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Farmers' farmland quality protection behavior: influencing factors and policy implications in eastern coastal China

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Introduction: Farmers' farmland quality protection behavior (FQPB) is influenced by many factors, which, by shaping decision-making processes of farmers impact the maintenance and enhancement of farmland quality.
Methods: In this study, the factors influencing FQPB in Yancheng Prefecture, in a typical area of Jiangsu Province, were explored using survey data of 190 farmers. The mechanisms underlying the influence of farmland utilization dynamics, agricultural production costs, agricultural machinery resource dynamics, family land resources, and agricultural cultivation patterns on FQPB were empirically tested using structural equation modeling.
Results: We found a significant inhibitory effect of farmland use dynamics on FQPB. The greatest effects were those related to farmland transfer and the proportion of transferred farmland. Agricultural machinery resource dynamics, and specifically, the use and the degree of ownership of agricultural machinery and equipment, were also identified as having a significant effect on FQPB. The significant contribution of the agricultural cropping pattern on FQPB included total cropping type, non-food crop cropping, and non-food crop type.
Discussion: Findings from this study reaffirm that policies promoting moderate farmland transfer and encouraging food crop cultivation may enhance farmers' motivation to engage in farmland quality protection. Enhancing agricultural extension services may also strengthen farmers' willingness to participate in farmland quality protection.

KEYWORDS

farmer behavior, farmland conservation, questionnaire survey, structural equation modeling, sustainable agriculture

1 Introduction

Governments around the world have long placed a high priority on protecting farmland. Farmland protection has become increasingly urgent due to mounting pressures from climate change, unsustainable land use, and rapid urbanization (Xu et al., 2021). Climate change has become a significant global environmental threat to food and nutrition security systems, with soil erosion, floods, and droughts causing land degradation and fragmentation, thus reducing crop yields. Despite the importance of improving soil health to ensure a transition to more sustainable agricultural systems (Scarlato et al., 2024), the agricultural sector continues to rely heavily on unsustainable practices (Hashakimana et al., 2023; Zuma et al., 2023). For example, in densely populated areas such as South Asia and Bangladesh, soil fertility has gradually declined due to increased cropping intensity, prompting mounting concern over the sustainability of crop production systems (Alam et al., 2024). The widespread abandonment of arable land, particularly in aging or out-migrating rural areas, has led to reduced land use efficiency and accelerated biodiversity loss. Although such abandonment may provide a degree of ecological resilience under the uncertainty of climate change (Gaede Wolpert et al., 2024), it also contributes to the underutilization of farmland and degradation of rural landscapes. With encroachment via urbanization and industrialization, the amount of arable land has been shrinking (Alam et al., 2024), increasing the mismatch between the demand for food and agricultural resources (Zhang et al., 2023). The United Nations Department of Economic and Social Affairs (UNDESA) predicted a world population of 9.7 billion people by 2050 (Monteiro et al., 2024), such that increasing global food production and preserving farmland have become prioritized in efforts to ensure national food security and sustainable development. However, in many rural areas, rampant illegal occupation and unregulated land transactions have intensified the waste and misallocation of farmland resources, undermining both agricultural productivity and ecological protection. Informal land exchange and unauthorized land use often result in fragmented land ownership and irrational resource use, further aggravating the loss of arable land and environmental degradation (Zhou et al., 2021).

To address these issues, it is essential to strengthen land tenure systems through transparent, market-based transactions. Such mechanisms enhance land use efficiency, promote sustainable agricultural development, and lay a foundation for the coordinated growth of urban and rural economies. Therefore, it is important to explore policy measures aimed at curbing illegal occupation and improving the quality of agricultural land. The latter is related to the stability and sustainable development of food production and the overall prosperity of the rural economy and the achievement of ecological balance (Zhang and Xu, 2017).

Significant progress has been made in developing technical pathways to improve farmland quality. A variety of land management practices have been developed in the agricultural sector to enhance soil fertility and sustain farmland productivity. Techniques such as straw incorporation, reduced nitrogen fertilizer application, conservation tillage, and crop diversification have been demonstrated to provide significantly improved soil structure, higher organic matter content, and lower degradation risks (Zuo et al., 2023; Yang et al., 2024). Mixed cropping, intercropping, and crop rotation have also been broadly recommended for promoting soil health and ensuring long-term yields (Hashakimana et al., 2023; Nkongho et al., 2024). However, despite their agronomic benefits, the adoption of these protective practices at the farm level remains uneven. Whether farmers are able or willing to implement such measures often depends on internal factors such as individual perceptions and on broader external constraints related to institutional environments and resource availability (Kuang et al., 2020; Lu et al., 2021).

Ensuring the sustainable use and protection of farmland cannot rely solely on top-down institutional reforms or macro-level policies. It also requires an understanding of the micro-level behavioral mechanisms of farmers, who are the direct agents of land use and conservation practices. Increasing attention has been paid to how both internal attributes and external environmental factors shape farmers' decisions regarding farmland quality protection behavior (FQPB). Internal factors include farmers' human capital and psychological state, whereas external environmental factors include land systems, policy subsidies, and technology promotion.

At the level of internal factors, non-cognitive skills, such as social communication skills, self-efficacy, stress resistance, and altruistic tendencies, have a significant positive impact on FQPB (Wang et al., 2022b). These skills help farmers build social capital and improve information channels, thereby increasing their acceptance and implementation of conservation measures. Farmers with strong non-cognitive skills are more likely to adopt sustainable agricultural practices and effectively improve the quality of their farmland. Perceptions also play an important role. Farmers who perceive high returns and social benefits may consistently implement improvement behaviors, while perceived risks and stress may inhibit them (Wang et al., 2022a). In terms of psychological factors, self-efficacy and social support can effectively reduce stress and promote positive behaviors (Li and Xue, 2022). While these internal cognitive and psychological aspects are critical, they do not operate in isolation. A broader set of external environmental conditions, including institutional arrangements, input costs, resource endowments, cropping structures, and technological settings, play critical mediating roles in influencing farmers' adoption of conservation-oriented practices, including the use of organic fertilizers, soil tillage, and farmland improvement strategies. Technologies such as artificial intelligence affect conservation behavior by shaping social norms (Guo et al., 2023). When farmland protection is valued in a social environment, technology acceptance will be even higher. In terms of policy, previous studies have emphasized the need to develop non-cognitive skills and promote technology, alongside explicit support such as subsidies and technical services (Gaede Wolpert et al., 2024; Wang et al., 2023a,b). Zhang et al. (2022) concluded that policy subsidies and government propaganda are necessary for farmers to participate in farmland conservation. Extension services and financial support reduce the burden of conservation and increase the likelihood of farmland conservation adoption (Boz, 2016). Action-oriented policies can positively influence farmers' land demand (Vergamini et al., 2024). Land use policies and off-farm employment opportunities will significantly influence farmers' awareness of land conservation, which in turn influences land use behavior and farmland quality.

The protection of farmland quality is a complex issue shaped by factors related to farmers' internal psychology and capability, and external elements such as policies, land systems, and technology diffusion, as well as the effectiveness of specific agricultural management practices and macro-level policy interventions. Previous studies have highlighted the significant roles of non-cognitive skills, risk perception, and institutional support in influencing farmers' behavior, while agronomic strategies such as straw return, intercropping, reduced tillage, and crop rotation directly impact soil quality and productivity. Furthermore, increasing attention has been paid to evaluating farmland protection policies from both institutional and farmer perspectives, and indicators have been developed to assess implementation effectiveness and pressure distribution (Chen et al., 2017).

