fertile swampy soil in the southern low-lying areas that are ideal for rice cultivation. During a long period of prosperity, Hexi's population continually increased, reaching a peak of 560 households and a total population of 1844 [49]. In terms of population distribution, the fishermen live mainly in the northern highlands, although a few lived in the south until 1998. Fishermen depend mainly on fishing for their livelihoods and supplement their income by farming and raising livestock.

### *3.2. Data Collection*

The survey for this study is based on in-depth interviews conducted in November–December 2021 and January–February 2022 at Hexi village. We interviewed a total of 40 fishermen, spending between 60 and 90 min with each interviewee and recording the interviews. The interviewees included 32 men and 8 women, who were as young as 33 and as old as 85. The 40 fishermen had lived in the village all their lives. Therefore, they were familiar with the history and overall situation of the village and were good informants because of their ability to clearly describe changes in the village in different policy periods. The survey covered agricultural cultivation, fishing, livelihood patterns and population loss.

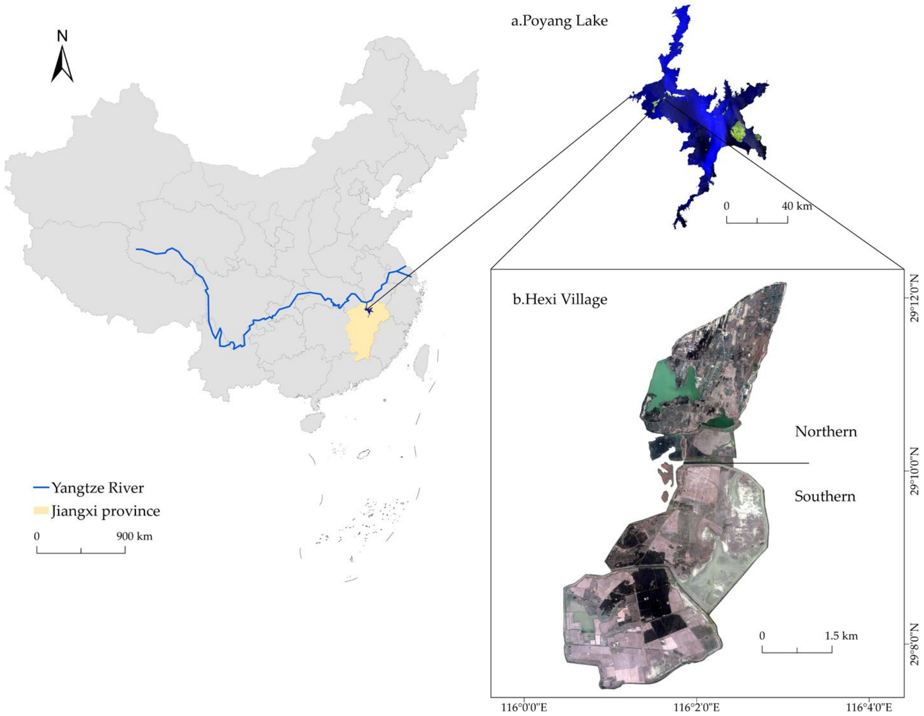


**Figure 2.** Location of Hexi village.

Through the interviews with the informants, we found that the fishermen's daily travel was very inconvenient and that they were rarely disturbed by the outside world. Each household owned fishing boats of the same size, each household owned roughly the same area of farmland, and their livelihood patterns and agricultural cultivation were highly consistent. In addition, the houses that the fishermen lived in were planned and built by the government. The consistency of livelihood patterns and the reasonable distribution of arable land resources suggested that the gap between rich and poor among the fishermen was relatively small. Therefore, the information from these interviews objectively and truly reflected the actual situation in the fishing village. It is worth noting that the purpose of our survey was to understand the overall livelihood changes and agricultural cultivation under different policies through the informants rather than to explore differences in the livelihood capital and strategies of individual farmers. In addition, we interviewed five relevant township officials and two contracted land traders to corroborate the information provided by the informants.

Another important role of field survey is to help us accurately determine the type and classification of land. We used high-resolution remote sensing images to draw a thematic map representing agricultural landscape changes, and we classified landscape types by comparing physical changes in these images in different years and seasons, as well as the current situation in the region. Using ArcGIS 10.2, we classified the landscape into seven categories: paddy fields, dry land, settlements, bamboo woodland, abandoned land, ponds, and gorgon fields. Gorgon is an annual aquatic herb of the water lily family Gorgonaceae that grows in ponds, lakes and marshes. The seeds of this species are rich in starch and are used for food and medicinal purposes [50]. The 1967 remote sensing image data come from the USGS KH-7 keyhole satellite, the 2003 data from the French SPOT satellite, the 2013 data from Google Earth, and the 2021 data from the official website of China Tianditu.

### 3.3. Research Methods

#### 3.3.1. Landscape Pattern Index

The landscape pattern index reflects the structural composition and spatial configuration and is generally analysed at three levels: patch, type, and landscape. We focused on the landscape level [51]. To better reflect the spatial pattern characteristics of the landscape and avoid redundancy of information, as well as to account for other studies, we selected the landscape indices characterizing patch density (PD), landscape shape index (LSI), aggregation index (AI), contagion (CONTAG) and Shannon's diversity index (SHDI) for analysis [46].

(1) Patch density (PD) is given by:

$$PD = \frac{n_i}{A_i} \tag{1}$$

where $n_i$ is the number of patches of landscape type i; and $A_i$ is the area of landscape type i [52]. PD is expressed in terms of the number of patches per square kilometre and represents the ratio of the number of patches to the area of the landscape for each landscape type; high PD indicates high fragmentation [53].

(2) Landscape shape index (LSI) is given by:

$$LSI = \frac{0.25E}{\sqrt{A}} \tag{2}$$

where A is the total area of the study area; and E is the length of all the patches in the study region [54]. The LSI reaches a minimum when the patch is perfectly regular in shape and increases as the patch becomes more complex [55].

(3) Aggregation Index (AI) is given by:

$$AI = \left[\frac{g_{ij}}{\max g_{ij}}\right] \times 100 \tag{3}$$

where $g_{ij}$ is the number of adjacent pixels of patch j in landscape type i. The AI reflects the spatial distribution of various landscape types. The AI is lowest if there are no common edges between pixels of a landscape type and highest when all pixels of a given landscape type have a maximum of common edges [55].

(4) The contagion index (CONTAG) is given by:

$$CONTAG = \left[1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right] \times \left[\ln(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\ln m}\right] \times 100 \tag{4}$$

where $P_i$ denotes the proportion of the landscape occupied by patch type i, $g_{ik}$ is the number of adjacencies between pixels of patch types i and k, and m is the number of patch types present in the landscape. CONTAG refers to spatial information about the type of landscape. An area with a high CONTAG has a dominant landscape type and good connectivity. Conversely, a low CONTAG indicates multiple landscape types and low connectivity [56].

(5) Shannon's diversity index (SHDI) is given by:

$$SHDI = -\sum_{i=1}^{m}(P_i \times \ln P_i) \tag{5}$$

where $P_i$ denotes the proportion of the landscape occupied by patch type i and m is the number of patch types present. The SHDI represents the degree of diversity of the landscape. If the landscape consists of one type, it is homogeneous and has a diversity index of 0. If the landscape consists of more than two types in the same proportion, the landscape diversity is the highest [52].

3.3.2. Moving Window Approach

We studied the nature, spatial structure, distribution patterns, and dynamics of landscape elements. The main principle was to visualize the spatial analysis of landscape indices at the regional scale by selecting the appropriate landscape indices from raster data and moving through the study area in a systematic manner using a target size window [57–59]. The size of the moving window was determined in relation to the study area. A moving window that is too large obscures details and microvariations in the landscape pattern, while a moving window that is too small makes it difficult to represent the overall characteristics of the landscape pattern.

For this paper, we created output raster images with various grain sizes using ArcGIS 10.2 and observed the stable interval of change in the landscape pattern index value. After repeated verification, we determined that 3 m was the best grain size for creating output raster images. We created separate moving windows with 10 m intervals and 30–150 m amplitude changes for comparison and validation to ensure that the landscape changes in the moving windows are truly reflected and find that the 90 × 90 $m^2$ window is a good reflection of most of the fluctuations in the indicators.

## 4. Results

### *4.1. Livelihood and Agricultural Landscape*

After we gathered the recollections of the fishermen, we learned that before the implementation of the household contract responsibility system in 1982, the Hexi village land was owned by the state and by the village collective, and fishermen could engage only in collective agricultural work. Agricultural production was influenced by the idea of "grain as the key link", and fishermen enthusiastically complied with the state's request to construct dikes and enclose lakes to create fields, resulting in a particularly rapid increase in the area of paddy fields, which reached 1863.25 hectares, as shown in Figure 3. The policy of the time severely restricted private productive activities; fishermen were not allowed to fish and raise livestock freely and were confined to collective farming.

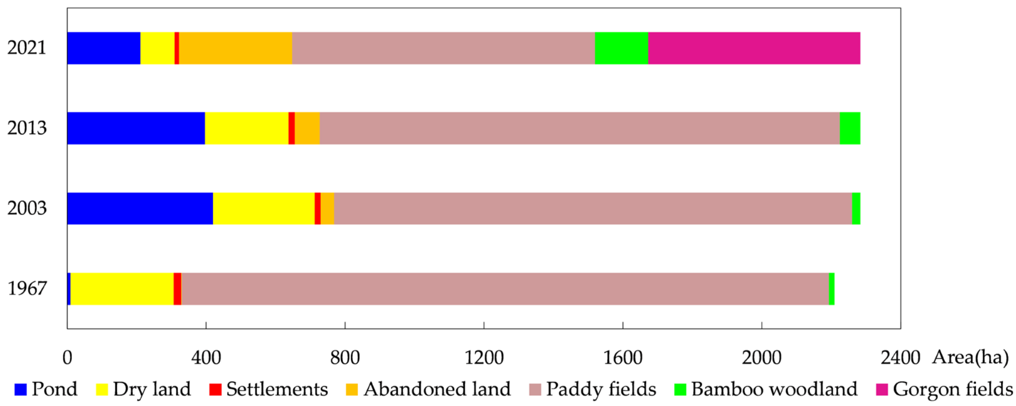


**Figure 3.** Changes in agricultural landscape area in Hexi village, 1967–2021 (in hectares).

After the implementation of the family contract responsibility system, the government did not severely restrict the productive activities of fishermen, and village collectives allocated land based on family size. Fishermen obtained land use rights, and their motivation for agricultural cultivation increased. As the population increased while arable land resources were limited, fishermen adopted aggressive livelihood strategies to maximise the use of arable land for economic gain. According to the recollections of the respondents, double-season rice was planted in paddy fields, and a variety of cash crops were grown in drylands. To maximise the benefits of dryland yield, different crops were grown in rotation. At the same time, Hexi's livestock industry progressed. The cost of raising cattle was low, and animal husbandry became a valuable source of revenue. Furthermore, the government no longer restricted the freedom to fish, so fishermen shifted their main production activities away from farming and towards the more profitable fishing industry. Fishing production increased year after year, and fishing became the primary source of income. During this time, fishermen's livelihoods were focused on fishing, while agriculture and livestock farming developed simultaneously. One of the older informants said the following:

> *"Apart from fishing and cattle breeding, we would grow a variety of crops on the drylands; we planted garlic in the spring, watermelons and winter squash in the summer, carrots in the fall, and onions and cabbage in the winter. After harvesting, these crops were transported by water to the wholesale market in Nanchang to be sold."*

Figure 4 shows that there are no drylands in the southern part of Hexi village and that the agricultural landscape is dominated by a single paddy fields. According to the recollections of informants in the south, the government implemented a flood relocation policy and a ban on uncontrolled arable land reclamation after the major floods in the middle and lower reaches of the Yangtze River in 1998. Fishermen in the south were relocated to Wucheng town, and their paddy fields were placed under government management and then entrusted to external contractors for cultivation. After the southern fishermen lost their arable land, they were no longer involved in agriculture or livestock raising. Fishermen in the northern area were systematically relocated to dry land on higher ground, with no change in their livelihood. An informant who used to live in the southern part of Hexi village said:

> *"My husband and I cultivated 130 mu of paddy fields here and raised a lot of raw cattle, but after the great flood in 1998, the government banned us from cultivating paddy fields around the lake and asked us to move to a resettlement house at Wucheng town, so we had no more arable land and a way to raise raw cattle."*

To protect the Yangtze River's fishery resources, the government prohibited fishing from April to June each year after 2003. The annual fishing moratorium coincided with the busy agricultural season and had little impact on fishermen's productive lives. The interviewees claimed that after the seasonal restriction on fishing was imposed, fishermen's catch and income declined, but only a small number of young fishermen chose to leave the fishing village for urban non-agricultural occupations. Therefore, only a small amount of arable land was abandoned from 2003 on at Hexi village. As shown in Figure 4, the area of arable land abandoned in fishing village was very low during this period, suggesting that seasonal restrictions on fishing did not lead to a significant loss of fishermen and that agricultural cultivation remained an important livelihood for them.

