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Farmers' Willingness to Adopt Maize-Soybean Rotation Based on the Extended Theory of Planned Behavior: Evidence from Northeast China

Yunzheng Zhang [1], Zainab Oyetunde-Usman [2], Simon Willcock [3,4], Minglong Zhang [1], Ning Jiang [1], Luran Zhang [1], Li Zhang [5], Yu Su [5], Zongyi Huo [5], Cailong Xu [6], Yuquan Chen [7], Qingfeng Meng [8] and Xiangping Jia [1,*]

[1] Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China; 82101231387@caas.cn (Y.Z.); 82101222500@caas.cn (M.Z.); ningjiang.nora@outlook.com (N.J.); zhang.luran@outlook.com (L.Z.)
[2] Net Zero and Resilient Farming, Rothamsted Research, Harpenden AL5 2JQ, UK; zainab.oyetunde-usman@rothamsted.ac.uk
[3] Net Zero and Resilient Farming, Rothamsted Research, North Wyke EX20 2SB, UK; simon.willcock@rothamsted.ac.uk or simon.willcock@bangor.ac.uk
[4] School of Environmental and Natural Sciences, Bangor University, Bangor LL57 2UR, UK
[5] School of Journalism and Communication, Tsinghua University, Beijing 100081, China; lizhang11@tsinghua.edu.cn (L.Z.); suy21@mails.tsinghua.edu.cn (Y.S.); huozy22@mails.tsinghua.edu.cn (Z.H.)
[6] Institute of Crop Science, Chinese Academy of Agricultural Sciences, Beijing 100081, China; xucailong@caas.cn
[7] College of Economic and Management, China Agricultural University, Beijing 100081, China; chenyuquan_cem@cau.edu.cn
[8] College of Agronomy and Biotechnology, China Agricultural University, Beijing 100081, China; mengqf@cau.edu.cn
* Correspondence: jiaxiangping@caas.cn

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Abstract

Context: For decades, maize monoculture practices dominated Northeast China, causing significant damage to the local soil and ecological environment. Crop rotation has, in recent years, been promoted as an environmentally friendly and sustainable technology in China. Despite its numerous benefits for the environment and crop productivity, farmers' willingness to adopt crop rotation remains low. Objective: This study aims to investigate the social–psychological factors influencing farmers' intentions to adopt maize–soybean rotation, with the goal of informing strategies for promoting sustainable agricultural practices. Methods: Based on a farm-level survey of 298 rural households in Northeast China, this study integrates value orientation into the Theory of Planned Behavior and employs structural equation modeling to investigate the social–psychological factors that affect farmers' willingness to adopt soybean-based rotation. Results and Conclusions: The findings confirm the applicability of the extended Theory of Planned Behavior in explaining farmers' decision-making. Farmers' attitudes (0.384) and perceived behavioral control (0.323) had significant positive effects on adoption intentions, whereas subjective norms (0.018) were not significant. More favorable attitudes and greater perceived behavioral control, reflecting higher risk tolerance and better access to external support, promoted adoption. Value orientations strongly shaped farmers' attitudes: altruism (0.148) and biospheric values (0.180) had positive effects, while egoism (0.044) showed no significant impact. These results offer guidance for policymakers to design targeted interventions promoting sustainable crop rotation. Significance: These results can help policymakers better understand what factors influence farmers' adoption of rotation and what targeted measures can be taken to popularize the improved agricultural system. To foster farmers' adoption of rotation, it is important to go beyond traditional supporting policies and to leverage innovative approaches to promote value orientation on sustainable farming practices.

Keywords: crop rotation; value-based theory of planned behavior; value orientation; structural equation model

1. Introduction

Crop rotation is an agricultural practice that involves alternating crops across seasons or years. This practice offers several agronomic, economic and environmental advantages and it is globally gaining renewed attention as a strategy to combat the impacts of persistent climate risks on agricultural production. For example, studies have shown the impact of crop rotation practices on yield improvement and resilience [1,2]; improvements of carbon sequestration and nutrient cycling [3]; reductions in greenhouse gas emissions [4], and profitability and improved economic returns [5,6]. The mitigation potential of crop rotation, especially including legumes, has also been proven effective under alternative future climate scenarios [7].

China is an example of this wider global phenomenon. For example, recognizing the benefits of crop rotation, the Chinese government has intensified its promotion in recent years through various policy measures. The Chinese government initiated the implementation of the arable land rotation system in 2016. That year, the State Council issued the *Pilot Plan for the Implementation of the Arable Land Rotation and Fallow System*, which proposed promoting crop rotation across 333,333 hectares in key regions, including the cold northeastern areas and the northern agro-pastoral ecotone, with 66,667 hectares allocated to Inner Mongolia. The plan aimed to establish an initial organizational and policy framework for land rotation and fallow practices within three to five years [8]. Additionally, the *Rural Revitalization Plan (2024–2027)* underscores the continued advancement of sustainable agricultural practices, including the promotion of crop rotation [9]. At the regional level, Inner Mongolia Department of Agriculture and Rural Affairs introduced the *Implementation Plan for Arable Land Rotation in 2023*, which further emphasized improving the rotation and fallow system in alignment with national policies on soybean and oilseed cultivation, as well as the broader goal of green agricultural development [10]. This study focuses on Keerqin Right Banner in Inner Mongolia, located in northeastern China. The region, one of China's major corn-producing areas, also serves as a key zone for promoting cereal–legume crop rotations. Understanding farmers' adoption behavior within this context provides insights for improving China's grain structure and informing strategies for national food security. Moreover, findings carry broader relevance for advancing global agricultural sustainability, enhancing resilience of food production, and supporting soil carbon management. By examining motivations and constraints influencing farmers' adoption of crop rotation in primary grain-producing areas of China, the study offers lessons applicable to other countries, particularly developing agricultural regions, and contributes to international efforts toward achieving Sustainable Development Goals (SDGs) related to food security, climate adaptation, and terrestrial ecosystem protection [11,12].

Despite these efforts, the promotion of rotation in China has been challenging and uptake has been limited. One possible explanation for this phenomenon is that maize offers higher economic returns compared to soybeans, leading to the prevalence of continuous maize cropping [13,14]. In addition, soybean production involves greater market uncertainty due to fluctuating prices and underdeveloped processing and marketing systems, increasing perceived economic risks, and reducing farmers' willingness to adopt rotation [15]. Moreover, mechanization and well-developed socialized services in maize production have significantly reduced labor requirements for field management, allowing farmers to engage in off-farm employment and earn additional income [16]. Furthermore, farmers' limited awareness of ecological benefits and operational standards of crop rotation, combined with insufficient policy communication and extension support, further lowers motivation to adopt rotation practices [17]. As a result of prolonged continuous maize cropping by farmers, soil nutrient cycling and ecological functions in the northeastern black soil regions have been significantly impaired. Long-term field trials in these areas show that 28 consecutive years of maize monocropping reduced microbial phosphorus acquisition by approximately 25%, disrupted C-N-P enzyme stoichiometry, and limited microbial nutrient-use efficiency [18]. Prolonged continuous cropping and intensive land use also decreased topsoil organic carbon by 20–40%, with SOC dropping from around 45 $g \cdot kg^{-1}$ to 25–30 $g \cdot kg^{-1}$, impairing soil ecological capacity and carbon sequestration function [19,20]. Pathogen accumulation has increased disease risk, with the average incidence of root rot reaching 23.9%, about 3.5 times higher than in newly cultivated land [21]. In contrast, implementation of maize–soybean rotation can raise topsoil SOC by approximately 5 $g \cdot kg^{-1}$, increase maize yield by around 12.6%, and reduce fertilizer input [22], highlighting the clear benefits of rotation for soil quality and sustainable crop production.

