frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 22 September 2025
DOI 10.3389/fsufs.2025.1644535

OPEN ACCESS

EDITED BY
Enoch Kikulwe,
Alliance Bioversity International and CIAT, Kenya

REVIEWED BY
Guoqun Ma,
Guangxi Normal University, China
Zhidong Wu,
South China Agricultural University, China

*CORRESPONDENCE
Longhai Tang
✉ 18-100@gduf.edu.cn

RECEIVED 10 June 2025
ACCEPTED 01 September 2025
PUBLISHED 22 September 2025

CITATION
Zheng W, Gong Z, Zhang W and Tang L (2025) Land psychological ownership driving adoption of pro-environmental fertilization technology among rice farmers in southern China.
Front. Sustain. Food Syst. 9:1644535.
doi: 10.3389/fsufs.2025.1644535

Land psychological ownership driving adoption of pro-environmental fertilization technology among rice farmers in southern China

Wolin Zheng[1], Zhenhan Gong[1], Weikun Zhang[2,3] and Longhai Tang[1]*

[1]School of Credit Management, Guangdong University of Finance, Guangzhou, China, [2]Jockey Club Enterprise Sustainability Global Research Institute, Hong Kong University, Pok Fu Lam, Hong Kong SAR, China, [3]School of Social and Public Administration, Lingnan Normal University, Zhanjiang, China

Driven by policies promoting environmental compliance, quality improvement, and rural revitalization, the adoption of pro-environmental fertilization technologies (PFTs) has become a critical component of China's sustainable agricultural strategy. Understanding how land psychological ownership (LPO) influences farmers' decisions to adopt such technologies is essential for enhancing agri-environmental governance. This study employs a binary logistic regression model to analyze survey data collected in 2022 from 489 rice farmers in southern China, examining their adoption choices regarding PFTs. The results indicate that LPO significantly increases the likelihood of PFT adoption, although this effect is moderated by factors such as land certification, social identity, and farmers' capabilities. Based on these findings, we propose an integrated policy approach that combines psychological empowerment, institutional support, and capacity-building measures—including land certification, village regulations, and farmer field schools—to facilitate the translation of LPO into sustainable farming practices. By integrating insights from behavioral economics and technology diffusion theory, this study offers a collaborative governance framework that aligns property rights incentives, social recognition, and skill development to address persistent challenges in environmental policy implementation.

KEYWORDS

land psychological ownership, pro-environmental fertilization technology, resource property rights, environmental governance, physical ownership

1 Introduction

National food security has long been vital to social stability in China (Jiang et al., 2019). Chemical fertilizers greatly increased food production, but their overuse has caused serious ecological damage. This situation has led researchers and policymakers to recognize that food security cannot be pursued at the expense of the environment (Van Wesenbeeck et al., 2021). In response, the government has promoted pro-environmental fertilization technologies (PFTs) through a series of policies.

Yet farmers' adoption of PFTs remains lower than expected. Studies show that while most farmers are aware of these technologies, fewer than one-third actually use them. Understanding the key drivers of adoption is therefore essential for improving environmental governance (Sheng et al., 2020; Allan et al., 2021). Existing research, however, has focused mainly on

economic incentives or awareness, while giving little attention to the psychological dimension of property rights (Zhong et al., 2022).

Theories such as the tragedy of the commons, the Coase theorem, and the endowment effect link property rights to conservation (Hardin, 1968; Thaler, 1980; Qu et al., 2023). Chinese scholars have further developed a composite property rights theory, which emphasizes that formal ownership (FO) shapes psychological ownership (PO) through emotional bonds (Qu et al., 2023). Within this framework, farmers' attachment to land strongly influences their land use decisions. Land carries both livelihood functions and symbolic meaning, which encourages sustainable practices through psychological attachment (Boley et al., 2021; Pai et al., 2024; Dang and Weiss, 2021). Despite this, few studies have examined how PO mediates the link between FO and behavior, especially in the adoption of PFTs. The role of land psychological ownership (LPO) in small rural settings remains largely unexplored.

PO theory, originally developed in organizational studies, focuses on individuals' sense of possession over objects (Boone, 2019). Research in consumer behavior shows that PO can exist without legal ownership and still increase willingness to protect resources. In China's land system, the gap between FO and PO highlights the limits of a simple linear model that moves from FO to PO and then to behavior.

Empirical findings across countries also show mixed results (Thompson et al., 2024; Arhin et al., 2023). Some studies, such as those by Boone and Bruce, found that formal property rights encourage cropland conservation (Boone, 2019; Bruce et al., 2022; Hayes et al., 1997; Brasselle et al., 2002; Fenske, 2011; Sitko et al., 2014). Others, particularly in African contexts, did not find significant effects (Fenske, 2011). This variation points to the moderating role of PO. Adoption is often constrained when farmers lack secure rights, adequate capabilities, or strong social identity.

To address these issues, we apply a binary logit regression model using survey data from 489 rice farmers in South China. Our analysis focuses on how LPO shapes PFT adoption decisions. The results highlight LPO's role in activating a pathway of emotional attachment, control preference, and responsibility, which drives pro-environmental adoption. We also identify the boundaries of this effect, which depend on land certification, social identity, and farmers' capability. In doing so, we move beyond property rights determinism and propose an integrated Institution–Psychology–Behavior (IPB) framework. This framework bridges property rights theory and collective action, offering a behavioral economics perspective on technology diffusion and addressing the persistent "incentive compatibility dilemma" in environmental governance (Rogers et al., 2014).

2 Literature review

2.1 The relationship between PO and FO

Notwithstanding legal ownership, PO enables individuals to cultivate a sense of "ownership" of things (Pierce et al., 2001), tangible or intangible. This perception arises from the individual's control, intimate knowledge, and self-investment in the entity, resulting in the individual perceiving the target as an extension of the self. Consequently, the individual assigns a higher value to the entity (Thaler, 1980), reflecting a psychological state in which people perceive objects as extensions of themselves. PO expresses virtual power, encompassing individuals' sense of control, identity, and efficacy over their possessions.

On the other hand, FO represents the de facto control of things protected by law. It expresses real power, including people's ownership, use, and residual rights to goods. Significant differences exist between PO and FO (Barzel, 1989). First, PO centers on an individual's sense or belief in possession of an object. It is not necessarily protected by law, nor does it necessarily depend on the physical possession (Pierce et al., 1991). Even if the exchange of goods occurs, PO may persist.

In contrast, FO is transferred once goods are exchanged and rights are legally reassigned (Jiang et al., 2019). The PO reflects the emotional and psychological bond between the individual and the object (Morewedge, 2021). FO, however, is based on a legal relationship and does not include the emotional attachment or self-extension associated with the object. Finally, PO is a higher-order, multi-dimensional construct. It contains cognitive components such as an individual's possession consciousness and protection belief, as well as emotional components such as pleasure and a sense of responsibility (Peck and Luangrath, 2023).

Respectively, FO primarily involves the cognitive elements of legal relations and social identity (Guan et al., 2025). PO is based on the 'sense of possession,' while FO is based on 'possession' itself (Adenuga et al., 2025). Therefore, PO is not contingent upon FO. The PO is based on the 'sense of possession,' while FO is based on 'possession' itself. Therefore, PO is not contingent upon FO.

2.2 The impact of LPO

The establishment of PO has been demonstrated to engender reinforced emotional attachment and a sense of control in the individual. This attachment has many positive outcomes, including increased employee commitment, innovation, and consumer purchasing intent. Achtypi et al. suggested that a sense of job mission amplifies PO, prompting employees to value their positions more highly and respond proactively to job-related threats with constructive actions (Achtypi et al., 2021). Farmers with a stronger sense of PO over their land are likelier to adopt sustainable farming practices, such as PFTs. This is due to their emotional connection to the land and long-term investment (Adenuga et al., 2025). People are naturally inclined to protect what they own and value. As such, when farmers feel a PO of the land, it strengthens their sense of belonging and identity, thereby increasing its perceived value. This psychological attachment triggers the endowment effect, which motivates farmers to adopt PFTs to care for and protect the land.

In organizational behavior, Jami et al. discovered that PO can galvanize employees' heightened sense of responsibility, propelling them to embrace team missions and innovate proactively (Jami et al., 2021). This, in turn, exerts a salutary influence on the organization's innovative capacity (Düger, 2021; Abbas et al., 2022). Similarly, Yue and Wang argued that live brand experiences can intensify PO, leading customers to perceive the brand as an extension of their self-worth (Yue and Wang, 2023). This perception increases their willingness to pay a premium and advocate for the brand. Chapman et al. contended that limited edition products can easily trigger PO, boosting

Abbreviations: LPO, Land Psychological Ownership; PFT, Pro-environmental fertilization technology; FO, Formal ownership; PO, Psychological ownership.

consumers' willingness to purchase limited edition products (Chapman et al., 2023). However, PO can also lead to negative behaviors. Pierce suggested that an excessive desire for control stemming from PO might precipitate counterproductive behaviors such as knowledge hoarding (Van Wesenbeeck et al., 2021). Kahneman et al. demonstrated that PO can heighten employee sensitivity, resulting in noncompliant behaviors obstructing collaboration and advisory input from others (Kahneman et al., 1990).

2.3 The LPO of farmers' behaviors of PFT

Scholarly inquiry into farmers' behaviors of PFT has broadened to encompass the sway of psychological factors, thereby enriching the theory of planned behavior and the theory of emotional motivation. Farani et al. have demonstrated that environmental responsibility and attitudes substantially influence farmers' engagement in pro-environmental actions (Yaghoubi Farani et al., 2019). Similarly, Rezaei et al. showed that subjective norms, ecological sentiments, and behavioral attitudes significantly impact farmers' ecologically conscious conduct (Rezaei et al., 2019). Teixeira et al. identified a link between the reverence for nature and the propensity for pro-environmental behavior (Teixeira et al., 2023). Despite these advancements, examining LPO on farmers' behaviors of PFT has not received adequate scholarly attention. The specific role of LPO in influencing farmers' adoption of PFTs remains underexplored, which presents an opportunity for a deeper analysis of how emotional ties to land can motivate sustainable farming practices. Current research treats LPO as a mediating or moderating variable, which may not suffice to uncover this phenomenon's more profound environmental governance implications (Collard et al., 2020).

Exploring the behavioral logic of farmers' behaviors of PFT from the vantage point of the LPO is essential for a profound understanding of the underlying psychological drivers and their influence on behavior. This approach can shed light on how the LPO can be harnessed to motivate and reinforce green production practices among farmers. Basing on this theoretical foundation and identified research gap regarding the direct role and contextual boundaries of LPO, our study develop several specific hypotheses regarding how LPO influences PFT adoption and the conditions under which this influence operates.