The government banned cattle farming for residents around Poyang Lake in 2013, and fishermen were forced to stop raising cattle, thus losing their income from livestock farming. When their income decreases, some fishermen will leave their fishing village, which will increase the risk of abandoning their farmland. In addition, cash crops are an important source of income for fishermen. After the government promoted the "vegetable basket" project, the production of greenhouse vegetables outside the village increased, leading to a decrease in the market demand for and purchase price of cash crops. The decline in cash crop returns led to a decline in fishermen's enthusiasm for cultivation, and the dry land gradually began to be abandoned on a large scale. When fishermen lost their income from raising cattle, coupled with the decline in returns from agricultural cultivation, many took on odd jobs during the fishing moratorium to increase their household income, and their livelihoods changed significantly. As shown in Figure 4, abandoned arable land and bamboo forestland in the village increased significantly in 2013 due to population loss and a decline in willingness to farm. One informant said:

> *"The grassy pastures of Poyang Lake provide abundant grass for cattle, and the cost of raising cattle is so low that each fisherman raises about 10 raw cattle, and adult raw cattle can be sold for 10,000 RMB, which is a substantial income. After the ban on grazing, the government stopped allowing us to raise raw cattle. And the purchase price of cash crops became lower, I didn't want to grow so many cash crops, and my income became less and less, so I went out to do odd jobs during the fishing ban."*

In 2021, the government imposed a ten-year comprehensive ban on fishing in the Yangtze River basin, and the fishermen had to stop fishing. Deprived of the income generated by fishing, the vast majority of fishermen chose to leave the village and migrate to towns to work in non-agricultural industries. With the massive loss of fishermen, large areas of arable land in the village were left uncultivated, with a decrease of 626.09 hectares of paddy fields and 142.51 hectares of dry land from 2013 to 2021, indicating that the problem of abandoned arable land has become serious. As shown in Figure 4, the agricultural landscape changed dramatically in 2021, with a rapid increase in abandoned land, a sprawling bamboo woodland and a loss of homogeneity in the agricultural landscape patterns. According to our observations and informants, the remaining fishermen earn their living mainly through rice cultivation and have become full-time farmers. By contracting abandoned paddy fields, they have expanded their rice cultivation to earn more income. Currently, four large rice growers in the north of the village operate 1110 mu of paddy fields (1 hectare = 15 mu) under contract, while the remaining paddy fields in the north of the village are cultivated by another 15 fishermen at a contract price of RMB 100 per mu. In addition, cash crops are no longer grown on a large scale on dry land, and only cabbage and rapeseed are now grown for household use; these cash crops are no longer sold to the public. In the southern part of Hexi village, 611.38 hectares of paddy fields were contracted by businessmen from Anhui Province in 2020 for the cultivation of gorgon, and two fishermen were employed in the village to grow this crop. An informant (a major rice grower) said:

> *"After the comprehensive fishing ban, many fishermen have left the fishing village. I am older, and it is difficult to find a job in the city. Now I am a full-time farmer, and I have contracted a total of 400 mu of paddy fields to grow rice."*

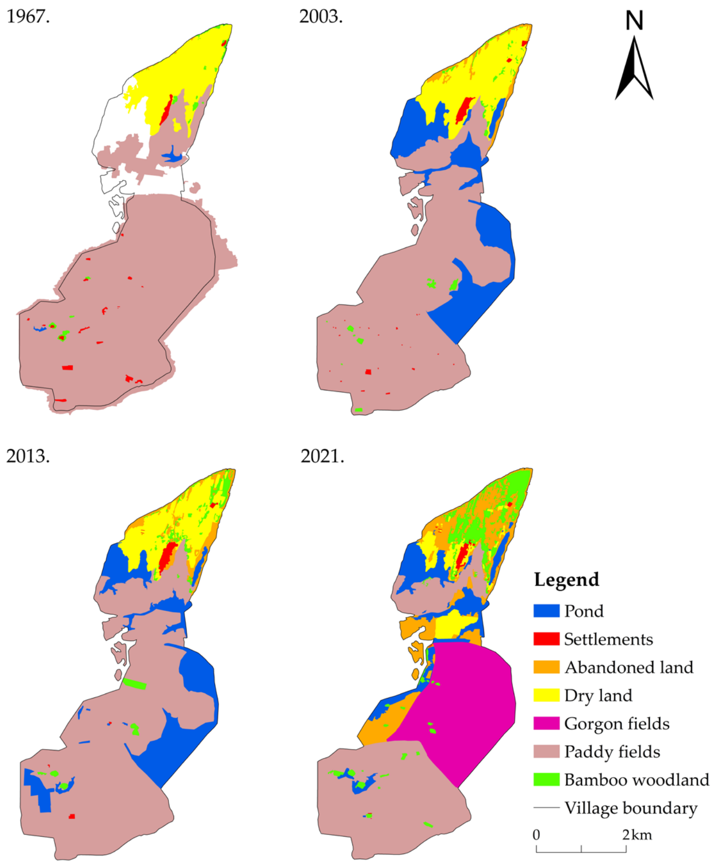


**Figure 4.** Dynamics of the agricultural landscape in Hexi village, 1967–2021. Note: In 1967, the construction of a dike in the northern part of Hexi village was not completed, and the empty area inside the village boundary represents a mudflat. It was not divided, and some fishermen reclaimed farmland outside the village boundary by creating fields around the lake during that period Hence, the reclaimed paddy fields outside the village boundary are also shown.

*4.2. Characteristics of the Spatial and Temporal Change of Agricultural Landscape Patterns*

Table 1 shows that from 1967 to 2021, Hexi's overall PD, LSI, SHDI increased each year, while the sprawl index CONTAG and AI decreased. These results indicate that the landscape patches in the study area are fragmented, as their shapes have become more complex and diverse. Moreover, the landscape pattern displays characteristics of diversity, while the overall agglomeration and spread of the landscape have decreased. On a temporal scale, the agricultural landscape pattern changed slowly from 1967 to 2003, remaining relatively homogeneous overall. The grazing ban policy was a turning point in the landscape pattern change, which changed most dramatically in the eight years from 2013 to 2021.

We use the moving window method to visualize the agricultural landscape in the village of Hexi (Figure 5). The agricultural landscape patterns in the north and south shows different trends, with the northern area showing high values on the four landscape pattern indices, PD, LSI, CONTAG, and SHDI. Moreover, the high-value area has expanded every year, and the low-value area of AI in the north has spread every year as well. This result indicates that the northern agricultural landscape is highly fragmented, with complex landscape patch shapes, high landscape diversity, high spread, and low agglomeration. The landscape pattern index has changed less in the south than in the north. The northern regional agricultural landscape pattern index corresponds to the overall trend in agricultural landscape change. Moreover, the agricultural landscape has changed more dramatically in the north than in the south, implying that the northern region is a critical zone for determining the overall agricultural landscape patterns. Anthropogenic disturbances are closely related to changes in the landscape pattern index. Changes in fishermen's agricultural practices and livelihoods have had a profound effect on local agricultural landscape patterns in the northern region.

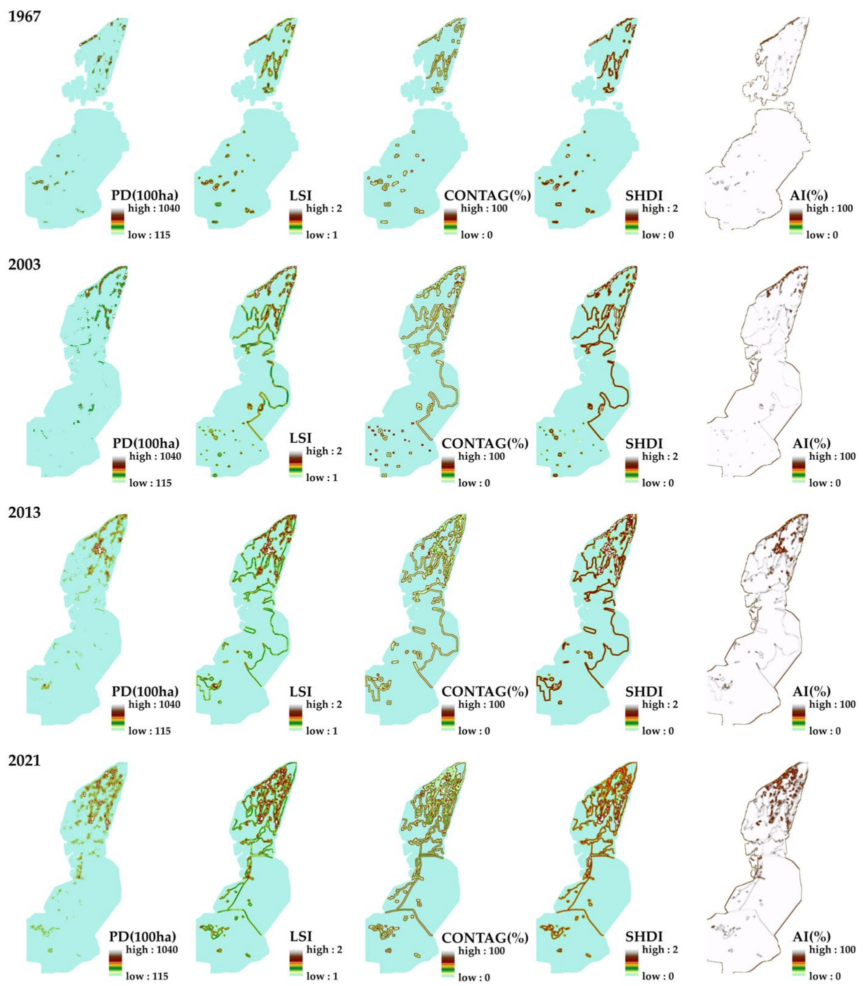


**Figure 5.** Spatial and temporal characteristics of agricultural landscape patterns in the study area.

**Table 1.** Changes in agricultural landscape pattern indices at the landscape level in the study area.

| Years | PD | LSI | CONTAG (%) | SHDI | AI (%) |
|---|---|---|---|---|---|
| 1967 | 1.44 | 2.27 | 84.60 | 0.54 | 99.79 |
| 2003 | 2.16 | 3.51 | 71.33 | 1.01 | 99.69 |
| 2013 | 2.16 | 4.70 | 69.62 | 1.06 | 99.55 |
| 2021 | 3.58 | 5.78 | 58.43 | 1.56 | 99.16 |

## 5. Discussion

### *5.1. The Hollowing out of Fishing Village*

The major agricultural regions of the world, particularly in developing countries, are experiencing a dramatic restructuring of livelihoods, including diversification of farm households, off-farm employment and permanent migration [60–63]. These livelihood transformations reflect complex and multiple influences, ranging from physical constraints such as resource scarcity and environmental change to changes in individual and societal aspirations to national policy interventions [64]. In China, the mass migration of farmers to non-agricultural sectors, the abandonment of rural land, and the massive reduction of the agricultural population have led to the hollowing out of the countryside, which continues to shape the agricultural landscape patterns [65–67].

Freshwater capture fishing was a low-cost, high-yield livelihood for Hexi villagers, and fishing was their primary source of income. Fishing required only small fishing boats and nets. Most small fishing boats were made of wood, and they could usually accommodate 2 to 3 people. Families owned 1 to 2 boats. Fishing operations were often family-based and could bring a family RMB 500–1000 a day under normal circumstances. The fishing income here referred to 2019. People can earn more through fishing than through working or farming. Fishing was a major way for the fishermen of Hexi village to earn a living. Once fishing was restricted or banned, fishermen were undoubtedly forced to change their activities. In general, fishermen have received little education, and those who have lived in the village for a long time generally have only two skills: fishing and farming. These limited skills make it difficult for them to engage in non-agricultural occupations. Faced with depleted fishing resources and declining natural capital, younger fishermen (under the age of 45) aspire to an urban lifestyle, and have taken the initiative to adjust their livelihood strategies, abandoning the fishing industry and choosing to leave their homeland or even relocate their families. This situation that has become increasingly prevalent since the introduction of the grazing ban in 2013. Due to their age and unwillingness to make a living outside the village, middle-aged and older fishermen have been forced to give up fishing and remained in the village to engage in farming activities only after the comprehensive ban on fishing was implemented. As a result, labour shortages and a reduction in agricultural inputs could lead to the shrinkage of arable land, a reduction in the arable land cultivation index, and a further reduction in agricultural output [67–69].

The bans have induced labour migration to towns and cities and caused changes in the price of and demand for cash crops. These changes in turn influenced fishermen to adjust their livelihood strategies. Labour migration is a direct effect of the transformation of fishermen’s livelihoods and an important factor influencing changes in agricultural landscape patterns. When many fishermen migrated to cities, villages became empty, and the remaining population was ageing, both of which have accelerated the abandonment of arable land. According to official government data and field research, the residential population of Hexi village was 937 and 246 in 1998 and 2018, respectively [49]. In 2022, it is 98. After the comprehensive ban on fishing took effect in the Yangtze River basin, the 98 remaining villagers were older fishermen who stayed behind and had weak livelihood capital. Fishermen living away from home planted Mao bamboo to demarcate the boundaries of their drylands and prevent encroachment. The bamboo woodland has expanded rapidly as a result of being untended for long periods. The abandonment of dry land has changed the production function, restored the surface vegetation, which is conducive to soil and water conservation, and has played a positive ecological environmental effect to a certain extent. In short, the abandonment of drylands and the uncontrolled spread of bamboo woodlands have fragmented the agricultural landscape patterns (Figure 6).

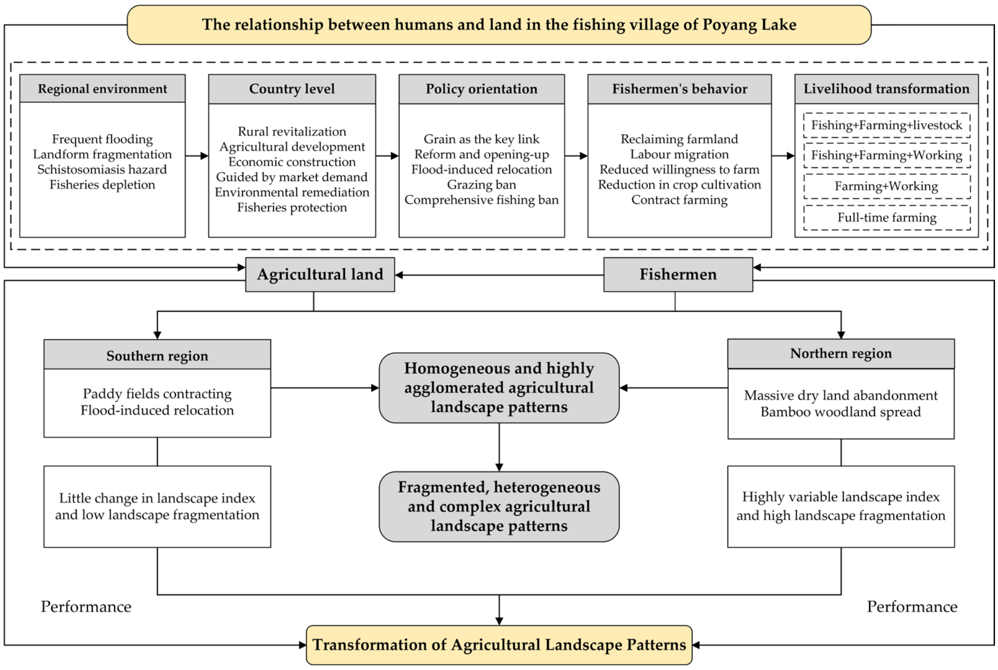


**Figure 6.** Transformation framework of agricultural landscape patterns.

### 5.2. Change of Cropping Structure

Competition between agricultural and non-agricultural activities has become increasingly intense in the context of the transformation to non-agricultural livelihoods, with farmers frequently opting for less time-consuming and more efficient methods of land use and moving towards a simpler cropping structure [70]. Moreover, a diverse agricultural landscape with a variety of land use types is seen as a product of the survival strategies adopted by peasant families living in precarious social conditions [71,72].

