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Farmer differentiation and cultivated use system resilience from a perceptive behavioral perspective: influencing mechanisms and governance strategies

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Introduction: The adaptive management strategy of the cultivated land use system is crucial for achieving sustainable development, particularly when viewed from the perspective of perceptual behavior. This study integrated farmers' behavior, perceptions, and willingness into the resilience evaluation index system of the cultivated land use system.

Methods: By resilience calculation method of cultivated land use system and linear regression method, it also explored the effect of farmer differentiation on the resilience of cultivated land use systems under the influence of socioeconomic systems, thereby providing a scientific reference for the adaptive management of cultivated land use systems.

Results: The key findings are as follows: First, in general, the production resilience of the peasant household cultivated land use system was low, with significant resilience differentiation of resource elements and stratification of ecological and scale structures. However, the total resilience remained relatively stable. Second, farmers' cultivated land use systems exhibit uneven resilience, with a lack of production and ecological protection, indicating low efficiency and weak functioning of the cultivated land use system. Third, farmers' differentiation into non-agricultural employment is high, with low dependence on land. The resilience of the cultivated land use system varies significantly among different types of farmers, with imbalance and production deficiency being the main types of resilience in the farmland use system. Fourth, the economic differentiation of farmers and the differentiation of cultivated land use negatively affected the resilience of the cultivated land use system; the more pronounced the differentiation, the lower the resilience.

Discussion: Based on these findings, the primary management strategies to enhance the resilience and adaptability of the cultivated land use system include improving the production resilience of the system, increasing the enthusiasm of different types of farmers to invest in the resource elements of the cultivated land use system, promoting the transformation of ecological protection consciousness and behavior among various types of farmers, and improving the willingness for cultivated land transfer.

KEYWORDS

scale of farmers, cultivated land use system resilience, farmer differentiation, adaptive governance, cultivated land use system

1 Introduction

Cultivated land serves as a fundamental resource for maintaining global ecological and food security and promoting human survival and sustainable development (Ares et al., 2001). With the impact of climate change, the economic crisis and the increasingly severe form of international trade, protecting cultivated land and ensuring food security have become key tasks for all countries (Tilman et al., 2002). However, the contradictions between people and land, such as the solidification of cultivated land property rights, the weak systematic management of cultivated land, the abandonment of farmland by farmers, and the extensive use of cultivated land, hinder the implementation of the cultivated land protection system, affect the production, life and ecological functions of cultivated land, and become the root challenges for the effective use and protection of cultivated land (Bahar and Kirmikil, 2021). From the perspective of the production function of cultivated land, the non-grain, non-agricultural, fragmentation and fertility degradation of cultivated land make the ability of cultivated land to supply food weaker and weaker, and affect the stability of grain production (Mander et al., 2007). From the perspective of the living function of cultivated land, less cultivated land management income can not guarantee the basic living needs of farmers, reduce the willingness of farmers to engage in agricultural production, and further lead to the loss of rural labor force. From the perspective of ecological function of cultivated land, the blind pursuit of extensive use of grain yield causes irreversible quality loss of cultivated land fertility, and further damages the balance of the ecosystem in the process of ecosystem circulation (Costanza et al., 1997). It can be seen that the balance and coordination of production, life and ecological functions of cultivated land are the key and difficult points in the process of utilization and protection of cultivated land. In the face of the complexity and uncertainty of cultivated land protection, how to coordinate the relationship between human activities and cultivated land use, and improve the social security and ecological protection functions of cultivated land while ensuring the production function of cultivated land is a hot topic of academic attention.

Modern research prioritizes enhancing the productivity of cultivated land, while ensuring its sustainable use and maintaining the quantity, quality, and ecology of the land. Numerous studies have examined the current state and dynamic changes in global cultivated land use, focusing on aspects such as characteristics of the cultivated land use system, quality evaluation, ecosystem service value, production efficiency, and carbon emissions. These studies suggest that the production and ecological potential of cultivated land can be improved through various methods (Amichi et al., 2012; Liang and Li, 2020; Niu et al., 2021). Consequently, scholars have proposed the protection of cultivated land through the construction of a "quantity–quality–ecology" evaluation system, comprehensive land improvement, and a balance between occupation and compensation, among other control measures and policies. These strategies aim to enhance the sustainable development capacity of cultivated land use system (Song et al., 2015; Lyu et al., 2022). However, because the cultivated land use system is one of the most complex subsystems in the socio-ecological system and is in a state of dynamic balance, it is insufficient to evaluate its quality solely using static methods. Resilience thinking, which refers to a system's ability to withstand disturbances in a changing environment and reorganize its elements to achieve a new balance and sustainable development, offers a fresh perspective. Therefore, this study explored how to maintain the stability of a cultivated land use system under internal and external forces, using resilience thinking and a dynamic balance perspective. This approach provides new theoretical support for understanding the operational laws of cultivated land use systems.

Resilience is a complexity, intersections and multi-disciplinary concept, which has undergone a transition from engineering resilience to ecological resilience and then to evolutionary resilience (Gunderson, 2000; Volkov et al., 2021). At present, many scholars have applied the resilience theory to the cultivated land use system, studying how cropland use systems adapt to stress, and its connotation has changed from expressing the state and adaptability of cultivated land to emphasizing the transformation ability of cultivated land to respond to pressure based on the existing state (Lyu et al., 2022). In terms of the resilience evaluation of cultivated land use system, scholars mostly set up a multi-dimensional evaluation model from the perspective of national, provincial and municipal scales, cultivated land natural resources, farming conditions, ecological services, production capacity, social security and other attributes and functions of cultivated land, and adopted multi-source spatial data and socio-economic data to carry out comprehensive evaluation (Ares et al., 2001; Nguyen et al., 2019; Léger-Bosch et al., 2020; Shonhe and Scoones, 2022). In terms of driving mechanism, many scholars have shown that the resilience of cultivated land use system is mainly influenced by climate, terrain, soil, farmers' agricultural production technology, farming methods, input and utilization and other natural environment and human factors. At the same time, rural labor transfer, location factors, urbanization level, "non-food," farmers' livelihood conditions, agricultural development policies, also affect the play of resilience (Sutcliffe et al., 2015; Maltou and Bahta, 2019; Calo, 2020). In summary, the study on the comprehensive evaluation and driving mechanism of large-scale cultivated land use system resilience has been perfected (Özerol and Bressers, 2017). However, there are few studies on the resilience of cultivated land use system based on rural and subject small-scale perspectives, and the driving mechanism of the resilience of cultivated land use system is not only the direct influence of a single factor, but also the correlation influence of multiple factors inside and outside the system is the key reason for the change of the resilience of cultivated land use system, and the correlation logic is also crucial to study.

Farmers' attitudes and behaviors toward agricultural development policies and farmland protection significantly influence the resilience of cultivated land. As key components of the cultivated land use system, farmers possess a strong sense of initiative and maintain extensive social networks, both of which significantly affect the system's resilience (Baird et al., 2020). The behavior, understanding, and willingness of farmers can influence the composition, structure, and morphological changes in the cultivated land use system (Bahar and Kirmikil, 2021). However, many studies treat farmers as separate entities from the cultivated land use system, rather than as integral parts of the system's resilience (Meng et al., 2019; Hossard et al., 2021; Rachunok et al., 2021). These studies were limited to evaluating the current situation of the inherent resources of the cultivated land use system, ignoring the resistance of farmers to the external pressures of the cultivated land use system and the use of internal resources. The mechanism of the resilience of the cultivated land use system and the reorganization of the elemental resources of the cultivated land use system have not been reflected. Therefore, based on the current situation of resource elements of the cultivated land utilization system, the perception, behavior, and coping measures of farmers to the pressure are reflected, which is a deep analysis of the operation law of the cultivated land utilization system and further sublimation of the concept and evaluation of the resilience of the cultivated land utilization system; therefore, it is crucial to incorporate farmers' perceptions, behaviors, understanding, and willingness within the cultivated land use system into the evaluation of cultivated land resilience. This involves constructing an evaluation framework for the resilience of a cultivated land use system, based on perceived behavior.

