Journal of
Agribusiness in
Developing and
Emerging
Economies

Demand for weather index insurance: evidence from Indian cotton farmers

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Received 28 August 2024
Revised 9 July 2025
Accepted 6 November 2025

Abstract

Purpose – Adverse climatic conditions have significantly impacted agricultural production in India. To manage climate risk, weather index insurance (WII) is emerging as a useful tool to transfer risk. However, despite the potential advantages, the adoption of weather-based insurance remains low. Thus, this study aims to examine the factors influencing farmers' willingness to pay (WTP) for WII.

Design/methodology/approach – A cross-sectional survey was conducted among 350 cotton farmers in the Virudhunagar district, selected through a multistage sampling approach, incorporating simple random sampling. Data were collected through personal interviews using a pre-tested questionnaire. The logit model is used to analyse how socioeconomic variables, risk aversion (determined using the multiple price list experiment) and risk perception (analysed using a risk matrix) affect weather insurance adoption.

Findings – Results show that 65% of the surveyed households are willing to participate in WII. Risk aversion and risk perception are positively and significantly associated with insurance uptake. Education, annual income, access to credit and weather-related yield loss also have a significant positive correlation with WTP. However, gender, family size, and access to irrigation are negatively associated with WTP.

Funding: This study was supported by the Australia-India Strategic Research Fund (AISRF). The Australian Research Council's fund is also acknowledged (Grant Number IE230100435).

Declaration of interests: 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.

Journal of Agribusiness in Developing
and Emerging Economies
Emerald Publishing Limited
e-ISSN: 2044-0847
p-ISSN: 2044-0839
DOI 10.1108/JADEE-08-2024-0275

Research limitations/implications – Future studies could be enhanced by including more diverse farm areas and considering other influential factors.

Originality/value – These findings can assist insurance companies and policymakers in understanding farmers' risk behaviour and promoting the adoption of WII to improve farmers' climate resilience.

Keywords Climate risk, Risk mitigation and adaptation, Willingness to pay, Weather index insurance, Cotton

Paper type Research article

1. Introduction

The frequency and severity of extreme climate-related events are increasing due to climate change (Doherty *et al.*, 2021; Budhathoki *et al.*, 2019), which poses a significant threat to agriculture and its allied sectors (Fahad and Jing, 2018). The vulnerability of rain-dependent agriculture to adverse weather conditions results in significant economic losses for farm households (Fahad and Jing, 2018). Repeated spells of drought and flooding (Maganga *et al.*, 2021) and the delayed onset of monsoon (Senapati, 2020) are significantly impacting crop yield loss and, therefore, income (Bogale, 2015).

Agriculture is the primary source of income for 70% of Indian rural households, with 82% comprising small and marginal farmers (Hagiwara *et al.*, 2023). Small and marginal farmers are more risk-averse and vulnerable to income shocks due to their dependence on natural resource endowments (Aditya *et al.*, 2018). Farmers often use several ex-ante risk management strategies to cope with risk. However, due to the covariate nature of risk, these strategies frequently fail (Aditya *et al.*, 2018). Therefore, non-structural measures such as crop insurance (Hossain *et al.*, 2022; Fahad and Jing, 2018; Islam *et al.*, 2021) have been recommended to mitigate weather-related risks and enhance farm resilience (Doherty *et al.*, 2021). This will ensure the financial security of farmers by smoothing their incomes and credit flow (Aditya *et al.*, 2018). Crop insurance not only protects farmers' livelihoods from natural disasters (Gulati *et al.*, 2018) but also promotes effective resource use in the production process and stabilises farm output and income (Venkatesh, 2008). Additionally, it instils a sense of self-reliance among farmers by empowering them with the right to claim compensation in the event of crop loss. Thus, crop insurance helps farmers mitigate the financial impact of unforeseen natural events (Kumar *et al.*, 2011). However, traditional crop insurance products are insufficient in the face of increasingly unpredictable and extreme weather events. An innovative financial product, WII, based on the pre-determined threshold value of weather parameters, has been developed to provide farmers with alternative risk management tools. WII offers many advantages, including higher transparency, quicker claim settlement, and lower transaction costs (Jin *et al.*, 2016; Ghosh *et al.*, 2021). However, WII is still underutilised in many agricultural economies, raising important questions about farmers' willingness to purchase WII. This motivates us to investigate the factors that influence farmers' demand for WII in tackling climate risks.

This study focuses on cotton farmers in the Virudhunagar district of Tamil Nadu, India, who experience frequent crop losses due to climate fluctuations. Cotton is one of the most significant commercial crops in India and plays a crucial role in the livelihood of an estimated 6 million cotton producers. Approximately 25% of the world's total cotton production is produced in India (Ministry of Textiles, 2023). It is anticipated that changes in temperature, drought, and erratic precipitation patterns in the world's cotton-growing regions may affect cotton productivity. This will have an impact on global supply chains in addition to local economies (Sahay, 2019). With the anticipated adverse climate-related events in the future, WII is considered one of the key climate risk mitigation and adaptation measures (Wang *et al.*, 2022).

This study analyses the influence of socioeconomic factors, risk preferences, and risk perception on cotton farmers' decisions to participate in weather index-based crop insurance. Despite insurance being available at subsidised rates, the insurance take-up rate is low in developing nations (Rajeev and Nagendran, 2023). Previous research indicates that improving the acceptance of agricultural insurance in emerging economies requires addressing several social, economic, and behavioural factors, as well as supply-side constraints (Mensah *et al.*, 2023; Carter *et al.*, 2014; Platteau *et al.*, 2017). Moreover, the decision of farmers to participate in agricultural insurance and their influencing factors vary not only among nations and regions due to various climatic, economic, political, and institutional circumstances (Dragos *et al.*, 2023; Jin *et al.*, 2016) but also at individual levels (Dragos *et al.*, 2023; Mensah *et al.*, 2023). Therefore, it is necessary to focus more on micro-level factors that influence the adoption of crop insurance (Fahad and Jing, 2018).