3 Theoretical derivation and hypothesis formulation

3.1 The effect of LPO on farmers' pro-environmental technology adoption decisions

The PO reflects an object's value in an individual's mind and necessarily involves the interaction between the individual and the object. From the perspective of psychological feeling, the degree of ownership of an object by an individual is a key factor in determining the strength of the role of PO. The emotional dependence and identification generated by the individual to the object is the essential driving force of the role of PO. The PO is expressed in the individual's subjective sense of ownership, and this subjective will reflects the distribution of benefits between the individual and society. Whether this relationship is stable and achievable is closely related to the motivation and expectations of both parties.

The PO has been proven to have a positive effect on individual behavior. According to Higgins' regulatory focus theory, farmers with a prevention focus are more inclined to pursue safety and avoid adverse outcomes (Avey et al., 2009). Compared with promotion-type psychological ownership, farmers with the conservative characteristics of prevention-type psychological ownership are more likely to adopt PFTs to prevent potential harm to their land (Sheng et al., 2020; Allan et al., 2021). Additionally, LPO enhances farmers' positive emotions toward environmental protection. According to the self-enhancement motivation theory, one of the basic human motivations is to construct and maintain a favorable self-image. Humans have an inherent motivation to pursue higher emotional states and positive self-perception. This emotional consistency is crucial in influencing the intensity and direction of self-enhancement motivation and significantly affects individual behavior in adopting environmentally friendly fertilization techniques (Zhong et al., 2022). The LPO reflects farmers' sense of ownership over ecological resources, suggesting an emotional connection that can bring pleasure and enhance their inclination to participate in environmental governance. As the PO of land strengthens, the preference for control over ecological resources also increases. The psychological realization of this sense of control enhances farmers' sense of efficacy and satisfaction, ultimately motivating them to participate actively in environmental governance (Xiong et al., 2024).

> Hypothesis 1: The LPO positively impacts pro-environmental behavior.

3.2 Impact of LPO on farmers' pro-environmental technology adoption decisions: moderating effects based on agricultural land certification, social identity, and capability

In the theoretical framework of property rights affecting behavior, the efficacy of LPO in driving PFT adoption is contingent upon the implementation environment. Property rights definition and implementation form a structural interlocking relationship as the former points to the subjective attribution of rights, and the latter involves the actual path of rights. The practical efficacy of property rights enforcement constitutes the boundaries of the effectiveness of property rights definition. When the boundaries of property rights are blurred, the enforcement of rights loses the benchmarks of behavioral expectations, resulting in the failure of exclusionary control to create stable value feedback and weakening the institutional incentives for benefits to be realized (Hardin, 1968). Based on this logical correlation, it can be deduced that if LPO directly influences farmers' decision-making motivation to adopt pro-environmental technologies through subjective attributional perceptions, property rights implementation inevitably becomes a key moderating field for the transformation of such perceptions into technology decisions (Thaler, 1980).

The strength of property rights enforcement is measured by the likelihood and cost of enforcing it and relies on a combination of legal certification, social identity, and capability (Qu et al., 2023). In

the chain of transmission from PO to technological decision-making, agricultural land certification (legal empowerment), social identity, and behavioral capabilities function as regulators through a threefold mechanism: (1) Agricultural land certification solidifies the exclusivity guarantee of technological gains through institutional rigidity. (2) Social identity re-configures the rules of the flow of technological factors through the toughness of the informal system. (3) Behavioral capabilities overcome the operational constraints of technological adoption through the elasticity of resources by enhancing resource flexibility (Boley et al., 2021; Pai et al., 2024; Dang and Weiss, 2021). Each of the three acts on the optimization process of technology factor allocation efficiency, amplifying the decision-making incentives of PO by reinforcing benefit exclusivity and enhancing the practical efficacy of PO by reducing the cost of technology transformation.

This moderating mechanism suggests that the depth of PO's influence on technological decision-making results from the combined shaping of the three dimensions of formal institutional rigidity, informal institutional resilience, and capability resilience (Pierce et al., 1991).

(1) The moderating effect of agricultural land certification

Through the triple path of institutional rigidity, property rights term incentives, and market synergy, agricultural land certification systematically regulates the intensity of PO on technology decision-making (Boley et al., 2021; Boone, 2019). The essence is to transform subjective ownership perceptions into a predictable framework of behavioral incentives by re-configuring the stability and accessibility of the property rights system.

Firstly, confirming agricultural land rights solidifies farmers' legal control over the land and reconstructs the perception of the spatial distribution of technological benefits by stabilizing property rights expectations (Bruce et al., 2022). When the contractual relationship is legally recognized as continuous, the sense of intergenerational inheritance endogenous to the psychological ownership of land is coupled with the motivation to maintain soil quality, and technological risks that were initially overestimated due to uncertainty of property rights are transformed into predictable earmarked investments (Hayes et al., 1997). The institutional commitment device created by land certification positively correlates the strength of incentives for technological decisions from LPO with the duration of property rights (Brasselle et al., 2002). In other words, by defining the exclusionary boundaries of technological benefits, agricultural land certification provides institutional rigidity for transforming LPO into technological adoption behavior (Deininger et al., 2011).

Secondly, agricultural land certification reduces contractual incompleteness in factor transactions through tenure certificates and unblocks the path from LPO to technical decision-making. Confirming agricultural land rights realizes the institutional separation of contractual and management rights. On the one hand, the contracting right with identity attributes strengthens farmers' sense of intergenerational responsibility for the ecological characteristics of the land, while the management right with market attributes reveals techno-economic gains through factor pricing. This property rights segmentation aligns the personalized features of PO with the rules of factor marketization and promotes the incentive compatibility of ecological and economic rationality in technology adoption (Brasselle et al., 2002; Fenske, 2011).

Finally, agricultural land certification reshapes the framework of market transactions through standardized property rights certificates, creating an operable regulatory interface between psychological ownership and technological decision-making. The legal effect of ownership certificates removes the informational ambiguity in the transfer of management rights and transforms subjective ownership identities into objective property boundaries; meanwhile, the principle of the legal right of ownership imposes rigid constraints on the relationship between rights and responsibilities of technology applications, so that the sense of long-term maintenance embedded in psychological ownership is solidified into an enforceable institutional commitment. These two aspects jointly reduce the transaction costs of technology transformation and enhance the efficiency of the spatio-temporal matching between psychological ownership awareness and technology adoption behavior.

> Hypothesis 2: Agricultural land certification moderates the impact of LPO on farmers' adoption of pro-environmental technologies.

(2) Moderating effects of social identity

Social identity sets behavioral boundaries through informal norms, defines values through cultural symbol systems, and reshapes information transmission paths through relational networks (Sitko et al., 2014). Together, they constitute a 'social filter' that transforms psychological ownership into technical decision-making, reinforcing incentives to conform to group norms and inhibiting technical choices that deviate from collective values.

First, social identity re-configures the value weights of technological decisions through the ethical constraints of informal norms. When communities develop a moral consensus on pro-environmental practices, social identity transforms individual responsibility perceptions in PO into norms of group obligation, shifting technological choices from economic to ethical rationality (Pierce et al., 2001). This normative identity binds individual technology adoption behaviors to community ecological values through the reproduction mechanism of collective memory, creating an implicit contract of 'duty to protect' (Barzel, 1989). In this context, technological decisions that go against group norms will lead to a depreciation of social capital, forcing farmers to prioritize the constraints of the informal system driven by psychological ownership (Barzel, 1989; Tang and Luo, 2022).

Secondly, social identity reshapes the cognitive framework of technological decision-making through the symbolic system of group affiliation. The symbolic significance of land as 'family ecological capital' is reinforced as an identity marker through the cultural resilience of social identity. When farmers' "land-family" psychological connection resonates with the community's cultural identity, the criteria for evaluating technology decisions shift from short-term economic gains to intergenerational transmission values (Morewedge, 2021). This reinforces a sense of inter-generational maintenance in PO and, through the reproduction of cultural symbolic systems, translates into a pathway of technological choice that meets the group's expectations and drives the momentum for pro-environmental technologies (Peck and Luangrath, 2023).

Finally, social identity amplifies the externalities of technology decisions through the trust transmission mechanism of relational networks (Roberts and Burleson, 2013). Farmers' technology choice behaviors are valued in a strong social identity environment by incorporating them into a network of relationships in a differential order pattern (Guan et al., 2025). Individual decisions driven by psychological ownership are translated into group behavior paradigms through the relational identity dimension of social identity (Adenuga et al., 2025). On the one hand, technology adoption by core farmers creates a demonstration effect through the social comparison mechanism, which triggers a chain reaction of herd mentality (Achtypi et al., 2021), on the other hand, community members reduce the perceived risk of technology conversion through information sharing and mutual verification of experiences, so that the decision-making incentives of PO break through the limitations of individual rationality (Sheng et al., 2020).

> Hypothesis 3: Social identity moderates the LPO, affecting farmers' pro-environmental technology decision-making.

(3) The moderating effect of capability

Capability of re-configuring the transmission interface between PO and technological decision-making through knowledge dimensions: (1) Technological knowledge base determines the base bandwidth of psychological ownership. (2) Technological decoding capabilities optimize the efficiency of psychological ownership-driven information processing, and technological adaptive capabilities stabilize the risk–benefit ratio of the transformation of psychological ownership practices (Adenuga et al., 2025; Jami et al., 2021). They jointly constitute the dual function of technological knowledge as a buffer and amplifier in the cognitive-behavioral transformation.

Firstly, technological knowledge's stock re-configures the psychological ownership threshold for practical transformation. The depth of farmers' understanding of pro-environmental technologies determines the boundary of their ability to transform psychological ownership into technology adoption (Shikuku and Melesse, 2020). When knowledge accumulation breaks through the threshold, the ecological maintenance consciousness in the LPO can effectively match the operational mapping of technology applications and reduce the decision-making block caused by information asymmetry (Yue and Wang, 2023). This moderating effect is realized through a dynamic balance between knowledge potential and technological complexity—the more affluent the knowledge stock, the less the path of psychological ownership driving technological decisions is distorted by knowledge thresholds (Chapman et al., 2023).

Second, technological decoding capabilities reshape the technological dissemination pathways of psychological ownership. The knowledge translation mechanism in capability translates the ecological values embedded in psychological ownership into an actionable framework for technology assessment (Kahneman et al., 1990; Warkentin et al., 2017; Foster and Rosenzweig, 1995). Farmers with strong decoding ability can penetrate the cognitive barrier of technological terms and visualize the abstract psychological ownership identity into the comparative advantage of technological parameters, thus establishing a direct mapping of 'land maintenance needs—technology feature response' in decision-making (Swanepoel et al., 2020). This moderating effect mitigates the risk of dissipating the efficacy of PO by incomplete technical information (Yaghoubi Farani et al., 2019; Rezaei et al., 2019).