As the social ecosystem continually evolves and globalization progresses rapidly, farmers' perceived behaviors shift, leading to their gradual detachment from the cultivated land use system (Zamchiya, 2013; Nyantakyi-Frimpong and Kerr, 2017). This detachment has resulted in changes in the intensity, scale, environment, and internal components of the cultivated land use system, thereby affecting its resilience efficiency (Olofsson, 2020; Yin et al., 2020). The most evident manifestation of the social and economic system's influence on farmers' behavioral perceptions is their differentiation (Shonhe and Scoones, 2022). Investigating the resilience characteristics, influence mechanisms, and adaptive governance strategies of cultivated land use systems among farmers with varying types of differentiation is crucial for enhancing the theoretical framework of sustainable cultivated land use and identifying adaptive transformation strategies for cultivated land (Angeler et al., 2015).

Based on this, on the basis of the previous comprehensive evaluation of the natural and functional attributes of the cultivated land use system, this study integrated the perceived behavior of farmers into the resilience assessment index system of the cultivated land use system, and highlighted human perception and subjective initiative more than previous studies. In addition, farmer differentiation, as the most intuitive manifestation of farmers' resistance to adaptation pressure, on the one hand, accepts the influence of social ecosystem, on the other hand, plays a role in the cultivated land utilization system. Therefore, combined with the existing research on the driving mechanism of cultivated land use system, analyze the impact of the differentiation of farmers' occupation and economy on the resilience of cultivated land use system under the background of globalization, its beneficial to better understand the mechanism of farmland use system resilience under internal and external pressure and environment, and then put forward targeted management strategies of farmland use system.

2 Theoretical framework

2.1 Connotation of cultivated land use system resilience

Resilience is the capacity of a system to respond to unexpected disturbances. This concept includes three aspects: the system's resilience in withstanding shocks, while preserving its existing structure and function; the system's adaptability in managing shocks through experiential learning, self-reorganization, and adjustment; and the system's ability to form a new developmental trajectory and achieve transformation and upgrading (Léger-Bosch et al., 2020). Cultivated land use systems are a combination of natural ecosystems, such as cultivated land, climate, hydrology, and biodiversity, and social and economic systems, such as human development, protection, and utilization (Calo, 2020). The resilience of the cultivated land use system refers to the ability of arable land systems to resist and adapt to disturbances using resource factors and to restore stable sustainable development. Resilience reflects the extent to which an arable land system can withstand external disturbances. The creation of a new development path to realize system renewal and transformation, while maintaining the basic structure and function of the cultivated land use system, is a further refinement of the concept of resilience of the cultivated land use system (Sundstrom et al., 2023). The development of the resilience function is closely tied to factors within the cultivated land use system, such as resource endowment, material economy, cultural customs, ecological environment, population, industry, and social networks. The connectivity and cooperation of these factors form the foundation for resistance to interference (Meng et al., 2019; Lyu et al., 2022). Therefore, the resilience of cultivated land-use systems refers to their capacity to adapt to external disruptions and achieve transformation and upgrading through internal factor reorganization and morphological-structural changes in response to the challenges posed by the external social environment. Resilience is crucial for maintaining the system's sustainable development (Bahta and Lombard, 2023). The resilience of cultivated land use systems can be divided into the following four components: resource element resilience, production resilience, ecological resilience, and scale structure resilience (Lyu et al., 2022). These components refer to the input and richness of various resource elements of cultivated land use systems, the strength of the production function and social security function, habitat quality and ecosystem service function, and the production form and spatial structure of cultivated land (Gunderson and Holling, 2002; Faria and Morales, 2020).

2.2 Farmers' behavior and cultivated land resilience

As primary stakeholders and actors in cultivated land use systems, farmers use these resources to withstand disturbances. Their decision making and resource access collectively determine the system's response to shocks and pressures (Legesse and Drake, 2005). Drawing from behavioral theory, it is evident that the system environment influences farmers' subjective initiative. Their perception of this environment dictates their livelihood behavior, which in turn shapes the composition and structure of the cultivated land use system. This forms a system's method of responding to pressure and reflects its resilience (Özerol and Bressers, 2017). Governance, defined as the maintenance of organizational order, promotion of development, and progress control by an independent collective within or outside the organization, relies on systems, methods, or means to maintain order. As the primary participants in governance activities, farmers' perceived behavior reflects the governance effectiveness (Muller et al., 2016). Consequently, evaluation of the resilience of the farmland use system should be grounded in the interaction between farmers and the system environment, focusing on farmers' environmental perceptions and resource use. In other words, the assessment of the resilience of the cultivated land use system should be approached from the perspective of farmers' perceptions and behaviors.

Agricultural land systems must possess adequate food and economic production capabilities to withstand the food crisis and the strain of agricultural labor shortages brought on by global population growth and rapid urbanization (Human and Soleimanian, 2018). Within this system, elements such as people, land, finance, technology, and machinery form an integrated entity, with changes in any element affecting the entire system (Hu et al., 2021). Farmer differentiation refers to the transfer and change of farmers' employment, identity and quality improvement, which is the final choice result of farmers' behavior perception (Yin et al., 2020). Driven by the external social environment, the choices made by farmers in terms of livelihood, residential area and future development will eventually lead to the differentiation of farmers in different directions of employment and identity, which will further affect the input of farmers to the elements of the cultivated land utilization system and the intensive management behavior of cultivated land scale (Adger, 2000; Zamchiya, 2013). Specifically, the differentiation of farmers can be divided into two categories: economic differentiation and farming utilization differentiation. The economic differentiation of farmers is mainly manifested in the diversified choices of farmers' livelihood and professional and part-time farmers' professional identity, while the differentiation of cultivated land utilization is mainly manifested in the differences of farmers' cultivated land utilization behaviors (Nyantakyi-Frimpong and Kerr, 2017). The more farmers tend to divide into non-agricultural and smallholder farming, the lower the resilience of cultivated land use system (Shonhe and Scoones, 2022). As the development gap between urban and rural areas widens, cities and towns are becoming increasingly attractive to farmers, placing the agricultural land system under the pressure of gradual labor force loss (Blesh and Wittman, 2015). Owing to their part-time employment, many farmers are unable to commit fully to agricultural production. This results in a decrease in farmers' investment in agricultural land, a lack of agricultural mechanization, and in some cases, even the abandonment of arable land (Baysse-Lainé and Perrin, 2018; Keleg et al., 2021).

Therefore, the decision of farmers to continue cultivation and the extent of their investment in the cultivated land system can influence the basic composition of the system. If the cultivated land system fails to maintain appropriate grain yield and economic benefits, it can affect its production function, which in turn can influence its resource elements and production resilience (Bertoni et al., 2018; Darnhofer, 2021). As a crucial component of the ecological environment, cultivated land systems offer a range of ecological service functions. This is fundamental for ensuring food production and agricultural development and demonstrates the ecological resilience of cultivated land systems (Ares et al., 2001). Moreover, the size of the cultivated land system, intensity of its contiguity, and structure of its planting can all affect the efficiency of land use, which can further limit the grain yield and economic output of cultivated land. The larger and more concentrated the cultivated land system and the higher the proportion of food crops, the stronger the functions and scale structure resilience of the cultivated land system.

However, the weaker the ecological protection consciousness of farmers, the more likely it is to damage the ecological environment of cultivated land because of the pursuit of cultivated land production efficiency, and then reduce the ecological toughness of cultivated land (Graeme, 2011; Gong et al., 2019). Concurrently, the unique household contract responsibility system in China, coupled with the characteristics of the natural geographical environment, has resulted in fragmented cultivated land in many regions, thereby reducing the prevalence of large-scale intensive production (Léger-Bosch et al., 2020). Under these circumstances, factors such as whether farmers possess stable property rights over cultivated land, their decision to transfer land, and their choice of management scale significantly affect the efficiency of cultivated land use. These decisions can further influence the resilience of the scale structure of cultivated land systems (Gong et al., 2019; Gyapong, 2020).