In response to these challenges, the Chinese government has introduced subsidy policies to encourage farmers to adopt crop rotation. These measures promote grain-legume rotation in Northeast China and advance maize-soybean intercropping, aiming to enhance soybean and oilseed capacity [23]. However, the subsidy policy implemented did not increase soybean planting areas in Northeast China [23]. Using prefecture-level data, subsidies for soybean producers have had limited effects on adjusting the maize-soybean planting structure, and the impact has diminished over time [24]. Therefore, relying solely on subsidies is not a sustainable strategy for promoting technology adoption. Beyond economic considerations, farmers' decision-making is also shaped by their intrinsic values and cognitive frameworks [25,26]. Instead, a more comprehensive approach is required, one that considers farmers' internal values and cognitive perceptions to foster long-term adoption of rotation practices.

Existing research on farmers' technology adoption primarily focuses on how socio-economic factors influence decision-making, while psychological factors have been largely overlooked. These influencing factors include farmers' endowment characteristics such as gender, age, and education level [27,28], as well as socio-economic variables like household size, income, landholding, and location attributes [29,30]. However, the explanatory power of these indicators is often insufficient [28], failing to provide compelling evidence as to why farmers make certain decisions [31]. Against this backdrop, people are increasingly aware of the importance of social psychological factors in understanding farmers' decision-making, which provides a more comprehensive perspective for analyzing farmers' behavior [32,33].

The theory of Planned Behavior (TPB) provides a comprehensive framework for analyzing the factors influencing individual decision-making in specific contexts from a psychological perspective. This theory posits that individuals form behavioral intentions before taking action, and these intentions are shaped by three key components: attitude, subjective norms, and perceived behavioral control [34]. These components reflect farmers' risk perceptions of crop rotation technologies, social pressures, and self-assessment of operational ability. In typical agricultural environments such as northeastern black soil regions in China, crop rotation decisions are influenced not only by economic returns and technological feasibility but also by socio-psychological factors [35,36]. To account for these diverse drivers, TPB moves beyond the rational economic model that emphasizes cost-benefit reasoning, integrating social influences, personal attitudes, and self-efficacy perceptions. This approach enables a more comprehensive understanding of decision-making behavior [37]. Therefore, TPB has been widely applied in studies of agricultural technology adoption. The framework shows good applicability and explanatory power for crop rotation decisions in northeastern black soil regions [17,38]. However, some scholars critique TPB for its emphasis on logical processes in behavior formation and its omission of certain emotions [39,40], cognition, and perceptual constructs [39,41,42], which play crucial roles in predicting and influencing environmentally related behaviors [43]. Despite these limitations, our study adopts TPB as the analytical framework. The three components—attitude, subjective norms, and perceived behavioral control—are explicitly classified and analyzed. Each component's influence on farmers' intentions to adopt crop rotation technologies is quantitatively examined. The analytical framework advances the understanding of sustainable agricultural adoption behavior, reinforces theoretical and methodological rigor, and improves the comparability and policy relevance of the findings.

Expanding TPB is an effective approach to enhancing its explanatory power, but studies incorporating values into the extended TPB framework remain limited in the context of sustainable agricultural technology adoption. To better understand individual behavior, the TPB model has been extended to include, for example, social trust, risk, and other factors to explain the influence on attitude [44–47]. These factors may change across various situations, while values are relatively stable and can have a lasting impact on individual behavior.

From a psychological perspective, individuals' value orientations (egoistic, altruistic, and biospheric) reflect distinct motivational bases for evaluating environmental and social issues. The Value–Belief–Norm (VBN) framework provides a theoretical basis for how these values shape individuals' perceptions and attitudes toward pro-environmental behaviors [48]. Specifically, individuals with egoistic values tend to evaluate actions in terms of personal costs and benefits, forming attitudes primarily driven by economic efficiency and risk avoidance [49–51]. In contrast, those with altruistic values emphasize the welfare of others and society as a whole, often demonstrating a stronger sense of social responsibility and concern for public well-being [48]. Individuals holding biospheric values recognize the intrinsic worth of nature and ecosystems, typically exhibiting more positive attitudes toward environmental protection and sustainable practices [49–51]. However, existing research on the influence of values on behavioral intentions primarily focuses on the consumption domain, while studies in the production domain remain limited [52–55]. To fill this research gap, our study investigates whether farmers' value orientations influence their willingness to adopt crop rotation practices within the TPB framework, using empirical evidence from the black soil region of Northeast China.

2. Theoretical Background and Research Hypotheses

2.1. Theory of Planned Behavior

TPB is widely applied in sociology, psychology, and economics to explain individuals' behavioral decisions in specific contexts. According to TPB, individuals' behavior is theorized to be driven by behavioral intention, which reflects an individual's expectation to perform a particular action. In the construct of TPB, behavioral intention is influenced by *attitude*, *subjective norm*, and *perceived behavioral control* [34].

Attitude is defined as an individual's subjective evaluation of specific behavior. When an individual holds a positive attitude toward a specific behavior, it can increase the likelihood of adopting that behavior [56]. In agricultural decision-making, farmers who perceive certain agricultural practices positively are more likely to develop a favorable attitude, thereby increasing their intention to adopt such techniques [57,58]. Conversely, farmers holding a resistant or negative view may be less inclined to implement these approaches.

Subjective norm reflects an individual's perception of social pressure from important people or organizations to engage in or avoid certain behaviors. Subjective norms capture social expectations [59], influencing farmers' decisions based on perceived recognition from family, friends, organizational groups, or neighborhood [60–62]. Thus, farmers are more likely to develop a positive behavioral tendency when crop rotation receives social support. Additionally, subjective norm is linked to social identity [63], as group affiliations shape farmers' decisions. If adopting crop rotation is seen as part of social identity, its widespread practice reinforces a sense of belonging, making farmers more likely to align with peers and adopt the technique.

Perceived behavioral control reflects an individual's comprehensive assessment of their own capabilities and available conditions (e.g., material resources, capital) before performing a specific behavior. It results from the combined effects of various factors. If farmers believe they have sufficient capability and resources to perform a particular behavior, they are more likely to form a positive behavioral expectation, which in turn promotes the adoption of technology [38,64]. Conversely, if farmers feel they lack the necessary abilities or face difficulties and obstacles, they may develop a negative behavioral expectation, which can hinder technology adoption. Therefore, the stronger the perceived behavioral control, the greater the behavioral intention is likely to be.

2.2. Value-Based Theory of Planned Behavior (V-TPB)

Although TPB has been broadly successful in explaining the mechanisms underlying behavior formation and its influencing factors, some scholars have questioned its comprehensiveness in identifying all relevant determinants of behavior [65,66]. Additionally, TPB has been criticized for its emphasis on logical reasoning in behavior formation while overlooking certain emotional [39], cognitive, and perceptual constructs [41,42], which play crucial roles in predicting and influencing environmentally related behaviors [50]. In response to these limitations and to further refine the theory, the Extended Theory of Planned Behavior was developed.

The Extended Theory of Planned Behavior includes additional factors that play a significant role in individual decision-making. For instance, knowledge (*KNL*) and perceived climatic threats of conservation tillage (*PCTCV*) have been introduced to enhance TPB, providing a more comprehensive understanding of farmers' intentions and behaviors toward conservation tillage [46]. Similarly, by integrating risk perception (*RP*) and moral norms (*MN*) into the theoretical framework of farmers' safe use of chemical fertilizers, the explanatory power of TPB regarding farmers' safety behavior intentions has increased by 11.2% [45]. Furthermore, incorporating farmers' trust in information sources as a driving factor for adherence to a nutrition management plan (*NMP*) has yielded insightful findings. The results indicate that trust in technical information sources, such as consultants and discussion groups, exerts greater influence on farmers' attitudes, subjective norms, and perceived behavioral control compared to trust in social information sources, such as family and media [44].