Study found that fishermen's cropping structure were gradually becoming simpler and more specialised. Since the rise of greenhouse vegetables, the purchase price and demand for cash crops have fallen, resulting in a continued reduction in fishermen's willingness to grow them. Fishermen took less input to cultivate drylands and reduced the cultivation of cash crops. Therefore, fishermen have more time and energy to fish and grow rice. Rice has a relatively stable purchase price and marketing channels, and fishermen have pinned their hopes to rice cultivation since the comprehensive fishing ban. Those who remain in the village have become full-time farmers, contracting abandoned paddy fields to grow rice on a large scale. With the aim of increasing rice yields, rice cultivation has shifted from small-scale operations to contract-based large-scale farming, and the widespread use of machinery, pesticides and fertilisers, which have promoted the intensification of rice cultivation. Contract-based large-scale farming means that left-behind fishermen rent paddy fields abandoned by other farmers, thereby expanding the scale of rice cultivation. Intensification refers to any process of obtaining more output, but is most often interpreted as increasing yields per unit of land [73]. The biggest change of agricultural landscape caused by the livelihood transformation is that the majority quitted farming and rented out paddy fields, and contract farmers managed large farm.

### 5.3. Innovations and Shortcomings

To understand the reasons for the transformation of agricultural landscape patterns, in-depth case studies are important, in addition to macrolevel studies [74]. Case studies are used to better integrate and understand the social and physical drivers of land use change at different temporal and spatial scales, and it is important to combine remote sensing data with field research to ensure that the findings are scientifically sound and accurate [75]. Traditionally, studies of agricultural landscape change have focused on changes in spatial patterns based on satellite imagery with little consideration of the social behaviour of farm households [76,77], such as livelihood choices, or the interaction of livelihoods and agricultural landscapes. However, there are some limitations to our study. We analysed only the one-way impact of livelihood transformation on agricultural landscapes and did not explore the impact of transformations of agricultural landscape patterns on livelihoods and the interaction between the two. Although we analysed the relationship between policy, livelihoods and agricultural landscape patterns qualitatively, the results of the study provide an objective picture of the actual situation in the region. Study found that the abandonment of cultivated land, especially dry land, has led to fragmentation, heterogeneity and complexity of agricultural landscape patterns. Therefore, the cultivation of dry land by fishermen is conducive to reducing the abandonment rate of cultivated land and inhibiting the disorderly expansion of bamboo woodland, which plays an important role in the optimization of agricultural landscape patterns.

## 6. Conclusions

This study quantifies the transformation of agricultural landscape patterns in fishing village by constructing a scientific research framework using long time scale satellite remote sensing imagery and mathematical analysis methods. In addition, we qualitatively analyse the relationship between policy changes and fishermen's livelihoods through in-depth interviews to provide a scientifically sound explanation for the dynamic changes and transformations in the agricultural landscape patterns of a typical fishing village in Poyang Lake.

We obtain the following conclusions: the livelihoods of fishermen have varied over the different policy periods. After grazing ban and comprehensive fishing ban, fishermen could not raise livestock and engage in fishing, so livelihood of fishermen has changed from diverse to single. With many fishermen migrate to towns and cities, the loss of population has been a serious issue. As the village has hollowed, the amount of abandoned land has increased. Since the rise of greenhouse vegetables, the purchase price and demand for cash crops have fallen, so people have become less willing to farm on drylands. We found that fishermen's cropping structure were gradually becoming simpler and more specialised. Those who remain in the village have become full-time farmers, contracting abandoned paddy fields to grow rice on a large scale. On a temporal scale, the agricultural landscape patterns changed slowly and remained relatively homogeneous overall, due to the relatively stable livelihood patterns of fishermen before the ban on grazing and fishing, the low number of population losses and the low abandonment of arable land at Hexi village. The grazing ban policy was a turning point in the landscape pattern change, which changed most dramatically in the eight years from 2013 to 2021. Especially after the implementation of the comprehensive fishing ban, the expanses of abandoned land and bamboo woodlands had increased, which caused agricultural landscape patterns gradually becoming fragmented, heterogeneous and complex.

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Article

# Enhancing Rural Resilience in a Tea Town of China: Exploring Tea Farmers' Knowledge Production for Tea Planting, Tea Processing and Tea Tasting

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**Abstract:** Rural areas have undergone visible transformations in recent decades. It leads to some ecological problems. Enhancing rural resilience is necessary in the face of these changes. However, previous literature often ignored the roles of indigenous actors in this process. Consequently, we conduct participant observation and in-depth interviews to explore the process by which local farmer knowledge is produced in Fenghuang, a rural area that concentrates on the tea industry in China, and how this process contributes to the agriculture resilience of individual and rural areas. We find that local knowledge is a dynamic composition of daily practice highlighting the nature of adaptability in farmers' pursuits. Such knowledge is found to be constructed, exchanged, and then reshaped into a new and heterogeneous form that involves a mix of scientific forces and local practices, building a solid basis for individual and rural resilience. In addition, both sustainable agriculture and successful market promotion can be achieved by knowledge production. In this way, the meaning of "place" is reconstrued, morphing from a barren and backward rural area to a green and unique land with idyllic beauty. This metamorphosis offers belongingness to tea farmers and imposes on them the responsibility to contribute their efforts to the land.

**Keywords:** local knowledge; resilience thinking; rural development; agriculture

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## 1. Introduction

Currently, due to increasing modernization and industrialization, several social, economic, and environmental problems have emerged globally [1]. These changes are experienced differently at various spatial scales and obviously affect rural areas [2]. Continuous productivist dominance leads to several social and ecological issues, such as crop degeneration, biodiversity reduction, and environmental deterioration [3,4]. These are manufactured risks derived from dramatic technical changes [2] that decrease farmers' ability to withstand disasters [5] and imply that we need to enhance rural resilience to the unpredictable, dynamic, and "slow burn" disturbances of the present [6].

Building resilient rural areas is closely related to traditional agricultural development [7,8]. Although large-scale and standard agricultural production plays a dominant role in many rural areas, research has noted that such expert knowledge fails to consider local areas' specific contextual needs, leading to maladjustments and problems [9]. Consequently, local agriculture knowledge, which is a type of knowledge rooted in the land, is the most adaptative in the face of crisis and requires close attention [5]. Farmers are vital in this process because their "tacit knowledge of the social context", which draws from lived and embodied natural experience, provides a solid basis for production [10] (p. 5). Only by strengthening the resilience of individuals and communities can rural areas develop successfully [8,11].

Additionally, in contrast with previous claims of resilience, which emphasize a "bounce-back" process that involves "accommodating disturbances without experiencing changes to the system," recent research suggests that in addition to recovery, being flexible and capable of reform is critically important [12]. This is an evolutionary approach that underscores the "bounce-forward" process [1]. In other words, a discussion of local knowledge is necessary to underscore the process through which indigenous experience absorbs external information, promotes itself, and becomes prepared to deal with unknown challenges, rather than being restricted to a range of traditional daily practices [7]. Consequently, this paper investigates how local knowledge changes and how it contributes to rural resilience.

In recent decades, considerable debate has centered around resilient development within the context of a developed world; however, many developing areas remain touched [13–15]. Therefore, we address our research questions by looking at the production and accumulation of local knowledge by tea farmers in Fenghuang, China, the cradle of Dancong tea. Dancong, a type of oolong tea, is famous due to the varied aroma of each type of tea tree in China. Residents of Fenghuang have made their living by planting Dancong tea trees for hundreds of years. This area was once poor due to its complex and challenging geophysical conditions. Nevertheless, after reform and opening up (a revolutionary Chinese economic policy) in 1978, the tea market became fully open and tea farmers owned the right to sell tea for profits. Additionally, with the growing popularity of tea tasting, Dancong sales rose annually, resulting in a Fenghuang economic development boom that largely eradicated farm poverty [16]. However, while healthy economic growth is necessary to create a resilient rural area, it is not sufficient. Extreme transformations have taken place in Fenghuang, which has experienced social and ecological conflicts between traditional agricultural practices and large-scale production practices that can lead to agricultural and environmental problems. It is important to understand how to deal with these problems in order to achieve a comprehensively resilient development. Moreover, it is important to determine how farmers can survive when faced with such dramatic changes while still preserving their resilience.

This paper elaborates the above questions by examining farmers' knowledge production and its role in rural resilience, a topic that has scarcely been considered in prior resilience thinking. Additionally, based on the viewpoints of farmers, this paper offers a new perspective and a fine-grained approach for reproducing the social-cultural understanding of rural resilience. The paper is structured as follows. First, the theoretical framework of local knowledge and knowledge production in the context of the rural resilience development approach is discussed, followed by an overview of related research. Then, we present our findings thematically around the process of local knowledge production and the effect of this knowledge on rural resilience, specifically sustainable agriculture and market promotion. Finally, we provide a discussion and conclusion.

## 2. Local Knowledge Evolution

While we focus on the development of local knowledge, our starting point is to clarify its nature. Many scholars have explored and enriched knowledge's meanings. Barth highlighted the characteristics of knowledge, which include a substantive corpus of ideas about the world, communication through various media as a series of representations, and distribution within a social context [17]. Local knowledge is presented in the same way within particular areas. Agrawal provided several definitions of local/indigenous knowledge, which is passed down through generations, gained from local people's everyday life experiences [18]. In the agricultural context, Fonte defined similar forms of knowledge as "the technical knowledge utilized by farmers and producers to grow or prepare food in the specific agro-ecological context in which they operate" [19] (p. 210). Similarly, Šūmane et al. [7] (p. 2) used the term "informal knowledge" to represent forms of knowledge that are rooted in practitioners' daily experiences; such knowledge comprises an "intimate understanding" of local culture and natural resources.

However, local knowledge often becomes marginalized when standardized industrial production expands [20]. In a similar vein, Nygren revealed that the modern system's mechanism of "decontextualization" removes discourse from local contexts and allows it to be expressed in an infinite space and time. It is accordingly incompatible with local knowledge because this trend emphasizes local and historical contexts [21]. Additionally, due to the domination of capital-based industrialization, local knowledge has been labeled as a source from "the other" who always requires assistance [19,20,22]. Moreover, when a local paradigm was applied to disaster risk reduction, the validity of such indigenous attempts was disparaged as primitive and insular [23].

Recent years have seen a growing body of literature that highlights the importance of local knowledge and clarifies the relationships between indigenous practices and formal scientific approaches. Local knowledge was important because it provides people with rich notions of alternatives to the scientific paradigm [24,25] that are local, shared, empirical, practical, and flexible [26]. This approach was emphasized as a means to resist the oppression of indigenous people's voices [27]. As the global environmental crisis has further intensified, local knowledge has been rediscovered as a resource that can help explain and solve the crisis. Specifically, local knowledge offers insights that complement scientific knowledge in many fields [28–30].

Nevertheless, adopting local knowledge wholeheartedly and uncritically may result in misunderstandings and misconceptions [31]. In addition, scholars still failed to "scale up" local knowledge from a specific area to a wider one, which led to disappointments in improving local knowledge to arrive at the level of scientific knowledge [32,33]. From this perspective, Berkes and Berkes [34] stated that local knowledge plays different roles from those of scientific measurements. Rather, local knowledge is indeed embedded within particular contexts; thus, it concentrates on the local area, enriching the contributions to the understanding of indigenous environments by presenting locally derived views at microscales.

Critical consideration of local knowledge is not only to clarify the function of local knowledge; it is also related to the relationships between local knowledge and scientific knowledge. Knowledge is unevenly distributed within populations and thus does not follow a fixed set of norms and values [25]. In this regard, scientists' data are based on testing the validity of theoretical models in a designed environment; in contrast, information belonging to indigenous people is practical because its source is nature [26,35]. Neither scientific nor local information, in isolation, is sufficient to ensure the sustainable use of natural resources. Thus, both scientific and indigenous knowledge can benefit from dialog and collaboration [25]. It is important to integrate knowledge from various actors, promoting communication among them to, for example, combine the knowledge of farmers and scientists [36]. Merged body of knowledge can complement the empirical data that science needs. Moreover, it offers tools, methods, and theoretical concepts to local communities, enabling them to make forward-looking decisions that are suitable for their real situations and beneficial for their future development [25,35,37].

In sum, while local knowledge develops within a particular context, it is not a static entity unable to interact with the "outside world"; it changes continuously because it reflects people's adaptations to changes in their environment [31]. However, local knowledge does not assume community homogeneity; therefore, it is a complex, heterogeneous, diverse, and highly localized source of wisdom that should be deeply explored [29,38].

## 3. Rural Resilience and Knowledge Production

The concept of "resilience" was adopted from the engineering field and refers to an object characteristic that returns to its initial state after being affected by an external force. In the 1970s, Holling [39] introduced the term into ecological research defining it as recovery capability after acute disturbance. Subsequently, it has been applied widely in the natural ecological field. After the 1990s, the concept of resilience was extended to social systems where its evolutionary nature was emphasized instead of the ability to maintain a state of equilibrium [6]. It is worth noting that resilience in the social context not only means recovering but also changing, adapting, and transforming in response to external stimuli [40,41]. Concretely, the research focus on resilience has ranged from swift recovery after "shock" disturbances, such as floods and earthquakes, to "slow burn" transformations including urban decay, population aging, and economic dependency [6].