In summary, the economic differentiation of farmers and the differentiation of cultivated land use affect the intensity and mode of cultivated land use, and then affect the resource elements, production, ecology and scale structure toughness of cultivated land use system. Therefore, this study assumes that the economic differentiation of farmers and the differentiation of cultivated land use will have an impact on the resilience of resource elements, production resilience, ecological resilience, and the scale and structure toughness of cultivated land use systems and then drive changes in the resilience of cultivated land use systems (Figure 1).

3 Research methods and data sources

3.1 Description of study area

To examine the current state of regional agricultural development, this study focused on 12 villages in Xiqiao Town, Shimenshan Town, and Wucun Town, all within Qufu City, Shandong Province, China. Qufu spans 815 square kilometres, has jurisdiction over eight towns and four villages. In 2020, agricultural land constituted over 70% of the city's total land area, marking it as one of China's highly urbanized regions with intensive agricultural land use. The selected rural areas have cultivated land accounting for 81% of their total land area, and half of their population engages in agricultural work.[1] The degree of rural agricultural mechanization is steadily increasing, and agricultural entities such as family farms, agricultural cooperatives, and leading agricultural enterprises are thriving, leading to a progressively diversified agricultural economy. However, rural cultivated land use systems face numerous challenges and disruptions owing to climate disasters such as droughts and floods, as well as external effects such as an unstable agricultural market and rapid urbanization. These factors affect farmers' perceptions of and the functionality of cultivated land during its use.

The three towns selected in this study represent different stages of rural development. Shimenshan Town, the most remote city center, is a traditional village with a focus on forestry and animal husbandry. Adjacent to Shimenshan is Wucun Town, a village undergoing agricultural modernization. It is characterized by a southern plain and a significant number of large grain producers, family farms, and agricultural cooperatives. Finally, Xizhou Town, located near the city center and primarily composed of plains, has a high *per capita* disposable income but lags in agricultural development. This is a typical characteristic of villages heavily influenced by urbanization. In summary, these three towns collectively represent a spectrum of rural development types (Figure 2).

1 http://www.qufu.gov.cn/

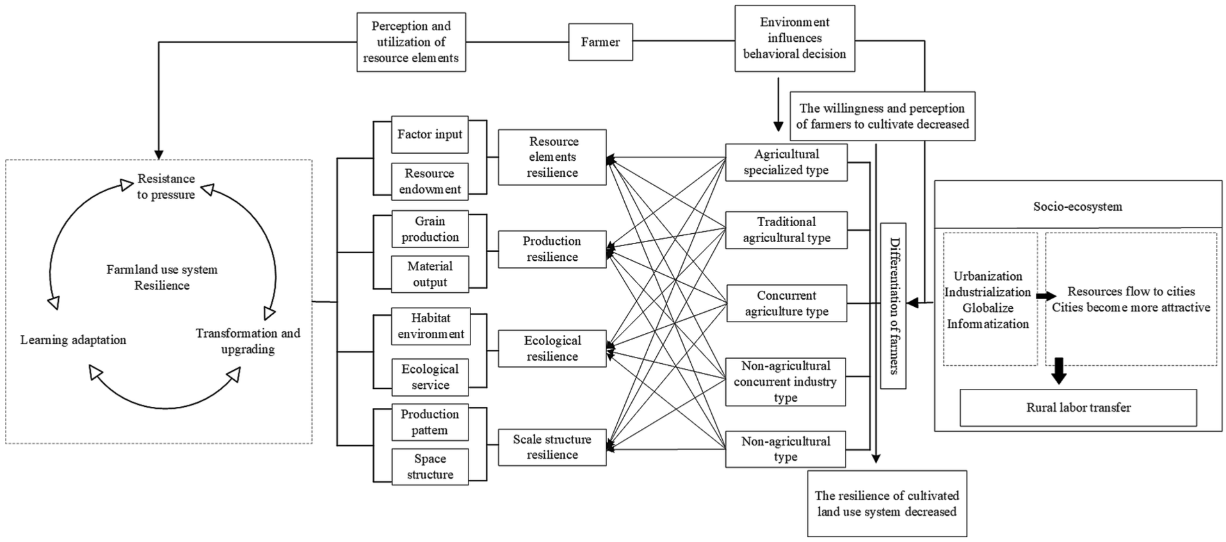

FIGURE 1
Theoretical framework.

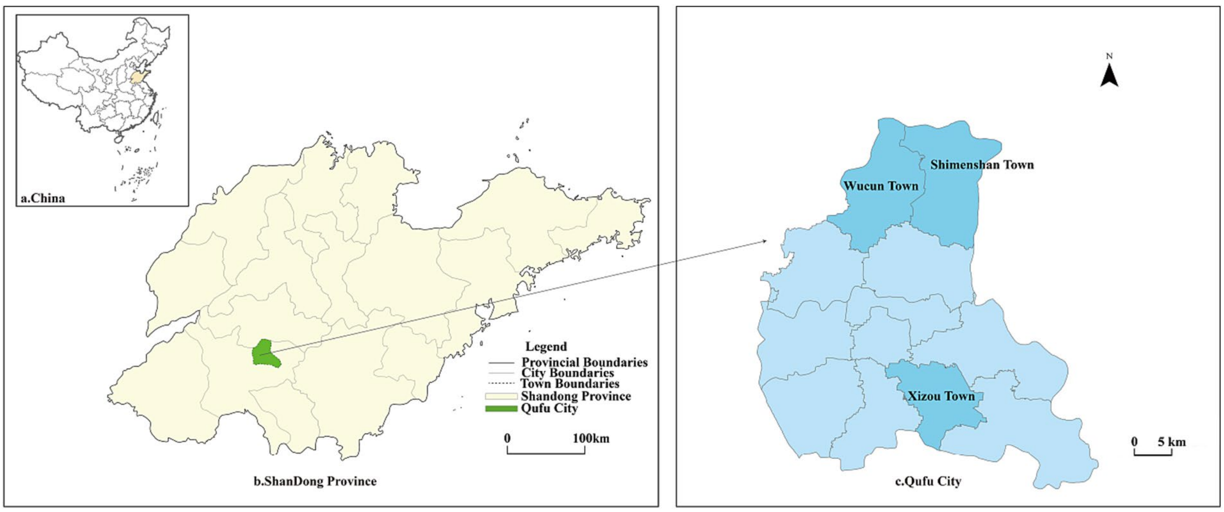

FIGURE 2
Study area map.

3.2 Research design

Data for this study were gathered from a survey conducted among farmers in Qufu City in 2020. First, the purpose of the study was clarified and a survey questionnaire was designed in accordance with the natural and social conditions of Shandong Province. This included questionnaires for both farmers and villages and three rounds of discussions were held. Subsequently, a few villages in Qufu City were chosen for a preliminary investigation, and the questionnaire was revised based on the findings of this pre-investigation. Finally, the towns of Shimenshan, Wucun, and Xizou were selected, each with distinct characteristics. In each town, four natural villages were chosen randomly, and approximately 30 farmers from each village were randomly selected for household surveys and face-to-face interviews. Each household questionnaire took between one and a half hours to complete and each village questionnaire took between half an hour and one hour.

3.3 Study population, sampling procedure, and sample size

The research population for this study primarily comprised a permanent rural population and village officials selected predominantly through random interviews conducted in rural areas. The farmers' questionnaire captured a wide range of information, including details about the farmers' family size, behavior related to cultivated land use, production, and management, and perceived behavior. The data used in this study included farmers' human, social, and material capital statuses and their perceptions of the ecological environment and policies, all of which were used to measure farmers' decision-making behavior. Additionally, it included the fundamental characteristics of the cultivated land use system, farmers' inputs and outputs related to cultivated land use, and changes over the past 5 years to assess the resilience of the cultivated land use system. The village questionnaire primarily investigated the overall natural and economic conditions of the rural areas, providing an understanding of the resilience of the cultivated land use system. Respondents were village officials. Shimenshan Town, Wucun Town, and Xiqiao Town in Qufu City were selected for the survey through random sampling. Subsequently, four natural villages were randomly selected in each town, and approximately 30 households were randomly chosen in each village for household surveys and in-person interviews. A total of 380 questionnaires were distributed to farmers and 12 to villages. After excluding invalid questionnaires, 324 valid farmers and 12 valid village questionnaires were obtained.

