Is the internet helping farmers build climate resilience? Evidence from rice production in the Jianghan Plain, China

Qingmeng Tong, Shan Ran and Xuan Liu
School of Economics and Business Administration, Central China Normal University, Wuhan, China, and
Lu Zhang and Junbiao Zhang
College of Economics and Management, Huazhong Agricultural University, Wuhan, China

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Abstract

Purpose – The main purpose of this study is to examine the impact of agricultural internet information (AII) acquisition on climate-resilient variety adoption among rice farmers in the Jianghan Plain region of China. Additionally, it explores the influencing channels involved in this process.

Design/methodology/approach – Based on survey data for 877 rice farmers from 10 counties in the Jianghan Plain, China, this paper used an econometric approach to estimate the impact of AII acquisition on farmers' adoption of climate-resilient varieties. A recursive bivariate Probit model was used to address endogeneity issues and obtain accurate estimates. Furthermore, three main influencing mechanisms were proposed and tested, which are broadening information channels, enhancing social interactions and improving agricultural skills.

Findings – The results show that acquiring AII can overall enhance the likelihood of farmers adopting climate-resilient varieties by 36.8%. The three influencing channels are empirically confirmed. Besides, educational attainment, income and peer effects can facilitate farmers' acquisition of AII, while climate conditions and age significantly influence the adoption of climate-resilient varieties.

Practical implications – Practical recommendations are put forward to help farmers build climate resilience, including investing in rural internet infrastructures, enhancing farmers' digital literacy and promoting the dissemination of climate-resilient information through diverse internet platforms.

Originality/value – Strengthening climate resilience is essential for sustaining the livelihoods of farmers and ensuring national food security; however, the role of internet information has received limited attention. To the best of the authors' knowledge, this study is the first to examine the casual relationship between internet information and climate resilience, which fills the research gap.

Keywords Agricultural internet information (AII), Climate resilience, China, Rice production, Recursive binary probit model

Paper type Research paper

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1. Introduction

Climate change profoundly affects the human environment and poses huge challenges to the achievement of Sustainable Development Goals. The global average temperature could rise by 4.4°C by the year 2100 under a high-emissions scenario (IPCC, 2022); meanwhile, the severity and frequency of extreme weather events such as droughts and floods are on the rise (Foguesatto and Machado, 2021). To address climate change effectively, countries worldwide have embraced widespread cooperation. For instance, the Copenhagen Agreement, proposed during COP15, stipulates that developed nations would offer financial assistance to support developing countries in reducing carbon emissions and adapting to climate change [1]. Similarly, the Paris Agreement sets the objective of restraining the rise in global average temperature to well below 2°C above pre-industrial levels [2]. These international collaborations and agreements have made significant strides in mitigating the progression of this global concern.

As one of the fast-growing developing countries, China is also deeply impacted by the serious consequences of climate change. According to the *Blue Book on Climate Change in China 2022* released by the China Meteorological Administration (CMA), China's average surface temperature, coastal sea level, permafrost active-layer thickness and many other indicators of climate change have broken observed records in 2021 [3]. Over the past decade, weather-related disasters have caused annual direct economic losses of over \$50bn, about 0.4% of GDP (Teng *et al.*, 2021). Therefore, it is imperative for China to promptly implement measures to address climate risks and alleviate their detrimental effects.

Among the various impacts of global warming, the declining productivity in agriculture and the rise of rural poverty have been garnering increasing attention (Hertel and Rosch, 2010). As the world's population continues to expand and the demand for food production rises, climate change is expected to bring significant uncertainty to agricultural production and food security (Lobell *et al.*, 2008). Moreover, farmers who have limited resource endowments are among the most vulnerable to climate change and need more effective adaptation measures to ensure sustainable livelihoods. Consequently, there is an increasing number of studies focusing on climate resilience in agriculture (Tambo and Wünscher, 2017; Haworth *et al.*, 2018; Liu *et al.*, 2022). Resilience is "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance" (Pörtner *et al.*, 2022). Nelson *et al.* (2007) pointed out that the phrase "climate adaptation" refers to decision-making processes and actions that absorb shocks, meanwhile the concept "climate resilience" encompasses both preparedness for unexpected events and system renewal. Therefore, the notion of climate resilience involves the ability to maintain a capacity for transformation. Among the various commonly used approaches to enhancing climate resilience, the adoption of improved crop varieties such as those resistant to climate stress has proven to be a particularly promising and effective strategy (Lobell *et al.*, 2008; Thornton *et al.*, 2009; Deressa *et al.*, 2009; Vermeulen *et al.*, 2012), due to its effectiveness in mitigating the adverse impacts of climate change thereby minimizing losses (Acevedo *et al.*, 2020).

The literature on factors that influence farmers' climate resilience is substantial, covering psychological perceptions (Li *et al.*, 2013; Takahashi *et al.*, 2016), individual and household endowments (Roco *et al.*, 2015) and external environmental factors such as policy interventions (Eise *et al.*, 2021). Despite a wealth of relevant research findings, the role of agricultural internet information (AII) based on emerging information and communication technologies (ICTs) has received little attention. Particularly, empirical research on the extent to which AII contributes to the adoption of climate-resilient varieties among farmers is lacking.

Since the mid-1950s, the information revolution, which is characterized by the computer and dominated by new information technologies, has brought human society to a new era of information. Over the past few years, the integration of the internet and agriculture has emerged as a new trend in modern farming (Ma *et al.*, 2020; Zheng and Ma, 2021). In addition, the effectiveness of farmers' adaptation to climate change has been enhanced by the internet, as shown in several studies. For example, Srivastava and Das (2021) have highlighted the potential of smart agricultural systems developed through the internet in mitigating climate change risks such as water scarcity. Previous studies also collectively agreed that climate information access significantly influences farmers' ability to adapt to climate change (Kalafatis *et al.*, 2015; Owusu *et al.*, 2021). The internet can play a unique role in this regard by offering high degrees of freedom, instantaneity, sharing and openness for transfer and exchange of information (Adamides *et al.*, 2020). Specifically, the internet can enable more frequent communication among agricultural stakeholders, thereby reducing the cost of access to agricultural technologies and relevant policies about climate adaptation (Mtega and Msungu, 2013). Over the longer term, the AII can help farmers to increase agricultural productivity by optimizing the distribution of production factors and cultivation structure (Nakasone *et al.*, 2014). Therefore, the utilization of internet-based information is becoming increasingly prevalent in the development of climate resilience.

However, there is limited understanding of how AII relates to the climate resilience of farmers. Furthermore, there are certain questions that demand comprehensive research to be adequately answered. For instance, to what degree does the internet facilitate farmers in implementing climate-resilient practices, such as adopting new crop varieties? What are the underlying impact mechanisms at play? Hence, conducting empirical research from a micro-level perspective of farmers will greatly contribute to answering these critical questions.