Although prior studies have significantly advanced our understanding of the effects of internal psychological factors and external environmental conditions on FQPB, they have concentrated mainly on major grain-producing regions and broader macro-level policy contexts. In contrast, the implications of the ongoing shift toward non-grain cultivation remain underexplored, particularly in economically developed coastal areas. The General Office of the State Council's Opinions on Preventing the "Non-Grainization" of Arable Land and Stabilizing Grain Production (Guobanfa [2020] No. 44), together with the 2025 No. 1 Central Document, explicitly call for preventing the "non-grainization" of arable land, thereby reinforcing the hard constraint that farmland should be prioritized for grain production. Against this policy backdrop, the rapid expansion of non-grain cultivation in coastal regions directly challenges farmland quality protection. The shift toward cash crops further intensifies the tension between farmers' market-oriented decisions and national food security objectives, creating behavioral logics that differ from those of grain farmers. Additionally, the transformation of high-quality farmland into land for cash crop production introduces new behavioral and institutional dynamics that have not been sufficiently addressed. Moreover, relatively little attention has been given to the influence of external environmental systems at the micro scale, and the roles of non-grain cultivation patterns and agricultural mechanization resources in shaping farmers' FQPB decision-making remain inadequately understood. In this study, we used survey data from 190 farm households in Binhai and Dongtai counties to investigate the decision-making mechanisms underlying FQPB in eastern coastal China. We constructed an overall model of farmland quality protection decision-making by farm households and examined the effects of farmland use dynamics (FUD), agricultural production costs (APC), the dynamics of agricultural machinery resources (DAMR), household land resources (HLR), and agricultural cultivation patterns (ACP) on the FQPB of farm households. Our findings provide empirical insights into the behavioral logic of farmland conservation in economically developed rural regions, contribute to the literature on farmland protection in coastal China, and offer evidence-based guidance for the formulation of targeted policy interventions and practical implementation strategies.

The objectives of this study were to identify which of 16 potential influencing factors significantly promote or inhibit FQPB, and to develop region-specific, sustainable farmland protection policies for coastal areas based on our findings.

2 Theoretical analysis and research hypotheses

2.1 Theoretical analysis

In the context of intensifying land-use pressures and ongoing agricultural transformation in coastal China, understanding the behavioral logic behind farmers' engagement in farmland quality protection has become increasingly urgent. While existing research has highlighted the roles of internal motivations, such as awareness or attitudes, the external production and institutional environment often sets the actual boundaries of farmers' behavior. Decisions about whether and how to invest in land conservation are frequently shaped by shifting land tenure arrangements, rising input costs, uneven access to mechanization, and ecological uncertainties associated with cropping choices. These conditions form a complex decision-making landscape in which farmers must weigh short-term productivity against long-term sustainability.

This study examined a set of interrelated external factors that significantly influence farmers' capacity and willingness to undertake farmland protection practices. We explore farmers' FQPB in terms of five key dimensions: farmland use dynamics, agricultural production costs, access to agricultural machinery resources, household land resources, and agricultural cultivation patterns. These five dimensions correspond to three core external mechanisms: institutional stability, resource accessibility, and cost-benefit alignment, which together constitute the theoretical foundation of this study.

The institutional stability mechanism is reflected in FUD. When land tenure is insecure or land transfers are frequent, farmers' expectations of sustainable land use decline, discouraging long-term conservation investments. By contrast, stable land use arrangements enhance farmers' confidence and sense of security, providing an institutional foundation for long-term conservation behavior. In coastal regions where land transfer markets are highly active but plot fragmentation remains severe, institutional stability is not only about tenure security but also about whether land consolidation can reduce transaction costs and enable economies of scale. Thus, institutional stability shapes not only farmers' confidence in land use, but also the structural feasibility of implementing conservation practices.

The resource accessibility mechanism is primarily shaped by APC and DAMR. High production costs limit farmers' ability to adopt labor- or input-intensive soil improvement measures. However, access to mechanization can ease labor constraints and reduce the effort required to implement conservation-oriented practices such as deep tillage or straw return. In developed coastal areas, labor shortages due to off-farm employment intensify the reliance on mechanization, making access to machinery services a decisive factor in whether conservation practices are adopted. Moreover, the interaction between production costs and mechanization availability is non-linear: while mechanization can offset labor shortages, high service fees may also reproduce cost pressures, thereby reshaping the accessibility of resource inputs. The interaction between production costs and technological access defines whether farmland protection is a viable option or an economic burden.

The cost-benefit alignment mechanism is represented by HLR and ACP. Farmers with larger or more consolidated landholdings are more likely to view their land as a long-term asset, making them more inclined to invest in sustainable management. Simultaneously, environmentally sound cultivation practices such as crop rotation, intercropping, and water-saving irrigation can enhance soil health while maintaining yield stability, thereby increasing the economic feasibility of conservation. However, in regions characterized by severe land fragmentation and non-grain crop expansion, household land resources may fail to generate scale economies, weakening their predictive power. Under such conditions, cultivation patterns—such as cash crop specialization or intensive vegetable production—often become more decisive than land size *per se* in determining cost-benefit expectations. This highlights the contextual dependence of the mechanism.

These three mechanisms (institutional stability, resource accessibility, and cost-benefit alignment) are deeply interwoven, collectively shaping how farmers adapt to environmental uncertainty. For example, institutional stability (through land consolidation) can reduce production costs and increase the efficiency of mechanization, thereby linking stability to resource accessibility. Similarly, household land resources condition whether mechanization access translates into reduced costs, or whether fragmented plots undermine these benefits. In this way, the three mechanisms interact dynamically, creating region-specific feasibility space within which farmers assess whether, how, and to what extent they should engage in farmland quality protection.

2.2 Research hypotheses

2.2.1 Farmland use dynamics and FQPB

Farmers' land use behavior is influenced by a variety of factors, including land characteristics, land tenure, market prices, spatial structure, and policies. These external factors play a more important role than internal factors (e.g., farmer characteristics) in shaping farmers' land conservation awareness (Liu and Luo, 2018) and thus specific land conservation behaviors. As landowners are direct participants in agricultural production and direct users of farmland, their decisions on whether to adopt conservation agriculture practices, how to fertilize the soil, and the degree of resource utilization of agricultural waste directly impact the effectiveness of measures aimed at protecting farmland quality (Alam et al., 2024). Therefore, land tenure stability, land transfer, and the sustainable use of farmland resources are key considerations in farmland protection. Stable land tenure can enhance farmers' sense of responsibility for the land and encourage them to implement effective conservation measures. At the same time, a reasonable land transfer mechanism can help optimize resource allocation and improve land use efficiency, thereby supporting the protection of farmland quality.

The protection of farmland quality is closely related to farmers' land use behavior. With an increased awareness of soil conservation and the adoption of conservation behaviors, farmers can effectively maintain the quality of their farmland to ensure the sustainable development of agriculture. Therefore, external factors not only shape farmers' land use behavior, they also promote the protection of farmland quality. The crucial role of landowner decision-making in this process underlines the key role of farmers in achieving sustainable agricultural development. In this paper, factors such as land transfer and land tenure stability are integrated into the dynamics of arable land use. Based on the above analysis, we propose the following hypothesis:

Hypothesis 1 (H1). Farmland use dynamics have a negative effect on the adoption of FQPB by farmers.

2.2.2 Agricultural inputs and FQPB

Agricultural inputs refer to the resources and elements invested in agricultural production to improve crop yields and quality, including labor, material resources, capital, and technology. Labor inputs mainly include the working hours and labor intensity of farmers, technicians, and managers. Inputs arising from agricultural production materials include seeds, fertilizers, pesticides, feed, and irrigation water, while capital inputs refer to the funds invested in agricultural production, such as the purchase of machinery and equipment, the construction of infrastructure (warehouses, irrigation systems, and so forth), and other investments in fixed assets. Technical inputs are those arising from the applications of modern agricultural technology, management methods and information technology, such as the adoption of precision agriculture technology (Zhang et al., 2023) and smart irrigation systems (Xu et al., 2023d). Land inputs are also a component of agricultural inputs and refer to the area of land used for agricultural production and its management, including soil improvement, crop rotation, and fallowing.