Further, optimizing technology adaptation moderates the perceived risk structure of psychological ownership. When farmers have the knowledge base to localize and improve technology, they can adapt technology solutions to plot characteristics, significantly reducing the uncertainty of translating PO into technological practices. This ability can resolve the conflict between standardized technical protocols and heterogeneous land characteristics by re-configuring the fit between 'technical pre-conditions—actual state of the land' so that the risk of technology application does not adversely inhibit the sense of ecological responsibility in psychological ownership (Dang and Weiss, 2021; Adenuga et al., 2025; Luo et al., 2019) (Figure 1).

> Hypothesis 4: Capability plays a moderating effect in LPO, influencing farmers' pro-environmental technology decisions.

4 Data sources, variable setting and model selection

4.1 Data sources

In this study, samples were drawn using a combination of probability sampling and random sampling proportional to size, as well as a one-on-one on-site interview to fill out the questionnaire. We ensure that all methods are ethical and experimental protocols have been approved by designed institutions. In addition to this, we ensured that all procedures involving human participants were performed in accordance with the ethical standards of the Institutional Research Board, the 1964 Declaration of Helsinki and its later amendments, or similar ethical standards. Subjects or their legal guardians who participated in the questionnaire study had signed written informed consent. The specific sampling process is as follows: first, based on the size of the rural population in 10 prefecture-level cities in Guangdong Province and Hainan Province (Haikou County, Dongfang County, Danzhou County, Chengmai County, and Lingao County in Hainan Province; and Jiangmen City, Yangjiang City, Zhanjiang City, Maoming City, and Qingyuan City in Guangdong Province), one county and district were selected in each city using the probability proportional to size sampling (PPS) method; second, based on the proportion of the number of administrative villages in each township, two townships were selected in each county and district PPS method to select two townships; further, based on the proportion of the agricultural population in each administrative village, the PPS method was implemented to select five administrative villages in each township; and finally, five farming households were selected in each administrative village through simple random sampling. The above multi-stage composite sampling design sampled 100 administrative villages and 500 farm households.

In terms of data quality control, this study screened the samples based on the following criteria: firstly, limiting the dominant industry of the sample villages to rice cultivation or agricultural production units with rice as the main crop; secondly, excluding samples with missing data, logical contradictions, and invalid responses (including 'not applicable,' 'unclear,' or 'refused to answer,' etc.). After strict

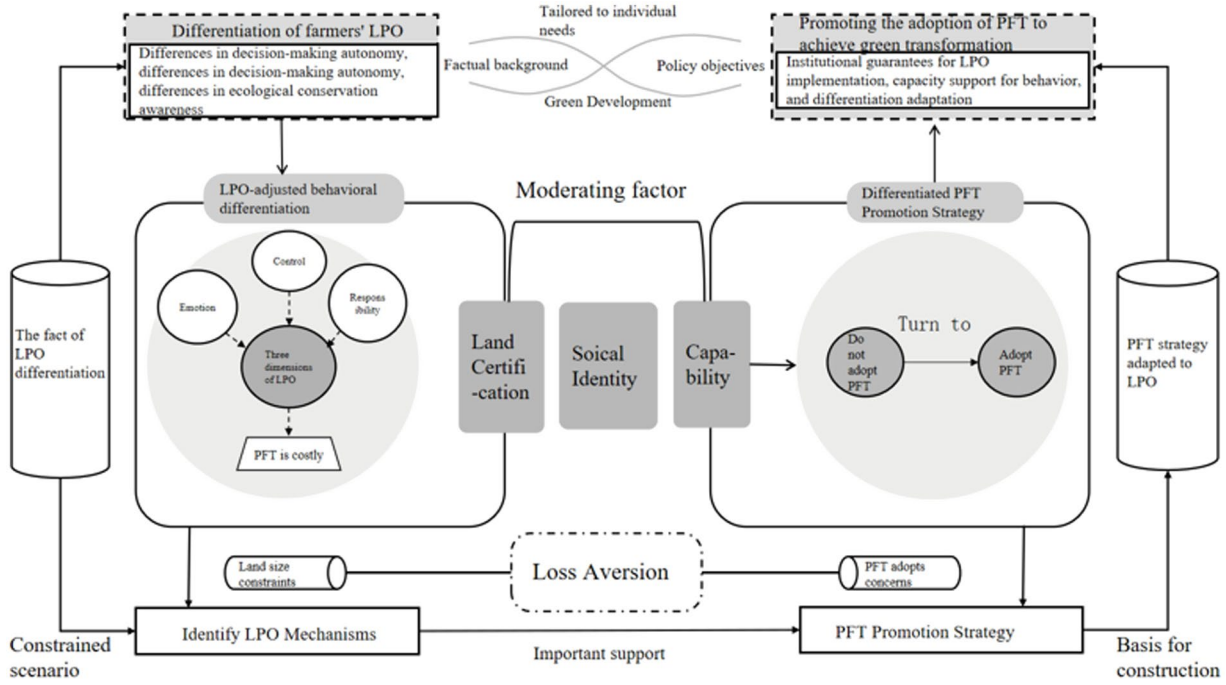

FIGURE 1
Theoretical framework.

screening, 489 valid questionnaires were retained, with an effective recovery rate of 97.80 percent.

The sample's demographic characteristics showed that the average age of the respondents was 45.1 years, and the gender composition showed significant differences, with 68.9 percent of the respondents being male. Regarding educational attainment, 57.99 percent of the sample had only completed junior high school and below. Characteristics of family structure showed that 66.67 percent had a family size of less than five persons. Analysis of economic indicators found that 50.23 percent of households had an annual income of less than RMB 50,000, and it is worth noting that 10 percent of households had annual incomes exceeding the RMB 80,000 threshold, driven by the implementation of the rural revitalization strategy and the policy of non-farm transfer of labor.

Data on agricultural production characteristics show that 63 percent of respondents consider the fertility of arable land to be at the lower-middle level and that more than 50 percent of terrain conditions are hilly and mountainous. Regarding risk management awareness, 55.25% of farmers have purchased agricultural insurance, indicating a strong understanding of risk prevention. Infrastructure assessment shows that most sample villages have good transport accessibility, but the overall level of economic development is medium.

4.2 Variable selection

4.2.1 Explained variable

The variable explained is the farmers' PFT behaviors. The study employs a binary measure to operationalize this construct: "In the most recent year, were green and pollution-free fertilizers or pesticides utilized?" This dichotomous indicator is a proxy for engagement in environmentally benign agricultural practices. Affirmative responses are coded with a value of 1, indicative of the use of green and pollution-free inputs, while negative responses are coded as 0, reflecting otherwise.

The empirical data shows that 43.4% of the surveyed farmers have engaged in green production by using green and pollution-free fertilizers or pesticides. Conversely, a substantial proportion, comprising 56.6% of the farmers, have not adopted such environmentally considerate practices. These statistics underscore a relatively low propensity among farmers to participate in environmental stewardship through their production choices, suggesting a subdued behavioral response to ecological concerns. It is thus imperative to delve deeper into the factors that may foster or hinder the adoption of green production practices among farmers, offering a valuable contribution to the literature on environmental economics and agricultural policy.

4.2.2 Explanatory variables

The core explanatory variable in this economic study is the LPO, which is fundamentally underpinned by the perception of ownership. To quantify this concept, the study employs the survey question: "Who do you think owns the land resources in your village?" Responses are coded as follows: a value of 1 for "the state," 2 for "the collective," and 3 for "the villagers." The coding scheme reflects the strength of the LPO with a response indicating ownership by "the state" is assigned the lowest value 1, suggesting the weakest LPO, while the opposite, indicating ownership by "the villagers," is assigned the highest value 3, indicating the most decisive LPO.

The statistical analysis of the LPO status among farmers reveals that 34.7% of the respondents believed ecological resources were owned by the state, 51.6% by the collective, and 13.7% by the

individual villagers. These findings suggest a nuanced perception of ownership, with most farmers attributing ownership to the collective, which may imply a moderate level of LPO. The significant proportion of farmers who believe in collective ownership indicates a shared sense of responsibility and attachment to ecological resources, a critical factor in environmental management and policy-making.

4.2.3 Moderating variable

The generation mechanism of farmers' pro-environmental technology decisions is essentially the result of the coupling of individual behavioral choices driven by the psychological ownership of land and the constraints of the institutional environment. Classical technology adoption theory stresses that particular behavior is driven by internal cognition and needs to be embedded in the 'legitimacy-feasibility' framework of the external institutional environment. Precisely, the institutional environment can reshape the transmission path from psychological ownership to technology decision-making through the following three-dimensional regulatory mechanisms:

Institutional Rigidity. Formal institutions, represented by agricultural land certification, determine whether LPO can be translated into stable technology investment expectations by clarifying property boundaries and legal guarantees (Hayes et al., 1997; Teixeira et al., 2023). For example, the issuance of certificates of title reduces the risk of land encroachment and increases farmers' trust in the long-term benefits of pro-environmental technologies, thereby increasing the explanatory power of PO for decision-making (Boone, 2019).

Institutional Resilience. As a manifestation of informal institutions, social identity moderates the strength of psychological ownership of land through community normative pressure and group modeling effects (Collard et al., 2020; He, 2023). When pro-environmental technology is perceived as an identity marker for 'responsible land users', high social identity amplifies the positive incentives of PO on technology adoption; conversely, it may dampen its effect (Avey et al., 2009).

Operational Elasticity. Capability centered on resource endowments (capital, skills, information acquisition) determines whether LPO can be transformed into actual behaviors beyond the limits of objective conditions (Hayes et al., 1997). Even if farmers have strong LPO, they cannot develop motivation for technological decision-making without technological and operational capabilities (Higgins, 2012).

This study incorporates agricultural land certification, social identity, and capability into the moderating variables system. The theoretical rationale is that the three correspond to the rigidity of the formal system, the resilience of the informal system, and the flexibility of the capacity to act, which can systematically deconstruct the differentiated expression of psychological ownership in different institutional contexts. This analytical framework not only echoes the principle of 'institutional diversity' but also provides a synergistic intervention path of 'rigid regulation - flexible norms - capacity building' for policy design.