Generally, two crucial phases are frequently included in WTP investigations. The first phase asks whether farmers are willing to pay for WII, while the second phase involves determining how much farmers are willing to pay for WII (Wang *et al.*, 2022). Our study focuses on the first stage and investigates how farmers' socioeconomic characteristics and attitudes and perceptions of risk affect their decision to adopt WII. These factors are often overlooked when determining the drivers of WII adoption in India. Farmers' perception of uncertainty towards new technology allows risk attitude to play an important role in crop insurance adoption. In addition, the risk behaviour of farmers depends on local factors, which may have varying influences on WTP (Liu, 2013). Since there is limited research available on this topic in India, arriving at definitive conclusions can be a challenging task. Thus, a thorough understanding of the unique conditions of each location is essential for informed decision-making. Accordingly, this study evaluates farmers' risk perception using a risk matrix and risk preferences using the experimental method.

This study first contributes to the literature with an increasing interest in WII. This kind of insurance overcomes critical issues in traditional indemnity-based insurance, such as information asymmetry, moral hazard, and a longer loss claim process. Secondly, this study focuses on cotton farming. Prior studies have largely investigated farmers planting food crops, including rice, maize, wheat, and others, and their preference for weather index-related insurance. However, there is very little empirical evidence available regarding cotton farmers and their adoption of WII in India. More future studies with different types of crops are expected. Finally, this study can assist insurance companies and policymakers in understanding the risk behaviour of Indian cotton farmers and help them to design the most comprehensive risk coverage according to farmers' preferences. With the increase in uptake of weather index-related insurance, farmers' climate resilience can be improved significantly.

The rest of the study is structured as follows. Section 2 reviews prior studies. Section 3 introduces the study area. Section 4 explains the sampling approach and data collection. Section 5 describes methodologies. Section 6 presents results and discussion, and Section 7 concludes and provides some recommendations for future research.

2. Literature review

Index-based insurance products have emerged as a viable alternative to traditional claim-based insurance. The United States first experimented with area-yield index insurance in the 1950s, while today, a growing number of countries are piloting weather and satellite-based index insurance products. Developing countries, in particular, are showing interest in weather-index-based crop insurance due to future anticipated adverse climate conditions (Clement *et al.*, 2018). In 2020, a total of 265 million insurance contracts were sold across developing countries, according to a survey. Notably, 80% of these contracts were index-based insurance programs, indicating the growing adoption of this type of insurance (Kramer *et al.*, 2022). Since 1972, the Indian government has implemented a new agriculture programme every decade to address the shortcomings of earlier schemes (Singh and Agrawal, 2020). Despite ongoing efforts by national and state authorities to promote its adoption, low rates of crop insurance adoption continue to be reported in India (Biswal and Bahinipati, 2022).

Several studies have examined the factors that influence farmers' decisions regarding crop insurance adoption. Jin *et al.* (2016), Fahad *et al.* (2018), and Islam *et al.* (2021) found that risk aversion has a positive effect on crop insurance adoption. However, Trestini *et al.* (2018) discovered that farmers in Italy and Poland, who are more risk-averse, prefer other risk management techniques over insurance. Some studies revealed the importance of designing contracts with minimum basis risk under compound risk aversion (Elabed and Carter, 2015) and considering both risk and loss aversion (Shin *et al.*, 2022). Arshad *et al.* (2016) and Doherty *et al.* (2021) found that past adverse events also impact farmers' risk management decisions. Furthermore, van Winsen *et al.* (2016) found that farmers' attitude towards risk is a driving factor in risk management, rather than the level of risk present. Aditya *et al.* (2018) found that farmers who have experienced yield loss are more willing to pay. Rayamajhee *et al.* (2022) also argued that the major factor affecting the adoption of weather insurance is how households perceive future and past climate risks. Some studies have shown that farmers who experienced significant losses due to deficient or excessive rainfall are more interested in WIAI (Weather Index Agricultural Insurance) when they have insurance knowledge and trust in the accuracy of local weather forecasts (Liu *et al.*, 2010).

A study by Okoffo *et al.* (2016) found that females tend to be more risk-averse and therefore more likely to adopt crop insurance. However, other studies, such as Akter *et al.* (2016) suggests that gender differences in insurance choices are due to disparities in financial literacy and trust in insurance companies. Doherty *et al.* (2021) and Islam *et al.* (2021) found that age has a negative effect on WTP, while Okoffo *et al.* (2016) found age has a positive influence. Education has been shown to have a positive association with WTP in studies by Jin *et al.* (2016), Okoffo *et al.* (2016), and Fahad *et al.* (2018), while Arshad *et al.* (2016) found a negative effect on flood insurance adoption. Wang *et al.* (2016) suggested that education and farming experience have a significant effect on farmers in Huan province, China, in response to new crop insurance policies. Family size was found to have a negative influence on insurance purchase (Fahad *et al.*, 2018); Okoffo *et al.* (2016).

The positive correlation between household income and crop insurance purchases was highlighted by Budhathoki *et al.* (2019), which contrasts with the findings presented by Wang *et al.* (2016) and Jin *et al.* (2016). In terms of farm size, Fahad *et al.* (2018) showed a positive effect, which contradicts the results presented by Okoffo *et al.* (2016). Arshad *et al.* (2016) found a low demand for crop insurance in Pakistan, with only farmers who have more farmland supporting drought and rainfall insurance. Some studies have reported that the farming experience has a positive impact (Fahad *et al.*, 2018; Jin *et al.*, 2016; Doherty *et al.*, 2021), while Mesfin *et al.* (2011) found a negative but insignificant impact.