Methods allowing the analysis and management of agricultural inputs enable farmers, agricultural enterprises, and policymakers to determine the rational allocation and optimization of agricultural inputs, protect the quality of arable land, significantly improve crop yield and quality to meet market demand, and enhance the efficiency and sustainability of agricultural production to increase farmers' income and economic benefits. For example, the application of precision agriculture technology and intelligent irrigation systems can increase the efficiency of resource use, thus protecting the quality of arable land; scientific farming methods such as crop rotation, intercropping, and fallowing can effectively improve the soil structure and thus the ecological function of arable land (Nkongho et al., 2024; Scarlato et al., 2024; Schomberg et al., 2023). The concept of land input density is related to agricultural inputs and specifically reflects the degree of concentration of various types of resources (e.g., labor, fertilizer, seed) invested per unit area of land. Farmers and agricultural managers can also optimize agricultural inputs by analyzing the intensity of land inputs to ensure that sufficient resources are invested in a given piece of land, thereby increasing output per unit area while maintaining soil health. Household land resource endowment affects farmers' perceptions of soil contamination risks and thus influences their decisions on fertilizer and pesticide use. The amount of household land resources also influences farmers' willingness to adopt conservation practices, such as returning straw to the fields, as farmers who own more land tend to be more inclined to adopt these and other land-protection practices. The rational management of agricultural inputs is key to protecting farmland quality. APC, DAMR, and HLR are all key components of agricultural inputs, reflecting respectively the capital, technological, and land dimensions of farmers' investment in production. Based on the results of a field survey and exploratory factor analysis, we examined agricultural inputs by dividing them into APC, DAMR, and HLR. Subsequent analysis led us to hypothesize that agricultural production costs, the dynamics of agricultural machinery resources, and household land resources have positive effects on the adoption of FQPB by farmers.

Hypothesis 2 (H2). Agricultural production costs have a positive effect on the adoption of FQPB by farmers.

Hypothesis 3 (H3). The dynamics of agricultural machinery resources have a positive effect on the adoption of FQPB by farmers.

Hypothesis 4 (H4). Household land resources have a positive effect on the adoption of FQPB by farmers.

2.2.3 Agricultural cultivation patterns and FQPB

Agricultural cultivation patterns such as mixed cropping, multi-crop rotation, and irrigation management are considered concrete manifestations of FQPB, as they reflect farmers' proactive management measures aimed at maintaining or improving farmland quality. For example, mixed cropping and multi-crop rotation are protective strategies adopted by farmers to maintain soil fertility, reduce pest and disease pressure, and optimize resource use. Although our study did not directly measure changes in soil quality indicators, a substantial body of agronomic research has demonstrated that diversified cropping systems enhance soil organic carbon, nitrogen retention capacity, and microbial activity, thereby contributing to the improvement of farmland quality.

Mixed cropping can significantly increase biomass and grain yield compared to monoculture, an advantage that is more obvious in southern China. Introducing winter forage crops into a maize-rice multi-crop rotation system increases not only the total crop yield but also the organic carbon stock of the soil, which increases the amounts of carbon and nitrogen stored in maize stover and pellets, thus improving soil quality. A multi-crop rotation system that includes the introduction of winter forage crops also provides significantly greater economic returns than a system based solely on maize and rice. A diversified cropping pattern can increase farmers' income while effectively reducing the carbon footprint (Akinola et al., 2023), with the latter mainly due to the significant increase in organic carbon levels with the introduction of forage crops. Thus, mixed cropping contributes to combating climate change and promotes the protection of arable land quality.

A proper irrigation system ensures that crops receive sufficient water during the growing process and thereby achieve a high growth rate and yield. By optimizing irrigation methods, farmers can make effective use of water resources, reduce water evaporation and loss, and further enhance the water retention capacity of the soil, thereby strengthening the drought resistance of crops, promoting the activity of soil microorganisms, and increasing soil fertility. The adjustment of the industrial structure is also closely related to protecting the quality of arable land (Chen et al., 2017). For example, the crop diversification achieved by introducing non-food crops increases both soil biodiversity and the organic matter levels, thus improving soil structure and fertility, as well as the activity of microorganisms and carbon stocks, resulting in improved overall farmland quality.

Therefore, a rational adjustment of industrial structure, particularly through the introduction of non-food crops, is a major step in realizing the sustainable protection of farmland quality. Multi-crop rotation (Yu et al., 2024) and mixed cropping in combination with effective irrigation management (Li et al., 2024b) offer a sustainable agricultural development model whose implementation can provide farmers with higher economic benefits while effectively protecting and improving the quality of arable land, thus promoting ecological sustainable development. The impact of agricultural cultivation patterns is described by the following hypothesis:

Hypothesis 5 (H5). Agricultural cultivation patterns have a positive effect on the adoption of FQPB.

We selected five external dimensions (FUD, APC, DAMR, HLR, and ACP) as potential external factors influencing farmers' farmland quality protection behaviors. This selection was based primarily on the close association between these factors and farmers' land management decisions. FUD plays a key role in shaping farmers' land use behaviors and protection decisions through mechanisms such as land transfer and tenure stability. APC directly affects farmers' decisions regarding input levels and conservation investments, thereby influencing their willingness to adopt farmland quality protection measures. The availability and mechanization level of agricultural machinery resources determine whether conservation tillage practices such as straw return and deep plowing can be feasibly implemented. The amount of land owned by households influences the extent to which farmers prioritize the long-term sustainable use of farmland. ACP enhances soil structure, fertility, and ecological functions through diversified cropping and irrigation management, thereby improving farmland quality. The influence of each of these external factors on FQPB is described in Figure 1.

3 Materials and methods

3.1 Research area

The survey was conducted in Binhai County and Dongtai County, Yancheng Prefecture, Jiangsu Province, China (Figure 2). Yancheng Prefecture, a large prefecture-level agricultural city developed on saline and alkaline land, is located along the central Jiangsu Coast, and has unique land and tidal flat resources. It also has the largest land area and longest coastline in Jiangsu Province, where the coastal tidal flat area accounts for 70% of that of the province. As the most potential land reserve resource in Jiangsu Province, the prefecture is important in the agricultural economy of the Yangtze River Delta region, where traditional cultivation practices have largely been replaced by modern integrated agriculture, forestry, animal husbandry, and fishery methods, and innovative technologies have continuously improved the efficiency of saline land reclamation. Yancheng Prefecture is not only a major agricultural region in coastal Jiangsu but also a nationally designated key zone for saline-alkali land improvement. This dual role provides both representativeness and particularity: it reflects the broader challenges of farmland protection in economically developed coastal regions, while also highlighting the distinctive context of saline-alkali soil improvement.

Binhai County is located in northeastern Yancheng Prefecture and has a total land area of 194,960 hectares and a county-owned tidal flat area of 18,700 hectares. The main soil types are rice

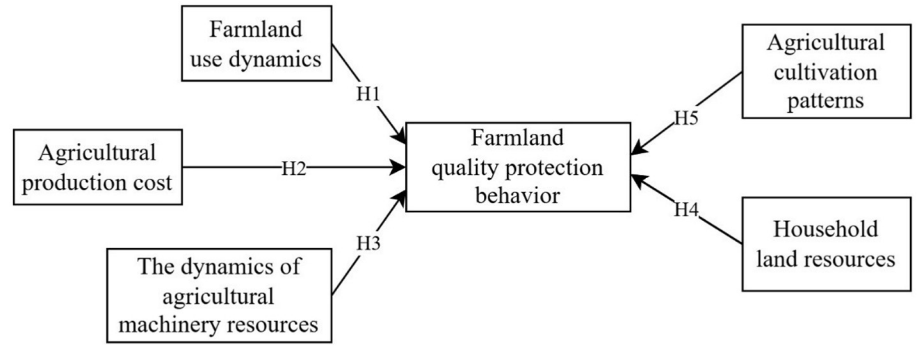

FIGURE 1
Conceptual model of the influence of external factors on farmland quality protection behavior (FQPB).

FIGURE 2
Maps showing the locations of Binhai county and Dongtai county.

soil, yellow tidal soil, and tidal salt soil. Through ditches dug to remove salt, the application of chemical enhancers, and the planting of salt-tolerant varieties of rice, soybeans, and other crops, the salty, alkaline land has gradually been transformed into high-yielding, good-quality land. Although Binhai County is a national commodity grain base county, it is also a provincial demonstration county for grain production mechanization. Dongtai County is a county-level city located at the southern end of Yancheng Prefecture and has a total area of 355,800 hectares, which makes it the largest city in Jiangsu Province. Its relatively flat terrain and fertile soil account for its use in the cultivation of agricultural products with special characteristics. It is also a national demonstration base for agricultural industrialization and an advanced city for grain production in China. Therefore, Binhai County and Dongtai County were appropriate choices for this study.