4.2.4 Control variables

The control variables include individual and household characteristics (age, gender, education, religious belief, number of persons in the household, total household income), land resource characteristics (number of plots contracted, soil fertility of contracted land), risk and protection mechanisms (agricultural insurance), and village environmental characteristics (village topography, transportation conditions in villages, level of village economic development). They interfere with the relationship between the core explanatory variables and pro-environmental technology adoption through three types of mechanisms: (1) If resource endowment interference (e.g., income, number of plots) is not controlled, the true association can be confounded between psychological land ownership and PFT adoption (e.g., higher-income farmers have both a stronger sense of psychological ownership and can bear the costs of technology). (2) Sociocultural disturbances (e.g., gender religious beliefs) should be carefully considered to avoid misjudging cultural preferences as a function of LPO (Beyers and Muza, 2022). (3) Environmental constraints (e.g., terrain, transportation) should be addressed to prevent external conditions limiting the technology's feasibility and ensure that psychological land ownership accurately reflects farmers' active decision-making. This is specified below:

(1) Age. The life-cycle hypothesis suggests that age influences risk preferences and technology learning ability. Older farmers may avoid new technologies due to risk aversion, but long-term farming experience may also enhance technology suitability judgments (Afridi et al., 2021).
(2) Gender. Gender role theory states differences between men and women regarding access to resources and decision-making power (Quisumbing and Pandolfelli, 2010). Farmers with male-dominated decision-making may be more inclined to invest in machinery-intensive technologies, while women may be concerned with ecological sustainability (Elliott and Esty, 2021).
(3) Education. The human capital theory emphasizes that education enhances information processing and technology awareness. Farmers with higher levels of education are more likely to understand the benefits of pro-environmental technologies and have a higher probability of adoption (Chua and Yau, 2022).
(4) Religious belief. Cultural values theory suggests that religious beliefs may shape ecological ethics. Certain religions advocate harmony with nature and may promote the adoption of pro-environmental technologies (Alchian and Demsetz, 1973).
(5) Number of persons in the household. Labor supply theory states that household size affects labor allocation and risk-taking capacity. Larger households may experiment with new technologies because of labor abundance but avoid long-term investments because of subsistence pressures (Xie et al., 2023).
(6) Total household income. Budget constraint theory suggests that income determines the ability to pay for technology investments. Higher-income households can afford the initial costs of pro-environmental technologies (e.g., organic fertilizer acquisition) (Kern and Mustasilta, 2023; Benjamin, 1992).
(7) Number of plots contracted. Economies of scale theory suggest that the number of plots affects the marginal returns to technology diffusion (Suri, 2011). Fragmentation of plots may increase the difficulty of managing the technology and inhibit adoption (Yang et al., 2019).
(8) Soil fertility of contracted land. The resource-based view suggests that the quality of resources affects the expected effectiveness of technology applications. Farmers with poor

soils rely on pro-environmental technologies (e.g., improved fertilizers) to boost outputs (Walker et al., 2004; Kawasaki, 2010).

(9) Agricultural insurance. Risk buffering theory states that insurance promotes investment in technology by reducing uncertainty (Marenya and Barrett, 2007). Insured farmers are more likely to experiment with pro-environmental technologies because of their increased risk resilience (Feder et al., 1985).

(10) Village topography. The geographical constraints hypothesis emphasizes that topography affects technology applicability and diffusion costs. Plains are more likely to adopt technologies because of the ease of mechanization, while mountainous areas may prefer adaptive ecological measures (e.g., terracing for water retention) (Addis et al., 2020).

(11) Transportation conditions in villages. Spatial economics theory suggests that accessibility determines the availability of information and resources (Cole et al., 2013). Easily accessible villages are more likely to access technical training and market support, facilitating technology diffusion (Bo and Ruimei, 2021; Binswanger and Rosenzweig, 1986).

(12) Level of village economic development. Regional development theory suggests that the economic level reflects the capacity to provide infrastructure and public services. Villages with high economic levels are likely to have better agricultural extension systems and lower barriers to technology adoption (Ma et al., 2022; Jacoby, 2000).

Controlling for these variables allows for more precise identification of the net effect of psychological ownership on technology adoption, avoids endogeneity bias due to omitted variables, and enhances the rigor of causal inference. Descriptive statistics are shown in Table 1.

5 Empirical analysis

5.1 The effect of LPO on farmers' behaviors of PFT

We first test Hypothesis 1 concerning the direct effect of LPO. Given the binary nature of farmers' behaviors of PFT, this study opts for the Logit Model to conduct empirical analysis. Model 5 delineates the LPO's impact on farmers' PFT behaviors, excluding control variables. Model 6, on the other hand, accounts for these variables and examines their influence on the role of LPO in shaping green production behavior. Both models consistently indicate a

TABLE 1 Descriptive statistics.

Variables	Description of variables	Mean	Standard deviation
PFT	Whether green and harmless fertilizers or pesticides are used (1 = yes; 0 = no)	0.434	0.497
LPO	Who do you think owns the land resources in your village? (1 = state; 2 = collective; 3 = villagers)	1.790	0.665
land certification	Knowledge of the content and substance of the certificate of agricultural land rights (1 = yes; 0 = no)	0.502	0.501
Social identity	In deciding whether to adopt pro-environmental technologies, how much do you think the practices of the majority of farmers around you affect you? (1 = very little; 2 = average; 3 = a lot)	1.977	0.820
Capability	Do you feel adequately equipped with the knowledge and skills required for pro-environmental technologies?	1.739	0.761
Age	Age (years)	45.105	12.388
Gender	Sex (1 = male; 0 = female)	0.689	0.464
Education	Educational level (1 = elementary school and below; 2 = junior high school; 3 = high school or secondary school; 4 = college and above)	2.365	1.020
Religious belief	Religious affiliation or lack thereof (1 = yes; 0 = no)	0.594	0.492
Number of persons in the household	Number of persons in the household (persons)	5.110	1.630
Total household income	Total household income in 2021 ($ million)	5.397	0.584
Number of plots contracted	Number of plots contracted (plots)	5.055	4.408
Soil fertility of contracted land	Soil fertility of contracted land (1 = very poor; 2 = poor; 3 = fair; 4 = good; 5 = very good)	2.936	1.360
Agricultural insurance	Has your household purchased agricultural insurance (1 = yes; 0 = no)	0.553	0.498
Village topography	The terrain in which your village is located (1 = mountainous; 2 = hilly; 3 = plain)	2.210	0.915
Transportation conditions in villages	Access to your village (1 = very poor; 2 = poor; 3 = fair; 4 = good; 5 = very good)	4.091	0.643
Level of village economic development	Level of economic development in your village (1 = very poor; 2 = poor; 3 = average; 4 = good; 5 = very good)	3.566	0.801

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

10.3389/fsufs.2025.1644535

significant positive impact of LPO on the propensity of farmers to engage in green production practices. Notably, the magnitude of this impact diminishes upon the inclusion of control variables, suggesting that the influence of LPO may be overestimated in the absence of such considerations.

Furthermore, the marginal effect of LPO on farmers' behaviors of PFT is quantified. The findings reveal that the marginal impact stands at 0.188, implying that for every 1% increase in the intensity of the LPO, the likelihood of farmers' involvement in environmental stewardship escalates by 0.188 percentage points. Consequently, Hypothesis 1 is substantiated. The rationale behind this outcome is rooted in the role of LPO as a manifestation of farmers' proprietary sentiments towards ecological resources and the environment. This sense of ownership fosters a sense of responsibility and a psychology of loss aversion, which, in turn, encourages their engagement in green production activities. Next, we turn to examining the hypothesized moderating effects.

5.2 Moderating factor of agricultural land certification

To test Hypothesis 2 regarding the moderating effect of agricultural land certification, this study incorporates an interaction term between the confirmation of agricultural land rights and LPO, augmenting Model 2. The findings are presented in Table 2. Before the inclusion of the interaction term, the main effect is observed to be statistically significant. However, once the interaction term is introduced, the main impact becomes statistically insignificant, while the interaction term itself is substantial.

The presence of the interaction term may engender multicollinearity between the explained variable and the interaction term, as it encapsulates the variance in farmers' behaviors of PFT attributed to the land's psychological ownership. The interpretation of the regression coefficients should be predicated on the initial significant main effect before introducing the interaction term. After adding the interaction term, the regression coefficients indicate that the interaction effect is positively and significantly associated with farmers' behaviors of PFT at the 1% confidence level. This suggests that agricultural land certification positively influences LPO and farmers' engagement in green production practices.

The theoretical basis for this discovery lies in the formal institutional role of confirming agricultural land rights. It has legal attributes and enhances the impact of LPO on farmers' behavior of PFT by delineating property rights boundaries. Therefore, Hypothesis 2 is supported by empirical evidence.

To investigate the moderating effect of social identity on the impact of LPO on farmers' behavior towards pro-environmental fertilizer application techniques, this study expanded Model 2 by introducing an interaction term between social identity and LPO. The results of the study are presented in Table 3. The main effect is statistically significant before including the interaction term. After including the interaction term, the regression coefficients show that the interaction effect is significantly and positively related to farmers' pro-environmental fertilizer technology behavior at the 1% confidence level. This indicates the positive impact of social identity on the psychological ownership of farmland and farmers' participation in green production practices.

TABLE 2 Relationship between agricultural land certification among LPO and farmers' behavior of PFTs.

Variables	OLS model		Logit model	
	Model 3	Model 4	Model 5	Model 6
LPO	0.092**	0.066	1.202***	1.156
	(0.038)	(0.046)	(0.434)	(0.984)
Land certification	0.643***	0.242*	4.562***	0.269
	(0.061)	(0.142)	(0.709)	(1.481)
LPO × land certification		0.235***		3.012***
		(0.066)		(1.075)
Age	−0.006***	−0.005***	−0.067***	−0.062**
	(0.002)	(0.002)	(0.025)	(0.025)
Gender	0.015	0.012	0.117	0.029
	(0.046)	(0.045)	(0.556)	(0.595)
Education	−0.012	−0.011	−0.050	0.074
	(0.025)	(0.024)	(0.318)	(0.319)
Religious belief	−0.005	0.021	−0.177	−0.021
	(0.047)	(0.047)	(0.530)	(0.542)
Number of persons in the household	0.017	0.012	0.237	0.240
	(0.013)	(0.013)	(0.177)	(0.191)
Total household income	−0.023	−0.031	−0.374	−0.503
	(0.041)	(0.040)	(0.484)	(0.506)
Number of plots contracted	0.007	0.008	0.086*	0.098*
	(0.005)	(0.005)	(0.051)	(0.056)
Soil fertility of contracted land	−0.013	−0.006	−0.153	−0.023
	(0.018)	(0.018)	(0.214)	(0.218)
Agricultural insurance	0.170***	0.173***	2.116***	2.162***
	(0.046)	(0.045)	(0.596)	(0.611)
Village topography	−0.033	−0.029	−0.306	−0.386
	(0.028)	(0.027)	(0.335)	(0.357)
Transportation conditions in villages	0.006	0.016	0.070	0.082
	(0.034)	(0.034)	(0.415)	(0.414)
Level of village economic development	−0.032	−0.026	−0.559	−0.571*
	(0.029)	(0.029)	(0.343)	(0.342)
Constant	0.269	0.428*	−1.166	1.973
	(0.234)	(0.234)	(3.137)	(3.181)
R-squared	0.302	0.295	0.626	0.650

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

The theoretical basis for this finding lies in recognizing the informal institutional role of social identity. Hypothesis 3 was supported by empirical evidence.

