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Citrus Specialization or Crop Diversification: The Role of Smallholder's Subjective Risk Aversion and Case Evidence from Guangxi, China

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Abstract: Specialization may lead to higher income for small-scale farmers but comes with increased risks, while diversification can mitigate risks and foster agricultural sustainability. Considering the influences of complex risks and farmers' subjective risk aversion, the decision for small-scale farmers to specialize in citrus cultivation or diversify with multiple crops remains uncertain. There is currently limited understanding of this issue among citrus smallholders in rural China. This study aims to fill this empirical gap by examining the impact of smallholder farmers' subjective risk aversion on their choice between citrus monoculture and crop diversification. It utilizes a subjective risk assessment approach that incorporates farmers' risk perceptions and risk attitudes towards citrus farming. Farm crop diversification is assessed through the utilization of both the count index and Shannon index. The empirical analysis employs survey data obtained from citrus growers in Guangxi, China, and applies an instrumental variable regression method with endogeneity consideration using the IV-Probit model and 2SLS model estimation. The results reveal that both risk perceptions and risk attitudes play important roles in citrus smallholders' land allocation decisions. Specifically, citrus farmers who perceive higher risks and adopt risk-averse attitudes are statistically more inclined to engage in land use diversification practices, including the practice of growing citrus as well as other crops, which contributes to reducing the risks of citrus farming and promoting local environmental conservation. These results contribute to a better scholarly comprehension of the relationship between risk perceptions, risk attitudes, and crop diversification among small-scale citrus farmers. They provide valuable insights for enhancing the sustainability of land use systems with citrus farming while also emphasizing the importance of maintaining essential diversification in small-scale farming throughout the process of agricultural modernization.

Keywords: risk perceptions; risk preferences; crop diversification; citrus smallholder; China

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1. Introduction

China is the world's largest citrus-producing region and boasts the largest agglomeration of smallholders in agriculture worldwide. For smallholder citrus farmers, specialized and moderately sized cultivation represents a crucial approach for enhancing agricultural revenue [1]. Since the reform and opening up of China in 1978, the agricultural sector has been dominated by smallholders who operate within the household contract responsibility system, which has observed significant growth in the past few decades. Meanwhile, rapidly rising off-farm wages due to industrialization continue to attract farmers towards employment opportunities in urban areas, rendering small-scale farming financially less attractive. Consequently, scale upgrading, in terms of land transfer, is developing rapidly to obtain higher returns. With the wide diffusion and rapid adoption of modern technologies, Chinese citrus production is increasingly characterized by monocultures of commercial citrus cultivars. However, the high returns of specialized cultivation are often accompanied by higher agricultural risks as compared to diversified cropping [2]. Additionally, the rapid development of increasingly specialized intensive farming poses new challenges for biodiversity and sustainable agricultural development [3]. In fact, agricultural diversification is emerging as a viable solution for enhancing food security and addressing sustainability issues in intensified agriculture [4]. Thus, in smallholder citrus-farming systems, striking a balance between economies of scale, risks, and sustainability is becoming an important question that cannot be overlooked and deserves timely investigation.

Guangxi Autonomous Region (a province equivalent) is the largest citrus-growing region in China, with approximately 613,000 hectares of citrus cultivation. In recent decades, citrus growers have increased significantly, with many farmers converting their crops from cereals to citrus in pursuit of higher agricultural returns. While citrus cultivation has boosted farmers' incomes and the regional rural economy in the last decade, it may also lead to the loss of agrobiodiversity and ecological issues [5]. Citrus is a perennial crop that usually needs 3–5 years to bear fruits, and this relatively long investment cycle exposes smallholders to potential risks, such as volatile citrus prices or serious plant diseases (e.g., the Huanglongbing disease) [6,7]. Despite the leading role that citrus plays in Guangxi, many small-household farmers only use part of their land for citrus cultivation and retain land to grow diversified crops, according to the farm household survey conducted in this study. It is not surprising that farming is susceptible to both climate and market risks, given that small farmers often resort to crop diversification as a means of managing such challenges [8]. Therefore, crop diversification plays a natural insurance role for smallholders [9,10], who are generally risk-averse [11,12]. Many farmers are not willing to engage in high-risk, high-return agricultural production investment and are cautious about investment on a larger scale, new technologies, and the adoption of new varieties [2,12]. Therefore, risk perceptions and risk attitudes of farmers may be key reasons for farmers' crop diversification [13], which require scholarly understanding.

Based on the empirical literature, it appears that past occurrences of extreme risk events can motivate crop diversification [14–16]. Thus, risk perceptions and risk attitudes are often used to interpret farmers' decision making, including land transfer and farm scale investment [2,17], fertilizer and pesticide use decisions [9,18], willingness to pay agricultural insurance, and capacity for coping with climate change [16,19]. While this literature is growing, the existing studies generally center on a certain driver or constraint of crop diversification while presenting little evidence regarding possible impacts of considering risk perception and risk preference jointly, especially their roles in land use for citrus specialization and crop diversification. Moreover, risk perceptions and risk attitudes are closely linked to farmers' decision-making processes, necessitating careful disentanglement in order to gain a more accurate understanding of their effects on various on-farm diversity outcomes. Therefore, it is crucial to promptly address these gaps. The measurement of farmers' risk perception and risk preferences can be effectively carried out using Likert scales and lottery choice experiments [11,20–25]. Additionally, the level of diversification at the farm level can be evaluated through well-established methods such as the Shannon index and count index [26–29]. These approaches lay the foundation for further research establishing quantitative relationships between these three factors.

The objective of this study is to empirically examine the potential correlations between the risk perceptions, risk preferences, and land use decisions of citrus farmers with regard to the choice of citrus specialization or crop diversification. We employ a comprehensive rural household survey conducted in Guangxi Province, a significant agricultural area located in Southern China. Due to the karst topography of Guangxi, the land is fragmented and many small farmers grow citrus and other crops simultaneously. Therefore, Guangxi presents an ideal context for our study due to its significance in the cultivation of citrus crops. We postulate that farmers' risk preferences and perceived risks in regard to citrus farming play critical roles in land use decision making, where risk-averse farmers with higher perceived risks tend to opt for diversified land use. This research aims to enhance our comprehension of smallholder citrus farmers' crop diversification strategies in China and similar contexts. The findings of this study can contribute to the empirical literature on the association between subjective risk perceptions, attitudes, and decision making in relation to specialized or diversified land use choices for horticultural crops.

The rest of this article is structured as follows. Section 2 presents the theoretical analysis framework. Section 3 describes the data sources, research design, and empirical methods. Section 4 reports estimation results from baseline models, as well as robustness tests. Section 5 discusses potential policy implications. Finally, Section 6 concludes the study.