While the Extended Theory of Planned Behavior has improved the understanding of behavior and offered new insights, certain limitations remain. For instance, factors such as knowledge and social trust may fluctuate depending on contextual changes. Additionally, farmers' attitudes and cognition, while important, are concrete constructs that may not fully capture the fundamental formation process of behavioral motivation. Given that values serve as the foundational principles guiding human cognition and behavior, it is essential to examine their influence on farmers' willingness to adopt new technologies.

From a psychological perspective, the Value–Belief–Norm (VBN) framework provides a conceptual basis for distinguishing social value orientations as egoistic, altruistic, and biospheric. These orientations reflect different ways individuals evaluate the costs and benefits of pro-environmental behaviors [48]. An increasing number of scholars have demonstrated that different value orientations influence attitudes, leading to individual behavioral heterogeneity [51]. While academic studies on the influence of values on human behavior encompass diverse perspectives, they have predominantly focused on consumer behavior and environmental protection. Our study examines four key constructs in farmers' decision-making regarding crop rotation: attitude, subjective norm, perceived behavioral control, and value orientations. Among these, attitude, subjective norm, and perceived behavioral control are treated as quantitative indicators, reflecting measurable beliefs and perceptions, while value orientations (egoistic, altruistic, and biospheric) are treated as qualitative indicators, representing underlying principles guiding farmers' decisions.

Egoistic value orientation drives individuals to prioritize their own interests in decision-making, emphasizing personal benefit maximization [49]. Some researchers argue that egoists are less likely to adopt environmentally friendly attitudes and engage in pro-environmental behaviors [49–51]. However, other studies suggest that self-centered consumers may develop a stronger affinity for organic food [67], as they are more willing to pay a higher premium for organic products when they perceive benefits to their health and safety. Here, we argue that if farmers believe adopting crop rotation can directly or indirectly enhance their income, they are more likely to adopt this technique.

Altruistic value orientation emphasizes prioritizing the interests of others and society as a whole when making behavioral choices. Some research suggests that altruistic motivations, such as environmental concerns, have a greater influence on young consumers' attitudes toward eco-friendly packaging than egoistic motivations, such as health concerns [54]. However, contrary to this view, some scholars have found that an altruistic orientation does not necessarily encourage individuals to choose organic food and may even suppress their willingness to purchase organic products [67]. In the agricultural context, here we argue that if farmers believe that adopting crop rotation can effectively control pests, reduce pesticide use, lower pesticide residues, and thereby provide healthier agricultural products to consumers, this perspective is likely to motivate them to adopt crop rotation practices.

Biospheric value orientation, unlike egoistic and altruistic values, conceptualizes the human-nature relationship based on the intrinsic value of life, whereas egoistic and altruistic values prioritize human interests above all else. Notably, biospheric values motivate individuals to respond positively to environmental issues [68,69]. When biospheric and altruistic values come into conflict, their influence on behavior may differ [70]. Research indicates that individuals with an altruistic value orientation are more inclined to donate to humanitarian organizations, whereas those with biospheric value orientation are more likely to support environmental organizations and endorse environmental protection policies [55]. Furthermore, some scholars argue that environmental values are not the primary drivers of attitudes toward organic food. Instead, altruistic values, such as concern for the well-being of others and society, play a crucial role [53]. However, other studies suggest that biospheric, altruistic, and egoistic values positively shape consumers' attitudes and willingness to purchase organic wine [52]. Despite differing perspectives, we propose that if farmers perceive crop rotation as reducing environmental degradation and promoting ecosystem balance, they are likely to adopt and advocate for it to enhance agricultural sustainability.

As an environmentally friendly practice, crop rotation technology represents a substantial shift for farmers accustomed to continuous maize cropping. This transition not only requires adjustments in planting methods but also challenges farmers' internal value systems, influencing their attitudes—particularly their willingness to adopt new technologies.

Building on the above discussion of value orientations and their potential influence on farmers' attitudes, this study proposes the Value-based Theory of Planned Behavior (V-TPB), which integrates egoistic, altruistic, and biospheric values into the classic TPB framework (Figure 1). Based on this framework, we propose four hypotheses to examine how these value orientations shape farmers' attitudes and their willingness to adopt crop rotation practices.

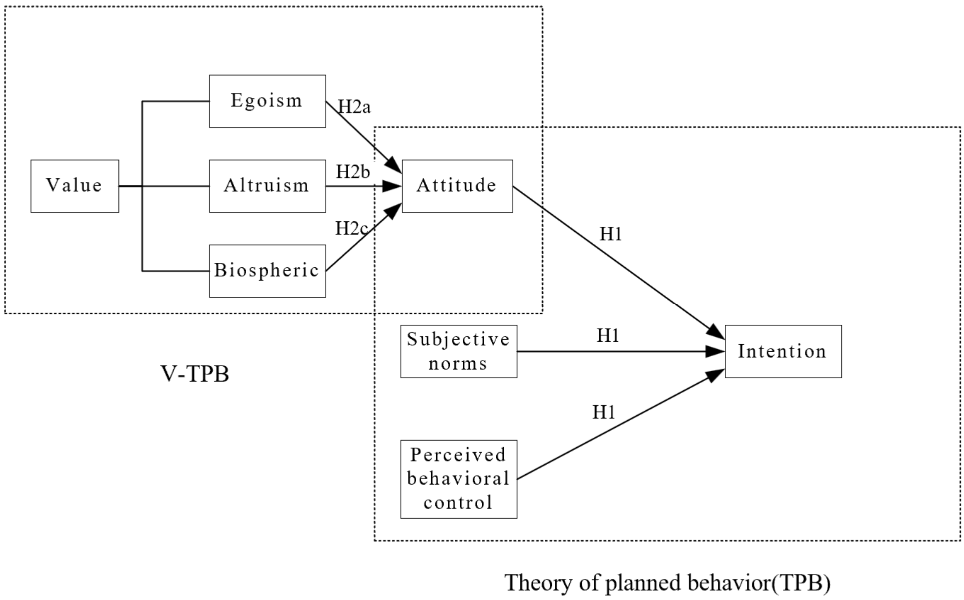

Figure 1. Research Framework. Notes: This model represents the original Theory of Planned Behavior (TPB) and its extension incorporating value-based constructs. It explores how values—egoism, altruism, and biospheric concern—influence behavioral intention through attitude. H1 indicates the effects of attitude, subjective norms, and perceived behavioral control on intention in the original TPB. H2a–H2c represent the influence of different value orientations on attitude.

H1: *Positive attitude, subjective norm and perceived behavioral control, in the classic TPB framework, influence farmers' willingness to adopt crop rotation techniques.*

H2a: *Egoistic value orientation has positive impacts on farmers' attitudes toward adopting crop rotation practices.*

H2b: *Altruistic value orientation has positive impacts on farmers' attitudes toward adopting crop rotation.*

H2c: *Biospheric value orientation has positive impacts on farmers' attitudes toward adopting crop rotation.*

3. Materials and Methods

3.1. Study Region

Our research area is located in Northeast China, where black soil degradation has been a persistent concern. In recent years, the combined effects of soil erosion and continuous maize monoculture have led to severe degradation of black soil in this region [71]. Over the past six decades, the organic matter content in the topsoil of black soil areas has declined by one-third, with some regions experiencing reductions of up to 50% [72]. This deterioration poses a significant threat to China's food security and ecological stability, highlighting the urgent need for effective measures to protect and sustainably manage black soil resources in Northeast China.