Castellani *et al.* (2014) found that the premium, compensation, and perceived drought frequency are the crucial factors that influence insurance adoption. According to some studies, farmers are more likely to make a payment if the premium rates are reasonable (Aditya *et al.*, 2018; Mutaqin and Usami, 2019). However, according to Ellis (2016) and Budhathoki *et al.* (2019), the acceptance of crop insurance is not correlated with premium rates, indicating that it is a normal good. Mensah *et al.* (2023) also found that farmers are very sensitive to elements such as premiums, projected payout, the sorts of risks covered by the insurance, and the nature of loss assessment criteria. Hill *et al.* (2016) showed that price discounts, positive prior experience with products, having received a payout in the first season, and reducing basis risk significantly increase the insurance uptake.

According to some studies, insurance policies that have simple terms and conditions, affordable premiums, less paperwork, transparent loss assessment procedures, and prompt compensation payments could potentially increase the demand for WII among farmers (Adjabui *et al.*, 2019). To make WII more appealing, it has also been recommended to include Drought Tolerant Seeds (DTS), credit, and weather information in the policy (Ali *et al.*, 2020). Moreover, Roder *et al.* (2019) emphasised that effective communication about the importance of insurance can be achieved through collaboration between the government and private insurers.

Various econometric models have been utilised by the studies to examine farmers' willingness to adopt or pay for crop and WII. Wodaju *et al.* (2025) employed the Zero-Inflated Ordered Probit (ZIOProbit) model to evaluate smallholder farmers' WTP for hypothetical WII. Meanwhile, Aheeyar *et al.* (2023), Jin *et al.* (2016), Carrer *et al.* (2020), and Rajeev and

Nagendran (2023) applied logistic regression models to identify the factors that influence enrolment or adoption decisions. Islam *et al.* (2021) utilised a multinomial logit model, whereas Ali *et al.* (2020) adopted a conditional logit model to investigate the effects of gender and product design. Akter *et al.* (2016) implemented a latent class logit model, and Sibiko *et al.* (2018) employed a mixed logit model to understand preferences for WII. Probit models were utilised by Fahad *et al.* (2018), Lin *et al.* (2015), and Hossain *et al.* (2022) to analyse the impact of socio-economic and demographic factors on farmers' decisions. Furthermore, Oduniyi *et al.* (2020) applied the Heckit sample selection model to assess both the WTP and the demand for livestock insurance. Despite extensive examination and promotion of agricultural insurance, the comprehension of the factors that drive farmers' adoption of crop insurance remains in development and necessitates further investigation.

3. Study area

The study was conducted in the Virudhunagar district of Tamil Nadu (Figure 1). It is located between 77°20′ and 78°26′ East longitude and 09°12′ and 09°47′ North latitude. The annual mean minimum and maximum temperatures in this district are 23.78 and 33.95 °C, respectively (Vikram *et al.*, 2023). The total geographical area of the district is 424,323 hectares (ha). Most of the operational holdings are concentrated in small, marginal,

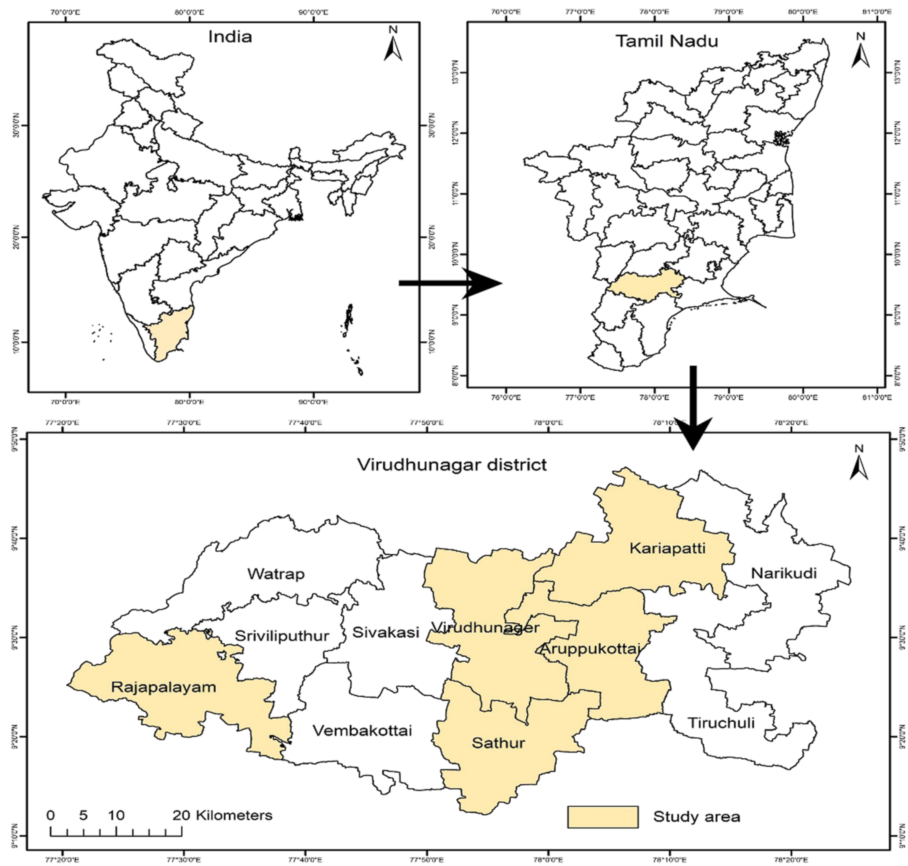

Figure 1. Map showing the study area. **Source(s):** Authors' own work

and semi-medium-sized areas. The main crops grown in this region are paddy, maize, jowar, bajra, horse gram, black gram, green gram, cotton and groundnut (Vikram *et al.*, 2023).