2. Theoretical Analysis Framework

2.1. Risks and Challenges Faced by Small Farmers in the Context of Globalization

In the context of globalization, small-scale farmers are confronted with a multitude of risks and challenges that significantly impact their livelihoods. Firstly, market volatility poses a major threat. Globalized markets are subject to fluctuating prices, currency exchange rates, and unpredictable demand. The market prices are increasingly influenced by the international market, intensifying the competition and threats from imported agricultural products, which further amplify market risks [30]. These uncertainties and the uncertain international economic environment can lead to financial instability and reduced profitability for small farmers [31,32]. Another challenge is the limited access to crucial resources, and unequal competition further exacerbates the challenges faced by small farmers. Small farmers often struggle to secure adequate land, water, credit, and modern technology. Without access to these essential resources, they face difficulties in improving their productivity and competitiveness on the global stage [33]. However, large-scale commercial agricultural enterprises often possess greater financial resources, economies of scale, and market power. As a result, small farmers find it challenging to compete on equal terms, making it difficult for them to establish a sustainable market presence [34]. Moreover, the consequences of climate change and environmental pressures compound the risks for small farmers. Globalization intensifies the impacts of erratic weather patterns, natural disasters, and environmental degradation on agricultural production. Small farmers are particularly vulnerable to these changes, which threaten their livelihoods and food security [35]. A lack of knowledge and information as well as policy and regulatory constraints further hinder small farmers' ability to adapt and thrive in a globalized market. They often lack access to updated agricultural practices, market trends, and quality standards [34,36]. Lastly, globalization effects social and cultural changes that impact small farmers. Urban migration, changing consumer preferences, and the erosion of traditional knowledge and practices disrupt rural communities and their farming traditions [37,38]. This can lead to a loss of identity and challenges in preserving their cultural heritage.

2.2. Risk Perceptions and Risk Attitudes of Small-Scale Farmers in a Risky Environment

Research has established that small-scale farmers operating in a globalized, complex, and diverse risk environment often demonstrate strong risk avoidance characteristics when perceiving and approaching risks [25,39]. Although risk perceptions among small-scale farmers in agriculture are intricate and varied [40], farmers typically rely on their personal experiences and observations to assess the extent of risks they encounter during the agriculture production process [8]. These risks include climate change, natural disasters, market fluctuations, price volatility, diseases, and pests. Drawing upon past experiences, social networks [41], and observations, small-scale farmers anticipate potential future risk events [25]. Additionally, they seek out risk-related information through communication and knowledge sharing with fellow farmers [2], cooperative members [42], government institutions, or agricultural experts. Since farmers, in real agricultural production, often cannot accurately judge the objective probability of risk occurrence, the differing sensitivity of farmers to risks, that is, risk preference, may lead to different risk decisions among farmers. Existing research has shown that different farmers exhibit heterogenous risk attitudes. Some farmers exercise caution and prefer conservative decisions and strategies to mitigate risks, while others are more open to taking risks and embracing new agricultural technologies or market opportunities [16]. Extensive research on farmers' risk attitudes has shown that in developing countries with imperfect financial markets, where farmers lack the option to diversify risks through market-based insurance tools, risk avoidance attitudes prevail [9,43]. Although the risk preferences of farmers, as a whole, tend to show risk aversion characteristics, there still exists significant variation in risk aversion attitudes among farmers [25,44,45].

2.3. Risk Responses of Small-Scale Citrus Farmers under the Influence of Risk and Risk Aversion

In a risk environment, different levels of risk perception and risk preference among farmers result in variations in farmers' risk-bearing capacity and different risk-coping strategies [8,32]. The stronger the farmers' perception of and concern about risks are, and the stronger their risk aversion attitudes and the greater their willingness to undertake corresponding risk-coping measures, such as purchasing agricultural insurance and engaging in diversified planting [46]. On the other hand, if farmers are less risk-averse and believe that risks are small or will not cause them significant losses, they may seek higher risks and returns through actions such as engaging in more specialized planting [15], expanding their planting scale [2], and adopting new agricultural technologies and varieties [47,48]. Farmers with limited resources and income stability often exhibit a more risk-averse attitude, preferring conservative approaches to ensure their livelihood security [44,49]. Conversely, farmers with better access to resources, market information, and education are more likely to display a risk-tolerant attitude, embracing innovative practices and adopting new technologies to maximize their returns [44,50].

For small citrus farmers, specialized citrus cultivation may yield higher comparative returns but also pose higher agricultural production risks and market risks [51]. As Guangxi is a less developed region with an incomplete rural financial market, individual small citrus farmers are confronted with the dual challenges of globalization and diverse agricultural risks. Therefore, diversified planting serves as an effective means of risk mitigation for small citrus farmers when making decisions to engage in more specialized citrus cultivation. Based on this context, this study proposes the research hypothesis that the stronger the risk perception and risk aversion attitudes of small citrus farmers are, the greater the likelihood that they will opt for simultaneously cultivating citrus and diversifying crops, with a higher crop diversification index, will be (Figure 1).

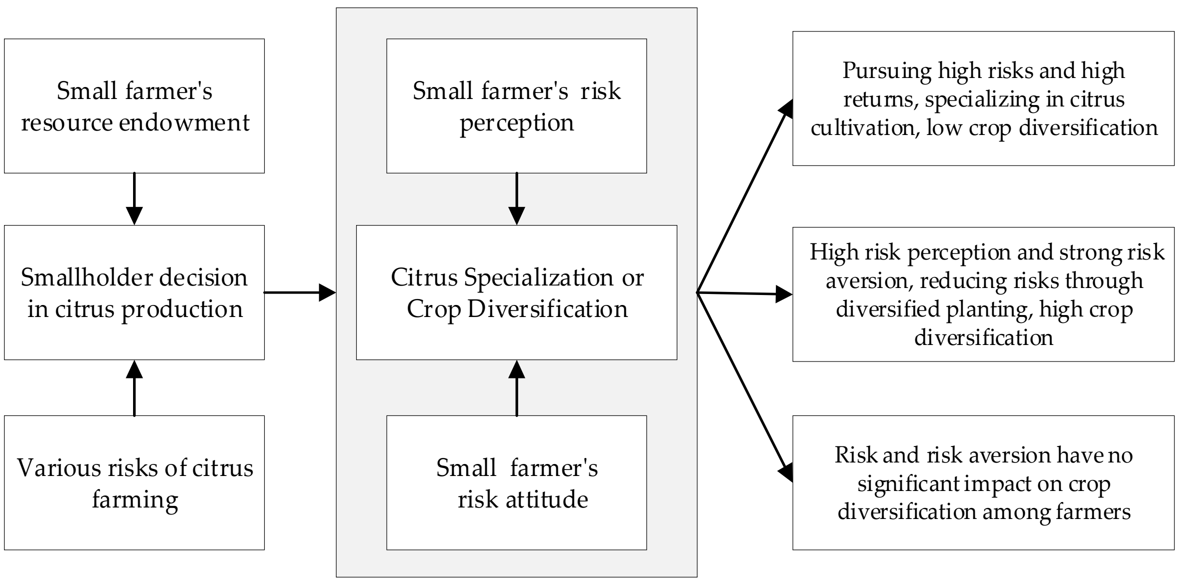

Figure 1. Theoretical analysis framework of specialized or diversified citrus farming.