4 Method of data analysis

4.1 Construction of index system

This study aimed to assess the resilience of cultivated land use systems at the farmer level. The evaluation begins with an examination of farmers' perceptions, behaviors, understanding, and willingness to use cultivated land. Relevant indicators were selected to establish an evaluation system centered on the resilience of resource elements, production resilience, ecological resilience, and the scale structure of the cultivated land use system. The resilience of resource elements within the cultivated land use system primarily stems from farmers' contributions to labor, technology, machinery, capital, and other elements of the system. The average labor input, average economic input, degree of agricultural technology training, and irrigation methods chosen by farmers were used as indicators for the measurement. The resilience of the cultivated land use system is reflected in its ability to ensure food security and satisfy farmers' economic output requirements. Therefore, it is measured by economic income per land unit, grain output per land unit, and *per capita* planting income. The ecological resilience of a cultivated land use system signifies the robustness of the system's ecological service functions and habitat quality (Drever et al., 2006).

The overuse of chemicals and environmental degradation can result in decreased ecological resilience. As such, the extent of farmers' fertilizer use, their readiness to reduce this use, and their methods of agricultural waste management are employed as indicators of ecological resilience (Bertoni et al., 2018; Feofilovs and Romagnoli, 2021). The resilience of the scale structure of a cultivated land use system embodies the characteristics and spatial structure of an area. A superior scale structure indicates more stable property rights over cultivated land, enhanced functions of the land use system, and increased resilience of the scale structure. Consequently, this is assessed by the fragmentation level of cultivated land, farmers' willingness to operate on a larger scale, and the stability of their property rights over cultivated land (He et al., 2011; see Table 1).

Differentiation among farmers can, to some extent, mirror their perceptions and behaviors within the cultivated land use system. Consequently, farmers were categorized into five types based on their economic income: the scale of cultivated land management (with scale management defined as more than 30 mu), labor input, and land dependence: agricultural professional, traditional agricultural, agricultural concurrent, non-agricultural concurrent, and non-agricultural (see Table 2).

4.2 Model specification

Drawing on the resilience theory, we developed a cognitive framework for the resilience of cultivated land use systems. This framework begins with the multidimensional aspects of cultivated land, including resource elements, production, and ecological and scale structure resilience. Using an index model, we constructed a resilience evaluation equation to assess the resilience of a cultivated land use system. On this basis, a linear regression model was used to calculate the regression coefficient of peasant household differentiation on the toughness of cultivated land use systems, and the relationship between the two was clarified.

4.3 Normalization of index data

To eliminate the dimensional influence among the indices, we used the deviation standardization method to normalize the indices as follows:

$$\text{Positive index}: \text{Ui} = (\text{Xi} - \min \text{Xi}) / (\max \text{Xi} - \min \text{Xi}), \quad (1)$$

$$\text{Reverse index}: \text{Ui} = (\max \text{Xi} - \text{Xi}) / (\max \text{Xi} - \min \text{Xi}), \quad (2)$$

Equations 1 and 2, where Ui is the standardized index variable value, Xi is the original value of the index variable, and minXi and maxXi are the minimum and maximum values of the original value Xi of the index variable, respectively.

4.4 Entropy weighting method

The index system is weighted, and given by the following equation:

$$W_j = \frac{(1 - e_j)}{\sum_{j=1}^{n} (1 - e_j)}, \quad (3)$$

Equation 3 where e_j is the index information entropy and W_j entropy is the index entropy weight of item j in the evaluation index system of cultivated land resilience.

4.5 Resilience evaluation equation

System resilience is the weighted sum of various resiliences within the system, and is given by

TABLE 1 Resilience index system of cultivated land use system at the scale of farmers.

Resilience type	Indicators	Indicator meaning	Direction	Unit	Weight
Resource elements resilience	Average labour input	Agricultural labour force/cultivated land area	+	People/hm^2	0.245
	Economic input per land	Economic input of planting industry/cultivated land area	+	Yuan/hm^2	0.252
	Agricultural technical training level	Have farmers received technical training (No = 1; Yes = 2)	+		0.252
	Irrigation mode	Indicates the construction degree of farmland water conservancy facilities (rainwater = 1; Flood irrigation = 2; Furrow irrigation = 3; Border irrigation = 4; Sprinkler irrigation = 5)	+		0.251
Production resilience	Average planting income	Planting income/cultivated land area	+	Yuan/hm^2	0.344
	Average grain yield	Grain output/cultivated land area	+	kg/hm^2	0.345
	Per capita planting income	Economic income of planting industry/agricultural working population	+	Yuan/person	0.311
Ecological resilience	Excessive application of chemical fertilizer	Fertilizer application rate/cultivated land area-225 kg/hm^2	–	kg/hm^2	0.333
	Willingness to reduce chemical fertilizer application	Willingness of farmers to reduce fertilizer consumption (No = 1; Yes = 2)	+		0.334
	Treatment methods of agricultural garbage	Garbage disposal methods such as pesticide bottles and agricultural films (Throw away the edge of the field at hand = 1; Take home and concentrate on the way out = 2; Recycling in garbage recycling station = 3)	+		0.333
Scale structure resilience	Degree of farmland fragmentation	Number of cultivated land plots/cultivated land area	–		0.330
	Farmers' willingness to operate on a large scale	Farmers' willingness to operate on a large scale (No = 1; Yes = 2)	+		0.335
	Stability of farmers' cultivated land property rights	Whether farmers' cultivated land is confirmed and certified (No = 1; Yes = 2)	+		0.335

$$R_j = \sum_{i=1}^{m} W_j \times U_{ij} \quad R = \sum_{j=1}^{n} R_j, \tag{4}$$

Equation 4, where R_j is the resilience of the resource elements, production, ecology, and scale structure of the cultivated land system, which are components of the resilience of the system. The variable m denotes the number of indicators and n signifies the component fraction of cultivated land resilience, which, in this case, was four. Finally, R denotes the total resilience of the system and is expressed as the sum of the normalized index variables.

4.6 Linear regression model

Resource element, production, ecological, scale structure, and total resilience of the cultivated land use system were used as dependent variables, and the economic differentiation of farmers and the differentiation degree of cultivated land use were used as independent variables to verify the impact of farmer differentiation on the resilience of the cultivated land use system:

$$y = ax_1 + bx_2 + c \tag{5}$$

Equation 5 where y is the dependent variable, x is the independent variable, a and b are regression coefficients representing the relationship between the independent and dependent variables, and c is a constant.

5 Results

5.1 Resilience measurement of cultivated land use system at the farmers' scale

The resilience of the farmers' cultivated land use system overall is relatively stable, but the resilience of production is generally low. There is significant differentiation in the resilience of resource elements and notable stratification in the resilience of ecological and scale structures. By applying the resilience evaluation equation to the cultivated land use system, the resilience of the resource elements, production, ecology, and scale structure were weighted and summed. This process resulted in 324 samples of resilient farmers' cultivated land use systems (see Figure 3). Figure 3A shows that the resilience value of the cultivated land use system at the farmers' scale was primarily concentrated between 1.20 and 2.00, demonstrating a strong characteristic of agglomeration. The sample of farmers exhibits a range of high and low values, with the highest being 2.59 and the lowest being 0.71, indicating a significant difference. This suggests that the resilience of the cultivated land-use system at the farmer level is relatively stable, although some farmers exhibit low resilience. Examining the resilience of resource elements, production, ecological

TABLE 2 Differentiation types of farmers.