To fill this research gap, this paper aims to investigate the impact of AII acquisition on the adoption of climate-resilient rice varieties, using a data set of farmers in the Jianghan Plain, China. This paper contributes to the existing literature mainly by quantitatively examining the impact of AII on the establishment of climate resilience. It not only adds value to the existing body of knowledge but also offers crucial insights for stakeholders, such as governments, in designing effective strategies to combat climate change. The rest of this paper is presented as follows: channels of influence are presented in Section 2. Model specification and data collection are provided in Section 3. Results and discussion are shown in Section 4. Finally, conclusions and implications are given in Section 5.

2. Channels of influence

The various channels, dimensions and levels of agricultural internet-based information provide a solid foundation for enhancing climate resilience. More specifically, AII acquisition can impact farmers' adoption of climate-resilient varieties through three primary channels.

First, the internet can facilitate information acquisition and eliminate potential barriers such as high costs and limited availability. This broadens access to relevant information and provides specialized support for farmers to build climate resilience. Farmers are often at a disadvantage compared to urban residents in terms of information access due to limited sources. As a result, the efficiency of collecting, processing and disseminating information may be hindered by delays and distortions (Zeng *et al.*, 2017). Such limitations are more pronounced when farmers are responding to the impacts of climate change (Antwi-Agyei *et al.*, 2015). However, the internet can overcome for the shortcomings of traditional information channels. For example, the use of internet technologies enables farmers to obtain timely information on agricultural production from various platforms (e.g. websites and social media), thus facilitating strategic measures like switching to adaptive varieties. The CMA has established an early warning information dissemination system that offers up-to-date weather disaster notifications through various platforms including central and local government websites, agricultural weather applications, as well as the 12316 network television stations located in grass-roots rural areas.

Moreover, obtaining agricultural information through the internet enhances farmers' awareness and cognition of climate change, which establishes a psychological foundation for them to reinforce household resilience (Le Dang *et al.*, 2014a). By accessing AII, farmers can gain insights into climate hazards and learn about the consequences of climate change, which can lead to increased emotional resonance and crisis awareness. Consequently, farmers become more aware of climate risks and the necessity for adaptations. In summary, the internet provides farmers with additional channels to acquire information that can aid in the adoption of climate-resilient varieties.

Second, farmers can expand their social networks and facilitate communication with other farmers or stakeholders, thus increasing the likelihood of adopting climate-resilient varieties. Chinese farmers' traditional social networks mainly comprise members of clans and those in the same villages. Communication among farmers, especially those living in distant locations, is infrequent and often limited. The closed nature of these networks has hindered the transmission of information related to climate-resilient technologies. However, the internet platforms have the potential to not only reinforce existing social relationships, but also increase external social interactions, thereby providing greater access to resources for building resilience (Michailidis *et al.*, 2011). Such peer effects have been widely confirmed in previous literature (e.g. Niu *et al.*, 2022).

In practice, farmers who have already adopted climate-resilient varieties can exchange farming experience (e.g. the performance of resistance and yield improvement), suggestions (e.g. the selection of seeds) and opinions (e.g. whether to adopt) within their own or nearby communities through internet communication. Non-adopters can easily refer to the shared experiences and feedback from adopters, thus increasing the likelihood of adoption. Moreover, when preparing to adopt a new climate-resilient variety, farmers within the same social circle are more likely to collaborate and act in unison by exchanging AII, which enhances the success rate of planting. To summarize, acquiring AII can strengthen farmers' social interactions and increase the likelihood of adopting climate-resilient varieties.

Third, the internet can enhance farmers' agronomic skills by providing remote training that transcends the constraints of time and space, thereby furnishing them with a sturdy foundation of knowledge and technology to adopt climate-resilient varieties. Conventional agricultural extension predominantly relies on field activities such as face-to-face guidance and instruction. However, such field training can be expensive and may fall short of the desired outcome because of restrictions on frequency and content. With the help of internet information, contemporary distance education and online training can overcome the spatial and temporal restrictions of traditional extension, creating a conducive learning environment for farmers to readily adopt new varieties and other technologies (Bentley *et al.*, 2019; Gao *et al.*, 2020). Thus, acquiring AII aids in improving farmers' human capital and provides a more flexible strategic space for strengthening climate resilience. Specifically, farmers can acquire knowledge on various agricultural technologies with greater ease and efficacy by accessing online courses and offline videos via regional or national agricultural platforms such as WeChat official accounts.

The advantages of acquiring AII are particularly evident when faced with travel restrictions. For example, during the COVID-19 pandemic, the Jilin Province in China organized a series of Web-based training activities to assist farmers in preparing for plowing and sowing, highlighting the benefits of internet amid such challenging circumstances. Agricultural experts from universities and research institutes were invited to create training videos, which were subsequently posted on various online platforms along with push notifications. Additionally, live-streamed lectures aimed at addressing farmers' queries have garnered a significant audience [4]. To sum up, farmers who acquire agricultural information via the internet are more inclined to use modern ICTs to gain knowledge on climate-resilient varieties. This, in turn, reduces technical barriers and enhances the likelihood of adoption.

3. Model specification and data collection

3.1 Model specification

The explained variable of this study is whether the farmers has adopted the climate-resilient variety, which is a binary outcome. To accurately characterize farmers' choices, the Probit model was selected as the basic model following Owusu *et al.* (2021), as it is commonly used for dichotomous responses. Assuming that farmers are rational (Adesina and Zinnah, 1993), the decision of adopting climate-resilient varieties can be expressed by a latent variable function as follows:

$$CR\_Variety_i^* = \beta_0 + \gamma AII_i + \sum \boldsymbol{\beta X_i} + \varepsilon_i$$
$$CR\_Variety_i = \begin{cases} 1, if\, CR\_Variety_i^* > 0 \\ 0, otherwise \end{cases} \quad (1)$$

Where $CR\_Variety_i$ is a binary outcome variable indicating whether the rice farmer i has adopted the climate-resilient variety (i.e. $CR\_Variety_i = 1$) or not (i.e. $CR\_Variety_i = 0$). AII_i is a dummy explanatory variable denoting whether the farmer acquires AII, which is of most interest in this study. The vector $\boldsymbol{X}$ encompasses a range of control variables such as farmers' demographic characteristics, household endowments and environmental factors. ε_i is the error term following a normal distribution.

Generally, consistent estimates can be obtained using an ordinary Probit model described above if the variable AII is exogenous. However, there might be a self-selection bias to include AII in determining farmers' adoption behaviors (Ma *et al.*, 2020). Specifically, some observable and unobservable traits (e.g. farmers' intelligence and motivation) may influence both the decisions of acquiring AII and adopting climate-resilient varieties. Such an endogeneity issue will lead to biased results and inaccurate conclusions.