3. Data and Methods

3.1. Study Area and Data Collection

This study is based on a household survey of small citrus farmers conducted in Guangxi, China, from June to November of 2021, employing a face-to-face methodology. Guangxi is an autonomous region located in Southern China, distinguished for its notable ethnic diversity, status as a rich biodiversity hotspot featuring karst landscapes [52], and preeminent position as the largest citrus-growing region in China. The investigation entailed an examination of seven regions, namely, Guilin, Nanning, Hezhou, Laibin, Liuzhou, Baise, and Wuzhou, all of which collectively account for roughly 85% of the entire citrus production output of the province. Figure 2 shows the locations of these regions (marked with black pentagon star), with larger cultivation areas in the northeast and central parts of the region. Guilin is the region with the largest citrus cultivation area in Guangxi. In 2021, the total citrus-planting area in Guilin was approximately 178,000 hectares, with a majority of citrus reticulata and kumquat varieties. The next most significant regions are Nanning and Liuzhou, with planting areas of approximately 76,000 hectares and 65,000 hectares, respectively. The predominant citrus varieties cultivated in these areas are Orah mandarin and citrus reticulata. Following these regions are Laibin and Hezhou, with planting areas of 54,000 hectares and 48,000 hectares, respectively, where the primary cultivated varieties include citrus reticulata and navel oranges. Last are Baise and Wuzhou, with planting areas of 46,000 hectares and 41,000 hectares, respectively, where the main cultivated varieties are citrus reticulata and Orah mandarin.

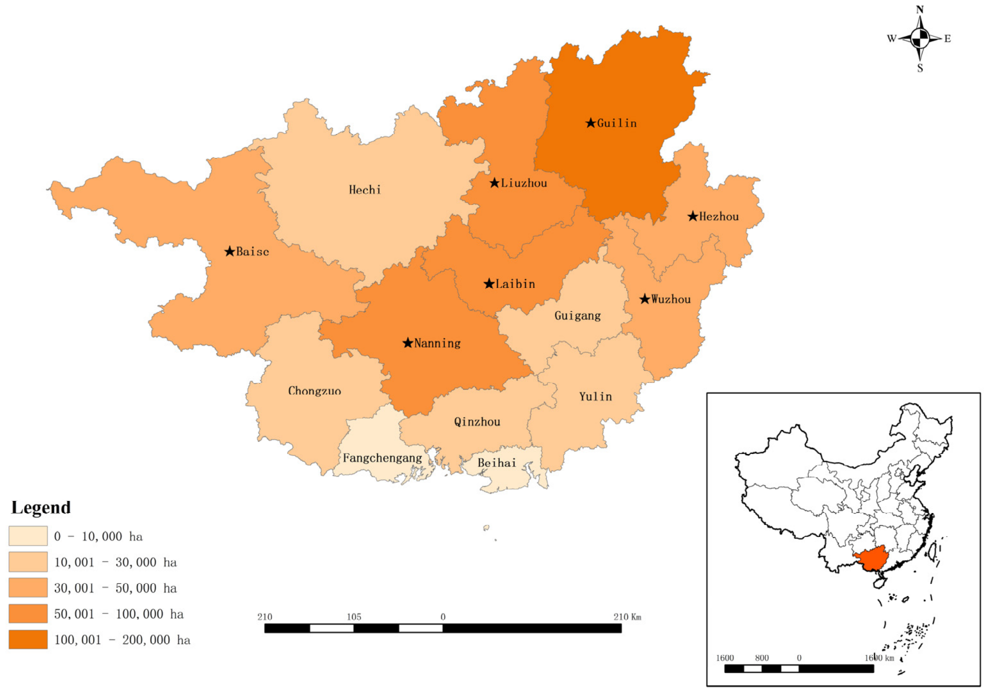

Figure 2. Distribution of citrus cultivation regions in Guangxi and study area of the household survey. The regions marked with pentagon stars are the surveyed areas.

The survey employed a stratified random sampling method to obtain a representative sample of smallholder citrus farmers in Guangxi. The stratification was based on the per capita citrus-planting area and the distribution of citrus-planting areas within each region. A total of 480 smallholder citrus farmers were sampled from 48 villages in 24 townships of 12 counties in Guangxi. For this purpose, 12 counties were initially selected based on the aggregate citrus cultivation area in the past five years (2016–2020). Two townships were randomly selected from each county, and two villages were chosen from each sample township, taking into account the different intensities of citrus distribution. Finally, ten farmer households were randomly selected from each village based on the smallholder citrus farmer list for each village. Among the 480 sampled smallholders, 429 (89.4%) were available and agreed to participate in the survey. Regarding the remaining 51 participants who were absent during the survey, we later contacted them via telephone or WeChat, and 32 of them were accessed. The observed characteristics of these absentees were found to be similar to those of the face-to-face respondents, mitigating concerns regarding sample selection. Based on the randomness of the sample selection in this survey, the sample size can ensure a 95% level of confidence according to statistical power analysis.

A structured questionnaire was employed in the household survey, encompassing a choice experiment aimed at eliciting the risk attitudes of the respondents and a nine-point Likert-scale to gauge farmers' risk perceptions concerning citrus farming. The questionnaire is divided into three main sections. The first section focuses on the basic information of the farmers and their families; demographic characteristics such as gender, age, and education; labor force, land scale, and the agricultural input–output situation of various crops including citrus; and questions related to crop diversification and various risks encountered in citrus cultivation. The second section consists of questions regarding farmers' risk perception, which is measured subjectively using a Likert scale. It aims to assess farmers' subjective ratings of various risks associated with citrus cultivation. The third section measures farmers' risk preferences through a lottery choice experiment. These methods are widely recognized in the academic community as strategies for measuring risk perception and risk preferences, which are convenient for assessing farmers and obtaining reliable information. The specific methods will be detailed further in Sections 3.2–3.4.