Resilience thinking has been adopted in rural agriculture studies for many years. Related research has focused on which factors contribute to weak or strong resilience. From a holistic view, Fraser et al. [42] suggested that for farming, environmental, economic, and social aspects act as positive incentives that can improve resilience. In addition, a relational perspective is emphasized that should include the above systems, instead of only focusing on economic values of agricultural production [1]. The role of local stakeholders was highlighted in this process. At the regional level, governments provide a platform for promoting collective wisdom, learning, and innovation processes [4,43]. At the community level, activation of community resources is frequently seen as an important path to developing resilience because it is a structural power of mutual assistance. The community thus owns the capability to anticipate potential risk and bounce forward through adaptability and evolution [44]. Additionally, public participation in community activities is beneficial for building resilience because such activities strongly enhance farmers' sense of belonging and attachment to a place [45]. Shared values and opinions constitute a "strong voice" for rural vitalization [43]. While the government and the community focus on general forces, the household, as the first defense against agriculture challenges, is paid more attention to individual experience. While agriculture experience is the base, abilities to cope, adapt, and transform are the keys to developing resilience [46]. In this process, researchers try to figure out how individuals' abilities to learn and innovate are fully activated to help the household successfully resist a crisis [47].

Resilience thinking emphasizes local knowledge production because it is the primary way to promote agricultural efficacy, even the whole rural development [48,49]. Previous studies have regarded "industrialization and technological innovation" as key drivers of development [50] (p. 30). In other words, scientific knowledge is considered a dominant tool for improving resilience. However, following debates about rural development patterns, the neo-endogenous (network) development model was presented [51–53]. This new approach paid attention to specific localities and advocated that practitioners should "rediscover a cultural/historical territory" [52] (p. 25). Concretely, it initiated practices to underscore the participation of local actors, such as the Farmer First model [54], the international assessment of agricultural knowledge, science, and technology for development report [55], which refers to the importance of local roles in enhancing rural agriculture sustainability and to farmers' resilience that involves economic, social, cultural, and environmental dimensions [5,7]. This finding goes beyond the argument that farmers are only able to guarantee household resilience, and enriches the understanding of the role of farmers to contribute to the sustainability of rural agriculture.

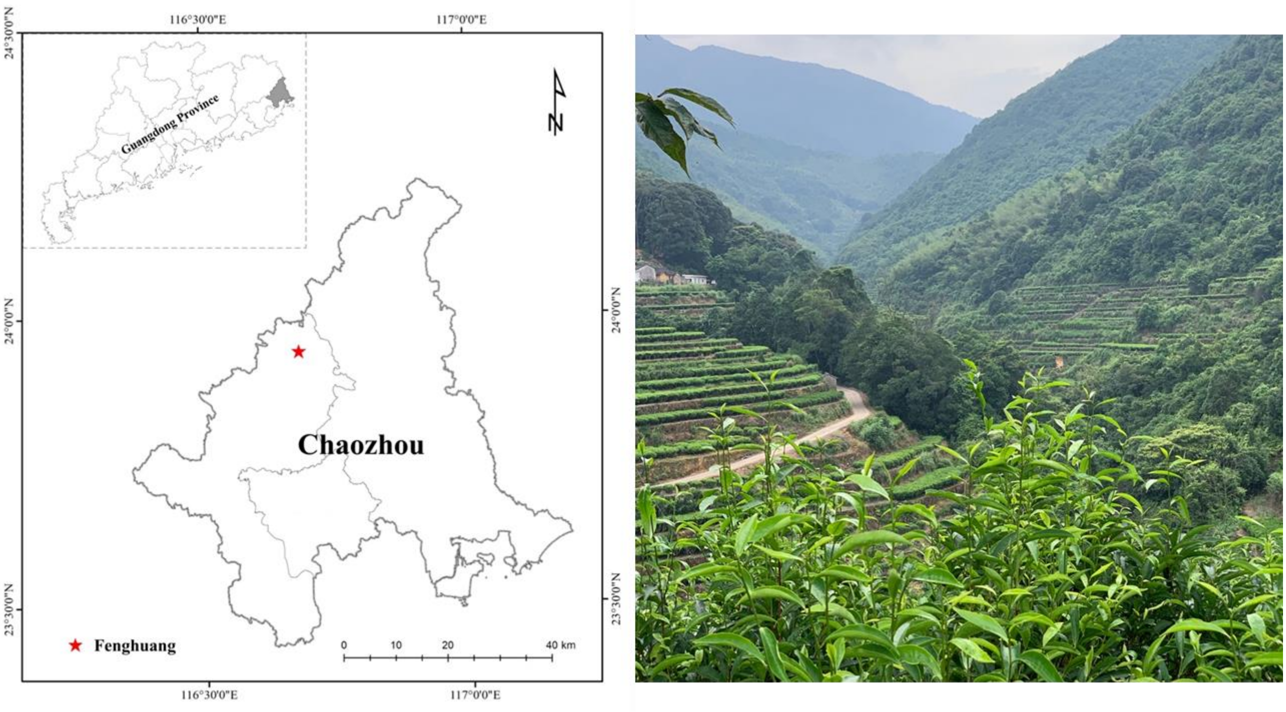
Neo-endogenous development model inspired the farmers to become primary participants, animating their knowledge production to vitalize their land and ensure genuine and lasting development [56]. It implies the significance of a process of continuous learning. School learning, e.g., Farmer Field Schools, is one of the most popular ways for farmers to learn new skills and techniques. It provides formal knowledge resources and encourages farmers to conduct season-long and participatory learning [57]. However, sometimes traditional learning modes are not applicable to farmers, who prefer seeking information on their own, rather than being trained in a school setting [58]. Therefore, social learning is recommended for learning from interactions and cooperation among farmers. It underscores the learning journey through observing, evaluating, and modeling others [59]. "A process of social learning" is critical for enhancing resilience because it challenges the stereotype of farmers as static and backward recipients, and shows instead their potential of active learning and the power of informal knowledge [7,60].

Knowledge is the source of the ability to manage complexity and uncertainty, particularly when combined in various ways [60,61]. Therefore, achieving resilience requires a consideration of the interactions among various actors and then elaborating on collaborative networks [62]. Echoing the neo-endogenous framework, how to identify place attributes and then achieve more adaptive schemas for rural areas through both internal and external actors became the key issue for increasing rural resilience. Bruckmeier and Tovery [48] (p. 326) noted that a "process-oriented view of 'knowledge in action" would identify sustainable development problems. Knowledge production must be treated as a dynamic process between local and extra-local resources. Lowe et al. [50] (p. 28) defined this pattern as "vernacular expertise" since it is "place-based but is also crucially nourished by outside sources and agents". For example, based on the specific context of a rural area, farmers are able to consider various conditions and then make suitable choices for farming [8,28]. Similarly, agricultural scientists and experts can compensate for the absence of knowledge regarding skills, values, and perspectives in the local context. Eventually, "more open, fluid, democratic knowledge networks where scientific/formal and local/informal knowledge are mutually enhanced" were built [7] (p. 3).

In the Chinese context, how knowledge production contributes to rural resilience is worthy of investigation. At the 19th National Congress of the Communist Party of China held on 18 October 2017, President Xi Jinping first mentioned the rural revitalization strategy and underlined the significance of solving the problems of "agriculture," "rural areas," and "farmers". The main goals of this strategy are to increase the income of farmers, promote the development of agriculture, and protect the stability of rural areas. Given the strong support from the state, a vibrant rural economy has gradually formed. However, many rural area problems, such as rural hollowing and environment degradation, appeared in this process. Previous studies focused primarily on the top-down process, especially the role of policy for solving problems [63,64]; however, adopting one-way dissemination of knowledge makes sustainable and resilient development unachievable [37]. Specifically, rural resilience is a hybrid network that requires both endogenous and exogenous nutrition [8,65,66]. The farmer is a significant group because they provide an intrinsic perspective on "cultural and environmental differences of rural areas" [13] (p. 244). Moreover, farmers, who used to be considered poor and backward, were able to make a living by themselves. It led to more vigorous knowledge production and resilient livelihood. Up-to-date research has paid scant attention to this bottom-up approach, largely ignoring the roles of farmers and how their local knowledge contributes to individual resilience and to the resilience of rural areas. In addition, although many studies have discussed the mutual interactions between local knowledge and formal knowledge, they are based on the context of capitalist countries [13]. In the context of socialism, how do local/informal knowledge and scientific/formal knowledge interact with each other to reconstruct rural governance and reshape rural areas? Research is needed to explore these questions.

## 4. Fieldwork Contexts and Methods

Fenghuang is the birthplace of Dancong tea, which is located in northern Chaozhou, Guangdong, China, and has a total area of 231.75 km$^2$ containing 239 natural villages (naturally formed by family, clan, or other historical reasons) and a population of 40,449 people (Figure 1a). To date, the town's tea plantation area covers about 4666.67 hm$^2$, has an annual output of 5 million kg of tea and an output value of 1 billion yuan. Tea production now occupies entire towns and is the leading agricultural industry (Figure 1b). Compared with tea from other regions, Dancong tea is primarily classified into various species and picked separately according to these species, which enables the locals to invent a proverb: single plant picking, single plant processing. Later, the tea is manually processed in small family workshops. Therefore, tea farmers play a major role in tea production because most of the tea mainly relies on their hands for production. Until now, automatic tea picking and tea processing machines have been adopted in some large tea enterprises in order to pursue higher productivity. However, this industrial tea production approach was not recommended and remained marginalized in Fenghuang.




(**a**) (**b**)

**Figure 1.** (**a**) Map of the research area in Guangdong, China. (**b**) Tea plantation in Fenghuang. Source: photograph by the first author.

Before the reform and opening up, tea farmers stayed away from the national market and Fenghuang seemed barren and backward from an outside perspective. Tea farmers planted and processed tea for living on a low income. However, after the full opening of the tea market in 1978, tea prices rose sharply so tea farmers eradicated poverty, and the tea economy developed in Fenghuang. However, as many stakeholders wanted to capitalize on the windfall economic profits, it caused some ecological problems, such as the death of ancient tea trees caused by over-picking and poor growth of tea trees caused by the abuse of chemical fertilizers and pesticides. For instance, some tea enterprises rented tea farmers' land and used automatic tea picking machines or hired unskilled workers to pick tea. They ignored the natural rules and picked excess tea leaves, causing the tea trees to fail to grow in a healthy way. Consequently, the number of old trees started to decline, and many died. According to Huang [67]'s survey of old tea trees (average tree age is above 100 years) in Wudong (one of the high mountain villages in Fenghuang) in 1998, there were 68 dead old trees at that time. A recent study conducted by an agricultural project team in 2016 found 47 newly dead trees and forecasted that the mortality rate of old tea trees would exceed 30% in the next 20 years. Moreover, tea quality decreased because of the poor growth of tea trees. It undoubtedly affected the terminal market where consumers' trust in food quality and safety was hurt.

When confronted with a series of ecological problems and their derived issues, local people realized the risks and their responsibility to protect the land. They made various efforts in the production of local knowledge in order to ease the crises and improve rural resilience. This paper explores this phenomenon.

The research data for this study were based on participant observation and in-depth interviews conducted in Fenghuang between 2018 and 2020. Semi-structured interviews lasting from 45 to 90 min were recorded. The interviewees consisted of 22 Fenghuang local tea farmers. Snowball sampling was adopted in this process. First, we contacted 3 tea farmers we knew, and they introduced us to 22 other tea farmers for interviews. However, because tea farmers' daily lives are simple and tea production techniques were repeatable and shared in the community, new content failed to appear when we interviewed the 22nd farmer, which means we reached data saturation and these farmers are able to represent the farmer group in Fenghuang [68]. Thus, we stopped the interviews. Since farmers are familiar with each other, the conversations were conducted naturally and showed real emotions. The participants included 19 males and 3 females, all of whom were older than 30 years. The oldest participant was 87 years old. In addition, we visited 3 government officials working in the Fenghuang district government, 5 tea traders, and 2 experts working in the local agricultural institute to gather complementary information.

We conducted most of our interviews at tea farmers' residences and tea processing sites (these two places were often in a single location) and asked open-ended questions on topics such as tea farmers' daily lives, interactions between people and places, tea production process, and tea tasting. We also accompanied the farmers as they picked tea and processed tea to gain more comprehensive perspectives. All the interview transcripts were transcribed and then read through several times to obtain a sense of the information they contained and to identify generalities. For detailed analysis, themes were generated through a coding process based on the information gathered during the interviews. Interrelated themes, such as the perception and construction of local knowledge, were analyzed and explained to explore how tea farmers' local knowledge is produced to build individual or family resilience and in what ways local knowledge stimulates resilient rural development.

## 5. How Local Knowledge Is Generated and Developed in Rural Areas

When faced with ecological problems, farmers built a strong local knowledge base to sustain their individual resilience. To be specific, local knowledge inheritance and production are important for resilience improvement. Firstly, Fenghuang is famous for having produced great tea for centuries, dating back to AD 1535; consequently, local knowledge production in Fenghuang has accumulated, grown, and been refined for many years. It is passed from generation to generation and is thus stable and largely protected from outside shocks (Figure 2) [5]. Secondly, farmers' knowledge is constituted through accumulating practice and is embodied through daily experiences [69]. Thus, their knowledge is adaptative according to specific conditions. Four sections of tea production—growing seedlings, picking tea, processing tea, and tasting tea—are introduced below in order to show how local knowledge is generated and spread.