Following existing literature (Ma *et al.*, 2018; Wang *et al.*, 2023), the researchers adopt an recursive bivariate probit (RBP) model proposed by Chiburis *et al.* (2012) to estimate the impact of AII acquisition on the adoption of climate-resilient varieties. According to the economic theory of agency, a farmer chooses to acquire agricultural information via the internet only if the utility increases compared with the situation of not acquiring AII. However, the utility cannot be directly observed. Similar to the equation (1), the behavior of obtaining AII can be specified as a Probit model as follows:

$$AII_i^* = \alpha_0 + \boldsymbol{\alpha X_i'} + \theta IV_i + \mu_i, AII_i = \begin{cases} 1, if\, AII_i^* > 0 \\ 0, otherwise \end{cases} \quad (2)$$

By using RBP, the treatment (i.e. AII acquisition) and outcome (i.e. climate-resilient varieties adoption) equations are estimated jointly. $\boldsymbol{\alpha}$, $\boldsymbol{\beta_i}$, γ, θ are parameters to be estimated. The

RBP model was estimated using the full information maximum likelihood approach. It should be noted that at least one instrumental variable (IV) should be included in the treatment equation to differ from the outcome equation for identification. A valid IV must be uncorrelated with the potential outcome other than through the treatment variable.

As suggested by Niu *et al.* (2022) and other researchers, the researchers used an indicator of peer effects as our IV, which is represented by the rate of AII adoption among farmers within the same village. It is reasonable to argue that the acquisition of AII by other farmers may prompt similar behavior of a farmer, however, it may not necessarily impact his/her decision to adopt climate-resilient varieties. Following Wang *et al.* (2023), the researchers also calculate the average treatment effect (ATE) to measure the overall causal effect of AII acquisition on the likelihood of adopting climate-resilient varieties, which can be written as below:

$$ATE = \frac{1}{N}\sum_{i=1}^{N}\{\Pr(CR\_Variety_i = 1|_{AII_i=1}) - (\Pr(CR\_Variety_i = 1|_{AII_i=0})\} \quad (3)$$

3.2 Data and variables

3.2.1 Data collection. The data for this study were gathered by conducting a survey of rice farmers in the Jianghan Plain of Hubei Province, China, between July and August of 2019. Known as "the home of fish and rice" in ancient Chinese history, the Jianghan Plain is a significant grain-producing area of China due to its vast flat terrain. Five counties within the Jianghan Plain have been recognized by the central government as the "Major Grain-Producing County" due to their exceptional contribution in grain production. The Jianghan Plain geographically lies in South-Central Hubei Province (Figure 1). Encompassing an area of over 46,000 km^2, it is situated between the latitudes of 29° 26' to 31° 37' N and the longitudes of 111° 14' to 114° 36' E."

Despite having advantageous conditions for agricultural production such as abundant sunshine and precipitation, the Jianghan Plain has been plagued by climate disasters. Local agricultural production is heavily reliant on surface irrigation through water pumps from

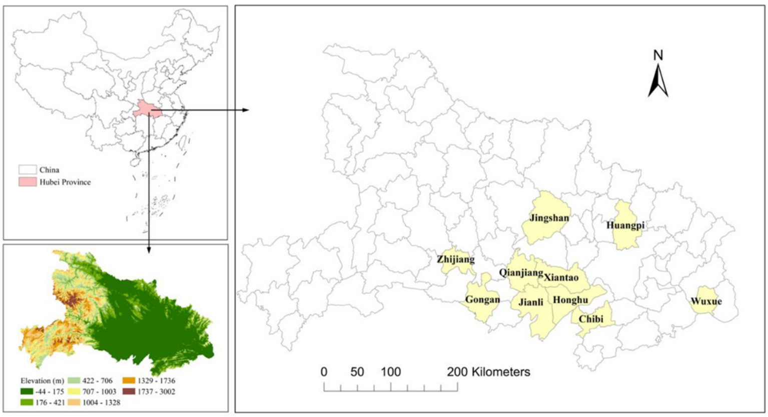


Figure 1.
Study area and surveyed counties

Note: The regions of lower elevation are indicated by darker shades of green, with the deepest green area representing the primary Jianghan Plain
Source: Created by the authors

nearby streams and ditches (Tong *et al.*, 2019), which can be significantly affected during abnormal climatic occurrences. The major crop for farmers in the Jianghan Plain is rice. However, the growth period of rice coincides with frequent occurrences of climate-related hazards in the region. For example, waterlogging because of the plum rains has caused serious losses in rice production (Cai *et al.*, 2001). Due to its crucial role in agriculture and the high susceptibility of farmer households to climatic disruptions, the Jianghan Plain serves as a suitable and representative region to investigate climate resilience in China.

To determine the sample size, the researchers adopted a simplified formula proposed by Yamane (1967). It can be written as $n = \frac{N}{1+N(e)^2}$, where n represents the sample size, N is the population size, and e denotes the level of precision or sampling error which is often set as 5%. To increase the representativeness, this paper chose a sampling error of 3%. According to the researchers' calculation based on the official data from *Hubei Rural Statistical Yearbook 2018*, the total number of agricultural households in the Jianghan Plain was about 377 million in 2017. When the above formula was applied, the appropriate sample size was 1110.

To determine the specific areas for the survey, the researcher adopted the following multi-stage sampling method. First, 30 counties/cities/districts located on the Jianghan Plain were ranked from high to low according to the total rice production in 2018.

Second, six counties were randomly selected among the top ten counties, three for the middle ten counties and one for the last ten. The counties selected for this study, along with their production rankings, are as follows: Jianli (1st), Gongan (4th), Honghu (7th), Xiantao (8th), Jingshan (9th), Qianjiang (10th), Wuxue (17th), Huangpi (18th), Chibi (20th) and Zhijiang (24th). The geographical distribution of surveyed counties is also presented in Figure 1.

Third, 2~3 townships/towns/streets were randomly selected in each county, and then 2 administrative villages were randomly selected in each township/town/street. Finally, 20–30 households were randomly chosen and interviewed in each village. The questionnaires were completed through face-to-face interviews with the head or the main agricultural producer of the household, resulting in a total sample of 1055 respondents which is very close to the expected size. Finally, 877 samples (83.12%) were deemed suitable for further analysis, after removing invalid samples with missing significant information and unrealistic responses as well as outliers. It should be noted that, the number of valid samples is much bigger than the required sample size given the 5% sampling error ($n = 400$). Therefore, our sample size is adequate to represent the population.