The total net area under cultivation in this district is 139,197 ha, out of which 60% of the area is grown under rainfed conditions. This district is characterised by an underdeveloped agricultural sector and general economic conditions primarily attributable to its rural background. In addition, various parts of this district have experienced recurrent droughts. Cotton is the primary cash crop grown in this area (mostly during the rabi season) and is subject to weather conditions such as drought and excess rainfall. Out of 19,858 ha of total cotton-grown area, 16,710 ha (84%) is cultivated under rainfed conditions. This district receives the highest rainfall through the northeast monsoon, which occurs between October and November (Vikram *et al.*, 2023). Low and skewed rainfall distribution, especially during the northeast monsoon period, causes water stress for winter-rainfed and summer-irrigated crops (Palanisami and Venkatram, 2008).

4. Sampling approach and data collection

The data was collected in the Virudhunagar district of Tamil Nadu using a multistage sampling technique combined with a simple random sampling method. First, we compiled a list of cotton farmers from the District Department of Agriculture and the District Cooperative Central Bank (DCCB). Out of this list, 5 blocks were randomly selected: Arruppukottai, Virudhunagar, Rajapalayam, Kariapatti, and Sattur. We then randomly selected 7 villages from each block and subsequently chose households at random from each village using the below equation as suggested by Raza Ullah *et al.* (2016) and Islam *et al.* (2021).

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

Where, n = Sample size in each village; N = Total number of cotton farming households in a village; e = Precision which is set at 15% (0.15).

The data used in the study was obtained through personal interviews with cotton farmers using a pre-tested schedule. The household survey questionnaire was developed based on input from key informants and subsequently pre-tested with 20 farming households in the study area. The survey was administered using a properly structured questionnaire during the period from mid-September to mid-October 2022. The initial sample size, calculated using the above given formula, was 393. However, following the implementation of data cleaning procedures, which entailed the removal of incomplete or ambiguous responses, the effective sample size utilised for the main analysis was subsequently reduced to 350. The farmers were considered as the heads of their households. They possessed considerable farming knowledge and were capable of making significant financial decisions. The interviews were focused on obtaining information regarding the households' socioeconomic status, farming practices, perception of drought and erratic rainfall over the past decade, their aversion to risk, the loss of yield that occurred over the last year, and their WTP for weather-based crop insurance.

5. Empirical methodology

5.1 Logistic regression

The logistic regression model is used to determine the relationship between WTP and farmers' socioeconomic characteristics, risk attitude, and risk perception. The dependent variable is WTP for WII, with a value of 1 if farmers are willing to pay and 0 otherwise. The logistic model is specified as per Eq (2):

$$y_i = \alpha + \sum_{j=1}^{m} \beta_j X_j + \varepsilon_i \quad (2)$$

where y_i is the dependent variable and X_j is a vector of independent variables, including gender, age, education, family size, log of annual income, farm size, farming experience, access to irrigation, access to credit, percentage of yield loss due to the weather parameters, risk attitude, perception of drought and perception of uneven distribution of rainfall. β_j is a set of estimated coefficients on the independent variables and ε_i the error term. The risk attitudes of farmers are measured by the experimental method, while risk perception is analysed using a Likert scale and a risk matrix. The definition and the expected sign of independent variables are presented in Table 1.

5.2 Risk attitude

The simplest and predominant way to assess farmers' risk attitude is to assume that the behaviour of the individual is based on the Expected Utility Theory (EUT) (Abdellaoui *et al.*, 2011). Some studies demonstrate that farmers often exhibit non-expected utility preferences, indicating that prospect theory (Tversky and Kahneman, 1992) provides a more reliable basis for understanding their decision-making process (Du *et al.*, 2017; Villacis *et al.*, 2021). However, eliciting risk attitudes according to prospect theory is a time-intensive process, if the primary goal of the study is to establish a correlation between risk attitude and various contextual factors, rather than to precisely ascertain risk aversion (Abdellaoui *et al.*, 2011).

Given that the main objective of this study is to assess the impact of farmers' risk attitude along with their socioeconomic variables on WTP for WII, this study assumes that the decision-making of cotton farmers can be explained using EUT based on constant relative risk

Table 1. Definition and expected sign of independent variables

Variable	Description	Definition	Expected sign
GEN	Gender	1 for male, 0 for female	+
AGE	Age	Age of head of the household in years	−
EDU	Education	Level of education (1 = no schooling, 2 = primary school, 3 = middle school, 4 = secondary school, 5 = higher secondary, 6 = graduate, 7 = postgraduate)	+
FSIZE	Family size	Number of members in a family	−
LOGINC	Log of annual income	Logged value of annual household income	±
FARMSIZE	Farm size	Size of the farm in acres	+
ACCIRR	Access to irrigation	1 for access to irrigation source and 0 otherwise	+
FE	Farming experience	Number of years engaged in farming activities	+
LS	livestock	1 for holding livestock and 0 otherwise	±
AC	Access to credit	1 for access to credit; 0 otherwise	+
LOSS	% Yield loss occurred due to weather parameters	Percentage of yield loss that occurred in the last year due to adverse weather events	+
Risk preferences			
RA	Risk aversion	Midpoint of CRRA	+
Perception of weather-related risk factors			
PD	Drought	1 for high-risk perception and 0 for low-risk perception	+
PUDR	Uneven distribution of rainfall	1 for high-risk perception and 0 for low-risk perception	+

Source(s): Authors' own work

aversion (CRRA). To elicit the risk attitude of sampled farmers in this study, an experimental method called the multiple price list (MPL) is used. This method is based on the work of Holt and Laury (2002). It is suitable for accurate CRRA estimations since this method reduces noise when EUT is fully assumed (Abdellaoui *et al.*, 2011). The main advantages of MPL design are that it is context-free and it is an intuitive design (Vollmer *et al.*, 2017), which is relatively easy for respondents to understand and to implement, allowing for truthful revelation of risk attitudes (Andersen *et al.*, 2006). This experimental method includes two options: the safe option and the risky option. There are nine tasks under each option. Option A is a safe option with a certain amount of 100% probability and the amount declines systematically throughout the nine tasks. Option B is a risky option with 50% probability and the amount remains unchanged for all the tasks. For example, if a farmer chooses Option A in the second task, they may gain Rs. 42 with a 100% probability. However, if a farmer chooses option B in the second task, he may gain Rs. 50 or Rs. 0 with a 50% probability.