3.2. Risk Preference Elicitation

A common lottery choice experiment methodology, as outlined by Binswanger and Sillers [11], Holt and Laury [21], and Yusuf [12], was employed to elicit the risk preferences of farmers. The experiment employed a "multiple price list" (MPL) design in which several lottery choices were presented to the farmers simultaneously. This risk preference elicitation technique was straightforward to explain to farmers, and the data obtained from this approach were readily interpretable [53]. The MPL design required each farmer to make ten choices between two lotteries, A and B, as presented in Table 1. Option A was the "safe" choice, with a less variable payoff than the "risky" option B. The farmer was required to choose either option A or B for each decision and switch to option B when the probability of a high payoff increased sufficiently. While ten decisions were made, only one was randomly selected as binding. The present study employed a utility function to ascertain the risk preference of the farmers based on their choices. In particular, the farmers' risk aversion was assumed to be characterized by constant absolute risk aversion, where $ar(w) = -U''(W)/U'(W)$ and $(x) = -exp(-ar \times x)$, with ar denoting the coefficient of absolute risk aversion. The design of the MPL experiment is outlined in Table 1. Hypothetical payoffs of USD 1500/2800 (CNY 10,000/19,000) from actual citrus-farming activities were used in the experiment. For the initial decision, both options offer a 10% probability of a high payoff, and thus only an individual with extreme risk-seeking tendencies would opt for Option B. Conversely, a risk-neutral farmer would select Option A, since its expected value surpasses that of Option B. As the decision-making process progresses, the likelihood of obtaining the higher payoff increases for both options. According to the risk preference experiment utilizing the MPL method, we outline the outcomes and distribution pertaining to farmers' risk aversion, as displayed in Figure 3. Notably, since the lottery choices only furnish a range of a farmer's ar, as demonstrated in Figure 3, we employ the midpoint of the feasible ar recognized via the farmer's selections as the metric in our analysis.

Table 1. Risk Preference Estimation Procedure Based on Lottery Choice Decisions.

Decision	Option A	Option B
1	10% of USD 1500, 90% of USD 1200	10% of USD 2800, 90% of USD 150
2	20% of USD 1500, 80% of USD 1200	20% of USD 2800, 80% of USD 150
3	30% of USD 1500, 70% of USD 1200	30% of USD 2800, 70% of USD 150
4	40% of USD 1500, 60% of USD 1200	40% of USD 2800, 60% of USD 150
5	50% of USD 1500, 50% of USD 1200	50% of USD 2800, 50% of USD 150
6	60% of USD 1500, 40% of USD 1200	60% of USD 2800, 40% of USD 150
7	70% of USD 1500, 30% of USD 1200	70% of USD 2800, 30% of USD 150
8	80% of USD 1500, 20% of USD 1200	80% of USD 2800, 20% of USD 150
9	90% of USD 1500, 10% of USD 1200	90% of USD 2800, 10% of USD 150
10	100% of USD 1500, 0% of USD 1200	100% of USD 2800, 0% of USD 150

Notes: Chinese yuan (CNY) was used during the actual experimental process. USD 1500 = CNY 10,000, USD 1200 = CNY 8000, USD 2800 = CNY 19,000, and USD 150 = CNY 1000 based on USD exchange rates in 2021.

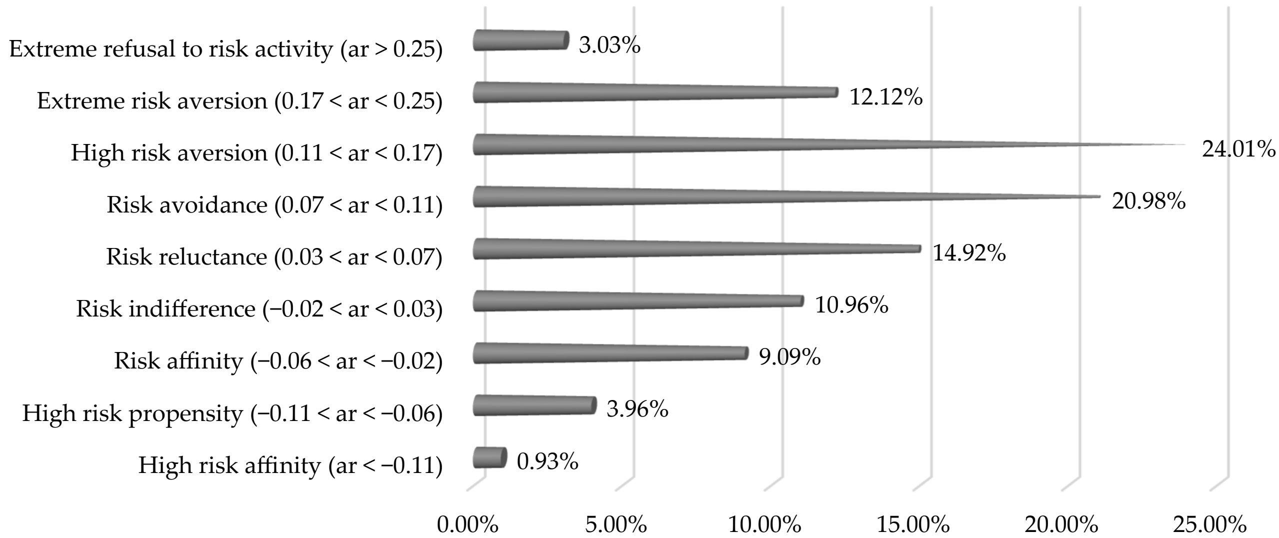

Figure 3. Distribution of Risk Attitude Coefficients with Aversion Class among Citrus Farmers.

3.3. Risk Perception Elicitation

To investigate the risk perceptions of farmers engaged in citrus farming, we adopted a methodology inspired by the works of Weber, Blais and Betz [40], Min, Huang and Waibel [15], Scharner, Pochtrager and Larcher [24], which entailed the use of Likert scale questions to examine farmers' intuitive judgments on risk. Risk perception, defined as the subjective evaluation of the likelihood and consequences of a particular risk, served as the measure of risk in this study. Specifically, we formulated four Likert scale questions to probe farmers' perception of the risks associated with citrus farming for their families, taking into account the existing studies [7,24,54–56] and the results of a pilot survey. For the sake of simplicity, these questions were designed to encompass yield risk, market price risk, weather and natural disasters, pests and diseases, farm management, and economic environment risk. Table 2 presents the risk perception questions employed in this study. The Cronbach's alpha for the scale used in this study was 0.786, indicating an acceptable degree of internal consistency reliability. Moreover, the scale demonstrated robust convergent validity, with all items significantly contributing to the risk perception construct. Table 3 shows that farmers are most concerned about market risk, with the highest average perception score of 7.46, followed by the risks of Huanglongbing (HLB) disease and other pests and diseases, with a score of 7.18. Next is the risk of weather and natural disasters, with a score of 6.85, and a slightly lower score for farm management and economic risks. In the following analysis, we use the sum of the scores of the four risk perception items as our measure of each famer's risk perception.