3.2.2 Variables

- *Dependent variable*. The dependent variable of this study is the farmer's behavior of adopting the climate-resilient variety. It is measured by the answer to a series of questions regarding whether the household has adopted the climate-resilient rice variety in response to climate change and its consequences. Specifically, four types of climate-resilient rice varieties were sequentially asked, including higher-yielding, more tolerant, shorter-duration and longer-duration varieties. The dependent variable *CR_Variety* is assigned the value of 1 if the farmer has adopted at least one type of climate-resilient variety, and 0 otherwise.
- *Independent variable*. AII acquisition is the core explanatory variable of this paper. Farmers acquire AII mainly through various internet channels by using mobile phones, computers and other terminal devices. Therefore, the researchers designed the following main question: "Do you acquire agricultural information from the following internet channels?" The listed options included "Website," "Mobile apps,"

"WeChat (e.g. groups and official accounts)," "Short videos (e.g. Weibo)" and "Others" in that order. If the respondent answered "Yes" to at least one internet channel for acquiring agricultural information, the variable *AII* takes a value of 1, otherwise it takes a value of 0.

- *Control variables*. Following previous studies, the researchers also added a series of control factors in the equation. Those variables include individual characteristics such as age, gender and education attainment (Below *et al.*, 2012; Le Dang *et al.*, 2019), perceptions of climate change (Maddison, 2007; Le Dang *et al.*, 2014b), household endowments such as total income, operating acres and the availability of agricultural labors (Croppenstedt *et al.*, 2003; Deressa *et al.*, 2009). Additionally, annual average temperature and precipitation at the county level are included additionally to capture the influence of climate conditions. Finally, county dummies are incorporated into the outcome equation to control for fixed regional effects.

3.2.3 Statistical description. Table 1 presents the definition, measurement and statistical summaries of all variables. The average age of respondents in the total sample is 58.8 years old, which aligns with the current aging trend observed in China's agricultural labor force (Zou *et al.*, 2018). Moreover, the average years of education attained by respondents is merely 6.77 years, which is equivalent to less than two years after elementary school. This

Variables	Definition and measurement	Mean	SD
CR_Variety	1 if the farmer has adopted at least one climate-resilient variety, 0 otherwise	0.609	0.488
AII	1 if the farmer acquires AII, 0 otherwise	0.302	0.459
Temperature	The annual average temperature of each county in recent 20 years (2000–2019), Degrees Celsius	16.86	0.339
Precipitation	The annual average precipitation of each county in recent 20 years (2000–2019), in 1,000 ml	12.30	0.921
Male	1= male; 0 = female	0.659	0.474
Age	Age, year	58.81	9.968
Education	Education attainment, year	6.766	3.492
Health1	1 if in "moderate" health and 0 otherwise. The base group is "poor")	0.194	0.396
Health2	1 if in "good" health and 0 otherwise. The base group is "poor")	0.652	0.477
Non_farm	1 if having non-farm work in 2018, 0 otherwise	0.253	0.435
Perception_temp	1 if perceiving that the high temperatures have become more extreme and frequent, 0 otherwise	0.812	0.391
Perception_pre	1 if perceiving that the pattern of precipitation has changed, 0 otherwise	0.359	0.480
Income	The total family income in 2018 in 10,000 Yuan	6.153	6.008
Area_paddy	The total acreage of paddy land, mu	16.62	53.88
Area_dry	The total acreage of dry land, mu	1.543	3.989
Labor	Number of agricultural labors	2.103	1.124
Machine	1 if owning large farming machines (e.g. tractors, harvesters, etc.), 0 otherwise	0.434	0.496
AII_village	The percentage of AII acquisition for other farmers in the same village, %	30.22	18.43

Source: Based on authors' design and calculations

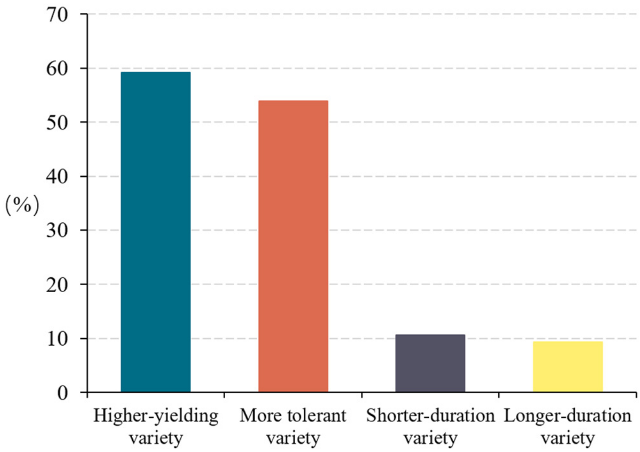
Table 1. Definition, measurement and statistical summaries of variables

number is considerably lower than the national average of 9.96 years among individuals over 15 years of age in China (National Bureau of Statistics [NBS], 2021). This may be explained by the limited availability of educational resources and high dropout rates which prevailed during the 1960s and 1970s (Wang and Yao, 2003).

The average operating acreage per household for paddy and dry land are 16.62 mu (1 mu = 1/15 hectare) and 1.54 mu, respectively. The data are consistent with the reality that farmers in the Jianghan Plain predominantly cultivate paddy crops, such as rice. Notably, our sample's total operating land per household largely exceeds the national average. According to data from the latest national survey, the average area of arable land per capita in China is 1.37 mu [Ministry of Natural Resources (MNR), 2021]. Within the context of the contract responsibility system, households in our sample are allocated a larger amount of land due to the high resource endowment in the study area. Additionally, farmers can further expand the scale of agricultural production through land transfer which is encouraged by the government (Wang *et al.*, 2019).

Figure 2 presents the percentages for the adoption of climate-resilient varieties. More than half of the farmers have adopted the higher-yielding variety (59.21%) and the more tolerant variety (53.97%). Meanwhile, only approximately 10% of farmers have adopted the longer- or shorter-duration varieties. Consequently, farmers prioritize the selection of high-yielding varieties most in response to climate risks. Besides, varieties that are more tolerant of adverse consequences such as heat, drought and flooding have also attracted farmers' interest. However, the adoption rate of varieties with longer or shorter durations is pretty low, probably due to the additional adjustment costs. Due to some collective agricultural activities (e.g. mechanical harvesting), the schedule for rice production in a specific area is typically predetermined. Modifying the growth period may lead to the unavailability of centrally supplied services. As a result, farmers are hesitant to adjust the growth cycle of rice to avoid delays in agricultural production.

The percentage of farmers who acquire AII is relatively low at around 30%. This could be attributed to the aging of China's agricultural labor force, as they may face challenges when it comes to using internet devices such as smartphones and computers (Ma and Wang, 2020). The percentages for different sources of AII acquisition are shown in Figure 3.