The farmers are not shown the difference in the expected amount between Option A and Option B. The farmers are asked to choose one option for each task and indicate when they would switch from option A to option B. A risk-loving farmer shifts to option B in the first four tasks, while a risk-averse farmer shifts to option B in the last four tasks. A risk-neutral farmer chooses option B at the fifth task, where the expected amount of option A and option B is the same. The choice tasks presented to the farmers are listed in Table 2.

To determine the range of the *r* value, this experiment assumes that individuals possess constant relative risk aversion utility, as demonstrated in Eq. (3).

$$u_i = \frac{x^{1-r}}{1-r'} \tag{3}$$

where *x* is the payoff in the option, and *r* is the coefficient of constant relative risk aversion (CRRA). Based on the CRRA values, the risk attitude of farmers is classified into three types: risk-lover if $r > 0$, risk-neutral if $r = 0$, and risk-averse if $r < 0$. For example, the upper and lower limits of *r* for a farmer who shifted from option A to option B at a second task are calculated as compounded inequalities given by:

$$\frac{50^{1-r}}{1-r} > \frac{0.5\times 50^{1-r}}{1-r} \text{ and } \frac{42^{1-r}}{1-r} > \frac{0.5\times 50^{1-r}}{1-r}$$

In the analysis, we use the middle value of the CRRA range before a farmer changed their choice. For instance, if they switched from option A to option B on the 6th task, their *r* parameter range would be between 0 and 0.23, with the middle value being 0.12.

Table 2. The experimental design to determine the risk attitude

Task	Option A	Option B	EV_a	EV_b	Eva – EV_b	CRRA interval
1	50	50(1/2); 0(1/2)	50	25	25	$-\infty$, -2.9
2	42	50(1/2); 0(1/2)	42	25	17	-2.9, -1.1
3	36	50(1/2); 0(1/2)	36	25	11	-1.1, -0.4
4	30	50(1/2); 0(1/2)	30	25	5	-0.4, 0
5	25	50(1/2); 0(1/2)	25	25	0	0, 0.2
6	20	50(1/2); 0(1/2)	20	25	-5	0.2, 0.3
7	16	50(1/2); 0(1/2)	16	25	-9	0.3, 0.4
8	14	50(1/2); 0(1/2)	14	25	-11	0.4, 0.5
9	12	50(1/2); 0(1/2)	12	25	-13	0.5, ∞

Note(s): EV – Expected Value, CRRA – Coefficient of Relative Risk Aversion
Source(s): Adopted from Holt and Laury (2002)

5.3 Risk perception

Farmers' perceptions of the risks associated with drought and uneven rainfall distribution are evaluated using a risk matrix that considers both the frequency and severity of these events. Farmers were solicited to assess various weather events, such as drought and rainfall that occurred over the past decade, by rating both the frequency and severity on a 5-point Likert scale. The frequency scale is defined as follows: a score of 1 indicates that the event occurred very rarely (0–2 years), 2 indicates a low frequency (3–4 years), 3 represents medium frequency (5–6 years), 4 signifies high frequency (7–8 years) and 5 indicates that the event occurred very frequently (9–10 years). In terms of severity, the scale is structured as follows: a score of 1 denotes very low severity, 2 indicates low severity, 3 reflects medium severity, 4 represents high severity, and 5 indicates very high severity. Following Ogurtsov *et al.* (2008) and Saqib *et al.* (2016), the responses of farmers are placed into a risk matrix, which is shown in Figure 2. The level of risk perception is considered low if the score ranges between 2 and 5 and high if the score is between 6 and 10. These risk perceptions are utilised in the analysis, where 1 is assigned if the farmer views the risk as high and 0 otherwise.

6. Results and discussion

6.1 Demographic profile of the sample

The socioeconomic and demographic characteristics of the respondents are presented in Table 3. The findings indicate that 84% of the farmers surveyed were male. The age of the respondents ranged from 25 to 68 years, demonstrating the generational diversity within the farming community. The average age of the sampled farmers is 49 years, indicating a demographic characterised by considerable experience in agriculture, with an average tenure of 26 years in the field. The experience levels varied considerably, with some individuals having as little as 1 year in the field, while others had accumulated up to 51 years of farming experience. This broad spectrum of experience not only represents different stages in agricultural careers but also highlights the opportunity for knowledge sharing and mentorship within the community. The mean family size is 4 members, with approximately 2 earning members per family. The educational background of the farmers varies from no schooling to postgraduate. On average, the education level of respondents is found to be at the middle school level, suggesting potential avenues for further training and knowledge development to enhance farming practices. The farm size of the sampled households ranges from 1 acre to a maximum of 30 acres, with an average farm size of approximately 5.7 acres. This diversity in

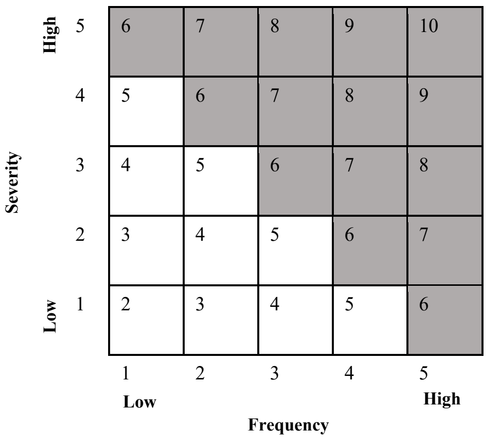

Figure 2. The Risk matrix. **Source(s):** Adopted from Ogurtsov *et al.* (2008) and Saqib *et al.* (2016)

Table 3. Descriptive statistics of socioeconomic characteristics of the respondents