3.2 Data collection

The data were obtained by 14 researchers during micro-surveys of rural households in Yancheng Prefecture, selected using a stratified random sampling method. First, we randomly selected five towns in Binhai County (Tianchang, Zhenghong, Wuxun, Jiepai, and Binhai Harbor) and five towns in Dongtai County (Gangang, Nanshenzao, Dongtai, Liangduo, and Wulie). We randomly selected villages from each selected town, and then randomly selected households from each selected village for the survey. The enumerators employed a combination of online and offline questionnaires, as well as interviews. To avoid measurement errors caused by misunderstandings, team members visited local governments and natural resource bureaus in Binhai and Dongtai before the formal survey to gain a deeper understanding of farmland use issues. The researchers familiarized the respondents with the concepts related to farmland quality protection and relevant terminology. After eliminating questionnaires with missing information or logical inconsistencies, 190 valid questionnaires were obtained, corresponding to a validity rate of 95%. The valid questionnaires obtained in Binhai County came from 37 households in Tianchang, 28 in Zhenghong, 31 in Wuxun, 19 in Jiepai, and 24 in Binhai Harbor. Those in Dongtai County came from 11 households in Gangang, 6 in Nanshenzao, 14 in Dongtai, 8 in Liangduo, and 12 in Wulie.

3.3 Variable selection

3.3.1 Farmland use dynamics

The tillage method (no-tillage, conventional tillage, rotary tillage, deep plowing, and so forth) used during agricultural production is an important factor affecting the carbon footprint of the cropping system (Han et al., 2024) and land adaptation to climate change (Chen et al., 2023). Tillage practices and land transfer arrangements also have significant impacts on farmers' management decisions and soil quality protection (Liang et al., 2025; Xu et al., 2022). For example, moderate tillage positively regulates soil aeration and water retention and can improve the structure of the soil. Arable land use must also be considered, as arable land may be leased, contracted, or bought and sold, with the transfer resulting in an optimized allocation of resources and an improved efficiency of agricultural production. The transfer of arable land involves the signing of arable land contracts between farmers and landowners; guaranteed arable land contracts can clarify responsibilities and rights, secure land tenure arrangements and well-defined land contracts can enhance farmers' incentives to adopt long-term conservation practices and improve soil quality (Deininger and Jin, 2005; Ma et al., 2014), and help promote good arable land management and arable land quality protection. Newly transferred farmland can also be improved under the binding terms of a contract or self-requirement. Therefore, tillage method, transfer conditions, contract type, and the proportion of transferred farmland were chosen to investigate the utilization status of farmland. The tillage of farmland was divided into tillage before planting and no tillage, with values of 1 and 0; the transfer of farmland was divided into transfer and no transfer, with values of 1 and 0; the signing of a farmland contract was divided into signed contract and no signed contract, with values of 1 and 0; and the proportion of transferred farmland was defined as the proportion of the area of transferred farmland in the total area of the farm.

3.3.2 Agricultural production costs

Farmers' economic behavior and decision-making are closely related to the cost of inputs (Taramuel-Taramuel et al., 2023). Research indicates that increases in fertilizer and pesticide prices tend to curb excessive application and encourage more judicious use of inputs, thereby indirectly promoting soil conservation (Wang et al., 2022c, 2023a,b). For example, farmers may reduce the amount of fertilizer used or choose more affordable fertilizers when faced with higher fertilizer costs. The inappropriate use of agricultural inputs such as fertilizers and pesticides (Nascimento et al., 2023) is the main cause of soil pollution. The increased mechanization of agricultural production can improve productivity, but excessive mechanization can cause soil compaction and degradation (Zhang et al., 2024b). Therefore, fertilizer, pesticide, and machinery costs were selected as cost variables, defined as average annual fertilizer costs, annual pesticide costs, and annual machinery rental costs, respectively, expressed in 10,000 Yuan.

3.3.3 Dynamics of agricultural machinery resources

The modernization of agricultural production, particularly with respect to tillage, seeding, and fertilization, is greatly influenced by the availability of farm machinery and equipment. Research has shown that the availability and adoption of modern machinery play a crucial role in facilitating conservation practices and improving soil conditions (Liu et al., 2022). Precision seeding is accomplished using appropriate seeders, and fertilization equipment can reduce fertilizer waste, thereby improving farm performance (Lairez et al., 2023). The use of more efficient equipment can reduce soil damage caused by traditional tillage methods and promote the implementation of precision agriculture (Chen et al., 2025). Therefore, we selected the use and ownership of farm machinery and equipment as dynamic variables representing farm machinery resources. We recorded the number of farming machinery and equipment items owned and used by each farmer in each year.

3.3.4 Household land resources

The land use and management practices associated with agricultural production are influenced by the size of the cultivated area. Farmers with larger cultivated areas may rely more on the use of fertilizers and pesticides in addition to being confronted by the problem of resource fragmentation over large areas of cultivated land, but they also create economies of scale that can support the adoption of conservation measures (Wu et al., 2018, 2021). Total land area can be used to understand a household's overall resource allocation and management strategy, by providing a comprehensive view of a household's use of land resources and overall planning. Similarly, the area of land in circulation can be used as an indicator of the flexibility of land use and market demand. Because both market demands and resource utilization may differ, changes in the area of land in circulation may lead to different management strategies and conservation measures (Huo and Chen, 2024). These findings highlight that household land resources influence not only production capacity but also the structural conditions under which farmland quality protection can or cannot be implemented. Thus, to represent production scale, land resource allocation, and resource adjustment, household land resources were measured based on household cultivated area, total land area, and transferred area.

3.3.5 Agricultural cultivation patterns

Farmers grow different crops, including food crops, cash crops, and mixed crops, depending on their household needs, the soil conditions, and local policies. For example, if the land is only suitable for cash or food crops, then farmers will choose to grow only crops of that type. Different cropping types may be used, such as monoculture, strip cropping, or pixel cropping (Ditzler et al., 2023), and these will have different fertilizer, irrigation, and management requirements. Research has shown that crop diversification is widely regarded as an important pathway for reducing dependence on chemical inputs and enhancing soil resilience (Li et al., 2025; Mihrete and Mihretu, 2025). Therefore, shifts toward cash crops or mixed cropping systems not only reflect farmers' economic strategies but also directly affect farmland quality protection by altering input intensity and ecological sustainability. Therefore, an analysis of agricultural cropping patterns will focus on the overall cropping type, whether or not non-food crops are grown, the type of non-food crops, and the irrigation method. In this study, the actual local situation, the type of crops planted, and the irrigation methods were each assessed based on assigned values of 1–3; whether to plant non-food crops was set as planted and not planted, with values 1 and 0; and the type of non-food crops was set as none, one, two, and three, with values of 0–3, respectively.

3.3.6 FQPBs

The inappropriate use of chemical fertilizers is a main cause of soil nutrient imbalance and pollution, such that organic fertilizers are now being proposed as replacements (Zhou et al., 2024). While a lack of organic fertilizers can lead to poor crop growth, reduced productivity and increased dependence on chemical fertilizers, their excessive use can result in the loss of nutrients from the soil. The presence or absence of soil-management practices, including soil thinning and the use of amendments, also affects soil quality (Hasan et al., 2024). Such practices are widely recognized as central components of farmland quality protection (Khan et al., 2024). Therefore, we examined the use and amount of organic fertilizers. The use of organic fertilizer was defined as use and no use, with values of 1 and 0; the amount of organic fertilizer use was divided into no use, use of one kind, two kinds, three kinds, and four kinds, with values of 0–4. Table 1 shows the variables included and their definitions.

3.4 Pre-test

Exploratory factor and validation factor analyses were conducted using SPSS 27.0. And Amos 28.0 to test the reliability and validity of each latent variable and to ensure the reliability and accuracy of the data, which is an important prerequisite for the meaningfulness of subsequent analyses.

3.4.1 Model reliability and validity

The internal consistency of each dimension was analyzed using Cronbach's coefficient reliability test. The Cronbach's coefficient ranges from 0 to 1; the higher the coefficient, the higher the reliability, where <0.6 is generally accepted as indicating unacceptable results 0.9 to 1 indicates excellent results. The validity of a questionnaire is commonly assessed using structural validity analysis, which is based on factor analysis. Whether the data are suitable for factor analysis is determined using a Kaiser-Meyer-Olkin (KMO) measure and Bartlett's spherical test. Once the above conditions are met, the validity of the model is tested. In this study, Amos 28.0 software was used to calculate the standardized factor loadings of each observed variable on its latent variable. Then these loadings were used to calculate the combined reliability (CR) and the average variance extracted (AVE) of each dimension.