Horqin Right Front Banner (Keyouqianqi), located in the northeastern part of the Inner Mongolia Autonomous Region, is an important part of the black soil region. As the key grain-producing area and major commercial grain base, Keyouqianqi had a total maize cultivation area of 2.66 million mu and a soybean cultivation area of 560,000 mu in 2023 [12,73]. Given the similarities in agricultural production conditions between Keyouqianqi and other areas of Northeast China, this region was chosen as the focus of our study.

3.2. Survey Procedure

Our survey was conducted in Keyouqianqi (Horqin Right Front Banner) in November and December 2023. Keyouqianqi was selected as the case study area because it represents a typical agro-ecological and socioeconomic setting within the Northeast China Black Soil Ecological Region. The area is characterized by fertile black soils, a maize-dominated cropping system, and a combination of smallholder farmers and emerging agricultural business entities. In addition, it has been one of the pilot regions for national programs promoting sustainable cultivation and maize–soybean rotation, making it representative of the ongoing agricultural transformation in the region.

To ensure representativeness in the sample, we combined typical sampling with stratified random sampling. Typical sampling was applied during the town-selection stage, where towns were chosen to reflect the main gradients of interest, including agro-ecological type, production intensity, and socio-economic conditions. Specifically, three predominantly agricultural towns and one agriculture-pastoral town-Eti, Barigastai, Eergetu, and Dashizhai (see Figure 2)-were selected to capture the spatial and ecological diversity within Keyouqianqi. Within each selected town, strata were established at the village level based on local production characteristics such as dominant cropping patterns and the proportion of smallholder and large-scale farming operations. Random sampling was then conducted within each stratum. Four villages were chosen from each town, and at least twenty farmers were randomly selected from each village. This two-stage design, involving the sequential processes of typical town selection, stratified village sampling, and random farmer selection, ensured broad coverage of the major regional farming typologies while minimizing potential sampling bias within each stratum.

Prior to conducting the formal survey, the research team established an interdisciplinary group composed of members from economics, psychology, agricultural sciences, and local agricultural extension. This group conducted a comprehensive review and refinement of the questionnaire to enhance its scientific rigor, practical relevance, and contextual appropriateness.

The group's feedback addressed multiple dimensions. Members with natural science backgrounds contributed by selecting Keyouqianqi as the study area based on local agricultural production conditions, soil types, cropping patterns, and ecological characteristics. This selection ensured that the survey sample accurately reflected the typical farming practices and decision-making behaviors of farmers in the Northeast China Black Soil Ecological Region. Economics-oriented members guided the identification of key factors influencing farmers' adoption intentions and production decisions, drawing on behavioral economics and agricultural decision-making theories. They also advised on the design of related variables, including attitudes, subjective norms, and perceived behavioral control, to ensure the questionnaire captured farmers' economic motivations and decision-making tendencies. Members with backgrounds in psychology and sociology suggested refinements to the wording of attitudinal and behavioral intention items to reduce ambiguity, improve consistency of interpretation across respondents, and enhance the reliability and internal consistency of the questionnaire. Local agricultural extension members contributed from a practical perspective by assisting in mobilizing farmers for survey participation and promoting awareness of crop rotation and sustainable farming practices. Their involvement improved respondents' understanding of the survey topics, facilitated efficient data collection, and enhanced engagement and willingness to complete the questionnaire.

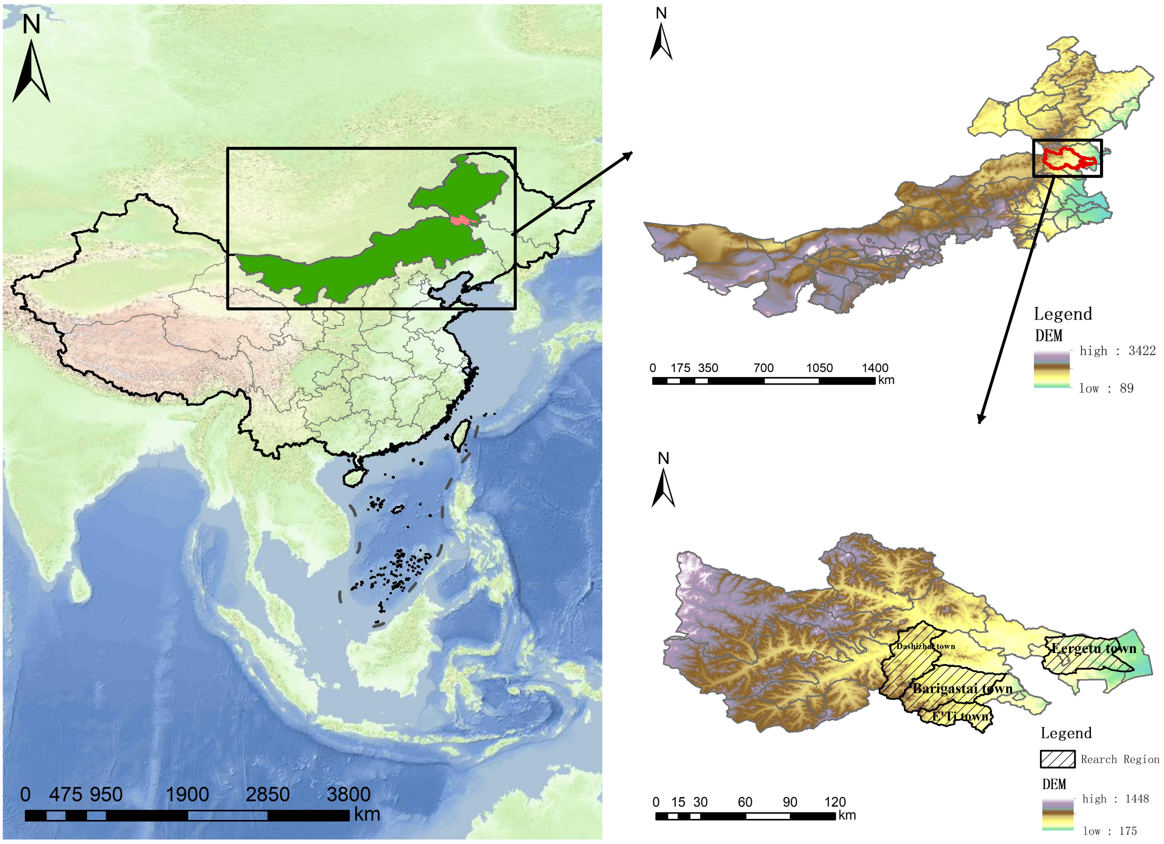

Figure 2. Study region and sample distribution within China.

The interdisciplinary group's contributions were fully incorporated into the final questionnaire, which consisted of two sections: one covering demographic and household or cooperative characteristics, and the other assessing the original and extended constructs of TPB.

3.3. Methodology

All questionnaires were administered in-person during the field survey. Upon completion, each questionnaire was checked on-site for completeness and consistency. Any missing information was immediately followed up with the respondent either on-site or by phone. Questionnaires with substantial missing responses that could not be completed were excluded from the analysis. Following this procedure, a total of 298 complete questionnaires were obtained and used for subsequent analysis.