**Figure 2.** Tea farmer's son learning how to process tea. Source: photograph by the first author.

Breeding good tea seedlings is the initial important step in tea production. The older tea farmer FH08, who is good at seedling work, said that tea tree breeding and planting can be traced back to the year of Kangxi (AD 1705) in the Qing Dynasty. Until the Guangxu Period, several strains of high-quality tea were bred in Fenghuang. This spirit of professionalism has been passed down to today's tea farmers:

> *"Usually, I will pay attention to the growth of each tea plant. Then, when picking tea, attention is given to the number of new leaves and the size of the leaves on each tea plant. In addition, when processing tea, attention is given to the color, aroma, and taste of each finished tea plant. By comparing different kinds of tea, I will determine the target of future seed breeding."* (FH19)

Such practices are normal agricultural skills that include unique cultural engagement, underscoring their inherent variety [70]. Farmers use their bodily experiences from the senses of their bodies, such as smell, touch, and vision, to form their knowledge and then apply it to practice. Local knowledge involves not only inheritance but also positive production. Due to the large production demand from the modern market, tea farmers have started to select specific types of Dancong tea based on a comprehensive assessment of breeding, pest resistance, and cold and drought tolerance.

The second significant step is picking tea. When we followed tea farmer FH02 in hiking to a peak to pick tea, he often introduced picking techniques he used for tea trees on the sides of the mountain road. For instance, he mentioned that the top leaves grow a pair of clips; then, 3–5 days later, the leaves mature. When 60–70% of the new tea leaves have reached the matured status, the tea leaves are ready to be picked. After many years of training, FH02 had become intimately familiar with the local environment and trees, so there was no need for him to perform repeated observations before picking. He can pick several pounds of tea leaves per day. Knowledge inhabits the land where people build connections with the countryside [36]. Such ties between farmers' daily experiences and the environment are being confirmed.

Since indigenous knowledge is place-produced, the essence of protecting the place where farmers grew up is inherently embedded in this knowledge. During the tea picking season, tea farmers hire tea pickers to help them perform the work. They are very active in teaching these workers the techniques of tea picking. The reason is that the farmers believe that tea trees are valuable treasures left by their ancestors. Only after the workers learn the techniques well can the tea trees avoid damage from careless and unskillful picking. In the words of farmer FH07:

> *"Generally, after picking several leaves, you have to put the leaves in the basket, you cannot hold them in your hand, the tea will be injured."*

Another farmer FH18 expressed his worries about tea picking:

> *"Some experienced tea workers leave an old leaf on the tree when picking, this old leaf will be helpful for the trees to grow new leaves for the next year. However, I hired some unskilled tea workers from outside, and they usually broke down the whole tea branch. I was so sorry that my tree was hurt. If the old leaves are not left intact, the tree will fail to absorb enough water, which has a serious impact on its overall growth."*

The accumulation of local knowledge and emotional connection with place is further highlighted in the tea production process. The five stages in the primary processing of Dancong tea are sun-drying green (shaiqing 晒青), making green (zuoqing 做青), killing green (shaqing 杀青), rolling (rounian 揉捻), and baking (beihuo 焙火) (Table 1). Tea farmers need to concentrate on each step in this process as soon as the tea leaves are picked.

**Table 1.** Introduction to five steps of tea processing.

| Tea Processing | |
|---|---|
| Sun-drying green | Put the tea leaves under the sun to dehydrate. |
| Making green | The tea leaves are shaken, collided, and rubbed by alternating manual and mechanical means to stimulate fragrance. |
| Killing green | The tea leaves are put into the pot for frying in order to further dehydrate and stimulate fragrance. |
| Rolling | The tea leaves are pressed and kneaded by a machine in order to be shaped into strips. |
| Baking | The tea leaves are roasted in an oven to dehydrate it thoroughly. |

All the tea is handmade by the farmers themselves. Wang [71] (p. 124) describes "Chaozhou gongfu tea" as "an integrated ceremony encompassing the reflected spirit, the etiquette, the skills of both preparing tea (which refers to the process of pouring hot water into a teapot filled with tea leaves and pour out the tea into small teacups) and pouring tea for guests." Similarly, tea farmers claim that their tea processing skills reflected the word "gongfu," which implies that adequate amounts of effort are required for tea processing. Farmer FH08 compared the sun-drying green process of Dancong with that of other kinds of tea as an example:

*"I used to see farmers in other places sun-drying the tea. They used a rake to turn the tea. However, the rake is so hard and sharp that it hurts the leaves. When the tea leaves are hurt, it is difficult to make high-quality tea. Look at this tea leaf, it is not injured, and the whole leaf is thick and intact. If the tea is injured, the scar will remain there forever, and when tasting this leaf, it will be bitter. That is why it failed to be a high-quality tea."*

Farmers use expressions such as "injured" or "hurt the leaves" to describe the tea's conditions, showing their tendency to protect the tea, which presents their attachment to the land through traditional practice [5].

When we interviewed farmer FH05, he mentioned that he stayed awake until 4:00 am in the previous night to process tea. Then, he rested for only 2 h and rose early to make green. He admitted that it is hard to stay up until late, but he did not worry much when processing tea only by himself. The mere availability of advanced technology does not convince most local people to apply it to their production [72]. Although technology modernization has led to the invention of automatic tea processing machines, tea farmers still doubt their reliability; instead, they prefer processing tea manually, which reflects their intimate and sensual attachment to nature [73]. In the words of FH03:

*"Only when my hands touch the tea leaves can I know how far it has come, what strength I need to use, and how long the process will take."*

In addition, better manual skills are able to enhance farmers' market performance and grow their income [7]. Considering the enormous potential profits from selling tea, farmers were motivated to update their knowledge and improve their tea processing skills. In the words of farmer FH16:

*"I kept on learning consumers' new preferences. For example, older people may like tea with a stronger and thick taste, so I would bake the tea longer to achieve this flavor. Younger people may prefer tea with a great aroma, so I bake the tea at a lower temperature and for a shorter time. In line with their needs, there will be countless repeat customers."*

During the slack season, tea farmers visit their neighbors to share problems they encountered in tea production and discuss how to solve these problems. The farmers even attend competitions so that they can interact with other farmers and learn new advanced tea plantation and production skills (Figure 3). This "social learning" process systematically improves farmers' local knowledge [58,59]. As farmer FH17 suggested:

*"My dad taught me how to process tea in the past, and some of his techniques are slightly out of date. After participating in tea competitions and meeting other tea farmers, I now know some other ways to improve my tea quality. For example, to make this tea smell better, you need to extend the 'killing green' process."*

**Figure 3.** Tea farmers in a tea processing competition. Source: WeChat channel "Zero distance with Fenghuang (与凤凰零距离)" (WeChat is one of the most famous social media in China).

As the final step of tea production, tea farmers should taste the tea to confirm its quality, which relies on their own tea-drinking habits based on their everyday experiences, such as the amount of tea leaves to put into the teapot. Farmer FH01 taught us pouring tea techniques: *"the amount of tea is also very important, if you use a full cup of tea leaves, it is too wasteful to achieve the correct tea flavor. The ratio of tea leaves and water is not correct. All of our efforts to make good tea would be ruined."* They denote that armed only with such skills, tea-tasting acts as a perfect terminus for tea production.

For each step of tea production, tea farmers possess corresponding local knowledge. Their knowledge is comprehensive and flexible, sourced from their daily practice and inspired by engagement with the materiality of Dancong tea and the natural environment [45,73]. Through inheritance, sharing, and self-improvement, local practices become exclusive knowledge shared among the members of a particular tea-farming community [7,72,74], which contributes to building solid protection for their individual enterprises.

## 6. The Role of Local Knowledge in Developing Rural Resilience

After the reform and opening up in 1978, environmental problems came along with economic development. In a rural area where tea is the pillar industry, if the environment deteriorates, the tea industry in the area will be seriously affected. Therefore, in addition to examining how the farmers' knowledge safeguards the resilience of individual households, it is important to investigate how farmers' knowledge contributes to the resilience of rural agriculture in the face of these problems [11,73]. Moreover, farmers often keep a benign interaction with scientific knowledge while preserving locality to protect their land and enhance rural resilience [53]. Therefore, in this section, we explore how local knowledge is involved in developing rural resilience through interactions with experts.

### *6.1. Local Knowledge and Sustainable Agriculture*

In Fenghuang, tea farmers' energic local knowledge is a resource that should be rediscovered to help develop sustainable agriculture and protect the natural environment. Local knowledge is the implicit, subjective, and contextual knowledge embodied in farmers' brains and bodies [75]. This tacit knowledge is passed down through generations and is rooted in the places farmers live, which are not accessible to outsiders [69]. Thus, rather than relying on scientific training, they relied on the family tradition, which is passed down through observing, imitating, and repeated practice. As farmer FH12 said:

> *"For skills, there is no book that can help us learn. That is why my daughter now follows me to pick tea, observing and practicing every day. These things are all based on my experience and understanding of this place and these plants."*

Consider picking tea leaves as an example. As mentioned above, tea farmers emphasize that when picking tea, they should leave 1–2 old leaves because *"old leaves are beneficial and help the tree grow new leaves next year."* Moreover, the number of tea leaves they picked depends on the tea's specific conditions as determined through observation and experience. In contrast to traditional practice, the scientific approach uses mechanical tea picking machines, which pick tea leaves at large scales, all using the same mode. In the words of farmer FH07, this machine process may *"pick tea leaves that do not need to be picked. Regardless of the situation, the tea tree will be overly damaged, lack of nutrients and die."* Thus, most of them reject using machines and insisted on spreading proper tea picking methods to others. Tea farmers may not be able to explain these planting and picking rules in academic language, but they protect their places with the indigenous understanding rooted in the environment to promote tea tree growth. Local practice is "trying to work with the social and biophysical idiosyncrasies of a particular farm," does not "expect uniformity," and can protect rural areas by preserving "variability" [9] (p. 387). In other words, local practice is an adaptative capability when facing outward challenges that help farmers protect their land and build resilience [11].

In terms of pest control, tea farmers adopt a primitive way to eliminate insects, they told me that if they sow a large area with pesticides, it would also hurt some beneficial insects, because *"an overclean environment is not conducive to the growth of tea trees."* Therefore, they do not apply the chemicals that the market sells. Consider moss as an example; moss attached to a tea tree will block its respiration and siphon off water and nutrients. To eliminate the moss, farmers manually peel the parasitic moss from the tea trees to promote good growth. An expert FH23 from the local agriculture institute mentioned that now they are working with farmers in order to develop pest control chemicals. However, he pointed out, "*Although we recommend using some pesticides, their potential side-effects are not fully studied. We do not know the land as well as tea farmers do. So far, their conservative manners are more appropriate*." As Kloppenburg [76] (p. 530) noted, science sometimes "fails to respect the exigencies and needs of a specific locality" and may cause problems such as biodiversity damage, soil pollution, and threats to people's health. That is why farmers use fewer chemicals [5]. Their deep place connections enable them to ecologically preserve the farm and offer a distinctive approach to combat modern and scientific threats to the land [73].

Additionally, some local knowledge provides exploratory experience for forming reliable scientific knowledge. Specifically, although farmers do not know the scientific laws which may embed in local knowledge, their indigenous experiences inspire experts to verify some theories. For example, in regard to the daily care of tea trees, tea farmers tend to take natural actions to look after the trees. They are worried that chemicals will attack the trees and affect the quality of the leaves. Farmer FH05 told us, *"I do not use those market-bought fertilizers because I am not sure what has been added to them. I compost and fertilize with soybean residue and the tea trees grow very well."* They also use "guest soil mulching"-replacing chemical fertilizer with acidic soil from other places to supplement the tea plant's nutrition. Expert FH24 said that while doing research in Fenghuang, they noticed farmers' methods of taking care of the trees. It inspired them to conduct a study on the acid-base preference of tea trees, which confirmed that tea trees are in favor of an acidic environment. Natural fertilizers that tea farmers use are acidic or neutral, and therefore suitable for tea tree growth.

However, local practices are exhibited by tea farmers and thus are influenced by their personal interests. Farmers protect their own plantations based on economic and identity considerations, but their interests make it difficult for them to obtain a global and long-term perspective. Thus, scientific knowledge provides farmers with a broader view and systematic training, which is able to encourage farmers to protect their land effectively and further enhance resilience [57]. It is often integrated and disseminated through formal organizations [7]. For instance, the Tea Farmers Association, a public interest civil society organization established in 2019, promotes the concept of green, ecologically sustainable development and provides scientific help for tea production. An official told us,

> *"The goal of establishing our association is to introduce some scientific management expertise to farmers. We will hold some classes and communication activities by inviting some experts from Agricultural University and professional agricultural organizations to teach farmers."*

Prompted to attend these school training activities by the government, some farmers join in and are exposed to scientific knowledge. In this way, farmers gain a new understanding of the nature in which they have lived for decades [57]. During the interviews, the farmers often mentioned the chemical composition of tea leaves and how to protect their tea trees from an expert viewpoint.

In addition, some people are skillful at indigenous practices and have become famous as tea plantations and tea processing professionals. Local people often called them "the pioneer." They systematize their knowledge and help local farmers improve their production. Skilled farmer FH08 said, "I was 18 years old when I became a tea maker. During the busy seasons, the neighbors sometimes failed to solve the problems of processing tea. They would come to invite me to help them. I ran to their home at night to help many times." Farmers place great trust in these high skilled colleagues [5]. Farmer FH13 showed his admiration as follows:

> *"I really admire him. He truly loves this place and commits himself to this place. There is no salary, no pay. It is just his hobby to help others."*

As a result, tea farmers trust the knowledge that these experienced farmers spread. Pioneer farmers often work with scientific platforms by participating in government-organized tea lectures and acting as teachers in training sessions organized by institutions [43]. In this way, sustainable scientific knowledge can be transmitted to tea farmers in such a way that farmers are ready to accept it.

In sum, local knowledge is useful and protective in small household production. It provides perfect contextual choices to farmers to protect the land. However, due to the stability and individualism of local practice, it showed some disadvantages resulting from modern dramatic changes. Governments and agricultural institutions assist in knowledge transfer and exchange in this process. Tea farmers subjectively assimilate the scientific knowledge appropriate to their environment and then generate new forms of knowledge—a mixture of scientific and local assets [8,28]. Local knowledge, as a prominent manifestation of rural endogeneity, provides a strong foundation for preserving their farms, while the scientific approach provides farmers with advanced and standard cultivation knowledge so they can better help restore the environment [15].