Table 2. Risk perception in citrus farming: responses to scale questions (1 = strongly disagree; 9 = strongly agree).

Scale Item	Definition	Mean	SD
Item 1	Weather and natural disasters have a major impact on my citrus growing	6.85	1.44
Item 2	My family could be exposed to great risks from lower market prices for citrus	7.46	1.13
Item 3	HLB disease and other pests and diseases are serious risks for my citrus farming	7.18	1.25
Item 4	Risks due to farm management and economic environment will result in a lower output for my citrus farming	6.33	1.19

Table 3. Descriptions of variables used to assess citrus farmers' land use choices.

Variables	Definition	Mean	SD
Diversification	1 if planting citrus and multi-crops, 0 if planting only citrus	0.611	0.488
Count index	The number of crops commercially grown by the household	2.578	1.556
Shannon index	According to the Shannon index formula	0.647	0.595
Risk perception	Farmers' perceptions of risk for citrus production	27.821	3.420
Risk attitude	Risk aversion coefficient estimated via experiment	0.093	0.109
Land	Total area of household farming land (hectares)	1.085	0.726
Land plots	Total number of household land plots	3.808	2.215
Asset	1 if household owns four-wheel-steering agricultural vehicles or cars, 0 otherwise	0.314	0.465
Age	Age of household head (years)	48.946	8.812
Education	Education of household head (years)	7.846	2.564
Female	1 if household head is female, 0 if male	0.142	0.349
Ethnicity	1 if household head's ethnicity is minority, 0 otherwise	0.382	0.486
Experience	Household duration of engagement in citrus cultivation (years)	8.379	4.651
Laborers	Number of family laborers working on the farm	2.568	1.202
Off-farm	Share of family off-farm income	0.181	0.255
Membership	1 if farmer is a member of a cooperative, and 0 if not	0.205	0.404

3.4. Crop Diversification Measures

In this study, two diversification indices were employed to assess the level of crop diversity at the farm level, whereby an elevated index value denotes a higher degree of crop diversification. The first is the count of crops grown per farmer household. The second is the Shannon Index [57], which measures the relative abundance of crops. Only the crops grown commercially are counted with these indices. Assuming that the count of citrus farmer i's planted crops is N_i, the Shannon index for measuring crop diversity can be expressed as follows [58]:

$$D_i = -\sum_{n_i=1}^{N_i} landshare_{ni} \ln(landshare_{ni}) \quad (1)$$

Although the level of specialization of citrus farming among small farmers in Guangxi is quite high, most small farmers still allocate certain proportions of their land to other crops. Figure 4 shows the distribution of the count index and Shannon index of the citrus famers, demonstrating the relatively high level of crop diversification. However, with the increase in these indices, the number of farmers decreases dramatically. Specifically, it can be noted that 38.93% of smallholder farmers engage solely in citrus cultivation, while approximately 34.73% of smallholders cultivate 3–4 crops, including citrus. The average number of crops planted per farmer amounts to 2.58, thereby yielding a Shannon diversity index of 0.65.

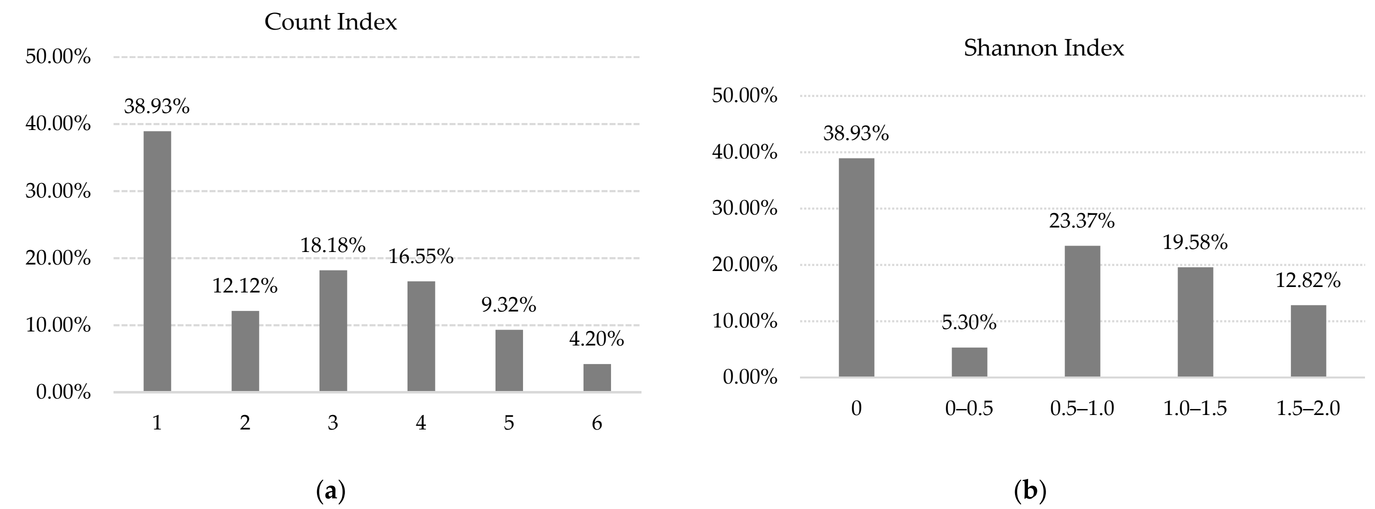

Figure 4. Crop diversification index distribution of citrus farmers. (**a**) indicates the crop diversity distribution of farmers using Count index derived from direct counts and (**b**) is of crop diversification distribution calculated by the Shannon index.

3.5. Empirical Models

3.5.1. The Impacts of Risk Perceptions and Risk Attitude on Citrus Specialization

In order to examine the effects of perceived risk and risk attitudes on citrus specialization and land use decisions made by farmers, we initially estimate a Probit model. Given that many small citrus farmers engage in the cultivation of crops other than citrus, the use of a Probit model is deemed appropriate. The Probit model is formulated as follows:

$$Y_i = \alpha_1 PR_i + \alpha_2 AR_i + \alpha_3 L_i + \alpha_4 X_i + \varepsilon_i$$
$$Y_i = \begin{cases} 1 \text{ if planting citrus and multi} - \text{crops} \\ 0 \text{if planting only citrus} \end{cases} \quad (2)$$

In Equation (2), the dependent variable, denoted as Y_i, takes a dichotomous value of either one or zero, indicating whether farmer *i* engages in citrus planting and multi-crop planting or not. The risk perceptions of citrus farming for farmer , denoted as

i, are outlined in Table 2. The absolute risk aversion coefficient for farmer *i*, denoted as AR_i, is computed according to the methodology described in Table 1 and Figure 3. The total area of farming land for farmer *i* is represented as L_i, while X_i is a set of demographic and socioeconomic characteristics that may influence farmer *i*'s choices regarding citrus specialization and land use. The vectors of parameters to be estimated are denoted as α_1, α_2, α_3, and α_4. The normally distributed random disturbance is denoted as ε_i.