The primary objective of this study is to empirically test V-TPB by integrating farmers' egoistic, altruistic, and biospheric value orientations into the traditional TPB framework. The model illustrates how these underlying values shape attitude(AT), subjective norm(SN), and perceived behavioral control(PBC), which collectively influence farmers' willingness to adopt crop rotation practices. Based on the hypotheses developed in the theoretical framework, the empirical analysis focuses on evaluating the structural relationships proposed in the V-TPB model, examining how farmers' value orientations are associated with their psychological determinants and adoption willingness.

To empirically examine the structural relationships proposed in the V-TPB model, Structural Equation Modeling (SEM) was conducted using AMOS 26. Before model estimation, a Pearson correlation analysis was first performed to examine the inter-associations among the selected socio-psychological indicators, ensuring that the variables were suitable for subsequent SEM analysis. SEM analyzes complex interactions among multiple variables, making it particularly useful for identifying key factors influencing farmers' decision-making processes [74]. SEM consists of two fundamental components: the measurement model and the structural model [75]. The measurement model evaluates the relationships between latent variables and their observed indicators, ensuring that the constructs are appropriately defined. In contrast, the structural model examines the interactions among latent variables to test hypothesized causal relationships. The analytical process starts with assessing the measurement model to verify reliability and validity. Next, the structural model is estimated to examine the proposed relationships.

The design quality of the questionnaire scales plays a crucial role in determining the reliability and validity of conclusions, making rigorous testing indispensable [66]. A well-constructed questionnaire enhances the accuracy of measurement by reducing errors. Cronbach's Alpha (α) coefficient was employed to assess the internal consistency of each dimension, with α values exceeding 0.70 indicating good reliability [76]. Ensuring high internal consistency is essential, as greater reliability minimizes measurement errors and enhances the credibility of the findings.

Before conducting validity testing, it is essential to evaluate the model's goodness-of-fit indices to determine whether it adequately represents the data. A well-fitting model enhances the credibility and accuracy of subsequent analyses. Model fit can be assessed using absolute fit indices, incremental fit indices, and parsimony fit indices. When these indices meet or exceed the recommended thresholds, the model is considered to have a good fit.

Once the model exhibits a satisfactory fit, Confirmatory Factor Analysis (CFA) is employed to evaluate its measurement quality, specifically in terms of convergent validity and composite reliability (C.R.). This step ensures that the observed variables effectively represent their respective latent constructs. A critical aspect of this evaluation is the analysis of standardized factor loadings (λ), which measure the strength of associations between observed variables and their underlying constructs.

In addition to factor loadings, C.R. is calculated to assess the internal consistency of measurement items within each construct. C.R. value exceeding 0.70 is generally required to confirm high reliability, ensuring that the construct is measured consistently across its indicators. If C.R. falls below this threshold, it may indicate measurement inconsistencies, requiring adjustments such as refining or removing problematic items. Furthermore, Average Variance Extracted (AVE) is used to assess convergent validity, with a recommended threshold of AVE ≥ 0.50, indicating that at least 50% of the variance in the observed variables is explained by the latent construct, thereby reducing the impact of measurement errors.

By systematically evaluating goodness-of-fit indices, standardized factor loadings, C.R., and AVE, researchers can ensure that their measurement model is both reliable and valid. This rigorous validation process enhances the accuracy of the findings and strengthens the robustness of the hypothesized relationships within the structural model. If any reliability or validity indicators do not meet the recommended thresholds, necessary modifications—such as refining, removing, or replacing measurement items—should be implemented to optimize the overall model quality.

4. Results

4.1. Socio-Economic Characteristics of Surveyed Farmers

Table 1 presents the characteristics of agricultural producers and farmers' organizations. The respondents are primarily farmers engaged in relatively large-scale cultivation, mostly belonging to small or medium-sized agricultural organizations, and are full-time agricultural producers who serve as the primary decision-makers in their farming operations. First, regarding cultivation size, farms are classified into three categories based on data distribution and a specified threshold. Nearly half of the surveyed households (44.63%) manage land areas exceeding 6.67 hectares, indicating a trend toward large-scale farming. In contrast, small-scale farmers, cultivating up to 3.35 hectares, constitute approximately a quarter of the sample (24.16%). This distribution highlights the ongoing intensification and expansion of agricultural production in Northeast China while also reflecting the coexistence of small-scale intensive farming practices. These trends illustrate the diverse and complex nature of agricultural production in the region. Second, in terms of farm type, the majority of respondents (81.54%) are smallholder farmers, whereas 18.45% are classified as family farms or cooperative. Third, most respondents in our study serve as primary decision-makers in agricultural production within their households and are full-time farmers, accounting for 88.59% of the sample. This finding underscores the predominant role of full-time farmers in agricultural decision-making. Additionally, a smaller proportion (8.39%) consists of part-time agricultural decision-makers, while non-agricultural decision-makers represent the smallest group, making up only 3.02%. The latter category likely does not participate directly in agricultural production decision-making.

Table 1. Socio-economic characteristics of surveyed farmers.

Variable	Category	Frequency	Percent (%)
Cultivation size	≤3.35 Ha	72	24.16
	3.35–6.67 Ha	93	31.21
	>6.67 Ha	133	44.63
Organization	Smallholder farms	243	81.54
	Family farm or cooperative	57	18.46
Farm decision	Yes, and full-time farming	264	88.59
	Yes, and part-time farming	25	8.39
	No farm decision	9	3.02
Age	Under 35 years	14	4.70
	35–50 years	139	46.64
	Above 50 years	145	48.66
Gender	Male	294	98.66
	Female	4	1.34
Education	Under 6 years	122	40.94
	7–9 years	143	47.99
	More than 9 years	33	11.07

Source: Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China.

The respondents are predominantly male, middle-aged or elderly, and have received a basic level of education (7–9 years). Regarding the age distribution of household heads, 46.64% fall within the 35–50 age range, while 48.66% are 50 years or older, indicating that middle-aged and older individuals constitute the majority. This suggests that an aging trend may exist in agricultural labor in Northeast China. Additionally, most household heads are male, and their educational attainment is generally limited to 7–9 years of schooling. Only a small proportion (11.07%) has received more than nine years of education.

4.2. Descriptive Statistics

The intention scale was adapted from prior studies using TPB to quantify agricultural technology adoption [31,77]. Our study assesses three key intention-related variables regarding the adoption of a maize-soybean rotation system: the intention to participate in maize-soybean rotation projects, the intention to improve soil quality through maize-soybean rotation, and the intention to promote a healthier soil ecosystem with maize-soybean rotation. A standard Likert scale was employed to measure these variables, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). The detailed questionnaire items and their corresponding evaluation metrics are provided in Table 2.

Table 2. Research measurement concepts and variables.