Variable	Mean	SD	Minimum	Maximum
WTP	0.65	0.48	0	1
GEN	0.84	0.37	0	1
AGE	49.08	8.88	25	68
EDU	2.88	1.42	1	7
FSIZE	4.19	1.59	1	13
INC	474,423.89	247,745.37	120,000.00	2,600,000.00
LOGINC	12.96	0.46	11.70	14.77
FARMSIZE	5.68	3.78	1	30
FE	25.51	11.57	1	51
ACCIRR	0.38	0.49	0	1
AC	0.60	0.49	0	1
LS	0.47	0.50	0	1
RA	0.15	0.58	−2.05	0.5

Source(s): Authors' own work

farm size indicates a mix of agricultural capabilities and highlights potential for innovative farming techniques tailored to both small and larger operations. Only 38% of farmers have access to irrigation sources, while nearly 62% of farmers grow their crops without irrigation and rely on rain. This reliance on rainfall significantly impacts their agricultural productivity and highlights the challenges associated with rain-fed farming concerning climate variability. The sampled farmers' income ranges from a minimum of Rs. 120,000 to a maximum of Rs. 2,600,000, reflecting the diverse economic conditions experienced by agricultural families. The average annual household income is approximately Rs. 475,000 and almost 60% of the respondents have availed credit for farming during the last year. The reliance on borrowed funds is indicative of the various challenges these farmers encounter, such as the necessity for investment in seeds, equipment, and other critical resources. For 47% of farmers, the income also comes from livestock. This mixed farming approach not only enhances financial stability but also helps reduce risks associated with solely relying on crop production. The average CRRA midpoint value of the overall sample is 0.15, indicating that most farmers in the sample are risk-averse.

6.2 Risk attitude of farmers

People have different attitudes towards risk, and this affects how they manage it, regardless of how they perceive it (Khanal *et al.*, 2019). Therefore, it is crucial to understand farmers' risk preferences to analyse their behaviour under uncertainty and risk (Sulewski and Kłoczko-Gajewska, 2014) as well as their decision-making regarding risk management strategies (Sulewski *et al.*, 2020). The respondents are categorised into 3 types based on their risk attitude using Holt and Laury (2002)'s multiple price list (MPL) experimental methods (Table 4). The results show that 74.86% of the respondents are risk-averse, 13.14% are risk-neutral, and only

Table 4. Distribution of farmers according to their risk attitude

Category	Frequency (n = 350)	WTP	Not WTP
Risk-averse	262 (74.86)	176	86
Risk-neutral	46 (13.14)	39	7
Risk-lover	42 (12.00)	11	31

Note(s): Numbers in parentheses are percentages
Source(s): Authors' own work

12.00% are risk-seekers. These results imply that the majority of the farmers are hesitant to take risks, and only a small fraction are willing to take risk. Moreover, out of the 262 farmers who are identified as risk-averse, 176 (67.18%) expressed their WTP for crop insurance, while 86 (32.82%) stated that they are not inclined to adopt it.

6.3 Risk perception

To develop an effective strategy for dealing with climate risks, it is important to have a clear understanding of those risks. An efficient risk management system begins with having the right perspective of risk factors (Sulewski and Kłoczko-Gajewska, 2014). Farmers' perceptions of the severity and frequency of weather-related risk factors during the past 10 years are presented in Table 5. Using the risk matrix shown in Figure 2, farmers' perceptions of subjective risk are divided into high and low.

The first two columns illustrate the number of farmers who perceive drought as high or low risk and are willing or unwilling to pay, respectively. The third and fourth columns show the number of farmers who perceive uneven rainfall distribution as high or low risk and are willing or unwilling to pay, respectively. The results show that approximately 67% of the respondents have perceived drought as a high-risk factor. Among those, 182 farmers are ready to purchase the insurance, while the other 51 farmers are not ready. Similarly, among 52% of the respondents who have a high-risk perception towards the uneven distribution of rainfall, 144 farmers are willing to adopt crop insurance, and 39 farmers are not willing to pay.

6.4 Willingness to pay

Before running the regression model, we checked for multicollinearity among the explanatory variables using the variance inflation factor (VIF) and tolerance (TOL). The results are presented in Table 6. A TOL value of less than 0.2 and a VIF value of more than 10 indicates the problem of multicollinearity. The estimated results show that the value of TOL ranges between 0.40 and 0.97 and the value of VIF ranges between 1.03 and 2.48, indicating a slight correlation between independent variables in the model.

Table 7 presents the results of the binary logistic regression analysis that investigates the factors linked to the WTP. The study reveals that several variables – including GEN, EDU, FSIZE, LOGINC, ACCIRR, AC, LOSS, RA, and PD and PUDR in the last decade have a significant impact on WTP for WII. Additionally, to evaluate the robustness of the findings, the probit model is employed (see Table A1Appendix). The results indicate no differences in the direction and significance levels of the coefficients between logit and probit regression models, thereby confirming the robustness of our research outcomes.

The coefficient of gender (GEN) is negative and significant, indicating the negative influence of gender, which confirms the findings of Trestini *et al.* (2018). As males are more willing to adopt new technology, a positive influence of gender is expected. However, the findings indicate that female farmers are 10.0% more likely to participate in crop insurance

Table 5. Distribution of respondents according to their risk perceptions

	Risk perception			
	Drought (n = 350)		Uneven distribution of rainfall (n = 350)	
	High	Low	High	Low
	233 (66.57)	117 (33.43)	183 (52.29)	167 (47.71)
Willing to pay	182	44	144	82
Not willing to pay	51	73	39	85

Note(s): Numbers in parentheses are percentages
Source(s): Authors' own work

Table 6. Multicollinearity diagnosis indices for explanatory variables

Variables	VIF	TOL
GEN	1.11	0.90
AGE	2.48	0.40
EDU	1.22	0.82
FSIZE	1.30	0.77
LOGINC	1.86	0.54
FARMSIZE	1.62	0.62
FE	2.23	0.45
ACCIRR	1.16	0.86
AC	1.04	0.96
LS	1.03	0.97
LOSS	1.29	0.78
Risk preferences		
RA	1.06	0.95
Perception of weather-related risk factors		
PD	1.20	0.83
PUDR	1.17	0.86