3.5.2. The Impacts of Risk Perceptions and Risk Attitudes on Crop Diversification

This study employs a Poisson regression model and an ordinary least squares (OLS) regression model to examine the effects of perceived risk and risk attitudes on farmers' crop diversification, with the count index and Shannon index as dependent variables. Additionally, to verify the robustness of our Poisson model estimates and statistical inferences, we estimate an OLS model with the Shannon index as the dependent variable, as crop diversification is our primary focus. The equations for the Poisson and OLS estimations are specified as follows:

$$D_i = \rho_0 + \rho_1 PR_i + \rho_2 AR_i + \rho_3 L_i + \rho_4 X_i + \tau_i \quad (3)$$

The dependent variable D_i is expressed in terms of both the count index and Shannon index, while the independent variables are the same as those in Equation (2). The error term τ_i and the parameters to be estimated, ρ_1, ρ_2, ρ_3, and ρ_4, are also included in the model. Although Poisson estimation is commonly used with maximum likelihood estimation, this approach may not always be appropriate when the response variable does not conform to a Poisson distribution. To assess the validity of the standard Poisson model for estimating the count index, we use the goodness-of-link test proposed by Pregibon [59]. If this test indicates that the model is inadequate, we will consider the use of a generalized Poisson regression model as an alternative [60,61].

3.5.3. Endogeneity

Although Probit, Poisson, and OLS regression models are useful for establishing the hypothesized links, they may be affected by endogeneity due to the potential influences of unobserved factors on the risk perceptions of smallholder citrus farmers and their land allocation decisions. To address this issue, we adopt an instrumental variable approach. We consider the potential existence of peer effects in the context of agricultural knowledge transfer [15,62] and risky behaviors [63], whereby an individual's risk perceptions regarding citrus farming may be influenced by their neighbors' risk perceptions through social interactions, knowledge sharing, and daily communication within the village. Therefore, we use the neighbors' risk perceptions as an instrumental variable. This choice is intuitively justifiable, as the instrumental variable should be correlated with farmer i's risk perceptions but should not directly affect their land use decision other than through its impact on their perceived risk.

4. Results

4.1. Descriptive Statistics

Table 3 presents detailed definitions and descriptive statistics of the outcome variables and covariates from the survey. Among the covariates, risk perceptions and risk attitudes are our primary interests. The summary statistics of the risk perception questions show that the farmers had a high level of risk perception in citrus cultivation; the mean of the scores for the four risk perception items was 27.82. The majority of individuals made five or more safe choices, with the average absolute risk aversion coefficient equaling 0.09, indicating that the majority of the sampled farmers were risk-averse. In addition, we include a series of controls regarding demographic and socioeconomic characteristics that could possibly affect farmers' citrus specialization and land use choices. These include household farming land [64], land plots [65], experience in growing citrus [15], household labor [13], off-farm work [2], cooperative membership [66], and demographic variables of the farm households such as age, gender, education, and ethnicity [27,28,67].

4.2. Land Use Decisions regarding Citrus Specialization or Citrus with Other Crops

The results of the regression analysis for the citrus farmers' land use decisions are presented in Table 4. Column 2 to Column 4 show the findings of standard Probit regression, IV-Probit regression, and 2SLS regression, respectively. All models are correctly identified. The IV-Probit and 2SLS regression results, as evidenced by the Wald test and F-statistic of exogeneity, reject the null hypothesis at the 1% significance level, indicating the endogeneity of citrus farmers' risk perceptions in explaining their land use decisions. Therefore, the instrumental variable approach is appropriate. The computed marginal effects of the IV-Probit and coefficient estimates from the 2SLS procedures are quite similar, which adds to the credibility of the impact estimates.

Table 4. Marginal effects influencing whether farmers grow other crops in addition to citrus.

Variables	Whether Planting Citrus and Multi-Crops		
	Probit	IV-Probit	2SLS
Risk perception	0.024 *** (0.004)	0.027 ** (0.013)	0.031 ** (0.014)
Risk attitude	0.645 *** (0.131)	0.628 *** (0.131)	0.737 *** (0.154)
Land	−0.078 *** (0.018)	−0.077 *** (0.018)	−0.114 *** (0.023)
Land plots	0.059 *** (0.006)	0.057 *** (0.006)	0.062 *** (0.007)
Asset	−0.106 *** (0.025)	−0.105 *** (0.026)	−0.127 *** (0.036)
Age	−0.002 (0.001)	−0.003 (0.002)	−0.001 (0.002)
Education	−0.007 (0.005)	−0.005 (0.006)	−0.005 (0.006)
Female	0.016 (0.037)	0.017 (0.037)	0.021 (0.044)
Ethnicity	0.198 *** (0.025)	0.202 *** (0.025)	0.251 *** (0.033)
Experience	0.001 (0.003)	0.001 (0.002)	0.001 (0.003)
Laborers	0.084 *** (0.011)	0.085 *** (0.011)	0.106 *** (0.014)
Off-farm	−0.038 (0.052)	−0.051 (0.051)	−0.042 (0.060)
Membership	−0.067 ** (0.032)	−0.071 ** (0.033)	−0.097 ** (0.038)
Observations	429	429	429
Wald x2	181.01 *** (0.000)	127.24 *** (0.000)	
F- statistic for IV sig.			62.03 *** (0.000)
F-statistic (2nd stage)			43.54 *** (0.000)

Notes: Standard deviations are reported in parentheses. **, and *** indicate statistical significance at the 5%, and 1% levels, respectively.

Table 4 indicates that the probability of farmers planting other crops alongside citrus is positively and significantly affected by their risk-averse attitudes and the perceived risk associated with citrus farming. In all the models, farmers' risk perception was highly significant, confirming its role in land allocation decisions. Farmers' risk attitudes were also significant at 1% levels. Hence, for smallholders, the perception of higher risks of citrus farming and stronger risk aversion can stimulate less specialization and more crop diversification. The implementation of a multi-crop planting strategy appears to be a viable approach for mitigating the potential risks of citrus farming. This strategy aligns with prior research findings, indicating that risk perception and risk attitude significantly influence farmers' decision-making processes regarding diverse agricultural activities in developing nations [9,12,18,43,68].