### *6.2. Local Knowledge and Market Promotion*

In the above analysis, we focus on how tacit practices can be used to achieve sustainable agricultural production by promoting its own strengths while absorbing external resources. However, environmental problems are not only detrimental to agricultural production but also lead to food quality and safety crises. Modern consumers are anxious about food safety, while Fenghuang's environmental problems have undoubtedly affected tea trees' growth and tea quality. It enables consumers to question tea's safety and lowers their willingness to buy tea. As a result, tea sales started to decrease. When faced with this shock, farmers activated their cultural knowledge and strengthen their integration with expert knowledge. It creates a new path to ease food crises and promote rural resilience.

After the 1980s, farmers, as small businessmen, began to pay attention to how to sell tea better. In this context, farmers learned to taste tea rather than drink tea. The tasting process involves using various vocabularies to describe the flavors of tea to help satisfy trends. When we tasted tea with farmer FH18, he introduced the various tea aromas to us:

*"In our high-mountain tea, you can feel the 'youxiang' (悠香) instead of 'piaoxiang' (飘香). 'Youxiang' means the aroma will not be high-profile; only after drinking several cups of tea can you feel it. It has an aftertaste. Unlike high-mountain tea, the aroma of low-mountain tea is transient and evaporates into the air; that is called 'piaoxiang'."*

Additionally, farmers often use the words "Shanyun (山韵)" or "Congwei (丛味)" to describe the flavor of tea. "Congwei", the unique taste of a tree, is considered to be the most original aroma. It was mentioned that "Congwei" will not disappear even after the stresses of several production procedures, emphasizing the preciousness of this aroma. "Shanyun" is the charm and rhythm of tea mountain. Farmer FH13 stated the following to describe "Shanyun":

*"What we admire is the 'shanyun', which is found only in high-mountain trees. It has a little mossy flavor. You can sense it slowly; it is unique to this place."*

Farmers' descriptions of tea strengthen the connection among place, tea trees and tea drinkers, creating a world in which nature and the tea drinker interact through the tea, which accords with current consumers' imagination of "yuanshengtai (原生态)" and the desire to have a closer relationship with nature [10]. It guarantees the sales of Dancong tea.

Furthermore, the pure handmade style of "single plant picking, single plant processing" is the production tradition of Fenghuang and the main characteristic of local skills. This nonmechanized production is in line with recent popular concepts of rural areas, that is, "organic" and "authentic". Such descriptions reduce consumers' insecurities about commodities that are not visible [10]. In other words, Fenghuang's unique identity has been reshaped through sensual knowledge as a green and refreshed village, rather than as a barren and dead space, which is heterogeneously based on its local socio-historical background.

Moreover, farmers repeatedly mentioned the goodness of this place, emphasizing that only the soil in Fenghuang can grow the ideal Dancong tea. This specific place identity is a reinterpretation of the local area. When local farmers feel and accept this interpretation, they rediscover their own local uniqueness and freed their previously repressed "natural" identities [52]. Consequently, they strengthen their sense of belonging to Fenghuang and make good use of the place image from the perspectives of their inner identities to promote the tea market, which shows that place attachment can contribute to resilience potentially by emphasizing the land's identity [11,45].

From a scientific perspective, given the ongoing developments in science and technology, scientists have conducted chemical tests on Dancong tea and found that it contains higher concentrations of amino acids and ether extracts than do other teas, which explains why Dancong tea has a pleasing aroma and sweet taste. Expert knowledge was gradually transferred to tea farmers through lectures and seminars [57]. Farmers have absorbed this information and used it to form strategies to improve tea sales:

*"In the past, foreigners did not adapt to drinking Dancong because they thought this tea was too refreshing, which caused them to fail to fall asleep at night. However, if you get used to drinking it, you will realize the goodness of Dangcong. This cup of tea is full of amino acids, and the polyphenol content of the tea is very high."*

Farmer FH15 stated the following with pride:

*"You can't underestimate it. It contains many beneficial elements. They are inside. After baking, some elements may be turned into others, because the aroma is different. However, all the chemical elements that are good for your health are still in the tea."*

They believe that their tea would sell better if they were to ease consumers' worries about food safety. Scientific reports are one of the most credible sources of knowledge and can enhance consumers' confidence. Consequently, farmers voluntarily acquire scientific knowledge and use it to construct business strategies that improve the Dancong brand over the long run.

As a result of this branding, from a tea drinkers' perspective, the "place" is not only a geographical site but also a mysterious village that grows healthy plants with a charming aroma [77]. The farmers' description of tea and tea mountains well matches consumer conceptions of ideal commodity production areas. In this way, the "place" was commodified and used directly in the marketing field. The tea derived from this locality has become very popular in the market because of its deep connection with the tea mountains.

Overall, the farmers fused local and foreign knowledge to form a special way of tasting tea, which corresponds to Lowe et al. [50]'s definition of "vernacular expertise." It is a creative combination of scientific objective knowledge and local subjective knowledge. This dynamic knowledge has reshaped the concept of natural identity attached to the place and enhanced the farmers' sense of belonging, which enhances resilience [45,66]. Simultaneously, the output of their tasting knowledge fosters a "natural," "ecological" and "healthy" tea production place in the eyes of consumers, which caters to consumers' motivations for buying the product and effectively counteracts the barriers to marketing tea products that may arise due to environmental degradation, further promoting the resilience of the rural tea industry.

## 7. Conclusions and Discussions

The development of the tea industry enables tea farmers to avoid hard times and has taken Fenghuang from poverty to prosperity, finally achieving thriving economic vitality. As many studies have indicated, top-down drivers issued by the government are important [10]. In Fenghuang's case, it led to economic development. However, as Gkartzios and Scott [13] stated, rural area development cannot be achieved without the combined efforts of diverse actors, especially when environmental problems come. Thus, it is important to determine how indigenous farmers play crucial roles as participants in rural resilient and sustainable development and how they interact with experts to form new types of knowledge in the face of "slow burn" challenges. This paper explored the process of local farmer knowledge production through the lens of rural revitalization in China (Figure 4).

Our study identified tea farmers' local knowledge as applied knowledge that has been accumulated over time and passed down through generations. Moreover, their knowledge is dynamic. Farmers are able to learn new forms of knowledge and apply them to their businesses, which is in line with Šūmane et al. [7]'s finding that combinations of diverse sources of knowledge contribute to resilient agriculture and their intimate interactions with the land. Additionally, as Yin et al. [78] (p. 145) mentioned, "nature is not only compatible with development but can even be a source of development." The enchantment of nature and its connection with humanity is so powerful that it enables farmers to seek more sustainable ways of living with nature [73]. The government should pay attention to the important role farmers play in local knowledge production, strengthen ties with local farmers, and cooperate with them for rural development.

In addition to the contextual knowledge from farmers' experience, local knowledge also changes in a multi-actor network [7]. In line with Li [65]'s emphasis on the role of local stakeholders in rural revitalization, in our study, pioneer farmers were significant in helping other farmers improve their knowledge and cooperate with the government and institutions through lectures that promote appropriate knowledge. In this way, farmers are able to acquire more advanced information and better prepare for natural or manufactured crises. In line with Glover [47]'s argument, our research manifests the evolutionary path of resilience; that is, resilience is not just a return to the original state; instead, continuous learning is necessary. The government, as a link between the local community and the outside world, must tighten the connections among the government, universities, institutions, and farmers and establish a wider cooperation platform in which farmers can participate. While many cases have revealed the inequality between scientific knowledge and local knowledge, it is necessary to emphasize the significant position of local participants [31,33], which in turn narrows the gap between the local and the external and contributes to a fair dialog that democratizes knowledge [5].

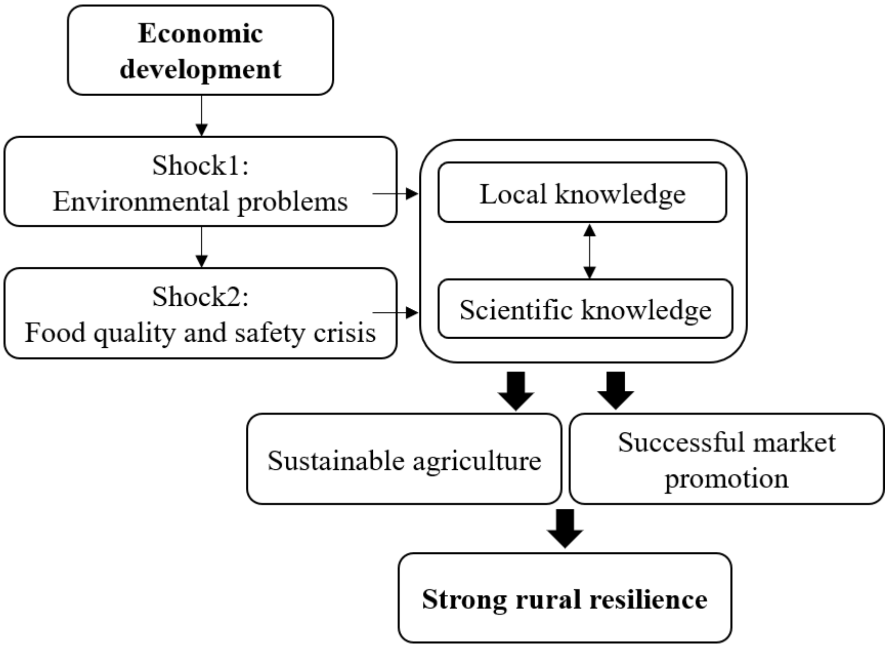



**Figure 4.** The theoretical framework shows how knowledge production contributes to strong rural resilience.

Additionally, Farmers' dynamic cultural knowledge reshapes the meaning of nature and strengthens the farmers' sense of belonging, enabling them to build new and more meaningful towns and communities [45]. These actions have created a solid brand for Fenghuang that helps it successfully enter national markets. Highly localized products make "the places where they are produced become unique" [79] (p. 319). This case study shows the role that activating cultural knowledge plays in enhancing rural resilience. Previous studies have focused on the economic value of agriculture and the economic resilience of rural areas while neglecting the contribution of culture, identity, and emotion to rural resilience, which are often flexible and widespread forces that need attention. In addition, the government should give weight to farmers' emotional belonging and identity and activate endogenous attributes.

Even though several attempts have been made to highlight the significance of local knowledge, methods to motivate local people need to be better explored since local residents are the most significant stakeholders in rural areas, but are often ignored in political, economic, and social contexts [61]. The constitution of knowledge is complex, and the boundaries between local knowledge and scientific knowledge often appear to be blurred. Future case studies can be expected to determine whether these two forms of knowledge can be translated into each other and what roles different actors play in improving the rural resilience process.

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# Farmer Heterogeneity and Land Transfer Decisions Based on the Dual Perspectives of Economic Endowment and Land Endowment

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**Abstract:** Guiding qualified farmers to transfer their land is an important way to alleviate the problem of land abandonment, improve land use efficiency, and achieve moderately large-scale land management. Based on the dual perspectives of economic endowment and land endowment, this paper uses the 2015 data of the China Household Finance Survey (CHFS), using the semilogarithmic ordinary least-squares method and the logit model, to explore differences in land transfer decisions under the effect of farmer heterogeneity. The circulation trading market was further improved to provide a reference. The heterogeneity of economic endowment and land endowment significantly affects the decision-making behavior of farmers in transferring land. The higher the land endowment is, the greater the probability that farmers transfer the land out and successfully trade, and they are more inclined to transfer the cultivated land to cooperatives, village collectives, and other institutions through formal channels, leading to a higher unit income of the transfer. Further research shows that land endowment has no significant difference in the impact of land endowment on whether farmers with different livelihood endowments transfer their land, but under the same land endowment, farmers with economic endowment advantages are more able to use their own endowment advantages to transfer their land out through formal channels and obtain higher gains income. Therefore, focusing on improving the conditions of land resources and increasing the endowment of farmers are important means to promote successful transactions in the land transfer market, ensure its sustainable operation, and promote further increase in the income of transfer farmers.

**Keywords:** land endowment; economic endowment; farmer heterogeneity; land transfer out

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## 1. Introduction

The extensive operation of traditional agriculture causes an increasing proportion of the rural population to move to neighboring towns or cities, which leads to an increase in the land abandonment rate year by year in rural areas, especially in remote mountainous areas or backward areas [1,2]. Land circulation can effectively alleviate the problem of land abandonment, increase efficiency of land use and ecological security, optimize the distribution of elements, marginal output level, and income poverty reduction triple effect [3–6], and realize land scale management, solving food security and quality control problems in developing countries [7]. For instance, Brauw et al. [8] reported that land transfer improves the mobility of Ethiopian farming households, thus increasing their incomes. Jin et al. [9] testified that land transfer rents are important for poor people in developing countries such as Vietnam. Peng et al. [7] reported that land transfer can increase farmers' income and enhance their pension security.

China is one of the largest developing countries in the world [10]. Collective land property rights are the basic system in rural China. Farmers have land contract rights, management rights, and the core of land transfer is the transfer of management rights. As early as 2004, the State Council of China issued the Decision on Deepening Reform and Strict Land Management, stipulating that the right to use construction land collectively owned by farmers can be transferred in accordance with the law. In 2014, the Chinese government issued the Opinions on Guiding the Orderly Transfer of Rural Land Management Rights and Developing Moderate Scale Agricultural Operations, calling for the development of land transfer. However, the development of land scale operations based on land circulation is not expected to go smoothly [11,12]. According to China's Rural Fixed Observation Points, the proportion of land transfer in the country as a whole rose from 17.1% in 2003 to 24% in 2013, an increase of less than 7%. In 2013, only six provinces saw more than 30% of land transfer [13]. Moreover, in recent years, China's land transfer has been "Involution", and the growth rate of land transfer has fallen year by year. For example, from 2014 to 2017, the year-on-year growth rates of the land transfer area were 18.3, 10.8, 7.2, and 6.9%, respectively. It is worth pondering why 61% of land remained un-transferred by the end of 2018, against the backdrop of a gradually improving land transfer market and more widespread nonfarming employment [14]. Therefore, it is significant to clarify the preconditions of successful land transfer transactions.