The results of the reliability and validity tests are presented in Table 2. The reliability coefficients of all potential variables were >0.6, indicating that the study data had good internal consistency. The KMO value for FQPB and agricultural machinery resource dynamics was at the critical value of 0.5, indicating acceptable data quality, while the KMO values of the other latent variables were >0.5. The chi-square values in Bartlett's test of sphericity were all significant at <0.001. The explanatory rate of the cumulative variance was $>50\%$, such that all measures were suitable for factor analysis. The CR values of all latent variables were >0.7, confirming the internal consistency of the latent variables. AVE estimates must be >0.5; if the AVE value is <0.5 but the CR value is higher than the threshold, then the convergent validity of the constructs is considered sufficient. The slightly low AVE values for FUD and ACP may stem from the heterogeneity and mixed measurement types of their indicators. Specifically, the three indicators of FUD (FT, TF, CSF) are binary variables, while PTF is a proportional indicator. Such restricted variance reduces the shared variance among the indicators. In the case of ACP, the indicators encompass binary (CNC), count (TNC), categorical irrigation type (IM), and composite categorical planting type (TPT), reflecting multidimensional and heterogeneous cultivation patterns rather than a homogeneous psychological trait. For FUD, FT (0.334) and CSF (0.410) exhibit relatively weak factor loadings; for ACP, IM (0.414) is relatively weak. We retained these indicators to preserve content validity, but doing so inevitably diluted the shared variance among the indicators, thereby lowering the AVE. The combination of the above criteria verified the convergent validity of the model (Table 2).

Discriminant validity was evaluated by comparing the square root of the AVE and the correlation coefficients between each latent variable. If the absolute values of the coefficients were all smaller than the corresponding square root of the AVE, the discriminant

TABLE 1 Latent variables and their definitions.

Latent variable		Variable definition	Unit	Mean	SD	Min	Max
FQPB	Use organic fertilizer (UOF)	Yes = 1, no = 0 (Q: Is organic fertilizer used?)	/	0.616	0.488	0	1
	Amount of organic fertilizer used (AOFU)	Not used = 0, 1 type = 1, 2 types = 2, 3 types = 3, 4 types = 4	/	0.984	1.010	0	4
FUD	Farmland tillage (FT)	Yes = 1, no = 0 (Q: Is the land tilled before planting?)	/	0.932	0.253	0	1
	Transfer of farmland (TF)	Yes = 1, no = 0 (Q: Will the land be converted into farmland?)	/	0.979	0.144	0	1
	Contractual status of farmland (CSF)	Yes = 1, no = 0 (Q: Is there a contract?)	/	0.958	0.201	0	1
	Proportion of transferred farmland (PTF)	Proportion of transferred land area to total operating area	%	0.889	0.195	0	1
APC	Fertilizer costs (FC)	Annual fertilizer expenditure, average	10,000 Yuan	13.974	18.845	0.05	160.6
	Pesticide costs (PC)	Annual pesticide costs	10,000 Yuan	6.376	7.664	0	55
	Cost of hired machinery (CHM)	Annual cost of machinery rental	10,000 Yuan	6.241	12.228	0	101.2
HLR	Household cultivated area (HCA)	Household cultivated area	Mu	295.588	351.728	6	2,200
	Total land area (TLA)	Total area of land under operation	Mu	297.850	353.503	6	2,200
	Flow area (FA)	Area of transferred contracted farmland	Mu	281.072	348.327	0	2,200
ACP	Total plantation type (TPT)	1 type = 1, 2 types = 2, 3 types = 3	/	1.253	0.482	1	3
	Cultivation of non-food crops (CNC)	Yes = 1, no = 0 (Q: Is a non-food crop cultivated?)	/	0.379	0.486	0	1
	Types of non-food crops (TNC)	None = 0, 1 species = 1, 2 species = 2, 3 species = 3	/	0.526	0.732	0	3
	Irrigation method (IM)	1 species = 1, 2 species = 2, 3 species = 3	/	1.058	0.256	1	3
DAMR	Use of agricultural machinery (UAM)	Number of agricultural machines used	Unit	4.637	2.370	0	9
	Ownership of agricultural equipment (OAE)	Number of owned agricultural equipment items	Unit	2.342	2.424	0	9

SD, standard deviation; Min, minimum; Max, maximum.

validity of the model was deemed satisfactory. As shown in Table 3, the outcomes aligned with the criteria established for the test of discriminant validity for all factors except agricultural production cost. In addition, most of the latent variables were significantly correlated with each other. Combined with the results of the content validity and convergent validity tests, this indicates that the latent variables had a certain level of correlation but also maintained a certain level of independence from each other, and therefore that the discriminant validity of the data was good. The content validity, convergent validity, and discriminant validity of the model all met the standards, which enabled further analysis of the model.

3.4.2 Model fit

The model was tested for goodness of fit using Amos 28.0 and the maximum likelihood method. The χ^2/df is usually used in SEM as a simplified goodness of fit indicator, with $\chi^2/\text{df} = 1$–3 considered excellent and < 5 acceptable. As shown in Table 4, the value was in the excellent range (2.194). The absolute fit indicator of the SEM, the RMSEA, was 0.079, which was < 0.08 and therefore acceptable. The values of the value-added fit indices TLI, CFI, IFI, and NFI of the model were 0.942, 0.954, 0.955, and 0.920, respectively, and thus > 0.9. Together with the simple fit indices, which were all higher than the critical value of 0.5, these values indicated the good overall fit of the model of the present study and its suitability for use in an analysis of the factors influencing the decision-making underlying farm household's FQPB.

4 Results and hypothesis verification

4.1 Socioeconomic and demographic profile of the respondents

The socioeconomic and demographic characteristics of the survey respondents are presented in Table 5. The majority of the surveyed farmers had a high level of education, with 97 (51.1%) having a high school education or higher and only 4 (2.1%) having no formal education. This distribution reflected the fact that nearly 80% of the respondents were young or middle-aged, living in an era of relatively abundant educational resources. The proportion of households engaged in pure agriculture was higher than that of households engaged in activities besides agriculture on a part-time basis. In 59.5% of the households, two people worked in agriculture, and in nearly 70% of households the annual household income was < 20,000 RMB. These results indicate that the majority of farmers in the study area depend on agriculture for their livelihood. In a related finding, the proportion of income derived from agriculture was generally high, accounting for >75%, of total

TABLE 2 Reliability and validity analysis of latent variables.

Latent variable	Observed variable	Standard factor load	Cronbach's α	KMO	CR	AVE
FQPB	UOF	0.926	0.753	0.500	0.873	0.776
	AOFU	0.833				
FUD	FT	0.334	0.618	0.645	0.719	0.431
	TF	0.675				
	CSF	0.410				
	PTF	0.995				
APC	FC	0.915	0.770	0.673	0.853	0.665
	PC	0.890				
	CHM	0.605				
HLR	HCA	1.000	0.997	0.754	0.997	0.991
	TLA	1.000				
	FA	0.986				
ACP	TPT	0.827	0.731	0.735	0.764	0.461
	CNC	0.626				
	TNC	0.772				
	IM	0.414				
DAMR	UAM	0.800	0.711	0.500	0.715	0.557
	OAE	0.689				

KMO, Kaiser–Meyer–Olkin; CR, combined reliability; AVE, average variance extracted.

TABLE 3 Discriminant validity test results.

Latent variable	FQPB	DAMR	ACP	HLR	APC	FUD
FQPB	0.881					
DAMR	0.292***	0.746				
ACP	0.226**	0.116	0.679			
HLR	0.172**	0.509***	0.258***	0.995		
APC	0.119*	0.499***	0.132	0.888***	0.815	
FUD	−0.072	0.355***	0.056	0.256***	0.258***	0.657

*$P < 0.1$.
**$P < 0.05$.
***$P < 0.01$.

household income in >60% of the surveyed farm households. Thus, the main source of income for most farm households was agricultural production. Regarding the implementation of measures to protect farmland quality, 61.1% of farmers reported using organic fertilizers and 67.9% reported adopting practices aimed at improving farmland quality. Among the farmers using organic fertilizers, the majority used one to two different types. The adoption of a wide range of measures to improve the quality of their farmland precisely likely reflects the fact that the farmers are relatively well educated and mainly earn their living from agriculture.