To investigate the moderating effect of capability on the impact of LPO on farmers' behavior towards PFT, this study expanded Model 2 by introducing an interaction term between capability and LPO (Zheng et al., 2020). The results of the study are presented in Table 4. The main effect is statistically significant before including the interaction term. After the inclusion of the interaction term, the regression coefficients showed that the interaction effect is significantly and positively related to farmers' behavior of PFT at the 5% confidence

10.3389/fsufs.2025.1644535

TABLE 3 Relationship between social identity among LPO and farmers' behavior of PFT.

Variables	OLS model		Logit model	
	Model 7	Model 8	Model 9	Mode; 10
LPO	0.106** (0.049)	0.229* (0.125)	0.824** (0.379)	3.481*** (1.274)
Social identity	0.214*** (0.036)	0.051 (0.098)	1.469*** (0.287)	1.655** (0.900)
LPO* Social identity		0.157*** (0.054)		2.039*** (0.590)
Age	−0.001 (0.003)	−0.001 (0.002)	−0.010 (0.020)	−0.019 (0.021)
Gender	0.047 (0.057)	0.039 (0.057)	0.278 (0.438)	0.049 (0.476)
Education	0.037 (0.030)	0.027 (0.030)	0.372 (0.240)	0.330 (0.248)
Religious belief	−0.080 (0.058)	−0.053 (0.058)	−0.584 (0.417)	−0.561 (0.437)
Persons in the household	0.036** (0.016)	0.029* (0.016)	0.299** (0.136)	0.317** (0.147)
Total household income	−0.052 (0.051)	−0.037 (0.051)	−0.309 (0.387)	0.026 (0.412)
Number of plots contracted	0.015** (0.007)	0.014** (0.007)	0.116** (0.050)	0.119** (0.052)
Soil fertility of contracted land	0.014 (0.023)	0.017 (0.022)	0.047 (0.165)	0.104 (0.169)
Agricultural insurance	0.182*** (0.058)	0.201*** (0.058)	1.348*** (0.432)	1.603*** (0.469)
Village topography	−0.124*** (0.034)	−0.117*** (0.034)	−0.901*** (0.265)	−1.088*** (0.290)
Transportation conditions in villages	0.017 (0.043)	0.037 (0.043)	0.183 (0.308)	0.393 (0.337)
Village economic development	−0.002 (0.038)	−0.015 (0.038)	−0.102 (0.268)	−0.355 (0.290)
Constant	−0.256 (0.299)	0.232 (0.338)	−5.824** (2.368)	0.429 (2.957)
R-squared	0.422	0.443	0.426	0.475

TABLE 4 Relationship between capability among LPO and farmers' behavior of PFT.

Variables	OLS model		Logit model	
	Model 11	Model 12	Model 13	Model 14
LPO	0.116** (0.049)	0.153*** (0.044)	0.890** (0.375)	1.387 (1.067)
Capability	0.224*** (0.037)	0.106*** (0.030)	1.497*** (0.292)	0.521 (0.923)
LPO * Capability		0.328*** (0.027)		1.243** (0.555)
Age	−0.001 (0.003)	−0.004** (0.002)	−0.013 (0.019)	−0.020 (0.020)
Gender	0.038 (0.057)	0.016 (0.044)	0.309 (0.442)	0.076 (0.469)
Education	0.037 (0.030)	−0.010 (0.024)	0.365 (0.232)	0.355 (0.234)
Religious belief	−0.151** (0.059)	−0.008 (0.047)	−1.201*** (0.436)	−1.226*** (0.446)
Persons in the household	0.032** (0.016)	0.010 (0.013)	0.250* (0.133)	0.250* (0.137)
Total household income	−0.040 (0.051)	−0.030 (0.039)	−0.220 (0.391)	0.049 (0.416)
Number of plots contracted	0.012* (0.007)	0.008 (0.005)	0.092* (0.049)	0.095** (0.050)
Soil fertility of contracted land	0.012 (0.023)	−0.005 (0.018)	0.052 (0.164)	0.101 (0.166)
Agricultural insurance	0.225*** (0.058)	0.179*** (0.045)	1.693*** (0.446)	1.832*** (0.465)
Village topography	−0.093*** (0.034)	−0.027 (0.027)	−0.660*** (0.256)	−0.662** (0.264)
Transportation conditions in villages	−0.002 (0.043)	0.009 (0.033)	0.028 (0.314)	0.082 (0.324)
Village economic development	0.005 (0.039)	−0.009 (0.030)	−0.059 (0.265)	−0.165 (0.274)
Constant	−0.214 (0.298)	0.333 (0.233)	−5.172** (2.302)	−1.762 (2.731)
R-squared	0.421	0.425	0.425	0.443

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

level. This indicates a positive impact of capability on psychological ownership of farmland on farmers' participation in green production practices.

The theoretical basis for this finding is to confirm the role of behavioral competence. Hypothesis 4 was supported by empirical evidence.

5.3 Robustness tests

5.3.1 Replacement of explanatory variables

To assess the robustness of our primary findings regarding the LPO to PFT adoption relationship and its moderators, we conducted several supplementary analyses. In this study, we have utilized two distinct measures as alternative explanatory variables to assess their impact on farmers' behavior of PFT. The first measure pertains to the frequency of waste separation or the practice of straw return to the field, operationalized on a Likert scale ranging from 1 (very infrequently) to 5 (very often). The second measure evaluates the willingness to adhere to green production practices in establishing family farms, aquatic product processing plants, or livestock farms, scaled from 1 (very unwilling) to 5 (very willing). These variables were empirically tested using the Ologit Model. The empirical findings, as presented in Table 5, demonstrate that LPO significantly influences farmers' propensity to engage in PFT behaviors.

TABLE 5 Robustness test for alternative explanatory variables.

Variables	Ologit model	
	Model 15: decision-making for waste separation or straw return to fields	Model 16: family farms, fish processing plants, or livestock farms leading with green production
LPO	1.216*** (0.296)	0.995*** (0.294)
Age	−0.026* (0.014)	−0.023* (0.014)
Gender	0.212 (0.327)	−0.093 (0.321)
Education	0.301* (0.170)	0.377** (0.169)
Religious belief	−0.476 (0.326)	−0.390 (0.319)
Number of persons in the household	0.230** (0.098)	0.102 (0.092)
Total household income	−0.477 (0.300)	−0.331 (0.287)
Number of plots contracted	0.065* (0.036)	0.102*** (0.037)
Soil fertility of contracted land	0.073 (0.127)	0.183 (0.125)
Agricultural insurance	1.265*** (0.337)	0.754** (0.323)
Village topography	−0.669*** (0.200)	−0.815*** (0.192)
Transportation conditions in villages	0.112 (0.241)	0.203 (0.235)
Village economic development	−0.174 (0.212)	−0.145 (0.204)
R-squared	0.231	0.216

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

TABLE 6 Robustness test for the elimination of outliers.

Variables	Model 17: reduced tail treatment	Model 18: clog log model
LPO	1.225*** (0.321)	0.900*** (0.250)
Age	−0.004 (0.003)	−0.015 (0.013)
Gender	0.032 (0.060)	0.136 (0.268)
Education	0.056* (0.032)	0.263* (0.148)
Religious belief	−0.090 (0.061)	−0.399 (0.257)
Number of persons in the household	0.036** (0.017)	0.201** (0.084)
Total household income	−0.065 (0.054)	−0.336 (0.239)
Number of plots contracted	0.010 (0.007)	0.030 (0.027)
Soil fertility of contracted land	0.028 (0.024)	0.067 (0.108)
Agricultural insurance	0.233***(0.061)	0.971***(0.290)
Village topography	−0.114***(0.036)	−0.451***(0.157)
Transportation conditions in villages	0.022 (0.045)	0.171 (0.230)
Level of village economic development	−0.013 (0.040)	−0.136 (0.180)
Constant	−2.741 (2.035)	−2.348 (1.539)
R-squared	0.318	0.216

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

5.3.2 Elimination of outliers

The primary techniques for addressing outliers in regression analysis encompass the method of tail shrinking and the complementary log–log modeling approach. In this study, the regression analysis was executed by initially applying the tail shrinking method to the continuous variables-namely, age, number of persons in the household, number of plots contracted, and total family income-based on the 1 and 99%. Subsequently, these variables were regressed using the clog log model. As delineated in Table 6, the results indicate that LPO significantly impacts farmers' PFT behaviors.

5.3.3 Measurement and elimination of potential estimation bias

This paper addresses the potential for estimation bias due to unobservable variables by employing a method that leverages observable variables to quantify the likelihood of such bias. The procedure commences by conducting two sets of regression analyses, namely, one with minimal or no inclusion of control variables and the other with a comprehensive set of control variables. The key explanatory variables' coefficients are then calculated for both scenarios, denoted as the regression without or with few controls and the regression with full controls. Subsequently, the F-statistic is computed using the formula. A value of suggests robustness in the results; the more significant the *F*-value, the less influence unobservable factors have on the current estimation. Moreover, the closer it is to, the less impact the known control variables exert on the estimation, implying that a substantial number of additional controls would be required to alter the existing conclusions. Conversely, a larger indicates a more significant influence of control variables on the explanatory variables, necessitating a more substantial adjustment to the baseline regression.

In light of the green production behavior among farmers, this study constructs two regression groups with constrained control variables and two groups with all control variables, conducting empirical regressions (as shown in Table 7). The *F*-values obtained across the four scenarios range from 5.566 to 8.335, averaging 7.176. This suggests that to enhance the robustness of the Logit model's estimated results presented in Table 8, the number of unobservable variables would need to surpass the current total of control variables by at least a factor of 5.566, equating to 66.792 additional control variables. Given this scenario's impracticality, the estimation results' robustness is underscored in Table 8. Taken together, the empirical results provide consistent support for our hypothesized relationships.

6 Conclusions and policy implications

6.1 Conclusion

Based on the theoretical framework and empirical findings presented above, we draw the following conclusions and discuss their implications. This study examines the effect of LPO on PFT adoption

TABLE 7 Measurement and exclusion of potential estimation bias.

Groups	Restricted control group	Complete set of control variables	*F*-value
Group 1	Without control variables	Add control variables other than education, religious belief	7.565
	Without control variables	Add all control variables.	8.335
Group 2	Add gender age control variables	Add control variables other than education, religious belief	7.238
	Add gender age control variables	Add all control variables	5.566

TABLE 8 Impact of LPO on farmers' behaviors of PFT.