Source: Based on author's calculations

Figure 2.
Percentages for the adoption of climate-resilient varieties

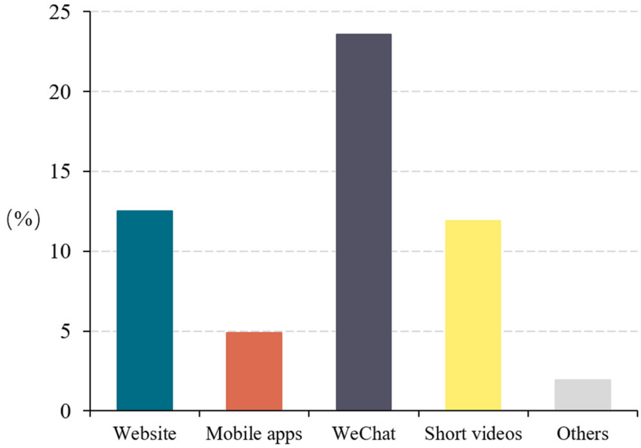


Figure 3. Percentages for different sources of AII acquisition

Source: Based on author's calculations

WeChat is the platform with the highest percentage of AII acquisition with a share of 23.6%. As the most extensively used social software in China, WeChat enables official accounts (e.g. those of central or local governments) to distribute and recommend agricultural information to users. Additionally, it provides social platforms (e.g. WeChat Moments) which allow people to share their views and repost news, facilitating the dissemination of agricultural information among farmers. Interestingly, although short videos are widely used in China, slightly over 10% of farmers acquire agricultural information through short videos, indicating a relatively low proportion. This is likely due to the fact that most people use short videos for entertainment purposes, such as watching funny clips, rather than for acquiring agricultural information.

4. Results and discussion

4.1 Empirical results

Table 2 presents the regression results for the RBP model. Columns 2–3 display the results of the AII acquisition equation, while columns 4–5 present the results of the climate-resilient varieties adoption equation. The correlation between error terms of the treatment and outcome equations, ρ, is statistically significant at the 10% level, implying the necessity of accounting for the endogeneity issue in this study (Chiburis *et al.*, 2012; Ma *et al.*, 2018).

4.1.1 Determinants of agricultural internet information acquisition. Results in Table 2 show that AII acquisition is associated with certain individual and household characteristics. The coefficient of the education attainment variable is significantly positive, indicating that better-educated farmers are more likely to obtain agricultural information via the internet. The result is in line with Ma and Wang (2020) suggesting that better education increases farmers' ability to use the internet. This is probably because certain internet information is presented in written form which necessitates reading and comprehension skills. Consistent with Wang *et al.* (2023) who found that richer residents have a higher tendency to use the internet, household income has a positive and significant impact on AII acquisition, probably because households with higher incomes are more likely to afford internet devices such as broadband, smartphones and computers. Besides, the high costs of mobile data discourage access to the internet for low-income households.

Variables	Dependent variable: *AII* Coefficient	Robust S.E.	Dependent variable: *CR_variety* Coefficient	Robust S.E.
AII	–	–	1.159***	0.297
Temperature	–	–	0.942***	0.197
Precipitation	–	–	−0.213***	0.079
Male	0.090	0.099	−0.089	0.118
Age	0.030	0.037	0.087*	0.050
*Age*Age*	−0.001*	0.000	−0.001	0.000
Education	0.054***	0.017	−0.020	0.017
Health1	−0.309	0.220	0.192	0.169
Health2	0.027	0.155	−0.054	0.150
Non_farm	0.138	0.105	0.049	0.126
Perception_temp	0.067	0.124	0.041	0.120
Perception_pre	0.133	0.134	0.066	0.116
Income	0.017**	0.007	−0.022	0.014
Area_paddy	0.001**	0.001	0.006***	0.002
Area_dry	−0.008	0.013	0.024	0.016
Labor	−0.040	0.057	−0.040	0.038
Machine	0.158**	0.072	0.001	0.164
County	–	–	Fixed	Fixed
AII_village	0.012***	0.003	–	–
Constant	−0.640	0.876	−15.765***	2.513
ρ	−0.596*	0.235		
Log pseudolikelihood	−958.315			

Notes: *, ** and *** denote significance at 10%, 5% and 1% levels, respectively. Cluster-robust standard errors at the county level are presented
Source: Model results based on authors' work

Table 2. Results for the RBP model

The coefficient of paddy acreage is positive and statistically significant, while the very small value implies a limited impact that is economically insignificant. The effect of owning large agricultural equipment on AII acquisition is significantly positive because farmers who purchase machines are more likely to use the internet for searching information on the appropriate usage and maintenance procedures of their equipment. Finally, our results also show that the coefficient of the IV (i.e. *AII_village*) is positive and significant at the 1% level, indicating that that peer influence plays a discernible role in the acquisition of AII among farmers within the same community.

4.1.2 Determinants of adopting climate-resilient varieties. The coefficient of AII acquisition which is the primary explanatory variable of interest in this study is significantly positive, indicating that farmers who acquire AII are more inclined toward adopting climate-resilient varieties. However, the estimated coefficient for the RBP cannot be directly interpreted as the marginal effect. Therefore, the researchers calculated the ATE according to equation (3) and the results are reported in Table 3. It can be found that AII acquisition can increase the likelihood of adopting climate-resilient varieties by 36.8%. As discussed in Section 2, the internet has enriched the information channels and provided a more flexible decision-making environment for farmers to cope with climate change. Furthermore, AII acquisition facilitates social interactions that enable farmers to understand the technologies and evaluate the effects of adopting climate-resilient varieties.

In developing countries like China, the main workforce in agriculture predominantly comprises traditional farmers who lack systematic and comprehensive knowledge of agronomy due to poor education (Mwangi and Kariuki, 2015). As a result, they face high barriers to adopting new technologies in the face of climate risks. This paper finds that ICT-based internet information can effectively increase the adoption of climate-resilient strategies by enhancing farmers' human capital and social capital. Earlier studies have predominantly examined how farmers' climate change adaptation is influenced by their access to climate information such as disaster and extreme weather forecasting (e.g. Ngigi and Muange, 2022). This paper offers a broader perspective on the potential of ICT in managing climate risks. Through internet platforms, agricultural information related to climate, policies, technologies, economics and relevant supporting resources can be disseminated instantly at very low cost. Consequently, AII acquisition improves the decision-making process for farmers who have limited access to information in a conventional information dissemination environment and incentivizes proactive adjustments to strengthen climate resilience (Boon *et al.*, 2022).