Types of farmers' differentiation	Proportion of agricultural income	Farmland management scale	Labour input	Land dependence
Agricultural specialty type	Over 80%	Scale operation	Agriculture	Strong
Traditional agricultural type	Over 80%	Small-scale peasant management	Agriculture	Strong
Concurrent agriculture type	50–80%	Small farmers and scale management	Agriculture	Stronger
Non-agricultural concurrent industry type	10–50%	Small farmers and scale management	Non-agricultural	General
Non-agricultural type	Below 10%	Small farmers and scale management	Non-agricultural	Weak

aspects, and scale structure of the farmers' cultivated land use system (Figures 3B–E, respectively), it is evident that the production resilience value of the system is the lowest, primarily ranging between 0.10 and 0.20, with only a few farmers achieving higher values. The resilience value of the system's resource elements was mostly below 0.30, with a few exceeding 0.3, and the values for the sample farmers' resource elements were dispersed. Furthermore, the ecological and scale structure resilience values of the system displayed clear stratification. The ecological resilience value is mainly concentrated between 0.3 and 0.9, with dense stratification, while the scale structure resilience exhibits a distinct three-tier stratification, approximately at 0.20, 0.60, and 1.00, with most farmers around 0.60. This analysis revealed that the resilience of the cultivated land use system varies among farmers, but all share the issue of low production resilience. Combined with other international research results, the perceived behavior of farmers does not significantly improve the resource factors, production, ecology, and scale structure toughness of the cultivated land use system but will affect the differentiation characteristics of the various types of toughness of the cultivated land use system.

5.2 Proportion of cultivated land use system resilience at the farmers' scale

Examination of the resilience of farmers' land use systems showed that resource element and production resilience are relatively low, whereas ecological and scale structure resilience are comparatively high (Figure 4). Specifically, the resource element resilience in these systems constituted less than 25% of the total resilience, with a noticeable disparity between the high-value and low-value samples. This significant polarization suggests that farmers' investment in resource elements of land use systems is low and that investment behaviors vary among different farmers. The proportion of production resilience to total resilience is also low, typically below 15%, indicating a weak production function within the land-use system, which fails to ensure food security and farmers' economic income effectively. Conversely, ecological and scale structure resilience accounted for a substantial portion of the total resilience, mostly ranging between 20 and 60%. This suggests that farmers' awareness, behavior, and willingness to manage the scale of ecological protection, concentration and contiguity of cultivated land, and stability of property rights are the primary contributors to the resilience of their land use systems. Considering the background of international food security, it is necessary to learn from the practices of countries with high food output to improve the productivity of the cultivated land use system by ensuring the scale and structure of the cultivated land use system and promoting the input of resource elements such as technology and machinery to ensure the production demand of the cultivated land use system.

Based on the proportion of each cultivated land use system's resilience to the total resilience, we categorized the resilience of farmers' cultivated land use systems into seven types: resource factor scarcity, production scarcity, ecological scarcity, ecological protection, high-scale structure resilience, unbalanced, and balanced. Among these resilience types, the unbalanced and production shortage types were more prevalent, whereas the balanced and ecological protection types were less common (Table 3).

Specifically, the category with the highest proportion was production shortages, which accounted for 45.68% of the total. The defining characteristic of farmers within this category is extremely low resilience in their cultivated land use system, whereas other types of resilience are either high or moderate. This suggests that these farmers have a higher level of input factors, stronger ecological protection awareness, greater willingness to manage on a larger scale, a more robust integrity of cultivated land, and stronger stability of property rights during land use. However, the cultivated land use system has not achieved effective input–output transformation, and the efficiency of resource factor use is low. This may be due to farmers balancing the production and ecological functions of the cultivated land use system.

In addition to production deficiencies, imbalanced resilience constituted a significant proportion (38.27%). This is characterized by low resilience in resource element production and high resilience in scale structure ecology, indicating that these farmers invest less in resource elements and exhibit low intensity in the use of cultivated land systems. However, their ecological protection, scale management behaviors, and cognitions are relatively strong, which could further decrease the resilience of resource elements and production in cultivated land use systems. Moreover, several categories such as resource element deficiency, ecological deficiency, ecological protection, high-scale structural resilience, and imbalance account for a smaller proportion. Nevertheless, they highlight the variations in farmers' behaviors regarding cultivated land use and the imbalance among the various functions of the cultivated land use system.

5.3 Farmers' differentiation and cultivated land use system resilience

5.3.1 Resilience structure of cultivated land use system under the background of farmer differentiation

Farmers in the research area exhibited a significant shift toward non-agricultural employment, reducing their reliance on land. Traditional, professional, and concurrent agriculture account for only 12.65% of

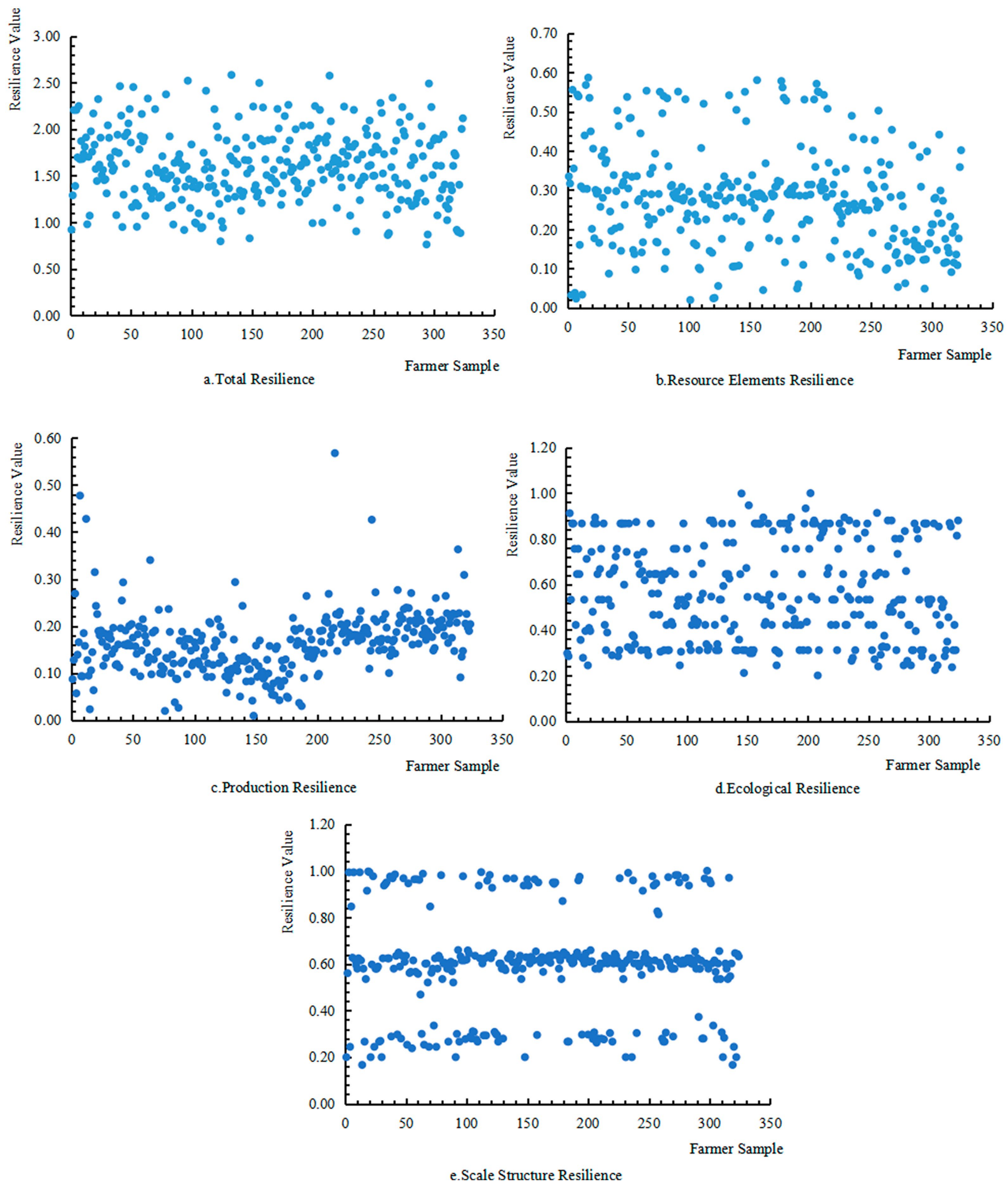

FIGURE 3
Evaluation results of cultivated land use system resilience at the scale of farmers. **(A-E)** represents the total resilience, resource elements resilience, production resilience, ecological resilience and scale structure resilience of cultivated land use system, respectively.