Construct	OVs	Measurement Items	Mean	S.D.	Factor Loading (λ)	Reliability and Validity Test
Intention	IN1	If there is a maize-soybean rotation project, I would like to participate.	3.58	1.170	0.931	AVE:0.609 C.R.:0.753 α:0.750
	IN2	I tend to adopt maize-soybean rotation to improve the soil quality on my land.	3.32	1.270	0.906	
	IN3	I tend to adopt maize-soybean rotation to promote healthier soil ecosystem.	3.27	1.232	0.840	
Attitude	AT1	The optimal use of maize-soybean rotation on my land is beneficial to me.	3.61	1.096	0.698	AVE:0.798 C.R.:0.922 α:0.922
	AT2	The maize-soybean rotation benefits both agricultural product sales and consumers.	3.60	1.100	0.802	
	AT3	The maize-soybean rotation is beneficial to ecological environment.	3.62	1.135	0.618	
Perceived behavior control	PBC1	I can address the risks of additional costs associated with maize-soybean rotation.	3.32	1.352	0.695	AVE:0.603 C.R.:0.819 α:0.809
	PBC2	I believe scientists can help solve the challenges of applying rotation techniques.	3.65	1.131	0.857	
	PBC3	I believe the government will support me in the implementation of rotation practices.	3.78	1.085	0.769	
Subjective norm	SN1	When I propose crop rotation, my relatives and friends around me will show a positive attitude.	2.79	0.991	0.604	AVE:0.504 C.R.:0.751 α:0.707
	SN2	When I use rotation technology, village cadres or village planting experts will give affirmation.	2.83	1.100	0.933	
	SN3	When other farmers adopt rotation technology and encourage me to follow it, I will do it.	3.05	1.183	0.680	
Egoism	EG1	I believe people act in their own interests most of the time.	3.67	1.197	0.728	AVE:0.566 C.R.:0.791 α:0.777
	EG2	People give things to others primarily to obtain something in return.	3.21	1.304	0.882	
	EG3	When people do good for others, it is often driven by vanity.	3.17	1.315	0.692	
Altruism	AL1	People are really selfless in helping others.	3.41	1.248	0.911	AVE:0.596 C.R.:0.814 α:0.807
	AL2	People always help others without expecting anything in return.	3.42	1.306	0.567	
	AL3	People are able to put the interests of others before their own.	3.36	1.347	0.603	

Table 2. *Cont.*

Construct	OVs	Measurement Items	Mean	S.D.	Factor Loading (λ)	Reliability and Validity Test
Biospheric	BI1	Nature should not be disturbed.	3.81	1.117	0.830	AVE:0.505 C.R.:0.745 α:0.726
	BI2	Human activities can easily disrupt the balance of nature.	3.89	0.968	0.686	
	BI3	Nature must be protected from human harm.	3.95	1.094	0.606	

Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. AT stands for attitude, PBC for perceived behavioral control, SN for subjective norm, EG for egoism, AL for altruism, and BI for biospheric. 3. The response scale for the variable 'IN' ranges from 1 (Extremely weak) to 5 (Extremely strong), while all other variables range from 1 (Strongly disagree) to 5 (Strongly agree); S.D. in the range of 1–2.33 indicates a Low level; 2.34–3.67 indicates a Moderate level; 3.68–5.00 indicates a high level. 4. The mean values for the variables are as follows: IN (M = 3.390), ET (M = 3.609), PBC (M = 3.582), SN (M = 2.889), EG (M = 3.350), AL (M = 3.399), and BI (M = 3.881).

By using structural equation modeling, we calculated the mean scores and standard deviations for each variable (Table 2). Farmers' intentions to adopt crop rotation technology show a moderate level (mean = 3.390), indicating an ambivalent or hesitant mindset. Their attitude toward crop rotation is similarly neutral, with a mean score of 3.609, reflecting neither a notably positive nor a distinctly negative stance. However, their AT toward crop rotation is more favorable compared to SN and PBC, which they regard as moderate, with scores of 3.582 and 2.889, respectively.

In the quantitative analysis of individual value orientations, we found that the mean score for EG was 3.350. This score represents a moderate level of prioritizing personal interests, indicating a tendency toward self-interest and personal satisfaction in decision-making. By contrast, the AL score was slightly higher at 3.399, suggesting a moderate inclination to consider and enhance the welfare of others, although this tendency remains at a medium level and shows a slight shift away from pure self-centeredness. Notably, the BI score reached 3.881, significantly higher than both EG and AL. This result indicates a more positive AT among respondents toward the relationship between humans and nature.

4.3. Correlation Analysis

Table 3 presents the results of the Pearson correlation analysis based on the mean values of latent variables. According to the results, IN is positively correlated with AT and PBC, indicating that higher levels of positive attitude and stronger perceived control are associated with greater adoption intention. AT also shows a relatively strong positive correlation with PBC (r = 0.503, $p < 0.01$), suggesting a close interrelation between these two constructs in shaping behavioral tendencies. In addition, AT is positively correlated with BI and AL, implying that farmers with stronger pro-environmental and altruistic orientations tend to hold more favorable attitudes toward adoption. The correlations among other variables are generally weak or insignificant, and the overall directions are consistent with theoretical expectations. Most coefficients range between 0.1 and 0.5, with the highest correlation observed between AT and PBC (r = 0.503). Since all coefficients are below 0.8, there is no indication of serious multicollinearity, confirming that the data are suitable for subsequent SEM analysis.

Table 3. Pearson correlation analysis results of latent variables.

Construct	Intention	BI	SN	AT	PBC	EG	AL
Intention	1						
BI	0.187 **	1					
SN	0.020	−0.057	1				
AT	0.460 **	0.213 **	0.047	1			
PBC	0.426 **	0.110	−0.019	0.503 **	1		
EG	0.007	0.165 **	−0.020	0.020	0.083	1	
AL	0.068	0.107	−0.044	0.217 **	0.122 *	−0.077	1

Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. ** represents significance at $p < 0.05$; * represents significance at $p < 0.10$. 3. AT stands for attitude, PBC for perceived behavioral control, SN for subjective norm, EG for egoism, AL for altruism, and BI for biospheric.

4.4. Measurement Model

The results of reliability and validity testing are presented in Table 2. Higher reliability of the questionnaire scales corresponds to lower measurement error. Factor loadings (λ) must first be examined for statistical significance to confirm their meaningful contribution. As shown in Table 2, all variables have λ values greater than 0.5, demonstrating acceptable explanatory power and supporting the construct validity of the measurement model. Then, we used Cronbach's Alpha (α) coefficient to test the internal consistency of each dimension. By conducting reliability analysis on the six latent variables and the overall questionnaire scale, we found that the reliability coefficients for all dimensions of farmers' intentions to adopt crop rotation technology ranged between 0.7 and 1 (Table 2). This indicates strong internal consistency, demonstrating that the scales used in this study are highly reliable.

We proceeded to assess the convergent validity (AVE) and composite reliability (C.R.) of each dimension in the scale. This evaluation was conducted by establishing a confirmatory factor analysis model, from which the standardized factor loadings of each measurement item on its respective dimensions were obtained. Using these factor loadings, we calculated the AVE and C.R. values for each dimension according to their respective formulas. This process ensures that each dimension has adequate convergent validity and composite reliability, supporting the robustness of the measurement model. In Table 4, the AVE values for each dimension exceed 0.5, and the C.R. values are all above 0.7, demonstrating strong convergent validity and composite reliability across all dimensions.

Table 4 indicates that all estimated indices align well with recommended threshold values, suggesting that the model has a good fit. Specifically, the ratio of x2/df to the degree of freedom for V-TPB is 1.293, which is less than the acceptable value of 2.00. Other indices, including the root mean square residual (RMR), root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), normed fit index (NFI), incremental fit index (IFI), Tucker–Lewis index (TLI), comparative fit index (CFI), parsimony normed fit index (PNFI), and parsimony comparative fit index (PCFI), all indicate that the model was adequately fitted. This satisfactory fit supports the subsequent validity tests, confirming that the model is well-suited to the data.

The discriminant validity of the scale measuring farmers' willingness to adopt rotation technology was also tested. According to the analysis results in Table 5, the standardized correlation coefficients between each pair of dimensions are all smaller than the square root of the corresponding AVE values, indicating good discriminant validity among the dimensions.

Table 4. The structural models fit indices.