Among other factors on the adoption of climate-resilient varieties, both climate variables have significant coefficients while with different signs. Averagely, farmers in counties with higher temperatures and lower precipitation are more likely to adopt climate-resilient varieties. Probably because farmers tend to adopt new varieties that are adaptable to temperature changes to ensure normal germination of rice seeds at higher ambient temperatures. At the same time, the demand among farmers for enhanced varieties will be more robust in areas with scant rainfall, owing to the heightened risks of inadequate surface irrigation.

Regarding the age variable, the coefficient of the primary term is significantly positive, whereas that of the square term is insignificant. This suggests that older farmers are more disposed to adopting climate-resilient varieties. Our finding contradicts with that of Khan *et al.* (2021) who found that age has an adverse effect on farmers' adoption of new seed varieties because they lack relevant information and are more dependent on conventional practice. As for this study, one possible explanation could be that older farmers possess extensive farming experience and are more adept at making cropping adjustments to contend with climate hazards (Thennakoon *et al.*, 2020). Similar to the results for the AII acquisition equation, the coefficient of *Area_paddy* is economically insignificant.

4.2 Mechanism tests

Based on the empirical evidence presented above, it can be concluded that AII acquisition has a significant and positive effect on farmers' adoption of climate-resilient varieties. Next, the researchers test three influencing channels proposed in Section 2. The mechanism variables are measured by farmers' responses to three questions, scored on a five-point Likert scale: "To what extent do you think that agricultural informatization broadens information channels?", "To what extent do you think that agricultural informatization enhances community interactions?" and "To what extent do you think agricultural

Table 3.
Results for the ATE

Dependent variable	# of samples in the treatment group	# of samples in the control group	ATE	S.E.	95% confidence interval	
CR_Variety	265	612	0.368***	0.078	0.216	0.521

Note: ***Denotes significance at 1% level
Source: Model results based on authors' work

informatization improves agricultural skills?" A response ranging from 1 to 5 indicates the level, from "Unaffected at all" to "Totally affected," respectively.

According to Zhang *et al.* (2016), agricultural informatization is defined as "the extent and methodology of revolutionizing the agricultural industry by efficiently using ICTs in farming production, operations, and management," which can be a proximity of AII acquisition. Thus, the mechanism variables gauge the degree to which AII acquisition has diversified channels of information, boosted social interaction and enhanced agricultural skills among the respondents. As the explained variables are ordinal, the three mechanism tests were conducted using ordered probit (Oprobit) models. As presented in Table 4, the coefficients of *AII* are significantly positive for all equations, confirming the proposed influencing channels.

5. Conclusions and implications

Although the internet's impact on agricultural development has been extensively discussed recently, its influence on building climate resilience has received little attention in the literature. In particular, there is a lack of empirical analysis on the causal effect of agricultural information acquisition through the internet on climate resilience. Using survey data for farmers in a representative rice-producing region of China, this study used an econometric model to quantify the impact of AII on the adoption of climate-resilient varieties while also addressing endogeneity issues. In conclusion, the researchers found that the acquisition of AII significantly increases farmers' likelihood of adopting climate-resilient varieties, with an ATE of 36.8%. Three mechanisms are proposed and tested, namely, broadening information channels, enhancing social interactions and improving agricultural skills. Furthermore, educational attainment, family income and peer effects are found to facilitate farmers' access to agricultural information through the internet, while climate conditions and age significantly impact the adoption of climate-resilient varieties. The conclusions of this paper have several policy implications.

First, the government should continuously increase investment in the development of internet infrastructures, particularly for communities at the village-level. Grassroots organizations such as village committees and local governments, should be responsible for ensuring full coverage installation which builds the "last mile" of internet information to both households and villages. To overcome possible market failures due to their nature as public goods and the associated costs (Greenstein, 2020), increased government intervention is essential in ensuring the development and success of internet infrastructures. According to the latest official data, as of June 2022, the number of China's rural internet users reached 293 million, accounting for 27.9% of the total internet users nationwide. However, the internet penetration rate in rural areas remained significantly lower at 58.8%, as compared

Variables	Broadening information channels Oprobit	Enhancing social interactions Oprobit	Improving agricultural skills Oprobit
AII	0.347*** (0.090)	0.294*** (0.088)	0.428*** (0.091)
Controls	fixed	fixed	fixed
Log pseudolikelihood	−1179.727	−1279.875	−1184.529
Pseudo R^2	0.069	0.032	0.050

Notes: ***Denotes significance 1% level. Cluster-robust standard errors at the county level are presented
Source: Model results based on authors' work

Table 4. Results for mechanism tests

to the rate of 82.9% in urban areas (Office of the Central Cyberspace Affairs Commission, 2022). Therefore, there remains tremendous potential for increasing the audience for rural Web-based information, which can be significantly expanded with the aid of existing infrastructures. Additionally, lowering internet usage fees such as data costs, may serve as an incentive for farmers to become more involved in the digital world.

Second, farmers' digital literacy should be enhanced through various approaches such as training, education, publicity and guidance. As the internet is a valuable source of information for farmers, their ability to effectively search for and use climate-resilient agricultural information is heavily reliant on their level of digital literacy. For instance, the ability to process information is crucial in identifying the authenticity and applicability of received information. While the internet has effectively eliminated the time and space constraints of conventional agricultural training, there is still a need for additional measures to provide intellectual support to Chinese farmers (Qian and Zhang, 2022).

Third, the agricultural department and organizations should reinforce the dissemination of climate-resilient information like climate warnings and suitable responses over internet platforms. To educate farmers on climate change, it is crucial to use the existing online platforms fully. Moreover, using popular and easily understandable forms such as videos and pictures will be highly beneficial to farmers with limited educational backgrounds. Finally, it is essential to supply comprehensive information that thoroughly fulfills the needs of farmers. For instance, for farmers who shift to climate-resilient varieties, providing pertinent information such as the price and locations where they can purchase is important.

Notes

1. https://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf
2. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
3. Available at: www.cma.gov.cn/2011xwzx/2011xqxxw/2011xqxyw/202208/t20220803_5016624.html
4. A typical news report can be found at: http://k.sina.com.cn/article_6456450127_180d59c4f02000zl9j.html

References

Acevedo, M., Pixley, K., Zinyengere, N., Meng, S., Tufan, H., Cichy, K., . . . Porciello, J. (2020), "A scoping review of adoption of climate resilient crops by small-scale producers in low-and Middle-income countries", *Nature Plants*, Vol. 6 No. 10, pp. 1231-1241, doi: 10.1038/s41477-020-00783-z.

Adamides, G., Kalatzis, N., Stylianou, A., Marianos, N., Chatzipapadopoulos, F., Giannakopoulou, M., Papadavid, G., Vassiliou, V. and Neocleous, D. (2020), "Smart farming techniques for climate change adaptation in Cyprus", *Atmosphere*, Vol. 11 No. 6, p. 557, doi: 10.3390/atmos11060557.