Source(s): Authors' own work

Table 7. Estimated results of binary logit model

Variables	Coefficients	Marginal effects
GEN	-1.361^{**} (0.600)	-0.100^{**} (0.043)
AGE	-0.033 (0.040)	-0.002 (0.003)
EDU	0.351^{**} (0.169)	0.025^{**} (0.012)
FSIZE	-0.355^{**} (0.178)	-0.026^{**} (0.013)
LOGINC	1.130^{*} (0.617)	0.083^{*} (0.044)
FARMSIZE	0.096 (0.076)	0.007 (0.006)
FE	0.022 (0.028)	0.002 (0.002)
ACCIRR	-1.680^{***} (0.469)	-0.123^{***} (0.031)
AC	1.073^{**} (0.449)	0.079^{**} (0.032)
LS	-0.424 (0.429)	-0.031 (0.031)
LOSS	0.192^{***} (0.023)	0.014^{***} (0.001)
Risk preferences		
RA	0.696^{**} (0.314)	0.051^{**} (0.022)
Perception of weather-related risk factors		
PD	1.625^{***} (0.438)	0.119^{***} (0.029)
PUDR	1.058^{**} ((0.430)	0.078^{**} (0.031)
Constant	-17.169^{**} (7.569)	
Summary statistics		
Log-likelihood	-83.20	
LR χ^2 (14)	288.64	
Prob > χ^2	0.000	
Pseudo R^2	0.634	
Observations	350	

Note(s): ***, * and * indicates significance level of 1%, 5 and 10% respectively. Numbers in parentheses are standard errors

Source(s): Authors' own work

than male farmers. A study by Maganga *et al.* (2021) reported that men tend to prioritise cultivating high-value cash crops compared to women who focus more on producing food crops. As a result, women may be more concerned about potential losses in crop yield for cash crops and therefore, more willing to participate in crop insurance programs (Jin *et al.*, 2016).

It is not surprising that education (EDU) plays a crucial role in the adoption of weather insurance. When farmers have a higher level of education, the probability of WTP for insurance increases by 2.5% for every unit increase in education. Similarly, the literature has confirmed that farmers with higher levels of education are more likely to adopt crop insurance (Jin *et al.*, 2016; Aditya *et al.*, 2018; Wang *et al.*, 2016). In a study conducted by Cole *et al.* (2013), it was found that financial literacy has no relation to insurance participation, which could be because farmers are already well-informed about the product. However, the surveyed farmers in our study are new to weather insurance, thus, education helps them to understand the anticipated climate risks and the advantages of crop insurance, ultimately leading to better decision-making.

The coefficient of family size (FSIZE) is negative and significant, consistent with the findings of Njue *et al.* (2018). The results of this study indicate that the likelihood of adopting insurance decreases by 2.6% for every additional member in a farming household. Previous studies (Ali, 2013; Wang *et al.*, 2022) also showed that family size has a negative impact, but it is not statistically significant. This finding is expected as the large family may have financial constraints and may thus not be willing to adopt WII.

A statistically positive and significant association is found between the log of annual income (LOGINC) and WTP, consistent with the findings of Petrolia *et al.* (2013). Those with higher incomes are more likely to adopt WII because they have more financial resources available to them. When the annual income of a household increases by one unit, the probability of a household adopting weather insurance increases by 8.3%. However, Jin *et al.* (2016) found a substantial inverse relationship between the log of household income and the demand for crop insurance and claimed that wealthy farmers might make up for the loss through other sources of income.

Our results show that the availability of irrigation facilities (ACCIRR) has a negative and significant effect on willingness to purchase crop insurance (Hazell *et al.*, 2010). Farmers who have no access to irrigation are 12.3% more likely to buy insurance. This could be because farmers without any irrigation sources may face more crop damage due to insufficient rainfall during key growth periods. As a result, farmers who rely on rainwater to cultivate their crops may be more likely to consider weather insurance as a means of safeguarding against rainfall shortages. In addition, farmers with access to irrigation have opportunities to cultivate more crops and are more likely to adopt other risk management strategies like crop diversification (Mesfin *et al.*, 2011).

Insurance demand is sensitive to price, with liquidity playing a significant role in the farmers' participation in weather insurance (Cole *et al.*, 2013; Giné *et al.*, 2008). In this study, access to credit (AC) is found to be significantly and positively correlated with WTP for crop insurance. This finding is consistent with the results presented by Bogale (2015). Farmers with access to credit have 7.9% higher chance of participating in weather insurance. On the other hand, farmers who lack access to credit may be less willing to adopt insurance products, even if they are easily accessible (Arshad *et al.*, 2016). Studies by Cole *et al.* (2013) and also concluded that credit constraint is the major impediment to buying insurance. Therefore, it is believed that more farmers can be facilitated to participate in crop insurance by connecting insurance products with microfinance institutions (Bogale, 2015), as well as by making early insurance payouts (Giné *et al.*, 2008).

The results show that the experience of yield loss (LOSS) has a positive and significant influence on crop insurance purchases. This finding is similar to the results presented by Aditya *et al.* (2018). Specifically, encountering a yield loss led to a 1.4% increase in the likelihood of WTP. This may be due to risk exposure in the past which makes farmers more risk-averse and, thus, more willing to pay (Aditya *et al.*, 2018).