farmers whose primary source of income is agriculture. A substantial majority (87.35%) were non-agricultural farmers who relied primarily on non-agricultural activities for their livelihoods. These findings indicate a severe loss of agricultural labor in the area, with agricultural production income constituting a minor portion of farmers' total income. Although most farmers possess the right to use their homesteads and manage contracted farmland, they often opt to transfer or use cultivated land extensively. By calculating the average resilience of the cultivated land use systems among different types of farmers, significant disparities were apparent. Professional and concurrent agricultural farmers exhibited higher average resilience (1.78 and 1.68, respectively), while non-agricultural farmers had the lowest average resilience (1.56). The data suggest that professional farmers who rely primarily on agriculture for their livelihood employ scientific agricultural technology and machinery,

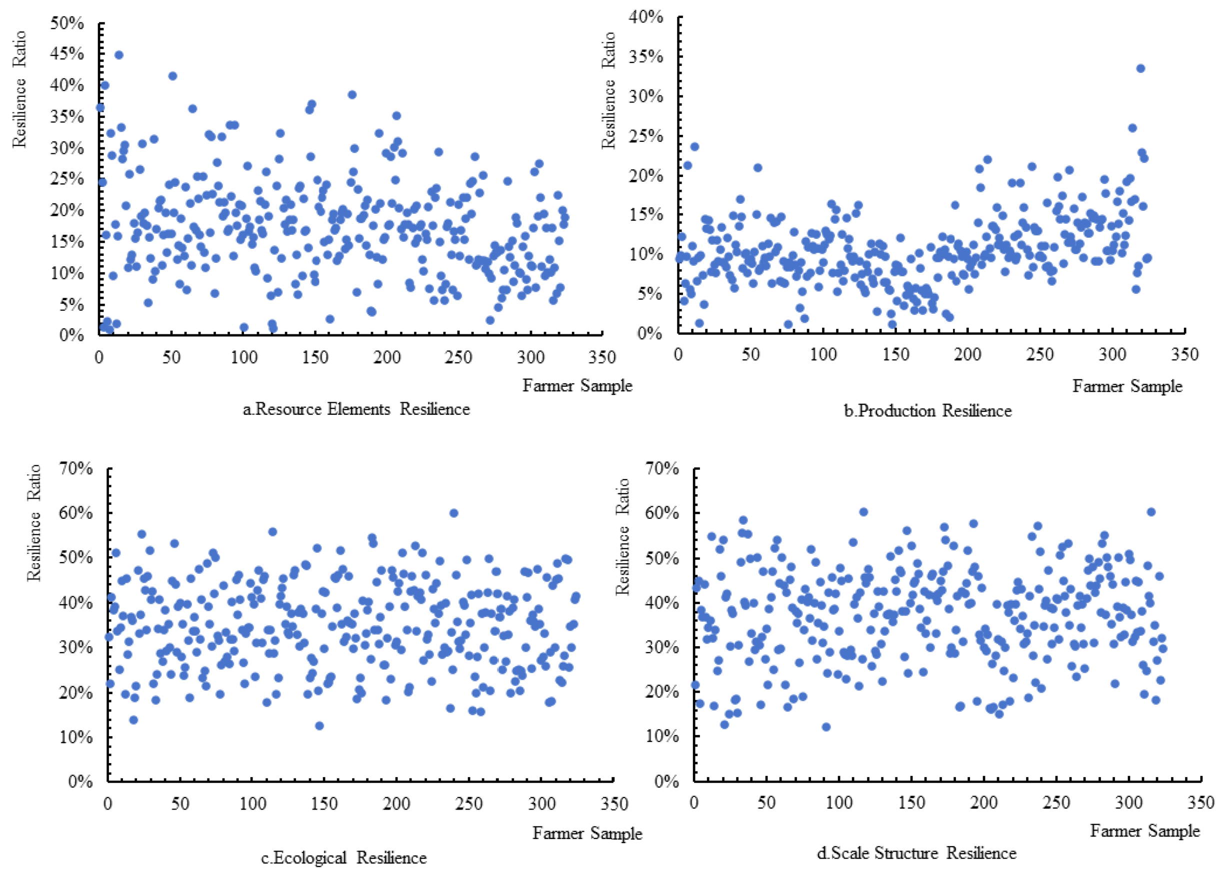

FIGURE 4
Proportion of various cultivated land use system resilience at the scale of farmers. **(A-D)** represents the resource elements resilience, production resilience, ecological resilience and scale structure resilience of cultivated land use system, respectively.

TABLE 3 Resilience classification of farmers' cultivated land use system.

Resilience types of cultivated land use system	Number of samples (pieces)	Percentage
Lack of resource elements	23	7.10
Production shortage type	148	45.68
Ecological deficiency type	11	3.40
Ecological protection type	2	0.62
High resilience type of scale structure	10	3.09
Unbalanced type	124	38.27
Balanced type	6	1.85

invest more in capital, labor, and land, and consequently reap better benefits. Cultivated land-use systems are intensive. Concurrent agricultural farmers, on the other hand, invest capital and technology acquired through non-agricultural labour into the cultivated land use system, thereby enhancing its resilience to some extent. In contrast, non-agricultural farmers who invest most of their production factors in non-agricultural activities demonstrate low efficiency and resilience in their cultivated land use systems (Table 4).

The resilience of farmers' cultivated land use systems can be classified into two main types: unbalanced and production-deficient. Traditional and professional agricultural farmers predominantly exhibit an unbalanced type, suggesting deficiencies in their production, ecology, scale structure, and resilience of resource elements within their cultivated land use systems. Conversely, farmers involved in concurrent agricultural and non-agricultural industries, as well as non-agricultural farmers, tend to display a high proportion of resilience and production deficiencies in their cultivated land use systems. This indicates that these farmers' resource elements are not being used efficiently and that the production function of their cultivated land systems is weak (Figure 5). Considering the proportion of differentiated farmers with various types of cultivated land use system resilience, traditional agricultural farmers have lower production resilience than other types, leading to an imbalance in their cultivated land use system resilience. For professional agricultural farmers, the imbalance in their cultivated land use system resilience was primarily the result of their higher-scale structural resilience. However, the resilience of the scale structure of the cultivated land-use system was the main factor limiting the resilience of the cultivated land use systems of traditional agricultural, agricultural, non-agricultural, and non-agricultural farmers (Figure 6). Therefore, the resilience of farmers' cultivated land use systems can be enhanced by improving the input and use efficiency of resource elements, increasing the resilience of resource elements and production, stabilizing farmers' cultivated land use property rights, and promoting scale operations.

5.3.2 Influence mechanism of farmer differentiation on cultivated land use system resilience

To investigate the effect of farmer differentiation on the use of cultivated land, the proportion of agricultural income was used to denote the extent of economic differentiation among farmers. A higher proportion of agricultural income indicated a lower level of economic differentiation. The scale of cultivated land use by farmers was used to represent the degree of differentiation in land use, with a cultivated land management area over 30 mu assigned a value of zero and all other values assigned a value of one. A larger scale of cultivated land management suggests that farmers rely primarily on agriculture for their livelihood, indicating a lower degree of differentiation. These two indicators serve as independent variables representing farmer differentiation, whereas the resource element resilience, production resilience, ecological resilience, scale structure resilience, and total resilience of the cultivated land use system are dependent variables. A linear regression model was used to assess the effects of farmer differentiation on the resilience of cultivated land use systems.