As anticipated, the availability and limitations of land resources exert a substantial influence on the decision-making process of small-scale citrus farmers with regard to crop diversification. The more land a farmer has, the greater the likelihood of specialization will be, but the fragmentation of a farmer's land weakens this possibility, prompting the farmer to plant multiple crops. Agricultural machinery assets and cooperative membership are also important factors for specializing in growing citrus, while ethnic minority households obviously tend to plant other crops in addition to citrus. In addition, the number of household laborers seems to be a positive factor influencing farmers to grow a variety of crop types. This may be because households with a large number of laborers grow citrus with multi-crops, which is conducive to making more efficient, collective use of labor time in the off season of a single crop throughout the year [69].

4.3. Risk Determinants Influencing Farmers' Crop Diversification

Table 5 reports the results of the Poisson and OLS estimation regressions (defined by Equation (3)), used with the instrumental variable regression to reduce the likelihood of estimation bias due to the endogeneity of risk perception. In this estimation, the count index and Shannon index were used as explanatory variables, respectively, and Poisson and OLS models were used to estimate the factors influencing crop diversity. As reported in Table 5, the estimation results are highly similar to those in Table 5, and farmers' risk attitudes and risk perceptions significantly promote the diversification level of farmers. From the regression results of the instrumental variables' regression, farmers' risk attitudes and risk perceptions remain significant, which further evidences the robustness of the regression results and risk factors as key drivers of farmers' crop diversification. Additionally, although farmers with more land and wealth may prefer more cost-effective specialized citrus cultivation, land fragmentation and ethnic characteristics further strengthen farmers' crop diversification decisions. In addition, membership to a farmers' professional cooperative was only significant in the 2SLS regression model of the diversification index, which indicates that the role of cooperative membership is limited, given that most members are small farmers [42].

Table 5. Results regarding the determinants influencing farmers' crop diversification.

Variables	Count Index		Shannon Index	
	Poisson	IV-Poisson	OLS	2SLS
Risk perception	0.025 *** (0.009)	0.017 *** (0.005)	0.027 *** (0.006)	0.012 *** (0.004)
Risk attitude	0.733 *** (0.274)	0.894 *** (0.228)	0.889 *** (0.199)	1.045 *** (0.215)
Land	−0.163 *** (0.053)	−0.178 *** (0.037)	−0.134 *** (0.031)	−0.145 *** (0.032)
Land plots	0.057 *** (0.014)	0.059 *** (0.011)	0.071 *** (0.009)	0.073 *** (0.010)
Asset	−0.237 *** (0.078)	−0.252 *** (0.063)	−0.185 *** (0.048)	−0.204 *** (0.051)
Age	0.003 (0.003)	0.002 (0.003)	0.001 (0.002)	0.001 (0.002)
Education	−0.009 (0.012)	−0.006 (0.009)	−0.011 (0.008)	−0.007 (0.008)
Female	0.004 (0.087)	−0.018 (0.074)	−0.008 (0.059)	−0.027 (0.062)
Ethnicity	0.257 *** (0.063)	0.262 *** (0.049)	0.264 *** (0.044)	0.274 *** (0.046)
Experience	0.001 (0.006)	0.003 (0.005)	0.001 (0.004)	0.00 (0.004)
Laborers	0.102 *** (0.026)	0.117 *** (0.021)	0.113 *** (0.018)	0.123 *** (0.019)
Off-farm	−0.092 (0.120)	−0.079 (0.095)	−0.065 (0.082)	−0.051 (0.084)
Membership	−0.085 (0.082)	−0.092 (0.068)	−0.078 (0.052)	−0.088 *** (0.034)
Observations	429	429	429	429
LR chi2/F-stat	179.60 *** (0.000)	GMM estimator	31.93 *** (0.000)	28.15 *** (0.000)

Notes: Standard deviations are reported in parentheses. *** denote significance at the 1% levels.

To ensure the robustness of our analysis, we incorporated an interaction term between farmers' risk perceptions and risk attitudes in the regression, as there may be a potential relationship between the two variables. Table 6 presents the estimates from the two models. The first model includes linear effects of both risk perception and risk preference, as well as an interaction effect between these two variables. The second model, on the other hand, only includes the interaction effect between risk perception and risk preference. The regression results in Table 6 indicate that the interaction effect between risk perception and risk preference is highly significant when the linear risk perception and risk preference terms are removed. Conversely, when these linear effects are included in the models, the interaction effects become insignificant. These results consistently support our earlier findings on the (linear) roles of risk preference and risk perception.

Table 6. Robustness results of risk determinants influencing farmers' crop diversification.

Variables	Shannon Index			
	OLS		2SLS	
Risk perception	0.036 *** (0.008)	-----	0.016 *** (0.005)	-----
Risk attitude	3.670 ** (1.625)	-----	1.801 *** (0.451)	-----
Risk attitude × Risk perception	0.098 (0.066)	0.035 *** (0.006)	0.065 (0.132)	0.034 *** (0.006)
F-stat (1st stage)	30.00 *** (0.000)	31.98 *** (0.000)	31.12 *** (0.000)	
F-stat (2nd stage)			25.72 *** (0.000)	31.79 *** (0.000)

Notes: Standard deviations are reported in parentheses. **, and *** indicate statistical significance at 5%, and 1% levels, respectively.

5. Discussion

The aforementioned findings consistently indicate that perceptions of and attitudes towards risk exert significant influences on the decision-making process of farmers pertaining to crop land. Incorporating multiple perception measures and the lottery choice experiment, it was found that subjective risk aversion behavior, to a certain extent, hinders the specialization process of small citrus farmers and promotes crop diversification in agricultural ecosystems. Small farmers' crop diversification decisions are significantly affected by the perceived risk and subjective risk-averse attitudes associated with the specialized cultivation of citrus, as well as the risk mitigation effects of crop diversification.

The findings of this study align with those of existing relevant studies, emphasizing the significance of crop diversification in addressing the risks and uncertainties associated with climate change and multiple agricultural risks for small farmers [70]. Small-scale farmers who implement a multi-season cropping system, incorporating long-rains crops, short-rains crops, permanent crops, and fruit crops, are able to mitigate the uncertainties posed by droughts or rainfall fluctuations [71]. In response to extreme climatic events, farm households primarily rely on crop diversification and crop variety adjustments as their primary adaptation strategies [72]. The decision of farmers to specialize in rubber cultivation is influenced by their perception of risk, whereby a higher risk perception increases the likelihood of diversifying and cultivating multiple crops [15]. Additionally, farmers exhibiting higher risk aversion are more inclined to adopt farm diversification strategies [25]. The presence of production risks and risk aversion significantly promotes the adoption of crop diversification strategies and expansion into livestock production by households [16]. However, this study does not provide evidence on whether diversification among small-scale farmers results in increased income and welfare. Nonetheless, previous research has indicated that increasing crop diversity can lead to enhanced land productivity and lower production costs and open up market opportunities for households while facilitating self-consumption. It appears that farmers engaged in crop diversification tend to generate greater benefits compared to those specializing in a single crop [28,29].