Variables	Logit model		
	Model 1	Model 2	
		Ratio	Marginal effect
LPO	1.392*** (0.234)	0.156*** (0.032)	0.188*** (0.047)
Age		−0.028 (0.017)	−0.004 (0.003)
Gender		0.217 (0.401)	0.033 (0.061)
Education		−0.371* (0.208)	−0.057* (0.031)
Religious belief		−0.592 (0.401)	−0.090 (0.060)
Number of persons in the household		0.258** (0.114)	0.039** (0.017)
Total household income		−0.346 (0.350)	−0.053 (0.350)
Number of plots contracted		0.077 (0.050)	0.077 (0.053)
Soil fertility of contracted land		0.149 (0.153)	0.023 (0.023)
Agricultural insurance		1.411*** (0.153)	0.214*** (0.051)
Village topography		−0.676*** (0.214)	−0.103*** (0.030)
Transportation conditions in villages		0.216 (0.302)	0.033 (0.046)
Level of village economic development		−0.168 (0.280)	−0.026 (0.043)
constant	−2.798*** (0.496)	−2.903 (2.011)	
R-squared	0.125	0.322	

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

among southern Chinese rice farmers, establishing three key findings. Firstly, LPO significantly enhances farmers' adoption of PFT through strengthened territorial belonging and control preferences, aligning with place attachment theories (Yueji et al., 2021; Intarakamhang and Macaskill, 2018). Our findings extend psychological ownership theory by contextualizing it within China's unique land certification system, addressing previous studies' oversight of socio-cultural contingencies (Adenuga et al., 2025; Yaméogo et al., 2018).

Secondly, formal property rights and informal norms jointly mediate the operationalization of PO. Land certification crystallizes technological benefits through ownership boundaries, social identity reweights decision-making ethics via cultural symbols, and capability optimization dissolves cognitive barriers—collectively forming a multidimensional regulatory system. This tripartite mechanism refines Pierce et al.'s psychological ownership framework (Efficacy/Effectance, Self-Identity, Place Attachment), revealing contextualized behavioral moderators (Pierce et al., 2003).

Finally, our triad framework linking people, land, and technology transcends traditional economic-technical dualism, aligning with Folke et al.'s adaptive governance framework (Folke et al., 2005; Rozelle and Swinnen, 2004). Findings emphasize policy synergies between psychological ownership and formal property rights, corroborating Kaur et al.'s evidence on land certification's behavioral effects (Kaur et al., 2023). Sustainable governance requires three-dimensional coordination of cultural identity reinforcement, certification system innovation, and capability building to balance institutional rigidity with behavioral resilience.

6.2 Limitations and future research

While our study provides important insights, several limitations should be acknowledged and addressed in future research. Firstly, the research primarily relies on questionnaire surveys and Logit model analyses, which possess inherent limitations. Questionnaire surveys may exhibit subjective biases, as farmers' responses could be influenced by their cognitive levels and societal expectations, leading to inaccuracies in reporting LPO and technology adoption behaviors.

The LPO, reflecting farmers' emotional attachment and sense of responsibility toward land resources, typically stems from long-term production experiences and intergenerational inheritance. Its formation exhibits significant path dependence and remains relatively stable in the short term. This study collected data on farmers' pro-environmental technology decisions in 2022, with these behaviors occurring significantly later than the formation period of PO. This temporal sequence suggests a potential "cause to consequence" relationship. Theoretically, technology adoption is a behavioral decision based on cost–benefit assessments or the influence of social norms, directly impacting production practices rather than farmers' cognitive structures regarding LPO. This further diminishes the possibility of endogeneity caused by reverse causality.

Regarding potential omitted variable biases induced by unobservable factors (e.g., implicit cultural beliefs, intergenerationally transmitted ecological consciousness), these can theoretically be mitigated through instrumental variable methods. For instance, ancestors' perceptions of land ownership, as historical and exogenous factors, may shape contemporary farmers' LPO through familial belief

transmission (relevance condition). Yet, ancestors' perceptions are not directly related to modern technology decisions (exogeneity condition), aligning with basic instrumental variable assumptions. However, constrained by the characteristics of cross-sectional data, this study's questionnaire lacks proxy variables directly reflecting ancestors' ownership perceptions, and existing indicators (e.g., land inheritance duration) cannot entirely exclude potential associations with contemporary technology adoption behaviors (e.g., ancestors' land management practices might influence technological preferences). Therefore, we acknowledge the insufficiencies in addressing endogeneity within this study's limitations and recommend future research improvements through the following approaches: (1) For optimization of instrumental variables, the multi-generational farmer tracking data to construct more precise indicators of ancestors' ownership perceptions will be collected. (2) For quasi-Natural experimental design, the farmer groups for "psychological ownership enhancement interventions" (e.g., property rights legal training) will be selected randomly, collaborating with local governments. By comparing the differences in PFT between intervention and control groups, the exogeneity of random assignment can be utilized to isolate the influence of confounding factors. (3) For dynamic panel models, multi-period behavioral data from farmers will be obtained with individual fixed effects employed to control for time-invariant unobservable heterogeneity and further disentangle causal directions through lagged variable analysis.

Respectively, the sample primarily originates from Guangdong and Hainan, regions with unique geographical and socio-economic characteristics. These areas are characterized by mountainous, hilly, and water-rich landscapes, fostering distinctive clan cultures and lifestyles. Factors such as land certification, identity, and capability may differ in other regions, reducing the generalizability of the study's findings.

Specially, it is necessary to extend the discussion of LPO to a deeper exploration within the context of collective systems. Although this study references rural China's collective land ownership system, it does not thoroughly examine its role in shaping psychological ownership and pro-environmental fertilizer technology adoption. Factors such as collective decision-making and the distribution of collective interests may significantly influence farmers' ownership perceptions. Future research should investigate these factors to provide a more comprehensive understanding of LPO and its relationship with technology adoption within collective systems.

6.3 Discussion

Despite these limitations, this study reveals LPO's mechanism and boundary conditions on farmers' pro-environmental technology adoption, offering a new theoretical perspective for agro-environmental governance. The LPO reflects the emotional connection and intergenerational responsibility between farmers and the land, motivating them to consider ecological sustainability beyond short-term economic interests. The study confirms that when farmers develop a stable sense of belonging to the land, their technological choices balance ecological benefits with production needs, challenging the traditional unidimensional view of rational decision-making and highlighting the independent role of emotional factors in environmental behavior.

At the regulatory level, the institutional rigidity of agricultural land certification reshapes the practice of PO through legal empowerment. Clear property rights reduce institutional risks and convert subjective ownership perceptions into actionable long-term investment incentives by stabilizing expectations. The moderating role of social identity demonstrates that when pro-environmental behaviors are integrated into the community value system, individual psychological ownership resonates with collective responsibility, elevating technology adoption from an economic choice to a symbolic expression of identity. Moreover, capability significantly moderates farmers' pro-environmental behaviors; even a strong emotional connection may not overcome the inertia of traditional farming if there is a lack of technological knowledge and operational competence. This suggests that policy design should integrate psychological incentives with skills cultivation.

The study integrates behavioral economics and institutional analysis to construct a dynamic interaction model linking psychological ownership, institutional environment, and technology adoption, offering new insights into addressing the decoupling between policy incentives and behavioral responses. Practically, it implies that strengthening the psychological foundation through property rights reform, cultivating environmental consensus via community networks, and lowering technological thresholds through competence training is essential. It also suggests that the role of PO may evolve with generational changes and technological iterations, warranting further research into its life-cycle patterns and regional heterogeneity for differentiated policy design.

Research-based on external benefits suggests that government financial subsidies are considered a core policy tool for correcting market failures in pro-environmental technology. The current subsidy mechanism implemented in China, such as the 2015 "Soil Organic Matter Improvement Subsidy Program Implementation Guidelines," reflects the prioritization of technology through differentiated subsidy standards (e.g., 15 RMB per mu for straw decomposing agents, 30 RMB per mu for organic fertilizer technology, and 15 RMB per mu for green manure planting). However, although this non-market-based, universal subsidy mechanism can stimulate short-term technology adoption, it fails to foster sustainable, environmentally friendly behaviors, leading to a typical "subsidy dependence" phenomenon. Research has found that by reshaping farmers' decision-making mechanisms, LPO can effectively activate the endogenous motivation for technology adoption. Therefore, policy design should systematically integrate farmers' heterogeneous goal preferences and the behavioral moderation effects of LPO within the existing technology subsidy framework, creating a "differentiated identification - dynamic incentives - coordinated implementation" strategy to align policy tools with farmers' behavior logic.

Empirical findings of this study show that land certificates (such as land rights certificates) significantly strengthen the promotion of LPO's positive impact on the adoption of PFT by enhancing farmers' exclusive control over the land and their long-term management expectations. This conclusion is corroborated by China's current "separation of land rights" reform and the policy to extend the land contract period for 30 years after the second round of land contracts expires. On the one hand, the land rights confirmation policy solidifies the relationship between farmers and land through legal documents, activating their psychological recognition of "land as an asset," motivating environmentally friendly production behaviors. On the

other hand, the policy of extending the contract period matches the long return cycle of PFTs, resolving the adoption barriers under short-term contracts. Based on this, it is recommended to embed an ecological agriculture incentive framework within the "second-round extension" policy, including bundling land rights certificates with technology, embedding soil health records and customized pro-environmental technology plans at the land plot level into the "second-round land extension" policy, achieving synergy between property rights protection and technology promotion through the "one certificate, one policy" approach; linking the subsidy duration with the adoption level, offering additional rewards to farmers who adopt pro-environmental technologies for three consecutive years; and designing property transfer premiums, where pro-environmental fertilized plots receive a 5–15% ecological premium on rural property transaction platforms, utilizing market mechanisms to reflect positive environmental externalities. This path can not only alleviate the "policy silo" phenomenon in the transition to green agriculture and technology adoption but also address the "discount rate dilemma" of pro-environmental technologies through the stability of the property rights system.

Undoubtedly, there are some limitations in this study. On the one hand, as a new technology, the PFT involves knowledge, technical, and investment barriers, and high transaction costs characterize it. When transaction costs rise to a certain level, the endowment effect's incentive for farmers to adopt PFTs may weaken. Future research could refer to Williams' analytical paradigm to explore the role of transaction costs in the mechanism through which the endowment effect influences farmers' adoption decisions. On the other hand, this study focuses on rice-growing regions in southern China. Given the unique farming systems and natural conditions in the south of the area, such as double-cropping systems and hilly terrain, the generalizability of the proposed policy recommendations remains to be verified. Future research could explore the configuration of different rice farming systems and natural conditions, analyze the heterogeneity of farmers' pro-environmental fertilization adoption decisions under the endowment effect, and propose regionally differentiated PFT promotion strategies, providing more detailed policy recommendations for the promotion of related policies.