The findings indicate that economic differentiation among farmers negatively affects the resilience of resource elements, ecological resilience, and the overall resilience of the cultivated land use system. In other words, the lower the proportion of a farmer's income derived from agriculture, the less resilient the cultivated land use system becomes. This can be attributed to the rapid urbanization and industrialization that has spurred the growth of non-agricultural industries in rural areas, leading to rural labor outflows. Consequently, farmers are more inclined toward non-agricultural development, resulting in less investment in the resource elements of the cultivated land use system. Coupled with the indiscriminate use of chemical fertilizers and pesticides to boost productivity and the lack of clean, environmentally friendly technologies, this leads to low ecological and overall resilience of the cultivated land use system. Furthermore, differentiation in farmers' cultivated land use has a significant negative effect on the production, scale structure, and overall resilience of the cultivated land use system. That is, the smaller the scale of a farmer's cultivated land use, the greater the differentiation and the less resilient the cultivated land use system becomes. Farmers who cultivate a certain amount of land tend to rely on agriculture as their primary livelihood, resulting in a strong degree of sustainable and intensive land use. However, when the scale of cultivated land use is small, farmers are more likely to seek non-agricultural livelihoods, and their willingness to intensively manage cultivated land diminishes. This leads to the serious issue of abandoned, idle, and offset use of cultivated land, which in turn reduces the production resilience, scale structure resilience, and overall resilience of the cultivated land use system (see Table 5). In summary, the economic differentiation of farmers and the differentiation of cultivated land use impact the resilience of resource elements, production resilience, ecological resilience, and the scale and structure resilience of cultivated land use systems. The hypothesis is not completely valid that the economic differentiation of farmers has a negative impact on the resilience of resource elements and ecological resilience, and the total resilience of cultivated land use systems. However, the differentiation in farmers' cultivated land use has a significant negative effect on the production toughness, scale structure toughness, and total toughness of cultivated land use systems.

6 Adaptive management of cultivated land use systems at the farmer scale

6.1 Measures to improve the cultivated land use system production resilience of various types of farmers

Production resilience is a critical factor that limits the enhancement of overall resilience in cultivated land use systems. Therefore, it is crucial to implement various strategies to improve the resilience of these systems. First, efforts should be made to enhance the level of mechanization, technical sophistication, and modernization of land use by farmers. This can be achieved by accelerating the rate of innovation and popularization of agricultural science and technology. Regardless of whether the farmers are traditional, professional, concurrently agricultural, concurrently non-agricultural, or non-agricultural, it is essential to address deficiencies in agricultural mechanization and achieve unified social services in this area. Second, comprehensive improvement of cultivated land should be promoted. This involves integrating the abandonment of cultivated land with the advancement of agricultural mechanization, effectively consolidating resources, reducing farming costs, and encouraging the development of high-standard farmland and infrastructure. This includes transforming fragmented and inefficient farmlands into a more productive system through slope-to-ladder, scale, ditch-to-ditch, road-to-road, dry-energy irrigation, and waterlogged energy drainage. Finally, the marketization, branding, and industrialization of agricultural products should be strengthened. This can be achieved by extending the agricultural industrial chain, selling agricultural products directly to the market, establishing unique agricultural brands, expanding agricultural sales channels, and integrating the production, processing, transportation, and sales of agricultural

TABLE 4 Differentiation degree of farmers and resilience structure of cultivated land use system.

	Traditional agricultural type (TA)	Specialized agricultural type (SA)	Concurrent agricultural type (CA)	Non-agricultural concurrent industry type (NACI)	Non-agricultural type (NA)
Mean value of resilience	1.61	1.78	1.68	1.61	1.56
Number of households	5	12	24	158	125
Proportion (%)	1.54	3.70	7.41	48.77	38.58

TA, SA, CA, NACI, and NA are the short forms of traditional agricultural type, specialized agricultural type, concurrent agriculture type, concurrent agriculture type, non-agricultural concurrent industry type, and non-agricultural concurrent industry type, respectively.

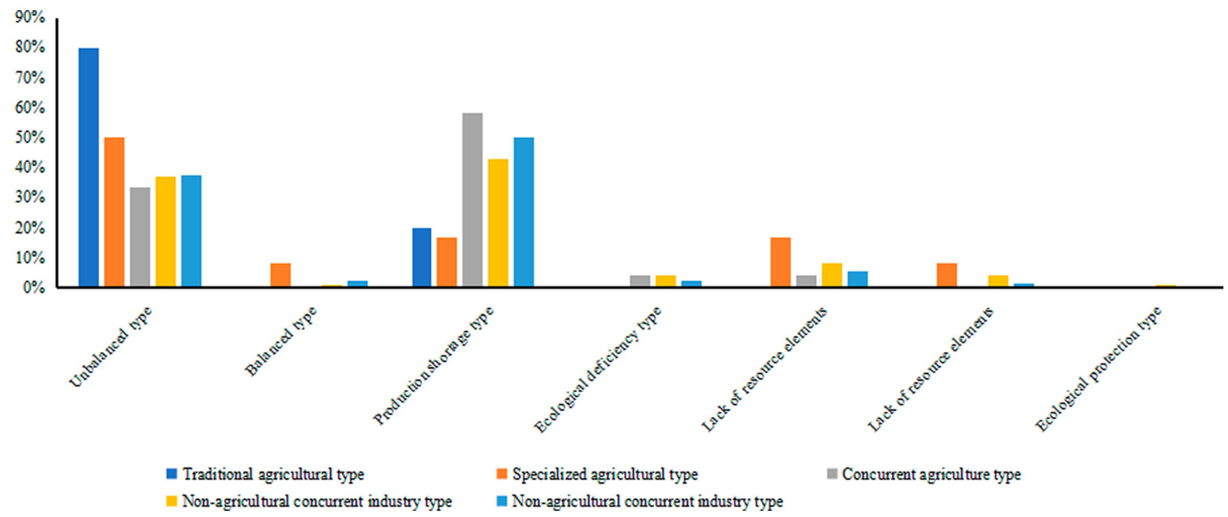

FIGURE 5
Resource resilience types of the cultivated land use system of differentiated farmers.

products into agricultural production. These measures can increase farmers' income and, in turn, enhance the production resilience of the cultivated land use system (Quendler and Morkūnas, 2020).

6.2 Enhance the enthusiasm of various types of farmers to invest in the resource elements of a cultivated land use system

The evaluation results of the resilience of the cultivated land use system at the farmer scale revealed that the primary reason for the system's low input was the farmer's minimal contribution to the system's resource elements. Therefore, to increase the resilience of cultivated land use systems, it is crucial to boost farmers' willingness to invest in the system's resources. First, the government should enhance its support for agriculture and rural areas, refine relevant laws and regulations, lessen the burden on farmers, and improve the corresponding social security systems and infrastructure. This will increase the appeal of agriculture and rural areas to farmers, encourage them to return to the countryside and invest in agriculture, and mitigate the negative effects of the dual urban–rural development structure on rural labor loss. Second, the training of agricultural science and technology talent should be strengthened, along with technical training for small farmers, agricultural cooperative members, and new professional farmers. This will enhance the role of talent and scientific and technological elements in increasing the resilience of the cultivated land use system and improve farmers' precise understanding and control of the demand for system elements. Finally, financing channels for farmers' agricultural production should be expanded, offering diverse preferential financing policies, relaxing financing conditions, and encouraging social capital to invest in agriculture and rural areas. This will alleviate financing difficulties in agriculture and rural areas and promote the inflow of funds into the cultivated land use system (Perrin et al., 2018; Kuang et al., 2020).

6.3 Promote the transformation of farmers' awareness and behavior of ecological protection and improve their willingness to transfer cultivated land

According to the research results, all types of farmers have a high awareness of ecological environmental protection, but due to the impact of farmer differentiation, farmers' ecological protection behaviors are less, and the phenomenon of cultivated land fragmentation is serious. Therefore, it is necessary to further improve the toughness of cultivated land use system, promote the transformation of farmers' awareness and behaviors of cultivated land protection, and enhance farmers' willingness to transfer cultivated land and improve the scale utilization efficiency of cultivated land. First, while farmers demonstrate a strong understanding of the ecological protection of the cultivated land use system, this has not yet translated into their behavior toward ecological protection, necessitating governmental intervention to mobilize the necessary resources, provide farmers with the requisite support for ecological agriculture, decrease the production cost of ecological agriculture, and incentivize farmers to protect the ecological environment of cultivated land through economic means. Second, advancement of ecological agriculture requires the development and implementation of new scientific and technological methods. These include the promotion of water-saving irrigation technology, development of circular agriculture, and use of biological pesticides and organic fertilizers. Coupled with increased publicity and mobilization, these measures can facilitate harmonious development of the ecological and production functions of cultivated land. Finally, it is important to stabilize the contracting and management rights of cultivated land, encourage the equitable distribution of cultivated land rights and interests, and reinforce the guidance and standardization provided by village collective organizations on cultivated land circulation. This can enhance farmers' willingness to transfer cultivated land; promote the diversification of cultivated land circulation subjects; achieve large-scale, intensive, and specialized management of cultivated land; and

FIGURE 6
Resilience structure of the cultivated land use system of various farmers. TA, SA, CA, NACI, and NA are respectively short form of traditional agricultural type, specialized agricultural type, concurrent agriculture type, concurrent agriculture type, non-agricultural concurrent industry type, non-agricultural concurrent industry type.