Adesina, A.A. and Zinnah, M.M. (1993), "Technology characteristics, farmers' perceptions and adoption decisions: a Tobit model application in Sierra Leone", *Agricultural Economics*, Vol. 9 No. 4, pp. 297-311, doi: 10.1111/j.1574-0862.1993.tb00276.x.

Antwi-Agyei, P., Dougill, A.J. and Stringer, L.C. (2015), "Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review", *Climate and Development*, Vol. 7 No. 4, pp. 297-309, doi: 10.1080/17565529.2014.951013.

Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R. and Tscherning, K. (2012), "Can farmers' adaptation to climate change be explained by socio-economic household-level variables?", *Global Environmental Change*, Vol. 22 No. 1, pp. 223-235, doi: 10.1016/j.gloenvcha.2011.11.012.

Bentley, J.W., Van Mele, P., Barres, N.F., Okry, F. and Wanvoeke, J. (2019), "Smallholders download and share videos from the internet to learn about sustainable agriculture", *International Journal of Agricultural Sustainability*, Vol. 17 No. 1, pp. 92-107, doi: 10.1080/14735903.2019.1567246.

Boon, E., Wright, S.J., Biesbroek, R., Goosen, H. and Ludwig, F. (2022), "Successful climate services for adaptation: What we know, don't know and need to know", *Climate Services*, Vol. 27, p. 100314, doi: 10.1016/j.cliser.2022.100314.

Cai, S., Chan, N.W. and Liu, P.S. (2001), "Management of flood disasters in the Jianghan plain, China", *Disaster Prevention and Management: An International Journal*, Vol. 10 No. 5, pp. 339-348, doi: 10.1108/EUM0000000006487.

Chiburis, R.C., Das, J. and Lokshin, M. (2012), "A practical comparison of the bivariate probit and linear IV estimators", *Economics Letters*, Vol. 117 No. 3, pp. 762-766, doi: 10.1016/j.econlet.2012.08.037.

Croppenstedt, A., Demeke, M. and Meschi, M.M. (2003), "Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia", *Review of Development Economics*, Vol. 7 No. 1, pp. 58-70, doi: 10.1111/1467-9361.00175.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M. (2009), "Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia", *Global Environmental Change*, Vol. 19 No. 2, pp. 248-255, doi: 10.1016/j.gloenvcha.2009.01.002.

Eise, J., Lambert, N.J. and Wiemer, E.C. (2021), "Leveraging communities' network strengths to support climate change adaptation information-sharing: a study with coffee farmers in Risaralda, Colombia", *Climatic Change*, Vol. 168 No. 1-2, pp. 1-19, doi: 10.1007/s10584-021-03206-w.

Foguesatto, C.R. and Machado, J.A.D. (2021), "What shapes farmers' perception of climate change? A case study of Southern Brazil", *Environment, Development and Sustainability*, Vol. 23 No. 2, pp. 1525-1538, doi: 10.1007/s10668-020-00634-z.

Gao, Y., Zhao, D., Yu, L. and Yang, H. (2020), "Influence of a new agricultural technology extension mode on farmers' technology adoption behavior in China", *Journal of Rural Studies*, Vol. 76, pp. 173-183, doi: 10.1016/j.jrurstud.2020.04.016.

Greenstein, S. (2020), "The basic economics of internet infrastructure", *Journal of Economic Perspectives*, Vol. 34 No. 2, pp. 192-214, available at: www.aeaweb.org/articles?id=10.1257/jep.34.2.192.

Haworth, B.T., Biggs, E., Duncan, J., Wales, N., Boruff, B. and Bruce, E. (2018), "Geographic information and communication technologies for supporting smallholder agriculture and climate resilience", *Climate*, Vol. 6 No. 4, p. 97, doi: 10.3390/cli6040097.

Hertel, T.W. and Rosch, S.D. (2010), "Climate change, agriculture, and poverty", *Applied Economic Perspectives and Policy*, Vol. 32 No. 3, pp. 355-385, doi: 10.1093/aepp/ppq016.

IPCC (2022), "Climate change 2022: impacts, adaptation and vulnerability", in Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A. and Rama, B. (Eds), *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK and New York, NY, USA, p. 3056, doi: 10.1017/9781009325844.

Kalafatis, S.E., Lemos, M.C., Lo, Y.J. and Frank, K.A. (2015), "Increasing information usability for climate adaptation: the role of knowledge networks and communities of practice", *Global Environmental Change*, Vol. 32, pp. 30-39, doi: 10.1016/j.gloenvcha.2015.02.007.

Khan, N.A., Qiao, J., Abid, M. and Gao, Q. (2021), "Understanding farm-level cognition of and autonomous adaptation to climate variability and associated factors: Evidence from the rice-growing zone of Pakistan", *Land Use Policy*, Vol. 105, p. 105427, doi: 10.1016/j.landusepol.2021.105427.

Le Dang, H., Li, E., Nuberg, I. and Bruwer, J. (2014a), "Farmers' perceived risks of climate change and influencing factors: a study in the Mekong Delta, Vietnam", *Environmental Management*, Vol. 54 No. 2, pp. 331-345, doi: 10.1007/s00267-014-0299-6.

Le Dang, H., Li, E., Nuberg, I. and Bruwer, J. (2014b), "Understanding farmers' adaptation intention to climate change: a structural equation modelling study in the Mekong Delta, Vietnam", *Environmental Science and Policy*, Vol. 41, pp. 11-22, doi: 10.1016/j.envsci.2014.04.002.

Le Dang, H., Li, E., Nuberg, I. and Bruwer, J. (2019), "Factors influencing the adaptation of farmers in response to climate change: a review", *Climate and Development*, Vol. 11 No. 9, pp. 765-774, doi: 10.1080/17565529.2018.1562866.

Li, C., Tang, Y., Luo, H., Di, B. and Zhang, L. (2013), "Local farmers' perceptions of climate change and local adaptive strategies: a case study from the Middle Yarlung Zangbo river valley, Tibet, China", *Environmental Management*, Vol. 52 No. 4, pp. 894-906, doi: 10.1007/s00267-013-0139-0.

Liu, Y., Ruiz-Menjivar, J. and Zhang, J. (2022), "Do soil nutrient management practices improve climate resilience? Empirical evidence from rice farmers in Central China", *Environment, Development and Sustainability*, Vol. 25 No. 9, pp. 1-26, doi: 10.1007/s10668-022-02475-4.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylor, R.L. (2008), "Prioritizing climate change adaptation needs for food security in 2030", *Science*, Vol. 319 No. 5863, pp. 607-610, doi: 10.1126/science.1152339.