Generally, the interviewed farmers were middle aged, educated, had a moderate number of family members involved in farming, and a positive attitude toward the adoption of measures to protect farmland quality. The standard deviation of most of the observed variables was < 1 (Table 1); thus, the differences between the survey data were small and the means well represented the sets of variables. However, the standard deviations and maximum and minimum values of fertilizer expenditure, pesticide expenditure, machinery rental cost, household cultivated area, total land area, and transferred area were large, attributable to high uncertainties and the different situations. The standard errors of each variable in this set of variables were < 0.085 (Table 5), which indicates that the selected sample had a high degree of confidence and its randomness was guaranteed. Therefore, the sample was considered representative.

4.2 Path estimation results for structural models

Based on the results of the exploratory factor and validation factor analyses, an SEM was constructed. Figure 3 shows the estimated normalized path coefficients and factor loadings of the model, and Table 6 shows its estimated results, including the non-normalized and normalized path coefficients, standard errors, critical ratios, and significance levels.

The SEM results supported our hypotheses that that FQPBs are directly influenced by variables such as farmland use dynamics, farm machinery resource dynamics, and agricultural cropping patterns. As shown in Figure 3 and Table 6, the influences of farmland use dynamics and agricultural cropping pattern on FQPB were weak, with standardized path coefficients of −0.202 and

TABLE 4 Results of overall model fit tests.

Category	Indicator	Adapter standard	Statistics	Adaptation to judge
Absolute fit index	χ^2/df	<3	2.194	Good
	GFI	>0.8	0.877	Good
	AGFI	>0.8	0.825	Good
	RMSEA	<0.08	0.079	Acceptable
Value-added compatibility indicators	TLI	>0.9	0.942	Good
	CFI	>0.9	0.954	Good
	IFI	>0.9	0.955	Good
	NFI	>0.9	0.920	Good
Simple fit index	PGFI	>0.5	0.615	Good
	PNFI	>0.5	0.722	Good

TABLE 5 Socioeconomic and demographic profiles of the survey respondents.

Variable	Category	Frequency (times)	Frequency (%)	Variable	Category	Frequency (times)	Frequency (%)
UOF	Used	116	61.1	Education level	Uneducated	4	2.1
	Not used	74	38.9		Elementary school	22	11.6
AOFU	Not used	74	38.9		Middle school	67	35.3
	1 type	63	33.2		High school and junior college	68	35.8
	2 types	41	21.6		College and above	29	15.3
	3 types	6	3.2	Number of family farmers	1	23	12.1
	4 types	6	3.2		2	113	59.5
FI	Improved	129	67.9		3	19	10.0
	Unimproved	61	32.1		4	26	13.7
Share of total household income contributed by agricultural income	0–25%	9	4.7		≥5	9	4.7
	26–50%	30	15.8	Employment type	Farming	102	53.7
	51–75%	28	14.7		Part-time work	88	46.3
	76–100%	123	64.7	Gross household income	0–20,000	126	66.3
Age	30–39	16	8.4		21,000–40,000	41	21.6
	40–49	48	25.3		41,000–60,000	7	3.7
	50–59	87	45.8		61,000–80,000	3	1.6
	≥ 60	39	20.5		≥ 81,000	13	6.8

Frequency (times), number of occurrences; Frequency (%), percentage of total responses.

0.185, respectively; both were statistically significant at the 5% level. These results indicate that farmland use dynamics and agricultural cropping pattern significantly influence FQPB, with farmland use dynamics having a significantly negative influence, supporting our hypotheses that farmland use dynamics have negative effects on the adoption of FQPB by farmers and agricultural cultivation patterns have positive effects on the adoption of FQPB by farmers. The dynamics of agricultural machinery resources strongly influenced FQPB; the standardized path coefficient of 0.348 was statistically significant at the 1% level. This supports our hypothesis that the dynamics of agricultural machinery resources have a positive effect on the adoption of FQPB by farmers.

The significance levels of the path coefficients of agricultural production costs and household land resources were > 0.1, according to which the relationship between these two variables and FQPB was not statistically significant. In the absence of sufficient evidence to support a significant effect of the independent variable on the dependent variable, our hypotheses that agricultural production costs and household land resources have positive effects on the adoption of FQPB by farmers were not supported.

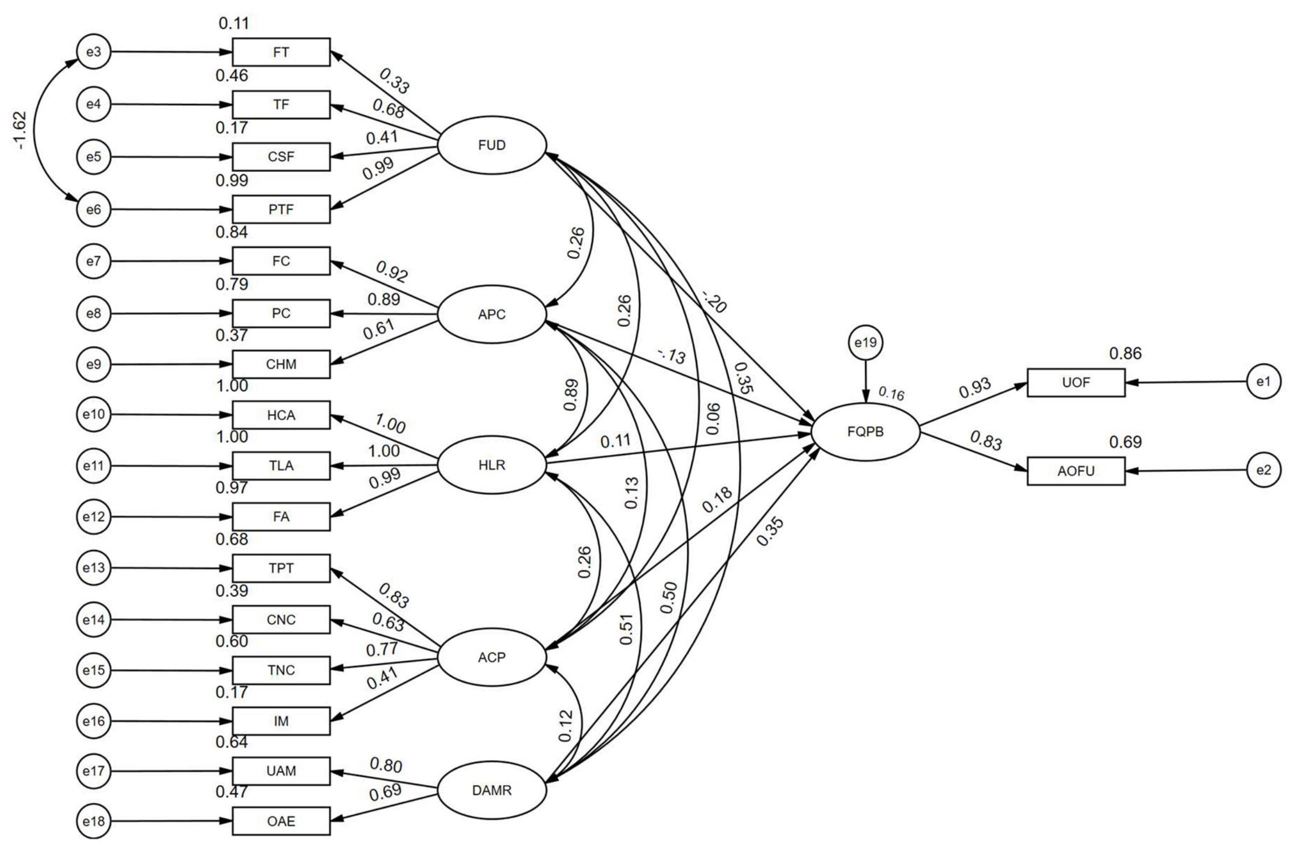

FIGURE 3
Structural equation model paths and coefficients. The portion of the variable not explained by the corresponding latent construct was designated measurement error (e).