6.4 Policy implications

In our study, the findings regarding the significant role of LPO and its moderating factors lead us to propose the following specific policy pathways for modernizing China's agricultural environmental governance system:

First of all, we established a long-term mechanism for cultivating PO to transcend traditional economic incentive frameworks by emphasizing the cultivation of emotional bonds and cultural identity between farmers and the land. Through the exploration of local cultural symbols, the reconstruction of village collective memory, and participatory rural planning, farmers' "land identity" could be strengthened, thereby activating a sense of intergenerational responsibility and generating an endogenous impetus for environmental governance (Taylor, 2019).

Then, we enhanced the dynamic adaptation of the property rights system to deepen agricultural land rights confirmation reforms by integrating pro-environmental technology adoption benefits into the property rights framework (Mac Donald, S., and Staats, H, 2022). Through the right confirmation certificate and technology bundling two dimensions, we believe the exclusive benefits of green production could be actualized. The second round of land contract extension policies is recommended to incorporate an ecological performance evaluation system and establish a linkage mechanism between contract duration and the technological return cycle, addressing the challenge of insufficient long-term investment incentives.

Finally, we constructed a Three-Dimensional Incentive Mechanism which include the legal, society and capacity level to link institutional rigidity, social resilience, and capacity elasticity. At the legal level, the framework should reinforce farmers' rights and responsibilities in applying PFTs. An ecological premium trading mechanism for land transfers could be introduced, and ecological performance should be integrated into the annual review of land certification. In this process, the adoption of PFTs serves as an explicit evaluation criterion. At the society level, rural communities need to cultivate a shared ethic of ecological responsibility. The demonstration effect could be strengthened through social networks, and a village-level ecological points system could be created to reward collective actions such as integrated pest management or the joint use of organic fertilizers. At the capacity-building level, an agricultural extension system centered on "knowledge decoding and technology adaptation" helps lower the cognitive barriers to technology transfer. Farmer field schools should emphasize practical training in fertilizer calculation and soil testing, equipping farmers with concrete skills such as nutrient budgeting and site-specific soil management (Peck and Shu, 2009). In terms of implementation, a phased approach is preferable. The first step is to pilot a "one certificate, one solution" model—combining land title confirmation with tailored technology packages—in national green agriculture demonstration zones. Once proven effective, this approach could then be scaled up more broadly.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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 provided their written informed consent to participate in this study.

Author contributions

WoZ: Writing – review & editing, Software, Funding acquisition, Resources, Writing – original draft. ZG: Writing – review & editing, Writing – original draft, Data curation, Validation. WeZ: Visualization, Project administration, Methodology, Writing – review & editing, Validation, Writing – original draft, Data curation. LT: Software, Writing – original draft, Investigation, Resources, Funding acquisition, Writing – review & editing, Conceptualization, Project administration, Formal analysis.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. The work was supported by the Ministry of Education, Humanities and Social Science Foundation research project (No. 23YJC790204); the Guangdong Province Basic and Applied Basic Research Fund Project (No. 2023A1515110314); the Guangdong Education Science Planning Project (No. 2023GXJK120); the Guangdong Province Philosophy and Social Science Planning Project (No. GD24YGL08); the Guangzhou Basic and Applied Basic Research Special Project (No. 2024A04J3286).

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.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Abbas, A., Chengang, Y., Zhuo, S., Bilal, Manzoor, S., Ullah, I., et al. (2022). Role of responsible leadership for organizational citizenship behavior for the environment in light of psychological ownership and employee environmental commitment: a moderated mediation model. *Front. Psychol.* 12:756570. doi: 10.3389/fpsyg.2021.756570

Achtypi, E., Ashby, N. J., Brown, G. D., Walasek, L., and Yechiam, E. (2021). The endowment effect and beliefs about the market. *Decision* 8:16. doi: 10.1037/dec0000143

Addis, E. M., Amera, M. M., and Biru, G. B. (2020). Land certification and farmers' decision on long term investment in Jimma zone, Southwest Ethiopia. *J. Degrad. Min. Lands Manag.* 7:2269. doi: 10.15243/jdmlm.2020.074.2269

Adenuga, A. H., Jack, C., and McCarry, R. (2025). Behavioural drivers of long-term land leasing adoption: application of an extended theory of planned behaviour. *Environ. Dev. Sustain.* 27, 16819–16839. doi: 10.1007/s10668-024-04661-y

Afridi, S. A., Khan, W., Haider, M., Shahjehan, A., and Afsar, B. (2021). Generativity and green purchasing behavior: moderating role of man-nature orientation and perceived behavioral control. *SAGE Open* 11:21582440211054480.

Alchian, A. A., and Demsetz, H. (1973). The property right paradigm. *J. Econ. Hist.* 33, 16–27. doi: 10.1017/S0022050700076403

Allan, R., Hawkins, E., Bellouin, N., and Collins, B.IPCC (2021). "Summary for policymakers. Global warming of 1.5 C" in An IPCC special report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global res. 2021. IPCC.

Arhin, I., Huiling, M., Jianjie, L., Edward, G., Augustine, A.-B., Xuan, C., et al. (2023). Analysis of the determinants of sustainable agricultural technologies adoption in tea production in China: a systematic review. *Int. J. Agric. Sustain.* 21:2239047. doi: 10.1080/14735903.2023.2239047

Avey, J. B., Avolio, B. J., Crossley, C. D., and Luthans, F. (2009). Psychological ownership: theoretical extensions, measurement and relation to work outcomes. *J. Organ. Behav.* 30, 173–191. doi: 10.1002/job.583

Barzel, Y. (1989). Economic analysis of property rights. New York: Cambridge University Press.

Benjamin, D. (1992). Household composition, labor markets, and labor demand: testing for separation in agricultural household models. *Econometrica*, 60, 287–322. doi: 10.2307/2951598

Beyers, J., and Muza, K. (2022). Christianity and Shona religion and ecology: an ethical-practical perspective. *J. Relig. Afr.* 51, 309–327. doi: 10.1163/15700666-12340206

Binswanger, H. P., and Rosenzweig, M. R. (1986). Behavioural and material determinants of production relations in agriculture. *J. Dev. Stud.* 22, 503–539. doi: 10.1080/00220388608421994

Bo, L., and Ruimei, W. (2021). A review of land tenure security and farmers' behaviors of land improvement. *Resour Sci* 43, 909–920. doi: 10.18402/resci.2021.05.05

Boley, B. B., Strzelecka, M., Yeager, E. P., Ribeiro, M. A., Aleshinloye, K. D., Woosnam, K. M., et al. (2021). Measuring place attachment with the abbreviated place attachment scale (APAS). *J. Environ. Psychol.* 74:101577. doi: 10.1016/j.jenvp.2021.101577

Boone, C. (2019). Legal empowerment of the poor through property rights reform: tensions and trade-offs of land registration and titling in sub-Saharan Africa. *J. Dev. Stud.* 55, 384–400. doi: 10.1080/00220388.2018.1451633

Brasselle, A.-S., Gaspart, F., and Platteau, J.-P. (2002). Land tenure security and investment incentives: puzzling evidence from Burkina Faso. *J. Dev. Econ.* 67, 373–418. doi: 10.1016/S0304-3878(01)00190-0

Bruce, A. B., et al. (2022). Opportunities and barriers to certified organic grain production on rented farmland in the US Midwest state of Indiana. *Land Use Policy* 122:106346. doi: 10.1016/j.landusepol.2022.106346

Chapman, J., Dean, M., Ortoleva, P., Snowberg, E., and Camerer, C. (2023). Willingness to accept, willingness to pay, and loss aversion. Cambridge, Massachusetts: National Bureau of Economic Research.

Chua, M. H., and Yau, Y. (2022). Early experience of land readjustment in Hong Kong: case study of the Kowloon Walled City. *Buildings* 12:757. doi: 10.3390/buildings12060757

Cole, S., Giné, X., Tobacman, J., Topalova, P., Townsend, R., and Vickery, J. (2013). Barriers to household risk management: evidence from India. *Am. Econ. J. Appl. Econ.* 5, 104–135. doi: 10.1257/app.5.1.104

Collard, P., Walford, A., Vernon, L., Itagaki, F., and Turk, D. (2020). The relationship between endowment and ownership effects in memory across cultures. *Conscious. Cogn.* 78:102865. doi: 10.1016/j.concog.2019.102865

Dang, L., and Weiss, J. (2021). Evidence on the relationship between place attachment and behavioral intentions between 2010 and 2021: a systematic literature review. *Sustainability* 13:13138. doi: 10.3390/su132313138

Deininger, K., Ali, D. A., and Alemu, T. (2011). Impacts of land certification on tenure security, investment, and land market participation: evidence from Ethiopia. *Land Econ.* 87, 312–334. doi: 10.3368/le.87.2.312

Düger, Y. S. (2021). The impact of team-member exchange on the intra-team knowledge sharing: the role of intra-team trust and psychological ownership. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, 69, 268–285. doi: 10.51290/dpusbe.931511

Elliott, E. D., and Esty, D. C. (2021). The end environmental externalities manifesto: a rights-based Foundation for Environmental law. *NYU Envt. LJ* 29:505.

Feder, G., Just, R. E., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: a survey. *Econ. Dev. Cult. Chang.* 33, 255–298. doi: 10.1086/451461

Fenske, J. (2011). Land tenure and investment incentives: evidence from West Africa. *J. Dev. Econ.* 95, 137–156. doi: 10.1016/j.jdeveco.2010.05.001

Folke, C., Hahn, T., Olsson, P., and Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.* 30, 441–473. doi: 10.1146/annurev.energy.30.050504.144511

Foster, A. D., and Rosenzweig, M. R. (1995). Learning by doing and learning from others: human capital and technical change in agriculture. *J. Polit. Econ.* 103, 1176–1209. doi: 10.1086/601447

Guan, J., Zhu, D., Cheng, S., and Li, Q. (2025). "It is my place": residents' community-based psychological ownership and its impact on rural tourism participation. *J. Sustain. Tour.* 33, 1303–1329. doi: 10.1080/09669582.2024.2346779

Hardin, G. (1968). The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality. *Science* 162, 1243–1248. doi: 10.1126/science.162.3859.1243

Hayes, J., Roth, M., and Zepeda, L. (1997). Tenure security, investment and productivity in Gambian agriculture: a generalized probit analysis. *Am. J. Agric. Econ.* 79, 369–382. doi: 10.2307/1244136

He, J. (2023). Group belongingness: investigating the formation, maintenance, and influencing factors of social identity and group membership. *Stud. Psychol. Sci.* 1, 32–40. doi: 10.56397/SPS.2023.09.03

Higgins, E. T. (2012). "Regulatory focus theory" in Handbook of theories of social psychology, vol. 1, Thousand Oaks, California: Sage Publications. 483–504.