Compared to specialized farms, crop diversification among small-scale farmers may not necessarily lead to higher profits [70]. However, crop diversification among small-scale farmers not only helps to mitigate agricultural risks but also has the potential to enhance biodiversity within farmland ecosystems, thereby promoting sustainable agricultural development. As a crucial region of high biodiversity in the southern region of China, Guangxi has undergone significant transformations in its land use patterns during previous decades, transitioning from conventional agricultural practices to the cultivation of specialized tropical and subtropical fruit crops [73]. This trend has resulted in a multitude of adverse ecological consequences, notably a reduction in agrobiodiversity and a subsequent risk to livelihood sustainability [74]. The econometric results suggest that crop diversification may be an effective strategy for coping with such livelihood risks. Smallholder citrus farmers, who always show a risk-averse attitude and are aware of the higher risks of citrus farming, are less likely to specialize in citrus farming and are more likely to plant other crops in addition to citrus. Although there are numerous citrus growers among them, small citrus farmers still prefer to intercrop citrus with a diverse range of other crops, maintaining a high crop diversity index. In some sense, this finding is consistent with the long-held recognition that risk-averse small farmers may diversify their portfolios of agricultural production as a risk management strategy to reduce farm income variation [25]. The implementation of land use diversification appears to present a viable strategy for managing potential risks in the context of citrus cultivation, while simultaneously affording positive spillover effects on farmland ecosystem biodiversity and fostering sustainable agricultural production objectives.

The confirmed roles of risk perception and risk attitude in decision making regarding crop diversification and land use warrant immediate policy implications concerning environmental and agricultural sustainability. While implementing risk insurance programs could enhance the specialization level of citrus cultivation in Guangxi, the current imperfect financial market necessitates that small-scale farmers rely on crop diversification to mitigate risks. The diversified production methods of small-scale farmers have positive effects on environmental protection and food security. To safeguard these benefits and to further assist small-scale farmers in reducing risks and increasing their income, it is worth considering the provision of policy support and ecological compensation from the government and relevant organizations. First, to prioritize food security and curb the competition for land between staple crops and citrus cultivation, it is important to assist small-scale farmers in comprehending the risks and potential benefits associated with specialized citrus farming. This approach can effectively discourage indiscriminate expansion into single horticultural crops, leading to improved food security, decreased non-grain cultivation on arable land, and enhanced crop diversity within farmland. Second, crop diversification may enhance biodiversity while addressing agricultural risks [75]. Maintaining a crop portfolio is an important strategy for smallholders to cope with agricultural production risks [76], especially in underdeveloped areas such as Guangxi, China. Guiding and supporting smallholders in Western China towards crop diversification can promote the sustainable development of agriculture that can also meet biodiversity conservation goals. Third, smallholders in ethnic minority areas, usually less developed areas [77], seem to have a stronger willingness to diversify their planting, possibly due to risk aversion. Crop diversification is the main strategy used to cope with natural risks in these areas, characterized by prevalent poverty and underdeveloped rural financial markets [77]. Greater risk perception and risk aversion have also promoted a certain degree of crop diversification on farmland in these areas. Therefore, for China's less developed regions that have a large number of small-scale farmers who have been active for a long time, it may not always be imperative to transform agriculture towards specialized and single-crop cultivation. However, it is necessary to provide small-scale farmers in these regions with essential economic support and ecological compensation in order to maintain crop diversity. Ensuring the preservation of a specific degree of agricultural diversity among smallholder farmers is not only beneficial for their agricultural risk management but also contributes to the achievement of sustainable agricultural development goals.

Although our findings do not provide direct support for the efficacy of these policies, they merit thorough consideration by both central and local governments aspiring to achieve sustainable agricultural development and promote rural revitalization in China's rural areas [78]. The comparative analysis of the count index and Shannon index, as measures of citrus farmers' crop diversification in Guangxi, further confirms the need to consider the contributions of diversified smallholder crop cultivation to agroecosystems and biodiversity. Whilst the outcomes may exhibit localized disparities within emerging economies, their potential instructive value may be extrapolated to regions possessing comparable agro-ecological circumstances or in parallel developmental stages, wherein agricultural stakeholders possess congruent risk attitudes and risk perceptions.

6. Conclusions

Utilizing data from a recent survey of small-scale citrus farmers in Guangxi Province, China, this study evaluated the effects of farmers' risk perceptions and risk preferences on their land use decisions, specifically with regard to the choice between specializing in citrus production or engaging in diversified crop farming. Through the estimation of an IV-Probit model and 2SLS model, it was found that several perceived risks of citrus farming, as well as risk aversion determined based on a lottery choice experiment, significantly affect farmers' probability of planting diversified crops together with citrus. These results were further compared with estimates from crop diversification regression models, with the Poisson model and OLS model using the count index and Shannon index as explanatory variables, which confirmed that farmers' risk perceptions in citrus farming and their risk-averse attitudes significantly contribute to higher levels of crop diversification. Our main findings regarding small citrus farmers' crop diversification were further validated in a robustness exercise, where interaction variables were added to the Shannon index regression model for considering the possible relationship between farmers' risk perceptions and risk attitudes. The present findings underscore the salient contribution of risk preferences in influencing the horticultural agricultural production of smallholder farmers, thus bearing significant policy ramifications for fostering sustainable agricultural development and smallholder farming practices in Western China.

Our study contributes to the existing literature by delineating the influence of farmers' risk perceptions and risk attitudes on specialized or diversified horticultural crop farming conduct in a typical citrus-planting area in China. Furthermore, we validated the consistency effects of different crop diversification indices and highlighted the necessity of formulating policy measures that cater to small-scale farmers' crop diversification practices in order to enhance their cost-effectiveness and welfare. Nonetheless, the study's limitations, such as its cross-sectional nature and geographical specificity, collectively necessitate further research to establish the generalizability of the findings. These results indicate that risk preferences exert a significantly greater impact than risk perceptions, as gauged in this study, and require further examination through alternative risk preference elicitation methodologies using a larger and more representative sample of farmers. The crop diversity of smallholder farmers has a positive impact on sustainable agricultural development and biodiversity, but the questions of how to maintain small farmers' crop diversification and improve their welfare in the development of agricultural modernization need to be studied in the future.

Author Contributions: For this paper, X.C. and D.Z. formulated and designed the research framework, while X.C., M.X., and X.F. conducted the survey and analyzed the data. Additionally, X.C., D.Z. and M.X. provided the analytical tools used in this paper. The paper was written by X.C., M.X. and D.Z. and was subsequently revised multiple times by all authors. All authors have read and agreed to the published version of the manuscript.

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