Based on the analysis of risk attitude (RA), it has been found that risk-averse farmers are more likely to purchase insurance. This is supported by a study conducted by (Sulewski *et al.*, 2020). With the increasing uncertainty in weather patterns, farmers with low tolerance of risk are more interested in participating in weather insurance schemes. According to the results, the highly risk-averse farmers have a 5.1% higher chance of buying insurance. However, this finding contradicts the argument put forward by Giné *et al.* (2008) and Cole *et al.* (2013). They claimed that risk-averse farmers are averse to uncertainty about crop insurance due to their lack of understanding about the product and lack of trust in the insurance provider (Cole *et al.*, 2013; Giné *et al.*, 2008). However, Cole *et al.* (2013) also stated that the likelihood of farmers' demand for insurance is higher when they trust the source of the product information. Hence, it is considered that farmers who are risk-averse and able to reap the benefits of insurance are more willing to participate in weather insurance schemes.

Farmers' subjective risk perception of drought (PD) and uneven distribution of rainfall (PUDR) is positively and significantly correlated with the decision to adopt weather insurance, which is similar to previous studies (Hossain *et al.*, 2022; Petrolia *et al.*, 2013). When farmers perceive drought as a significant risk, the probability of participating in crop insurance increases by 11.9%. Similarly, perceiving irregular rainfall distribution as a high risk leads to 7.8% more chances of purchasing insurance. According to prospect theory's certainty impact, people pay more attention to incidences for which they perceive the occurrence of risk events to be certain. Therefore, those who have had hazardous experiences tend to view post-hazard circumstances as a reference point where insurance compensation will be their profit (Yang *et al.*, 2020). This suggests that farmers who have a higher perception of risk are more likely to buy weather insurance than those who have a lower perception of risk.

7. Conclusion and recommendations

Agricultural production is a crucial sector of the Indian economy, but it is often affected by climate-related risks. Crop insurance has been available in the country since 1972, with subsidies for premium payments. However, the uptake of insurance among farmers needs to improve (Biswal and Bahinipati, 2022; Singh and Agrawal, 2020). In developing countries like India, with 82% small and marginal farmers, WII is an attractive risk management strategy (Jin *et al.*, 2016). Understanding farmers' risk preferences and attitudes is essential in improving WII adoption. Yet, little existing empirical evidence focused on the impact of risk preferences and risk perception on WTP for WII among cotton farmers in India. Our study contributes to the literature by exploring these factors, including farmers' perceptions of drought and uneven rainfall distribution.

Our results show that more than half of the interviewed farmers (65%) are willing to adopt WII and have a high-risk perception. The results of the risk experiment show that most of the farmers exhibited risk-averse behaviour. The study finds that risk attitude and risk perception have a significant positive impact on WII adoption. Variables such as GEN, FSIZE, and ACCIRR have a significantly negative influence on WTP for WII. Conversely, EDU, LOGINC, AC, and LOSS are positively and significantly correlated with the purchase of WII.

These findings herein are beneficial for policymakers seeking to comprehend farmers' behaviour by assessing their risk preferences and attitudes. This knowledge can enhance the adoption of agricultural insurance products. For example, one way to improve farmers' adoption of weather insurance is to educate them on how insurance can help manage risk and provide information about future climate change. Additionally, promoting the benefits of crop insurance can also increase insurance uptake. Another approach to enhance farmers' participation in crop insurance is to incorporate it into microfinance. However, it is worth noting that our study focuses solely on farmers' WTP for crop insurance. It does not investigate alternative methods of managing risk or farmers' preferences for such methods compared to WII. To fully comprehend the farmers' perspectives, it is also crucial to examine the factors influencing the simultaneous adoption of various risk management strategies they may use to reduce losses. While this study adopts an exploratory approach to identify the key determinants influencing the adoption of WII, we acknowledge the value of incorporating theoretically grounded hypotheses to guide empirical analysis. Future research could adopt theoretical hypotheses to enhance the analysis of factors influencing WII.

Additionally, this study employed an MPL design based on Holt and Laury (2002), assuming farmer behaviour aligns with EUT. Given that detailed risk assessment was not the primary objective, the experiment utilised small stakes. For a more accurate reflection of real farmer decision-making, future research is encouraged to incorporate context-specific payoffs and compare experimentally elicited risk attitudes with actual risk-related factors faced by farmers. Previous research demonstrated that basis risk is a significant factor in explaining the low uptake of weather index-related insurance in developing countries. However, we did not examine how this would have affected farmers' decisions to purchase WII in our study. Further research should include basis risk as one of the factors influencing the adoption of weather index insurance. Furthermore, future studies could cover more farm areas, a large number of farmers, consider more potential factors and conduct longitudinal studies to assess the long-term effects of WII on various aspects of farm performance, such as productivity, input utilisation, investment behaviour, and income stability.

Acknowledgments
We would like to express our gratitude to V. Bala Murugan, A. Suresh, and P. Saradha for their help in data collection. Q.X. Wang thanks the grant of the Australian Research Council (Grant Number IE230100435).

Appendix

Table A1. Robustness Test: Estimates of probit model

Variables	Probit Coefficients	Marginal effects
GEN	−0.653** (0.335)	−0.085** (0.043)
AGE	−0.012 (0.023)	−0.002 (0.003)
EDU	0.198** (0.094)	0.026** (0.012)
FSIZE	−0.213** (0.097)	−0.028** (0.012)
LOGINC	0.534* (0.326)	0.069* (0.042)
FARMSIZE	0.066 (0.043)	0.009 (0.005)
FE	0.005 (0.016)	0.001 (0.002)
ACCIRR	−0.799*** (0.257)	−0.104*** (0.032)
AC	0.675** (0.248)	0.087** (0.031)
LS	−0.147 (0.239)	−0.019 (0.031)
LOSS	0.102*** (0.011)	0.013*** (0.001)
Risk preferences		
RA	0.846** (0.264)	0.110** (0.032)
Perception of weather-related risk factors		
PD	0.964*** (0.241)	0.125*** (0.028)
PUDR	0.626** (0.238)	0.081** (0.030)
Constant	−9.209 (4.027)	
Summary statistics		
Log-likelihood	−81.170	
LR χ^2 (14)	292.700	
Prob > χ^2	0.000	
Pseudo R^2	0.6432	
Observations	350	

Source(s): Authors' own work

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