Intarakamhang, U., and Macaskill, A. (2018). Multi-group causal model of health literacy and behaviors on family wellbeing among Thai adults at risk of non-communicable diseases (NCDs). *J. Res. Health Sci.* 18:e00429

Jacoby, H. G. (2000). Access to markets and the benefits of rural roads. *Econ. J.* 110, 713–737. doi: 10.1111/1468-0297.00562

Jami, A., Kouchaki, M., and Gino, F. (2021). I own, so I help out: how psychological ownership increases prosocial behavior. *J. Consum. Res.* 47, 698–715. doi: 10.1093/jcr/ucaa040

Jiang, B., Bai, Y., Wong, C. P., Xu, X., and Alatalo, J. M. (2019). China's ecological civilization program–Implementing ecological redline policy. *Land Use Policy* 81, 111–114. doi: 10.1016/j.landusepol.2018.10.031

Kahneman, D., Knetsch, J. L., and Thaler, R. H. (1990). Experimental tests of the endowment effect and the Coase theorem. *J. Polit. Econ.* 98, 1325–1348. doi: 10.1086/261737

Kaur, K. P., Chang, K., and Andersson, K. P. (2023). Collective forest land rights facilitate cooperative behavior. *Conserv. Lett.* 16:e12950. doi: 10.1111/conl.12950

Kawasaki, K. (2010). The costs and benefits of land fragmentation of rice farms in Japan. *Aust. J. Agric. Resour. Econ.* 54, 509–526. doi: 10.1111/j.1467-8489.2010.00509.x

Kern, F. G., and Mustasilta, K. (2023). Beyond replication: secondary qualitative data analysis in political science. *Comp. Pol. Stud.* 56, 1224–1256. doi: 10.1177/00104140221139388

Luo, W. Z., Jiang, Y.-Z., Wang, X.-Z., Liu, H.-X., and Chen, Y.-S. (2019). Farmer cognition on water-saving irrigation technology analysis in groundwater overmining area of North China: a case study of Guyuan county, Zhangjiakou city, Hebei province. *J. Nat. Resour.* 34, 2469–2480. doi: 10.31497/zrzyxb.20191117

Ma, Q., Zheng, S., and Deng, P. (2022). Impact of internet use on farmers' organic fertilizer application behavior under the climate change context: the role of social network. *Land* 11:1601. doi: 10.3390/land11091601

Mac Donald, S., and Staats, H. (2022). Conservation as integration: desire to belong as motivation for environmental conservation. *Soc. Nat. Resour.* 35, 75–91. doi: 10.1080/08941920.2021.2023244

Marenya, P. P., and Barrett, C. B. (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy* 32, 515–536. doi: 10.1016/j.foodpol.2006.10.002

Morewedge, C. K. (2021). Psychological ownership: implicit and explicit. *Curr. Opin. Psychol.* 39, 125–132. doi: 10.1016/j.copsyc.2020.10.003

Pai, C. K., Chen, H., Lee, T. J., Hyun, S. S., Liu, Y., and Zheng, Y. (2024). The impacts of under-tourism and place attachment on residents' life satisfaction. *J. Vacat. Mark.* 30, 694–712. doi: 10.1177/13567667231164807

Peck, J., and Luangrath, A. W. (2023). A review and future avenues for psychological ownership in consumer research. *Consumer Psychol. Rev.* 6, 52–74. doi: 10.1002/arcp.1084

Peck, J., and Shu, S. B. (2009). The effect of mere touch on perceived ownership. *J. Consum. Res.* 36, 434–447. doi: 10.1086/598614

Pierce, J. L., Kostova, T., and Dirks, K. T. (2001). Toward a theory of psychological ownership in organizations. *Acad. Manag. Rev.* 26, 298–310. doi: 10.2307/259124

Pierce, J. L., Kostova, T., and Dirks, K. T. (2003). The state of psychological ownership: integrating and extending a century of research. *Rev. Gen. Psychol.* 7, 84–107. doi: 10.1037/1089-2680.7.1.84

Pierce, J. L., Rubenfeld, S. A., and Morgan, S. (1991). Employee ownership: a conceptual model of process and effects. *Acad. Manag. Rev.* 16, 121–144. doi: 10.2307/258609

Qu, X., Zhou, W., He, J., and Xu, D. (2023). Land certification, adjustment experience, and green production technology acceptance of farmers: evidence from Sichuan Province, China. *Land* 12:848. doi: 10.3390/land12040848

Quisumbing, A. R., and Pandolfelli, L. (2010). Promising approaches to address the needs of poor female farmers: resources, constraints, and interventions. *World Dev.* 38, 581–592. doi: 10.1016/j.worlddev.2009.10.006

Rezaei, R., Safa, L., Damalas, C. A., and Ganjkhanloo, M. M. (2019). Drivers of farmers' intention to use integrated pest management: integrating theory of planned behavior and norm activation model. *J. Environ. Manag.* 236, 328–339. doi: 10.1016/j.jenvman.2019.01.097

Roberts, N. A., and Burleson, M. H. (2013). Processes linking cultural ingroup bonds and mental health: the roles of social connection and emotion regulation. *Front. Psychol.* 4:52. doi: 10.3389/fpsyg.2013.00052

Rogers, E. M., Singhal, A., and Quinlan, M. M. (2014). An integrated approach to communication theory and research. Abingdon, Oxfordshire: Routledge, 432–448.

Rozelle, S., and Swinnen, J. F. M. (2004). Success and failure of reform: insights from the transition of agriculture. *J. Econ. Lit.* 42, 404–456. doi: 10.1257/0022051041409048

Sheng, Y., Tian, X., Qiao, W., and Peng, C. (2020). Measuring agricultural total factor productivity in China: pattern and drivers over the period of 1978-2016. *Aust. J. Agric. Resour. Econ.* 64, 82–103. doi: 10.1111/1467-8489.12327

Shikuku, K. M., and Melesse, M. B. (2020). Networks, incentives and technology adoption: evidence from a randomised experiment in Uganda. *Eur. Rev. Agric. Econ.* 47, 1740–1775. doi: 10.1093/erae/jbaa009

Sitko, N. J., Chamberlin, J., and Hichaambwa, M. (2014). Does smallholder land titling facilitate agricultural growth?: an analysis of the determinants and effects of smallholder land titling in Zambia. *World Dev.* 64, 791–802. doi: 10.1016/j.worlddev.2014.07.014

Suri, T. (2011). Selection and comparative advantage in technology adoption. *Econometrica* 79, 159–209. doi: 10.3982/ECTA7749

Swanepoel, A., Merwe, A. V. D., and Loggerenberg, J. V. (2020). An information systems ownership framework. *Int. J. Bus. Inf. Syst.* 34, 157–182. doi: 10.1504/IJBIS.2020.108341

Tang, L., and Luo, X. F. (2022). Can the neighborhood effect encourage rice farmers to apply biological pesticides: evidence from survey data of farmers in Hubei, Jiangxi and Zhejiang provinces. *J. Nat. Resour.* 37, 718–733. doi: 10.31497/zrzyxb.20220311

Taylor, S. (2019). The puzzle of altruism: why do 'selfish genes' behave so unselfishly? *Explore* 15, 371–375. doi: 10.1016/j.explore.2019.04.002

Teixeira, A., Gabriel, R., Martinho, J., Santos, M., Faria, A., Oliveira, I., et al. (2023). Pro-environmental behaviors: relationship with nature visits, connectedness to nature and physical activity. *Am. J. Health Promot.* 37, 12–29. doi: 10.1177/08901171221119089

Thaler, R. (1980). Toward a positive theory of consumer choice. *J. Econ. Behav. Organ.* 1, 39–60. doi: 10.1016/0167-2681(80)90051-7

Thompson, B., Leduc, G., Manevska-Tasevska, G., Toma, L., and Hansson, H. (2024). Farmers' adoption of ecological practices: a systematic literature map. *J. Agric. Econ.* 75, 84–107. doi: 10.1111/1477-9552.12545

Van Wesenbeeck, C., Keyzer, M., Van Veen, W., and Qiu, H. (2021). Can China's overuse of fertilizer be reduced without threatening food security and farm incomes? *Agric. Syst.* 190:103093. doi: 10.1016/j.agsy.2021.103093

Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecol. Soc.* 9:5. doi: 10.5751/ES-00650-090205

Warkentin, M., Goel, S., and Menard, P. (2017). Shared benefits and information privacy: what determines smart meter technology adoption? *J. Assoc. Inf. Syst.* 18:3. doi: 10.17705/1jais.00474

Xie, L., Zhang, J., Huang, W., Ke, D., and Li, L. (2023). Relationship between rural land titling and land transfer in China: a systematic literature review and meta-analysis. *Front. Sustain. Food Syst.* 7:1143595. doi: 10.3389/fsufs.2023.1143595

Xiong, W., Liu, D., Li, Z., Wang, Q., and Yao, S. (2024). How does ant Forest influence low carbon consumption behavior: an analysis based on the SOR model. *Sustainability* 16:1736. doi: 10.3390/su16051736

Yaghoubi Farani, A., Mohammadi, Y., and Ghahremani, F. (2019). Modeling farmers' responsible environmental attitude and behaviour: a case from Iran. *Environ. Sci. Pollut. Res.* 26, 28146–28161. doi: 10.1007/s11356-019-06040-x

Yaméogo, T. B., Fonta, W. M., and Wünscher, T. (2018). Can social capital influence smallholder farmers' climate-change adaptation decisions? Evidence from three semi-arid communities in Burkina Faso, West Africa. *Soc. Sci.* 7:33. doi: 10.3390/socsci7030033

Yang, G., Duanyang, Z., and Lili, Y. (2019). Family farms' policy preferences and willingness to accept compensation on green pest control techniques. *Resour Sci* 41, 1837–1848. doi: 10.18402/resci.2019.10.07

Yue, S., and Wang, H. (2023). The effect of sense of power on inaction inertia: from the perspective of endowment effect. *Curr. Psychol.* 42, 29071–29089. doi: 10.1007/s12144-022-03983-2

Yueji, Z., Qian, Y., and Fang, W. (2021). Mechanism of influence of social networks on banana farmers' adoption of resource conservation technologies: a case study of the drip fertigation system. *Resour Sci* 43, 1099–1114. doi: 10.18402/resci.2021.06.04

Zheng, W., Luo, B., and Hu, X. (2020). The determinants of farmers' fertilizers and pesticides use behavior in China: an explanation based on label effect. *J. Clean. Prod.* 272:123054. doi: 10.1016/j.jclepro.2020.123054

Zhong, Y.-P., Tang, L.-R., and Li, Y. (2022). Role of digital empowerment in developing farmers' green production by agro-tourism integration in Xichong, Sichuan. *Agriculture* 12:1761. doi: 10.3390/agriculture12111761