Theoretically, a farmer's resource endowment significantly impacts the farmer's transfer decision, and the transfer decision of different resource endowments is also disparate. In terms of studies on heterogeneous peasant households in land transfer, previous scholars usually differentiated peasant households according to part-time employment, working experience, income level, social security, and geographic feature and discussed the different transfer decisions of heterogeneous peasant households [15–17]. However, in addition to the above dimensions, the natural geographical conditions of land itself are also important factors that cannot be ignored in decision making regarding peasant household transfer [18,19]. In recent years, some scholars have gradually focused on the impact of natural endowments such as land area, slope, and degree of fragmentation on land transfer [20,21], but they are all based on small sample survey data in local areas, and the conclusions are weak in extrapolation.

Therefore, this paper uses land endowment and economic endowment to distinguish heterogeneous farmers. On the one hand, good land endowment and economic endowment can not only improve the price competitiveness of transfer-out farmers in the land transfer market and obtain higher transfer-out returns but also stimulate the transfer-out willingness of farmers or organizations pursuing high land return rates and promote the successful transaction of land transfer [22,23]. On the other hand, land endowment is an important factor and often ignored by researchers in the decision-making model of farmers' withdrawal from agricultural production. Then, how do different land endowments and economic endowments promote the "rational economic" farmer's agricultural production withdrawal (land transfer) decision change? So far, few studies have discussed this, and this paper attempts to answer this.

Compared with previous studies, the marginal contributions of this article are as follows: first, on the basis of a large sample of microdata (2015 Chinese Household Financial Survey data), this paper is used to assess the effect of heterogeneous farmers on land transfer decisions from a horizontal comparison perspective, which expands the analysis of the heterogeneous farmers and expands the framework of factors influencing farmers' land transfer decisions. Second, the land transfer decision is subdivided into whether to transfer out, the object of transfer, and the benefits of transfer and the differences in the transfer behavior of farmers with different land endowment and different economic endowment are compared and analyzed. On the basis of the above analysis, this paper responds to problems of land transfer path selection in theory and provides policy reference for further promoting effective land transfer and successful land transaction in practice.

## 2. Theoretical Analysis

### *2.1. Impact of Land Endowment on Land Transfer*

As the supplier of the land transfer market, whether farmers transfer their land depends on their judgment of the expected value of land. On the one hand, with the gradual increase in labor costs, the expected income of farmers in agricultural operation activities is low, which leads to the increasingly prominent problem of land abandonment in rural areas [18,24]. On the other hand, as the proportion of nonagricultural employment increases, a large number of young and middle-aged rural workers migrate to cities, increasing the opportunity cost of traditional smallholder productions.

It should be noted that according to prospect theory, under the hypothesis of the "rational economic person", farmers tend to transfer their land to obtain rental income in order to actively deal with the problems of land abandonment and high opportunity cost. However, a land transfer transaction requires the agreement of supply and demand. For the demand side, the land transfer decision is usually determined by the land operation scale under the maximization of net income, and the land transfer party needs to conduct cost–benefit analysis before deciding, that is, the net income of the land transfer must be greater than zero. Poor land endowment increases the agricultural operation cost of pesticides, fertilizers, machinery, and other aspects of the land transfer party, which may result in negative net income of the land transfer party [25]. Therefore, land with better land endowment has a higher probability of success in land transfer transactions. In order to avoid idled or abandoned land, farmers in China tend to transfer land to relatives, friends, and other acquaintances through informal channels, and implicit "human feeling" rent replaces explicit monetary rent. Studies showed that the rental income of individuals is significantly lower than that of enterprises and village collective organizations [26].

Accordingly, this paper proposes Hypothesis 1: land endowment has a significant positive impact on farmers' land transfer decisions, and the better the land endowment is, the more inclined farmers are to transfer it to organizations through formal channels to obtain higher rental income.

### *2.2. Analysis of Economic Endowment on Land Transfer*

The economic endowment of different peasant households is not the same, and there even are great distinctions. Under the constraints of livelihood capital such as economic income, social capital, and family labor structure, the choice of livelihood strategies of households is also subject to many restrictions. Compared with high-income families, low-income families have a single source of income and are mainly agricultural, so they rely more on land for livelihood and are less likely to transfer farmland out. In addition, due to the relatively weak social capital endowment of low-income families, they lack the right to speak in land transfer transactions and eventually become passive recipients of prices. Therefore, low-income families often obtain low rental income through land transfer. Accordingly, this paper proposes Hypothesis 2: economic endowment has a significant positive impact on farmers' land transfer decisions, and the better the economic endowment is, the more inclined farmers are to transfer it to organizations through formal channels to obtain higher rental income.

In conclusion, the theoretical analysis framework of this paper is shown in Figure 1.

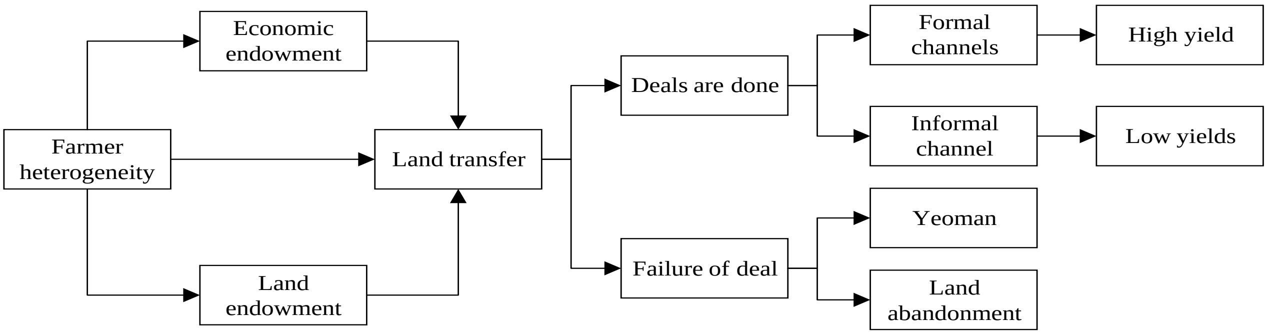


**Figure 1.** Theoretical analysis of household heterogeneity affecting land transfer.

## 3. Empirical Approach, Data Source, Variable Definition

### *3.1. Method*

This study mainly includes two parts: (1) The impact of household heterogeneity on the land transfer decision and transfer object. As the dependent variable is dichotomous, OLS regression is not suitable. Therefore, the logit model was used for empirical estimation in this paper. (2) The impact of household heterogeneity on land transfer rents. Since the circulation rent was positive, considering the requirement of normal distribution, a semilogarithmic OLS model was selected in this paper. For probing interactions of linear models, simplify the computations and facilitate the probing of interactions in ordinary least squares and logistic regression [27]. The basic model was set as shown in Equation (1):

$$Land = \beta_0 + \beta_1 Farmer + \beta_2 Control + \mu \quad (1)$$

where the explained variable Land represents the land transfer out, including the land transfer out, the transfer object, and the transfer income of the three related variables; Farmer denotes household heterogeneity, which is the core explanatory variable of this paper, including heterogeneity of land endowment and economic endowment, Control represents the set of factors influencing the land transfer of households, and $\mu$ is the error term that follows normal distribution.

### *3.2. Data Source*

The Chinese Household Finance Survey (CHFS) conducted by the Survey and Research Center for China Household Finance of Southwestern University of Finance and Economics is a very representative microdata base in China. It conducted a survey on land endowment in 2015 but cancelled relevant indicators in the new survey round in 2017. Therefore, we selected the cross-sectional data of CHFS in 2015 as the research sample of this paper.

The total sample of CHFS data for 2015 comprised 37,341 sample households in 29 provinces (excluding Xinjiang and Tibet), 353 counties, and 1373 communities or villages, which was based on modern hierarchical, multi-stage, and scale sampling (PPS) techniques and a computer-aided survey system (CAPI) [28]. The rural sample included 11,635 households, accounting for 31.2%. Considering that this paper focuses on the impact of land endowment on land transfer, a sample of 15,542 land-owning households (including 2732 land-transferring households) were screened, covering 29 provinces in China, composed of 6116 households in eastern China, 4842 households in central China, and 4584 households in western China.

This paper only considers land transfer because land endowment has strong externality, and the empirical estimation model is less likely to have endogeneity problems, so the estimation result is more accurate. If land transfer is considered, it is difficult to solve potential endogenous problems on the basis of existing data and methods. To be specific, farmers may carry out a series of intervention activities after transferring to the land, such as land leveling, building mechanical and tillage roads, power supply, drainage, irrigation, and other facilities, thus affecting the land endowment. Such endogeneity problems caused by reverse causality cannot satisfy the assumptions of the empirical model (that is, the independent variables are exogenous variables) and eventually lead to inaccurate empirical estimation results. In addition, there are no relevant indicators indicating the quality of land before and after transfer in the existing data, so it is impossible to obtain the relevant data of land endowment before transfer. Therefore, the final choice only considers the land transfer behavior.

### *3.3. Variable Definition*

#### 3.3.1. Explained Variables

This paper adopted three types of indicators to measure the land outflow situation of peasant households. The first is the land transfer decision, which refers to whether households transfer the management right of land to others or institutions, as a binary variable. The second is the objects of land transfer. In the original questionnaire, the objects of land transfer mainly included eight categories, which were divided into private (informal channels) and institutional (formal channels) according to the research needs of this paper, which are also binary variables. The third is the unit income of land transfer, which can be obtained by dividing the land transfer income (CNY) by the land transfer area (mu). In order to further satisfy the normal distribution hypothesis, we take logarithmic processing.

#### 3.3.2. Explanatory Variables

Land endowment and economic endowment are the core explanatory variables in this paper. The indexes used in existing studies to measure land endowment mainly focus on natural conditions such as land area and fertility [29,30], which basically belong to objective conditions. However, land transfer is a behavioral decision of farmers and also affected by subjective factors. We consider both subjective and objective dimensions to measure land endowment. Specifically, the subjective scoring method commonly used in subjective land endowment research is used for reference [31,32]. Farmers' subjective evaluation of land was used to measure the land, and the range from 1 to 5 was very poor, poor, average, good, and very good. For objective land endowment, referring to the previous studies [33–35], in this paper, the six binary indicators of suitability for large-scale mechanical farming, proximity to mechanical farming roads, irrigation facilities, power supply facilities, drainage facilities, and contaminated condition were selected to obtain the comprehensive index of objective land endowment by summarizing and adding them. The larger the value is, the better the land endowment is. Economic endowment is measured by the relative level of village average income; higher than the village average is classified as high-income families, and lower than the village average is classified as low-income families.

#### 3.3.3. Control Variables

To reduce the impact of missing variables on the research results, this paper referred to existing literature to determine the control variables to be used [36–38], mainly comprised three levels: householder characteristics, family characteristics, and community [39,40]. In terms of the characteristics of household heads, the gender, age, and education level are three important factors affecting the land transfer [41,42]. Generally speaking, the difference of risk preference and value expectation between male and female householders will affect the decision of land transfer. With the increase in the age of household heads, their labor capacity becomes weaker, and it is difficult to independently engage in large-scale agricultural operations, so they are more inclined to transfer land out to obtain rental income [43]. In addition, the higher the education level of farmers is, the higher the probability of nonagricultural employment, the less dependent they are on land for livelihood, so the more inclined they are to transfer land. At the level of family characteristics, relevant studies show that the structure of family members and employment are factors affecting land transfer market transactions. Therefore, this paper adopted four indicators to reflect the basic situation of families: family size, average education level (total education level of all family members/family size), average health (total health condition of all family members/family size), and nonagricultural employment ratio [44,45]. At the community level, village topographic features are controlled [46]. Table 1 shows the selection, definitions, and assignment of all variables for the empirical model.

**Table 1.** Variable selection, definition, and assignment.

| Variable Classes | Variable Name | Variable Meaning and Assignment |
|---|---|---|
| Explained variables | Land transfer decision | Whether to transfer the land management right to others or organizations: 1 = yes; 0 = no |
| | Land transfer objects | 1 = private (ordinary farmers of the village, ordinary farmers of the other village, professional large households, family farms); 0 = institutions (farmer cooperatives, village collectives, companies or enterprises, intermediary agencies) |
| | Land transfer income | Land transfer income/land transfer area, CNY/mu |
| Explanatory variables | Subjective evaluation of land endowment | 1 = very poor; 2 = poor; 3 = average; 4 = good; 5 = very good |
| | Objective evaluation of land endowment | Whether it is suitable for large mechanical farming: 1 = yes; 0 = no |
| | | Is it close to the mechanical farming roads? 1 = yes; 0 = no |
| | | Whether irrigation facilities are available: 1 = yes; 0 = no |
| | | Whether there is power supply: 1 = yes; 0 = no |
| | | Whether drainage facilities are available: 1 = yes; 0 = no |
| | | Is it contaminated? 1 = no; 0 = yes |
| | Economic endowment | Higher than the average income level of the village = high-income families; otherwise, low-income families |
| Control variables | Gender of head of household | 1 = male; 2 = female |
| | Age of head of household | Years |
| | Educational level of head of household | 1 = illiterate; 2 = elementary school; 3 = junior middle school; 4 = high school; 5 = technical secondary/vocational high school; 6 = junior college/higher vocational college; 7 = bachelor's degree; 8 = master's degree; 9 = PhD students |
| | Family size | Number of family members, people |
| | Family educational level | 1 = illiterate; 2 = elementary school; 3 = junior middle school; 4 = high school; 5 = technical secondary/vocational high school; 6 = junior college/higher vocational college; 7 = bachelor's degree; 8 = master's degree; 9 = PhD students |
| | Family health condition | 1 = very bad; 2 = bad; 3 = average; 4 = good; 5 = very good |
| | Nonagricultural employment ratio | Non-farm payrolls/family size, % |
| | Village terrain | 1 = hills or mountains; 0 = plains |

## 4. Results

### *4.1. Descriptive Results*

Table 2 shows the results of the descriptive statistical analysis of the relevant variables. Results show the following:

(1) The land transfer rate and unit income of low-income families were lower than those of high-income families. The land transfer rate of peasant households was about 18%, among which 89% of peasant households chose to transfer their land to private individuals through informal channels, with an average transfer income of CNY 713.61 per mu of land. Specifically, the land transfer rate of low-income families was about 13%, and that of high-income families was 18%. The land transfer rate of

low-income families was thus about 5% lower than that of high-income families. In terms of the transfer objects, there is little difference between low- and high-income families. The per mu income of land transfer for low-income families was CNY 385.77, significantly lower than CNY 742.90 for high-income families.