TABLE 5 Effect of farmer differentiation on cultivated land use system resilience.

	Resource elements resilience	Production resilience	Ecological resilience	Scale structure resilience	Total resilience
Economic differentiation	−0.117*	0.076	−0.104*	0.018	−0.022*
Cultivated land use differentiation	0.013	−0.193***	0.083	−0.137**	−0.165**

*, ** and *** indicate that the results are significant at the level of 10%, 5%, and 1%, respectively.

strengthen the resilience of the cultivated land use system (Urruty et al., 2016).

6.4 Improve the farmland property rights system and the farmland management system

As China's policy for protecting cultivated land has become increasingly extensive, there has been a certain level of protection or improvement in the quality, quantity, and ecological environment of cultivated land. However, the social issues prevalent in China's rural areas, such as uneven land rights, a wide income gap, difficulties in distributing collective rights and interests, subpar facility construction, and low land use efficiency, disrupt the internal operational order of the cultivated land system and diminish its state and ability to withstand interference pressure. Therefore, the Chinese government should give priority to the rural perspective and consider solving the internal problems of the cultivated land use system. First of all, it is necessary to further improve the system of three rights separation of agricultural land, improve the distribution mechanism of cultivated land income and transfer transaction mechanism, and promote the sharing of cultivated land property income and intensive use of scale. Secondly, ensure its internal stability by devising comprehensive policy actions that benefit farmers, bolster the sustainable intensification of cultivated land, and enhance the standards of rural infrastructure construction and public services. Finally, it is necessary to comprehensively evaluate the various factors affecting policy formulation and implementation in different rural areas, establish a governance organization of the cultivated land use system according to the actual situation in different regions, clarify the main body and object of governance, and adopt diversified and targeted governance means, so as to improve the governance capacity of the cultivated land use system and enhance the resilience of the cultivated land use system (Lyu et al., 2020).

This study integrated farmers' behavior, cognition, and willingness into the evaluation index system of cultivated land use system resilience. Evaluating the resilience of the cultivated land use system at the micro-scale emphasizes the importance of individual initiatives, thereby providing a more accurate reflection of the system's adaptive cycle. This study considers differentiation among farmers as a representation of their influence on the socioeconomic system and discusses its effect on the resilience of the cultivated land use system. Based on this understanding, the proposed countermeasures are practical and relevant to the real world. We conclude that the resilience of the cultivated land use system is primarily constrained by farmers' resource input and the productive capacity of cultivated land (Allison and Hobbs, 2004). From a long-term perspective, enhancing the resilience of the cultivated land use system requires a decrease in the trend of agricultural differentiation among farmers, an improvement in farmers' perception of agriculture and rural areas, an increase in resource input, and the transformation of behavioral consciousness regarding system resilience. This necessitates that farmers, under various incentives, balance the ecological functions of the cultivated land use system with their livelihood choices, thereby promoting the sustainable use of the system. The methods for achieving these goals are left for future research.

7 Conclusion

This study focused on typical villages in Qufu, Shandong, China, where a questionnaire survey was conducted with a random selection of 324 households. The resilience of the cultivated land use system as determined by farmers was evaluated from the following four perspectives: resource elements, production, ecology, and scale structure. This study also investigated how peasant household differentiation affects the resilience of farmland use systems. Based on these findings, adaptive governance strategies for cultivated land use systems have been proposed. The primary conclusions drawn from this study are as follows.

First, the proactive engagement of primary land users is crucial for determining whether an agricultural land-use system can undergo transformation and development. As the principal actors in this system, farmers' behaviors, understanding, and willingness influence the system's resilience. This influence is primarily evident in how farmers' behavioral choices and cognitive willingness affect the resource elements, production, ecology, and scale structure of the agricultural land-use system, particularly under the pressures of dual urban–rural development, globalization, and urbanization.

Second, the overall resilience of the farming system related to cultivated land use remained relatively stable, but the resilience of production was generally low. The resilience of resource elements varied greatly, and there was a noticeable stratification in the resilience of ecological and scale structures. When examining the various types of resilience within the farmers' cultivated land use system, the resilience of resource elements and production was relatively low, whereas ecological resilience and scale structure resilience were comparatively high. Among all the resilience types within the cultivated land use system, the unbalanced and production-deficient types were more prevalent, whereas the balanced and ecological protection types were less common. This suggests a disparity between farmers' cultivated land use behaviors and an imbalance between the various functions of the cultivated land use system.

Third, farmers in the study area exhibit a high degree of diversification into non-agricultural employment, which reduces their reliance on land. The resilience of the cultivated land use system varied significantly among farmers with different types of diversification. The primary types of resilience in the cultivated land use system among farmers are the unbalanced and production shortage types. The assumptions set forth in this study are not entirely valid; economic diversification among farmers negatively affects the resilience of resource elements, ecological resilience, and overall resilience of the cultivated land use system. In other words, the lower the proportion of farmers' income derived from agriculture, the lower the resilience of the cultivated land use system. The differentiation of a farmer's cultivated land use also has a clear negative effect on the production resilience, scale structure resilience, and overall resilience of the cultivated land use system. This implies that the smaller the scale of a farmer's cultivated land use and the greater the differentiation, the lower the resilience of the cultivated land use system.

Fourth, the evaluation results of the resilience of the cultivated land use system, viewed from the perspective of farmers' behavioral perceptions and the effect mechanism of farmers' households on this resilience, suggest that multiple strategies are needed. These include enhancing the production resilience of the cultivated land use system, increasing the eagerness of various farmers to invest in the resource elements of this system, encouraging a shift in farmers' understanding and behavior toward ecological protection, and improving their willingness to circulate cultivated land. These governance measures can strengthen the resilience of cultivated land use systems and boost their adaptability.

The world continues to face challenges on how to address the key issues that contribute to the food crisis, which has been exacerbated by conflict and climate change (Liang and Li, 2020). In both developed and developing countries, enhancing the ability of the cultivated land use system to resist external pressure and interference, and improving the resilience of the transformation and upgrading of the cultivated land use system are the basic and key tasks for maintaining social stability and ensuring people's livelihoods at this stage (Niu et al., 2021). However, in the face of the ever-changing international situation and agricultural development status, the perception and behavioral decision of farmers have become the key factors to improve the resilience of cultivated land use system. Therefore, in-depth understanding of the diversified decisions of different farmers in different environments and exploring their differentiated impact on the resilience of cultivated land use systems are conducive to countries around the world to go deep into local realities and accurately find differentiated strategies for improving the resilience of cultivated land use systems. The limitation of this study is that the perspective is only focused on China. How to explore the relationship between farmers' perception, behavior, differentiation and the resilience of cultivated land use system from a global perspective is the direction of future research expansion. At the same time, this study integrates farmers' perception into the cultivated land use system to explore the impact of farmers' differentiated behaviors on the resilience of the cultivated land use system. However, the interaction mechanism between people and land determines that not only farmers' behavioral perception will have an impact on the cultivated land use system, but also the cultivated land use system will in turn affect farmers' behavioral decisions. In this interactive mechanism, how to improve the resilience of cultivated land use system and promote sustainable development is the focus of future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

XW: Writing – original draft, Writing – review & editing. YNW: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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