Fit Index	Index	Recommended Level	V-TPB Model	GOF Judgment
Absolute fit indices	χ^2/df	< 2.00	1.293	Supported
	RMR	<0.05	0.075	Supported
	RMSEA	<0.08	0.031	Supported
	GFI	>0.90	0.931	Supported
	AGFI	>0.90	0.912	Supported
Incremental fit indices	NFI	>0.90	0.912	Supported
	IFI	>0.90	0.978	Supported
	TLI	>0.90	0.974	Supported
	CFI	>0.90	0.978	Supported
Parsimony fit indices	PNFI	>0.50	0.777	Supported
	PCFI	>0.50	0.834	Supported

Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. GOF judgement (Goodness-of-Fit judgement) represents whether each model fit index meets the recommended threshold. The term "Supported" indicates that the corresponding fit index satisfies the acceptable statistical criteria, implying that the hypothesized model shows an adequate or good overall fit to the observed data.

Table 5. Discriminate validity.

Construct	Intention	AT	PBC	SN	EG	AL	BI
Intention	0.609						
AT	0.551	0.798					
PBC	0.522	0.541	0.603				
SN	0.026	0.000	0.000	0.504			
EG	0.007	−0.038	0.002	0.000	0.791		
AL	0.079	0.173	0.213	0.314	0.008	0.596	
BI	0.209	0.188	0.342	0.273	0.071	0.218	0.505

Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. values on the diagonal are the square root of AVE while the off-diagonals are correlations. AT stands for attitude, SN for subjective norm, PBC for perceived behavioral control, EG for egoism, AL for altruism, and BI for biospheric.

4.5. Results of SEM

The results of the hypothesis test are shown in Table 6. The model fitting process produced standardized path coefficients (Std. Estimated), standard errors (S.E.), critical ratios (C.R.), and significance levels. A path coefficient is considered statistically significant at the 95% confidence level if C.R. > 1.96 and $p < 0.05$. The results indicate that attitude, perceived behavioral control, altruistic value orientation, and biospheric value orientation significantly influence farmers' intention to adopt crop rotation technology at the 1% significance level. In contrast, subjective norm and egoistic value orientation do not show a significant effect, suggesting their limited role in shaping adoption intentions within this model.

Figure 3 shows the results of the hypothesis tests and the standardized path coefficients of the structural model for V-TPB. The model indicates that while the path coefficients for AT ($p < 0.01$) and PBC ($p < 0.01$) are statistically significant, the coefficient for SN is not ($p = 0.775$). Specifically, the standardized path coefficient for farmers' AT toward crop rotation is significantly positive at 0.384, indicating that more favorable AT strengthens adoption intentions. This result supports the hypothesis related to AT and highlights AT as the most influential factor in shaping farmers' intentions. Conversely, the standardized path coefficient of SN is not significant, suggesting that the hypothesis related to SN is not supported. The standardized path coefficient for PBC is significantly positive at 0.323, implying that greater risk tolerance and improved access to external support enhance farmers' intention to adopt crop rotation, thereby confirming the hypothesis related to PBC.

Table 6. Results of hypothesis test.

Paths	Std. Estimate	S.E.	C.R.	Supported
H1: AT → Intention	0.384 ***	0.076	5.160	Yes
SN → Intention	0.018	0.085	0.286	No
PBC → Intention	0.323 ***	0.090	4.153	Yes
H2a: EG → Attitude	−0.052	0.073	−0.933	No
H2b: AL → Attitude	0.148 ***	0.060	2.573	Yes
H2c: BI → Attitude	0.180 ***	0.056	3.005	Yes

Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. Std. Estimate refers to standardized path coefficients, S.E. is the standard error, C.R. is the critical ratio (Std. Estimate divided by S.E.) with ∣C.R.∣ > 1.96 indicating significance at $p < 0.05$, Supported indicates whether the hypothesis is supported (Yes = significant, No = not significant). 3. AT stands for attitude, SN for subjective norm, PBC for perceived behavioral control, EG for egoism, AL for altruism, and BI for biospheric. 3. *** represents significance at $p < 0.01$.

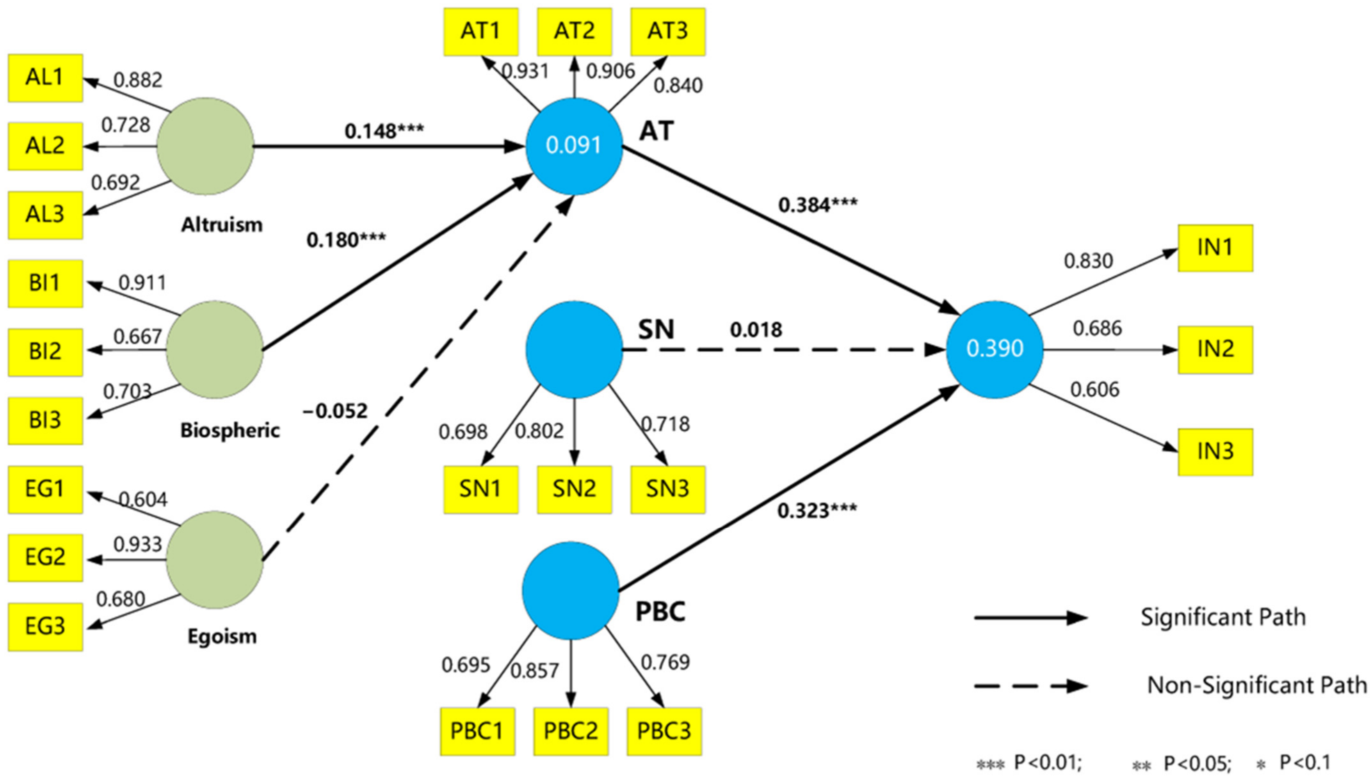

Figure 3. Standardized PCs of the structural model for V-TPB (Value-Based Theory of Planned Behavior). Notes: 1. Author's computation based on field survey data collected in Keyouqian Banner, Inner Mongolia, China. Data were analyzed using IBM SPSS Amos 26.0 (IBM Corp., Armonk, NY, USA). 2. Circles represent latent constructs, and rectangles denote observed indicators. All path coefficients are standardized. Solid arrows represent statistically significant paths, while dashed arrows indicate non-significant paths. Blue-colored nodes represent the original components of the Theory of Planned Behavior (TPB), and green-colored nodes denote the extended value orientation constructs. Numbers inside the circles represent the R^2 values for the corresponding latent variables. 3. AT stands for attitude, SN for subjective norm, PBC for perceived behavioral control, EG for egoism, AL for altruism, and BI for biospheric.