(2) The land endowment of low-income households was significantly worse than that of high-income households. The average subjective land endowment level of all sampled households was between average and good, which was 3.35. In terms of the objective land endowment, the average of the whole sample of peasant households reached the standard of three out of six indicators. Specifically, the average subjective evaluation of land endowment of low-income families was 3.21, slightly lower than that of high-income families, 3.37. The objective evaluation of land endowment of low-income families is indeed lower than that of high-income families, with an average of 2.75 items reaching the standard, lower than the 3.08 items of high-income families.

(3) The heads of peasant households are mostly middle-aged and elderly, and educational level is generally low. The average age of the household head of the whole sample was 52.35 years old, and most of them had primary or junior high school education. Specifically, the average age of heads from low- and high-income families was 55.87 and 51.92 years old, that is, the average age of heads from low-income families was higher than that from high-income families. The average educational level of the heads of low-income households was 2.25, lower than the 2.75 of high-income households.

(4) There were significant differences between low- and high-income households in average levels of education, health status, and share of nonfarm employment. The average number of household members in the full sample was about four, the average level of education was between primary and secondary school, the average health status was between bad and fair, and more than two-thirds of the household members on average worked off-farm. Specifically, there was no significant difference in the number of members between low- and high-income families. The average educational level and health status of members of low-income families are lower than those of high-income families. The share of family members in nonfarming employment was 65% for low-income households on average, 6% lower than that for high-income households.

**Table 2.** Descriptive statistics.

| Index | All Samples | | Low-Income Families | | High-Income Families | | Units |
|---|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation | |
| Land transfer decision | 0.18 | 0.38 | 0.13 | 0.34 | 0.18 | 0.39 | - |
| Land transfer objects | 0.89 | 0.31 | 0.88 | 0.33 | 0.90 | 0.31 | - |
| Land transfer income | 713.61 | 4750.25 | 385.77 | 1379.59 | 742.90 | 4939.77 | CNY/mu |
| Subjective evaluation of land endowment | 3.35 | 0.99 | 3.21 | 1.03 | 3.37 | 0.99 | - |
| Objective evaluation of land endowment | 3.04 | 1.64 | 2.75 | 1.59 | 3.08 | 1.64 | - |
| Gender of head of household | 1.14 | 0.34 | 1.13 | 0.34 | 1.14 | 0.35 | - |
| Age of head of household | 52.35 | 12.91 | 55.87 | 13.07 | 51.92 | 12.83 | Year |
| Educational level of head of household | 2.70 | 1.15 | 2.25 | 0.9 | 2.75 | 1.17 | - |
| Family size | 4.07 | 1.84 | 4.06 | 2.02 | 4.07 | 1.82 | Person |
| Family education level | 2.43 | 1.01 | 2.04 | 0.83 | 2.48 | 1.02 | - |
| Family health condition | 2.18 | 0.88 | 2.51 | 0.95 | 2.14 | 0.86 | - |
| Nonagricultural employment ratio | 0.71 | 0.32 | 0.65 | 0.32 | 0.71 | 0.32 | % |
| Village terrain | 0.42 | 0.13 | 0.45 | 0.13 | 0.41 | 0.11 | - |

### *4.2. Empirical Results*

#### 4.2.1. Influence of Land Endowment on Land Transfer

Table 3 presents the empirical estimates.

**Table 3.** Impact analysis of land transfer.

| Index | Model (1) Whether to Transfer | Model (2) Transfer Objects | Model (3) Transfer Income | Model (4) Whether to Transfer | Model (5) Transfer Objects | Model (6) Transfer Income |
|---|---|---|---|---|---|---|
| Subjective land endowment | 0.228 *** | −0.126 * | 0.433 *** | | | |
| | (9.90) | (−1.90) | (7.48) | | | |
| Objective land endowment | | | | 0.194 *** | −0.085 ** | 0.503 *** |
| | | | | (14.52) | (−2.17) | (14.83) |
| Economic endowment | 0.272 *** | 0.197 | 0.238 | 0.249 *** | 0.210 | 0.158 |
| | (3.38) | (0.87) | (1.15) | (3.10) | (0.92) | (0.77) |
| Head characteristics | | | | | | |
| Gender | 0.084 | 0.173 | −0.515 *** | 0.108 * | 0.167 | −0.440 *** |
| | (1.36) | (0.97) | (−3.31) | (1.73) | (0.94) | (−2.92) |
| Age | 0.019 *** | 0.008 | −0.001 | 0.019 *** | 0.008 | −0.001 |
| | (9.79) | (1.59) | (−0.30) | (9.77) | (1.54) | (−0.30) |
| Degree of education | 0.030 | 0.056 | −0.015 | 0.031 | 0.052 | −0.011 |
| | (1.19) | (0.83) | (−0.23) | (1.22) | (0.77) | (−0.17) |
| Family characteristics | | | | | | |
| Membership | −0.155 *** | −0.054 | −0.035 | −0.157 *** | −0.053 | −0.027 |
| | (−10.88) | (−1.38) | (−0.90) | (−10.91) | (−1.36) | (−0.72) |
| Average education level | 0.049 * | −0.071 | 0.049 | 0.036 | −0.066 | −0.001 |
| | (1.86) | (−1.00) | (0.71) | (1.35) | (−0.91) | (−0.01) |
| Average health level | 0.045 | −0.000 | 0.060 | 0.046 | 0.008 | 0.065 |
| | (1.54) | (−0.01) | (0.80) | (1.56) | (0.11) | (0.89) |
| Nonagricultural employment ratio | 2.824 *** | 0.914 *** | −0.984 *** | 2.874 *** | 0.913 *** | −0.950 *** |
| | (25.21) | (4.33) | (−4.30) | (25.32) | (4.33) | (−4.24) |
| Community characteristics | | | | | | |
| Village terrain | −0.174 *** | −0.022 * | −0.127 *** | −0.181 *** | −0.030 ** | −0.135 *** |
| | (−15.38) | (−1.91) | (−4.72) | (−17.09) | (−2.32) | (−5.17) |
| Constant | −5.281 *** | 1.433 ** | 3.772 *** | −5.158 *** | 1.273 ** | 3.522 *** |
| | (−23.66) | (2.35) | (6.57) | (−24.14) | (2.23) | (6.57) |
| Sample size | 15,542 | 2732 | 2732 | 15,542 | 2732 | 2732 |

*, **, and *** represent significance at 10, 5, and 1% levels, respectively; numbers in brackets are t values of robust estimates.

(1) The influence of land endowment on land transfer decision: Columns one and four of Table 3 report the impact of subjective and objective land endowment, respectively, on peasant households' land transfer decisions. In both the subjective and the objective dimension, land endowment improved the probability of land transfer decision at a significance level of 1%, which verified Hypothesis 1.

(2) The influence of land endowment on the object of land transfer: Columns two and five of Table 3 report the impact of subjective and objective land endowment, respectively, on the land transfer objects of peasant households. The results show that the higher the land endowment, the more likely the peasant households are to transfer their land to institutions through formal channels. The subjective and objective dimensions pass the test at a significance level of 10 and 5%, respectively, verifying Hypothesis 1.

(3) The influence of land endowment on land transfer income: Columns three and six of Table 3 report the impact of subjective and objective land endowment, respectively, on peasant households' income from land transfer. Estimation results show that land endowment increased the unit income of land transfer at a significance level of 1% in both subjective and objective dimensions, which verified Hypothesis 1.

#### 4.2.2. Influence of Economic Endowment on Land Transfer

Table 3 reports the impact of economic endowment on land transfer. From the estimation results, economic endowment increased the decision-making probability of land transfer at a significance level of 1%. However, the object and income of land transfer are not significant, so Hypothesis 2 is untenable.

In order to further analyze the difference of household heterogeneity affecting land transfer among households with different economic endowments, we conducted sub-sample regression according to the economic endowments, which also helped in verifying the robustness of the above regression results. Table 4 reports the impact of land endowment on the land transfer behavior of high- and low-income families. The results show that there was no significant difference in the impact of land endowment on the land transfer decision of the two types of farmers. According to the regression results in columns three and four, the impact of subjective land endowment on the objects of land transfer is still significant in the sample of high-income families but becomes insignificant in the sample of low-income families. Columns five and six are the estimated results of land endowment for the land transfer benefits of the two types of farmers. This is basically consistent with the regression results of the whole sample, but the coefficient of subjective land endowment affecting the land transfer income of low-income households was significantly lower than that of high-income households. This reflects that compared with high-income families, low-income families are often in a weak position of land transfer and eventually become passive recipients of the market price of land transfer, resulting in their unit rental income being significantly lower than high-income families.

**Table 4.** Subsample regression results.

| Index | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | **Whether to Turn Out** | | **Transfer Objects** | | **Transfer Income** | |
| | **Low-Income Families** | **High-Income Families** | **Low-Income Families** | **High-Income Families** | **Low-Income Families** | **High-Income Families** |
| Subjective land endowment | 0.226 *** | 0.228 *** | −0.083 | −0.130 * | 0.289 * | 0.448 *** |
| | (2.92) | (9.46) | (−0.41) | (−1.83) | (1.67) | (7.29) |
| Objective land endowment | 0.199 *** | 0.193 *** | 0.077 | −0.102 ** | 0.314 *** | 0.520 *** |
| | (4.16) | (13.85) | (0.55) | (−2.51) | (2.68) | (14.69) |
| Control variable | Control | Control | Control | Control | Control | Control |
| Sample size | 1692 | 13,850 | 224 | 2508 | 224 | 2508 |

*, **, and *** represent significance at 10, 5, and 1% levels, respectively; numbers in brackets are t values of robust estimates.

## 5. Discussion

In this study, a large sample size survey of 15,542 households was selected to study the impact of household heterogeneity on land transfer from the perspective of land endowment and economic endowment. This study not only focuses on the decision of land transfer, but also investigates the objects and income of land transfer, which is more comprehensive and practical. At the same time, this study further analyzed the difference of household heterogeneity affecting land transfer among households with different economic endowments and found that the results remained robust. As the largest developing country in the world, the research results of rural China have strong practical significance. They can provide references for other developing countries to realize large-scale land management.

The results of this study have some similarities and differences to previous studies. From the perspective of land transfer, land endowment significantly impacts the land transfer decision, especially when the head of a household is older and thus more inclined to transfer land. This result is consistent with the findings of He et al. [36], who argued that land transfer can liberate the rural elderly from the heavy burden of traditional farming [6]. More specifically, with the increase of age, the income of famers through farming gradually decreases, while the rent obtained from land transfer can bring them higher income. At the level of family characteristics, the higher the share of nonagricultural employment among family members, the greater the probability of land transfer. As Hoq et al. [47], Wang et al. [48], and Pfeiffer et al. [49] considered that the labor force mainly works in towns/urban areas and is more stable and of higher income than in rural areas, they are more willing to transfer land since they are less dependent on land. In terms of economic endowment, this is further supported by the fact that low-income families are less likely to transfer land than high-income families.

In terms of the land transfer objects, the higher the proportion of nonagricultural employment among household members is, the more inclined they are to transfer their land to private individuals through informal channels. There are two possible reasons: On the one hand, farmers with a higher proportion of nonagricultural employment are less dependent on land. In order to avoid idle and abandoned land, farmers tend to transfer land to relatives and friends through informal channels and use hidden "human rent" instead of "monetary rent" [50]. On the other hand, the lower the proportion of nonagricultural employment among household members is, the lower their social capital and smaller their acquaintance network are, so they are more likely to choose formal channels in land transfer transactions. Meanwhile, this is consistent with the fact described in a paper by Du et al. [51], that China's rural society is an "acquaintance society".

At the same time, the results of the present study were different from the findings of Cheng et al. [52], who founded the "male and female co-negotiation" land transfer model. Especially in terms of land transfer income, the gender of household heads showed that the unit income of female-headed households in land transfers was lower than that of male-headed households. This is because in most rural areas of China, female heads of households have weak negotiation abilities in land transfer transactions and generally become passive recipients of market prices. This is consistent with [53,54] and other studies, where female-headed households remain somewhat marginalized.

In addition, this study has several deficiencies that can be addressed in future studies, as follows: (1) We selected the cross-sectional data of CHFS in 2015 as the research sample of this paper. However, the influence of farmer heterogeneity on land transfer is a dynamic process. Thus, future research could use panel data to further expand and verify the relationship in greater detail. (2) Based on the empirical evidence from rural areas of China, this paper studies the relationship between farmer heterogeneity and land transfer, and whether this relationship is applicable to other countries or regions remains to be discussed.

## 6. Conclusions and Implications

On the basis of the survey data of the CHFS in 2015, OLS and the logit model were used to quantitatively study the differential influence of farmers' heterogeneity on land transfer decisions from the dual perspective of land endowment and economic endowment.

Generally speaking, the higher the land endowment is, the higher the probability of a land transfer and the successful transaction of farmers, the more inclined they are to transfer the land to institutions through formal channels, and the higher the unit income of the land transfer. There was no significant difference in the impact of land endowment on whether farmers with different economic endowments transfer land. However, under the same land endowment, compared with low-income families, high-income families can transfer land out through formal channels and obtain higher returns by virtue of their endowment advantages.

In addition to their theoretical significance, the results of the present study have definite policy implications. As noted earlier, the land endowment and land transfer have a strong positive correlation. Thus, the government should insist on the further construction of high-standard farmland (high-standard farmland aims at building infrastructures to improve farmland's productivity, such as roads, irrigation, power supply, and drainage). Through the moderate infrastructure construction above, the overall land endowment for families will be improved. However, at the same time, it is worth noticing that under the same land endowment, the land transfer income of low-income families is significantly lower than high-income families. Therefore, the government needs to be aware of the income between high- and low-income families in land transfers. So, building an official land transfer platform and providing land transfer services to guide low-income families correctly is a key issue to obtain an even rental income and improve the transactions' success rate.

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