5 Discussion

Most of the farmers surveyed had farmland transfer contracts, some of which were verbally agreed upon, while others were signed. However, neither adequately guarantees the stability of farmland property rights. Formal written contracts provide stronger legal enforceability and greater security expectations, which can enhance farmers' sense of long-term responsibility for land management and increase their willingness to invest in farmland, thereby promoting engagement in FQPB (Li and Wang, 2021). The confirmation and registration of land rights endow farmland with clear legal status, strengthening farmers' recognition of land ownership and effectively reducing uncertainty and institutional risks in farmland transactions (Zhao et al., 2022). Under well-defined and predictable land tenure conditions, farmers are more likely to regard farmland as a stable asset, which encourages long-term investment in farmland quality protection (Qian et al., 2022). Ensuring the long-term stability of the property rights for arable land will give farmers a sense of security regarding their livelihoods that will also free them to prioritize protective development of that land, such as using organic instead of chemical fertilizers and pesticides (Xu et al., 2023b). Farmers' actual control over land tenure also influences their investment decisions related to farmland quality protection. This control is reflected in factors such as the length of the land transfer period and whether ownership disputes arise during the transfer process. When farmland transfer relationships are relatively stable and last for a relatively long period, farmers are more inclined to formulate long-term agricultural production plans (Xin and Li, 2019). In contrast, if tenure disputes occur during the transfer process, transferees often begin to question the continuity and security of land use, fearing possible future disruptions or interference. As a result, their willingness to make long-term investments is weakened, and they tend to adopt short-term production strategies instead (Zhou et al., 2022). Because farmland quality protection is inherently a long-term process, the required inputs, such as time, labor, and financial resources, typically yield returns only over multiple years. If farmland tenure is unstable, farmers' expectations of future benefits may be weakened, thereby reducing their willingness and motivation to invest in long-term conservation practices (Lu et al., 2022). Our findings are consistent with previous research highlighting the critical role of tenure security in promoting sustainable land management behaviors.

The insignificant effect of APC on farmland quality protection behaviors may be attributed to the buffering role of government policies. To promote agricultural and rural development, both national agricultural policies and regional measures in coastal Jiangsu have provided financial subsidies, systematically targeting efficiency gains in agriculture, income growth for farmers, and revitalization of rural areas. These policies reduce farmers' sensitivity to fluctuations in production costs. In China, agricultural

TABLE 6 Structural equation model estimation results.

Influence path	Non-normalized path coefficient	Normalized path coefficient	SE.	CR	*P*
FQPB←HLR	0.000	0.110	0.000	0.543	0.587
FQPB←APC	0.000	−0.125	0.000	−0.611	0.541
FQPB←ACP	0.209	0.185	0.101	2.075	*
FQPB←DAMR	0.083	0.348	0.029	2.887	**
FQPB←FUD	−0.091	−0.202	0.037	−2.443	*
FT←FUD	0.083	0.334	0.013	6.605	**
TF←FUD	0.097	0.675	0.011	9.015	**
CSF←FUD	0.083	0.410	0.013	6.605	**
PTF←FUD	0.195	0.995	0.016	12.293	**
FC←APC	1.000	0.915			
PC←APC	0.396	0.890	0.021	18.465	**
CHM←APC	0.429	0.605	0.045	9.464	**
HCA←HLR	1.000	0.999			
TLA←HLR	1.005	0.999	0.004	280.263	**
FA←HLR	0.977	0.986	0.012	79.938	**
TPT←ACP	1.000	0.827			
CNC←ACP	0.764	0.626	0.097	7.889	**
TNC←ACP	1.419	0.772	0.156	9.107	**
IM←ACP	0.266	0.414	0.051	5.218	**
UAM←DAMR	1.000	0.800			
OAE←DAMR	0.881	0.689	0.136	6.490	**
UOF←FQPB	1.000	0.926			
AOFU←FQPB	1.865	0.833	0.298	6.263	**

*$P < 0.05$.
**$P < 0.01$.

policy support is substantial, covering inputs, facilities and equipment, and production-related services. For instance, Jiangsu Province has lowered the proportion of premium subsidies borne by major grain-producing counties and expanded the coverage of full-cost insurance and planting income insurance for rice, wheat, maize, and soybeans. Previous studies indicate that subsidy reforms and the provision of socialized services can reduce fertilizer and pesticide inputs as well as mechanization costs, thereby offsetting the behavioral effects of individual cost differences (Zhang et al., 2024a). Furthermore, descriptive statistics show that most farmers' expenditure levels are relatively similar, with limited variation across the sample, which also weakens the explanatory power of cost-related factors. Existing research suggests that farmland quality protection behaviors are not primarily driven by short-term economic costs but are more strongly influenced by policy incentives, technical service provision, and broader social norms in agriculture (Wang and Huan, 2023). This finding highlights the collective and institutionalized nature of farmland protection, suggesting that cost pressures alone are insufficient to explain farmers' behavioral choices.

The effect of household land resources on FQPBs was non-significant. However, Duan and Luo (2024) found that the probability of FQPB implementation was higher for farmers with larger farms. Zhang et al. (2020) also determined that a large amount of farmland encouraged farmers to adopt quality-protection measures. In their study of small-scale farmers, Xu et al. (2023c) concluded that the cultivation scale has a significantly negative effect on FQPB, among professional farmers and the sample as a whole; this was not supported in our study for either small-scale or large-scale farmers. These differences may be related to the regional heterogeneity. In areas where farmland is fragmented and capital is scarce, households may own relatively large amounts of land but still lack the economies of scale needed to support high-cost conservation practices. In regions with more advanced farmland consolidation, scale effects may motivate engagement in quality protection (Xu et al., 2023a). The lack of a significant effect in our sample is likely attributable to severe land fragmentation in the study area. Even households with relatively large total landholdings may hold it in multiple small and dispersed plots, which limits the ability to realize economies of scale necessary for high-cost quality protection practices. In recent years, Yancheng City in Jiangsu Province has been implementing the reform pilot of "small plots into large plots" and advancing the construction of high-standard farmland to address the problem

TABLE 7 Differential analysis of FQPB.

Study characteristics	Duan and Luo (2024)	Zhang et al. (2020)	Xu et al. (2023c)	This study
Study area	China's 13 major grain producing areas	Three counties in northern Jiangsu province	Hainan Province	Yancheng and Dongtai, Jiangsu
Main crops	Rice, wheat, maize and soybean	Rice, maize and soybean	Mango	Rice, wheat, maize, soybean, peanut and sweet potato
Study objective	Family grain farms	Farmers other than large-grain growers, family farms, and other new agricultural management practices	Small, specialized mango growers	Traditional farmers Large farmers Heads of agricultural cooperatives Heads of family farms
FQPB	Traditional cultivated land leveling, organic fertilizer application, soil testing, and formula fertilization	Subsoiling, straw application, organic fertilizer application, cover crops, and green manures	Organic fertilizer application, soil testing, and formula fertilization	Organic fertilizer application Amount of organic fertilizer used
Kay findings	Participation in cooperatives significantly promoted cultivated land quality protection behavior adoption	Perennial out-migration constrained protective inputs, while local part-time farming promoted them	Significant differences in cultivated land quality protection behavior between smallholders and professional farmers	FUD had a negative effect on FQPB; DAMR had a positive effect; ACP had a positive effect on FQPB
Heterogeneity/ Key contributing factors	Stronger effects among: younger farmers, less-educated farmers, non-party members, larger scale of operation, longer establishment years, larger labor force, or provincial demonstration	Effects varied by: farmer characteristics, farming conditions, and external environment	Differences mainly explained by internal characteristics, with smaller contributions from external characteristics	Key contributors to FUD effect: TF, PTF; key contributors to ACP effect: TPT, CNC, TNC; key contributors to DAMR effect: UAM, OAE

of land fragmentation, but many households in our sample still operate fragmented plots. Therefore, the absence of significant results in our Jiangsu sample may reflect differences in regional context compared to earlier studies. It may also be related to the different characteristics of the farmers, as well as the selected FQPB. While household land resources do not show a significant effect in this region, this finding provides novel insights into farmland quality protection behaviors in economically developed coastal areas, highlighting the role of land consolidation and scale effects. Table 7 compares the FQPBs determined in the above three studies and in our own, to demonstrate the behavioral variability and serve as a reference for researchers in subsequent studies. Note that in the study of small and professional farmers of mango cultivation in Hainan Province, the organic fertilizers referred to in Table 7 were commercial organic fertilizers made from animal and plant residues, animal, and poultry manure, and so forth, after fermentation and maturation, whereas the organic fertilizers in our study included stable manure, biogas fertilizer (nitrogen, phosphorus, and potassium), crop residue fertilizer (nitrogen), cake fertilizer (nitrogen), and grass ash (phosphorus and potassium). An analysis of the farmers' behaviors in the quality protection of arable land was based on three approaches: before sowing (plowing, deep soil loosening, arable land improvement, and so forth), during sowing (organic fertilizer use and its quantity, soil testing and formulation, planting green manure crops, and so forth), and after sowing (straw application, and so forth).