Additionally, the V-TPB model demonstrates that both AL ($p < 0.01$) and BI ($p < 0.01$) exert significant positive influences on farmers' attitudes toward crop rotation, with path coefficients of 0.148 and 0.180, respectively. Thus, hypotheses H2b and H2c are confirmed.

In contrast, the path coefficient of EG on farmers' attitudes toward crop rotation is not significant ($p = 0.351$), indicating that hypothesis H2a is not supported.

5. Discussion

Our research utilizes survey data from Northeast China to explore psychological factors, particularly value orientation, influencing farmers' willingness to adopt crop rotation. Unlike previous research which has primarily explored farmers' technology adoption decisions from an economic benefit perspective [13,14,16], our analysis applies the environmental psychology framework proposed by [48], refining value orientation into three dimensions: egoistic, altruistic, and biospheric values. By adopting this perspective, the investigation moves beyond the rational economic agent assumption, providing a more nuanced psychological approach to understanding farmers' decision-making processes. Consistent with existing findings that government subsidies alone are insufficient to promote lasting behavioral change among farmers [24,78], our analysis highlights the role of altruistic and biospheric values in strengthening farmers' sense of social responsibility and community awareness. This highlights that the value-driven approach can effectively complement the shortcomings of purely economic incentives, offering deeper insights into the mechanisms underlying farmers' adoption of sustainable agricultural practices.

The application of TPB in this research produces results that are not entirely consistent with those of other studies, highlighting both similarities and divergences. On one hand, our finding that more favorable attitude strengthens adoption intentions aligns with previous research [45,46,79], reinforcing its crucial role in predicting and explaining individual behavioral intentions. Additionally, the positive influence of perceived behavioral control on behavior is consistent with findings from [39,45,46], suggesting that both individual ability perceptions and external environmental factors play a vital role in strengthening farmers to adopt new technologies. Specifically, when farmers are confident in their ability to manage the risks associated with maize-soybean rotation, their strong sense of self-efficacy serves as a driving force for adopting the practice [80]. Moreover, if farmers perceive that external entities, such as scientists or government agencies, can assist them in overcoming challenges, their motivation to adopt rotation increases [9]. Furthermore, those with sufficient financial resources are better able to withstand potential initial setbacks [31]. On the other hand, our study deviates from prior research regarding the role of subjective norms. Our results indicate that subjective norms do not significantly affect farmers' behavioral intentions, which is different from previous studies that emphasized the importance of social influence [31,44–46]. A possible explanation for the discrepancy lies in the geographical and social context of our study area. The surveyed region has a relatively low population density in China, which may limit daily interactions among farmers. When farmers' communication does occur, discussions may remain superficial, preventing the formation of strong peer influence or social pressure. Alternatively, our result may indicate that there is little variation in subjective norms across our sample, perhaps with these norms consistent at state-level or above.

Our V-TPB model confirms that values serve as a fundamental cognitive framework in shaping individual attitudes. This result aligns with previous research emphasizing the critical role of values in forming behavioral intentions [52–54,81]. However, our study reveals notable differences from prior research regarding the specific mechanisms through which egoistic, altruistic, and biospheric values influence farmers' adoption of crop rotation technology. Regarding egoistic values, previous studies suggest that egoists prioritize personal benefits when making sustainability-related choices [69,82,83]. In contrast, our study presents different findings, likely due to differences in research subjects. While prior studies primarily examined consumers whose sustainability choices are often driven by personal health benefits [67], our study focuses on farmers whose decisions are constrained by the economic feasibility of agricultural production. For those prioritizing short-term economic returns, financial security and profitability remain key considerations. Consequently, egoistic farmers are less inclined to adopt crop rotation, as it requires long-term investment and delayed returns.

With respect to altruistic values, the results are consistent with [84], demonstrating that farmers who prioritize societal well-being are more inclined to adopt crop rotation. This is likely because they recognize its role in producing safer, higher-quality, and more environmentally friendly agricultural products [53]. These findings suggest that beyond self-interest, farmers with altruistic values are motivated by public health concerns and environmental sustainability, reinforcing the broader societal benefits of sustainable agricultural practices.

We also confirm that biospheric values significantly influence farmers' adoption of crop rotation, which is in line with [68], who highlight the role of environmental concern in shaping pro-environmental actions. As crop rotation enhances soil quality, reduces reliance on fertilizers and pesticides, and improves water efficiency, farmers with strong biospheric values are more inclined to embrace this practice. Previous research has primarily examined biospheric values in the context of consumer preferences [55,85], while this study extends the analysis to agricultural production, demonstrating that biospheric concerns are not only relevant to consumption choices but play a vital role in farmers' decision-making. The differences may stem from decision-making contexts—consumers prioritize personal benefits, while farmers weigh economic feasibility, risk, and sustainability.

Thus, to foster farmers' appreciation for crop rotation, both the government and scientists can implement intervention strategies. The government can promote positive values like benevolence, altruism, and environmental awareness through educational guidance. Additionally, it can foster a supportive social atmosphere to reinforce these values [48]. In addition, leveraging new media platforms (e.g., the internet and social media) as communication tools enables the dissemination of information on the benefits of crop rotation [86]. These promotional efforts not only enhance farmers' understanding but also transform their perceptions and attitudes. This encourages them to shift from passive recognition to the active adoption of crop rotation practices [87]. Meanwhile, scientists play a crucial role in supporting adoption by offering technical training programs, workshops, and field demonstrations, equipping farmers with essential skills and knowledge. As farmers accumulate experience through agricultural practice, they can enhance their ability to manage risks and strengthen their resilience in agricultural production.

6. Conclusions

Here, we advance understanding of the factors influencing the willingness of maize and soybean farmers in Northeast China to adopt crop rotation technology. Using TPB, we identified key factors influencing the willingness of farmers in Northeast China to adopt crop rotation technology. Building on this, the research innovatively introduced value theory by categorizing social value into three dimensions: egoistic value, altruistic value, and ecological value. Our V-TPB model confirmed that values serve as a fundamental cognitive framework in shaping individual attitudes; specifically, it found that altruistic and biospheric values significantly influence farmers' adoption of crop rotation. Thus, we recommend that those promoting sustainable agricultural practices like crop rotation can promote positive values like benevolence, altruism, and environmental awareness through educational guidance in order to increase adoption rates.

Our study has limitations regarding sample size and regional coverage. The research focused on the Korqin Right Front Banner in Inner Mongolia, a key maize-producing region in Northeast China, which is representative and suitable for exploring the determinants of farmers' adoption of crop rotation. However, due to the limited sample size and the study area not covering all maize- and soybean-producing regions in China, the applicability of the findings may be limited. Future research could expand the sample size and include multiple regions to examine regional variations, thereby enhancing the robustness and broader applicability of the results.

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Institutional Review Board Statement: This study involved only non-interventional field surveys of adult farmers and did not include any clinical procedures, collection of biological samples, or physical/psychological interventions. According to the policies of the Institute of Agricultural Information, Chinese Academy of Agricultural Sciences (CAAS), and consistent with the *Measures for the Ethical Review of Biomedical Research Involving Humans (2023 Revision)* of the People's Republic of China—which apply exclusively to biomedical research—such social-science questionnaire investigations are exempt from formal Institutional Review Board review.

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

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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