Effective irrigation is a key factor in a farmer's ability to implement measures to protect the quality of farmland (Wollni et al., 2010). Most of the surveyed farmers relied mainly on traditional surface irrigation methods rather than ordinary sprinkler and micro-irrigation systems. Our results show that although ACP as a whole positively influences FQPB, the irrigation method (IM) factor has a relatively low loading on ACP (0.41), indicating that the positive effect of ACP on FQPB is largely driven by other components rather than by the current irrigation mode, which may be attributed to inherent limitations of traditional surface irrigation technologies, such as excessive surface ponding, uneven water distribution, low infiltration efficiency, and risks of soil salinization. These issues reduce water use efficiency and damage soil health, thereby weakening the effectiveness of protective measures such as the application of organic fertilizers (Masseroni et al., 2023). In contrast, methods such as drip or sprinkler irrigation offer higher water-use efficiency and more stable soil moisture control, which collectively enhance fertilizer utilization and support soil conservation behaviors (Dominguez-Bohorquez et al., 2025). In saline-alkali environments, drip irrigation has been shown to reduce soil salinity by 37.7% and increase crop yields, making it easier to implement conservation practices (Du et al., 2023). In Binhai and Dongtai counties, cultivated land is highly fragmented, with small, scattered plots remaining prevalent, particularly in areas where high-standard farmland consolidation projects have not yet been fully implemented. This fragmented land structure complicates the adoption of efficient irrigation systems. In the absence of moisture control and drainage improvements, traditional surface irrigation fails to provide a stable soil environment conducive to high-quality farmland protection practices (Li et al., 2024a); efficient irrigation technology would enhance the quality of farmland conservation efforts. Although the effect of the irrigation mode on promoting conservation practices was not directly examined in this study, we infer the need to optimize irrigation systems in the study area, and plan to conduct further empirical validation in this region. The use of more efficient irrigation technologies and the improvement of the irrigation infrastructure will increase the efficiency of farmland water use and thus incentivize farmers to actively implement soil-conservation practices. The use of farm machinery was found to have a positive effect on FQPB, in agreement with Zhang et al. (2020), who found that many farmers mainly rely on the purchase of farm machinery services to implement soil quality-protection measures, and that these convenient services can effectively promote the adoption of more scientific farming methods. Farmers who do not have access to conservation tillage equipment may choose to forgo these measures.

Beyond these empirical findings, our study advances the literature in two important ways. First, while prior studies have primarily examined farmers in major grain-producing regions and focused on internal psychological factors or macro-level policy contexts, we highlight the underexplored issue of non-grain cultivation in economically developed coastal areas. The conversion of high-quality farmland to cash crop production introduces behavioral and institutional changes that remain insufficiently examined. Second, we foreground the influence of external environmental systems at the micro scale, showing how non-grain cultivation patterns and agricultural mechanization resources shape farmers' decisions regarding FQPB.

6 Conclusions, policy implications and limitations

FQPB is influenced by a variety of factors. Before implementing protective measures, farmers weigh the potential benefits, crop yield, and cost savings. They also consider the expected quality of the agricultural products and the ability to ensure a secure livelihood. As quality of life improves, increased attention is paid to ecological benefits such as ecological environment and soil fertility. Although the ultimate goal of farmers is to maximize economic benefits, they are increasingly citing the importance of ecological and social factors. Farmers will make rational economic decisions when considering the adoption of measures to protect the quality of farmland, such as replacing chemical fertilizers with organic fertilizers, using soil conditioners, and adjusting irrigation methods. However, they must first be willing to make the required investment and confront the uncertainty of returns. Any decision will be centered on avoiding actions that risk causing significant economic loss.

The questions included in the survey were in line with the current state of agriculture in Yancheng Prefecture and Dongtai County. They emphasized agricultural mechanization and cash crops and explored the impact of agricultural machinery, equipment resources, and non-food cultivation on the protection of farmland quality. As such, our study expands the field of research on the protection of farmland quality and identifies the most variables most strongly related to promoting/hindering protection. It also provides a micro-level analysis of the factors that impact farmland quality protection. The results showed that FQPB is hindered by changes in land tenure and promoted by the planting of non-food crops, by improving farmers' economic wellbeing. As such our results indicate that both economic and non-economic factors determine FQPB.

Based on the main findings of our survey, we offer the following policy recommendations. First, ensuring the security of transfer contracts requires clear definitions of the land contract period, transfer method, and scope of the land use. Farmers should be provided with contract templates and advised to participate in written contracts while avoiding verbal agreements, to safeguard the legal validity of the contract. Agricultural insurance and the establishment of transfer guarantee funds can be used to reduce transfer risks and ensure the stability of farmland property rights. Second, modern irrigation technologies, such as drip irrigation, sprinkler irrigation, micro-irrigation, and smart irrigation, should be strongly promoted. The optimal irrigation technique will depend on the soil characteristics and farmland area. Introducing irrigation technology subsidies may guide and encourage farmers to adopt new irrigation equipment, and technical training may help farmers to understand and master their use. Third, addressing issues regarding the supply and maintenance of agricultural machinery services is a prerequisite for ensuring their adoption. For small farmers, the cost of directly purchasing agricultural machinery may be burdensome. As an alternative, the agricultural machinery rental market can be developed, with equipment rental offered by agricultural machinery cooperatives or agricultural machinery service companies. Providing support to agricultural machinery service enterprises should include the construction of modern platforms that ensure the availability of comprehensive technical services, offer training on how to operate machinery, and facilitate operation skill and safety awareness.

Based on our survey data, we explored mechanisms underlying farmers' adoption of farmland quality improvement practices and obtained useful conclusions and policy implications. However, our study had some limitations. First, the factors influencing FQPB were measured using a self-developed questionnaire, which had good reliability and validity, but also several drawbacks, such as the limited sample size. Future research should expand the sample scope and size to assess the stability and generalizability of the results. Second, the findings may have limited generalizability to other saline-alkali regions with different environmental conditions. Future research should expand the geographical scope of our findings by including a larger number of counties or cities. Third, we primarily examined the influence of external environmental factors. Future research should investigate the interactive mechanisms among internal factors, external conditions, and farmers' behavioral responses, to examine the decision-making logic underlying FQPB more comprehensively. Despite these limitations, our study has important implications for agricultural regions in eastern China that share similar characteristics, such as active land transfer, significant labor outflow, the expansion of non-grain cultivation, and a continuing need for farmland improvement. Beyond China, the findings may also offer insights for agricultural regions in other countries that face comparable pressures from farmland transformation and labor migration. Overall, our study offers valuable insights into the relationship between agricultural stakeholders and farmland quality protection in similar agroecological contexts.

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. The participants [OR participants legal guardian/next of kin] provided their written informed consent to participate in this study.

Author contributions

NY: Validation, Visualization, Conceptualization, Data curation, Methodology, Formal analysis, Writing – original draft, Software. YX: Resources, Writing – review & editing, Project administration, Supervision, Formal analysis, Investigation, Conceptualization, Data curation. RZ: Project administration, Writing – review & editing, Visualization, Funding acquisition.

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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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