Ma, W. and Wang, X. (2020), "Internet use, sustainable agricultural practices and rural incomes: evidence from China", *Australian Journal of Agricultural and Resource Economics*, Vol. 64 No. 4, pp. 1087-1112, doi: 10.1111/1467-8489.12390.

Ma, W., Abdulai, A. and Goetz, R. (2018), "Agricultural cooperatives and investment in organic soil amendments and chemical fertilizer in China", *American Journal of Agricultural Economics*, Vol. 100 No. 2, pp. 502-520, doi: 10.1093/ajae/aax079.

Ma, W., Nie, P., Zhang, P. and Renwick, A. (2020), "Impact of internet use on economic well-being of rural households: Evidence from China", *Review of Development Economics*, Vol. 24 No. 2, pp. 503-523, doi: 10.1111/rode.12645.

Maddison, D. (2007), *The Perception of and Adaptation to Climate Change in Africa*, Vol. 4308, World Bank Publications, Washington, DC.

Michailidis, A., Partalidou, M., Nastis, S.A., Papadaki-Klavdianou, A. and Charatsari, C. (2011), "Who goes online? Evidence of internet use patterns from rural Greece", *Telecommunications Policy*, Vol. 35 No. 4, pp. 333-343, doi: 10.1016/j.telpol.2011.02.006.

Ministry of Natural Resources (MNR) (2021), "Bulletin of key data of the third national land survey", available at: www.mnr.gov.cn/dt/ywbb/202108/t20210826_2678340.html

Mtega, W.P. and Msungu, A.C. (2013), "Using information and communication technologies for enhancing the accessibility of agricultural information for improved agricultural production in Tanzania", *The Electronic Journal of Information Systems in Developing Countries*, Vol. 56 No. 1, pp. 1-14, doi: 10.1002/j.1681-4835.2013.tb00395.x.

Mwangi, M. and Kariuki, S. (2015), "Factors determining adoption of new agricultural technology by smallholder farmers in developing countries", *Journal of Economics and Sustainable Development*, Vol. 6 No. 5, available at: www.iiste.org/Journals/index.php/JEDS/article/view/20710/21632

Nakasone, E., Torero, M. and Minten, B. (2014), "The power of information: the ICT revolution in agricultural development", *Annual Review of Resource Economics*, Vol. 6 No. 1, pp. 533-550, doi: 10.1146/annurev-resource-100913-012714.

National Bureau of Statistics (NBS). (2021), "Key data from the 7th national census", available at: www.stats.gov.cn/tjsj/zxfb/202105/t20210510_1817176.html

Nelson, D.R., Adger, W.N. and Brown, K. (2007), "Adaptation to environmental change: contributions of a resilience framework", *Annual Review of Environment and Resources*, Vol. 32 No. 1, pp. 395-419, doi: 10.1146/annurev.energy.32.051807.090348.

Ngigi, M.W. and Muange, E.N. (2022), "Access to climate information services and climate-smart agriculture in Kenya: a gender-based analysis", *Climatic Change*, Vol. 174 Nos 3/4, pp. 1-23, doi: 10.1007/s10584-022-03445-5.

Niu, Z., Chen, C., Gao, Y., Wang, Y., Chen, Y. and Zhao, K. (2022), "Peer effects, attention allocation and farmers' adoption of cleaner production technology: Taking green control techniques as an example", *Journal of Cleaner Production*, Vol. 339, p. 130700, doi: 10.1016/j.jclepro.2022.130700.

Office of the Central Cyberspace Affairs Commission (OCCAC) (2022), "Cyberspace Administration of China (CAC), and China internet network information center (CNNIC)", The 50th Statistical Report on China's Internet Development, available at: www.cnnic.net.cn/NMediaFile/2022/0926/MAIN1664183425619U2MS433V3V.pdf

Owusu, V., Ma, W., Renwick, A. and Emuah, D. (2021), "Does the use of climate information contribute to climate change adaptation? Evidence from Ghana", *Climate and Development*, Vol. 13 No. 7, pp. 616-629, doi: 10.1080/17565529.2020.1844612.

Pörtner, H.O., Roberts, D.C., Adams, H., Adler, C., Aldunce, P., Ali, E. and Fischlin, A. (2022), "Climate change 2022: impacts, adaptation and vulnerability", IPCC Sixth Assessment Report.

Qian, Y. and Zhang, W. (2022), "The current situation and causes of farmers' digital literacy", In *2022 8th International Conference on Humanities and Social Science Research (ICHSSR 2022)* (pp. 2334-2337, Atlantis Press, doi: 10.2991/assehr.k.220504.422.

Roco, L., Engler, A., Bravo-Ureta, B.E. and Jara-Rojas, R. (2015), "Farmers' perception of climate change in mediterranean Chile", *Regional Environmental Change*, Vol. 15 No. 5, pp. 867-879, doi: 10.1007/s10113-014-0669-x.

Srivastava, A. and Das, D.K. (2021), "A comprehensive review on the application of internet of thing (IoT) in smart agriculture", *Wireless Personal Communications*, Vol. 122 No. 2, pp. 1-31, doi: 10.1007/s11277-021-08970-7.

Takahashi, B., Burnham, M., Terracina-Hartman, C., Sopchak, A.R. and Selfa, T. (2016), "Climate change perceptions of NY state farmers: the role of risk perceptions and adaptive capacity", *Environmental Management*, Vol. 58 No. 6, pp. 946-957, doi: 10.1007/s00267-016-0742-y.

Tambo, J.A. and Wünscher, T. (2017), "Enhancing resilience to climate shocks through farmer innovation: evidence from Northern Ghana", *Regional Environmental Change*, Vol. 17 No. 5, pp. 1505-1514, doi: 10.1007/s10113-017-1113-9.

Teng, F., Wang, T. and Guo, J. (2021), "2021 Carbon neutrality targets and climate risk: an assessment of economic damage from climate change", The Institute of Energy, Environment and Economy and Chatham House, Beijing, available at: www.3e.tsinghua.edu.cn/storage/app/media/uploaded-files/download/202112/WS1%20report%20EN.pdf

Thennakoon, J., Findlay, C., Huang, J. and Wang, J. (2020), "Management adaptation to flood in Guangdong province in China: Do property rights matter?", *World Development*, Vol. 127, p. 104767, doi: 10.1016/j.worlddev.2019.104767.

Thornton, P.K., Jones, P.G., Alagarswamy, G. and Andresen, J. (2009), "Spatial variation of crop yield response to climate change in east Africa", *Global Environmental Change*, Vol. 19 No. 1, pp. 54-65, doi: 10.1016/j.gloenvcha.2008.08.005.

Tong, Q., Swallow, B., Zhang, L. and Zhang, J. (2019), "The roles of risk aversion and climate-smart agriculture in climate risk management: Evidence from rice production in the Jianghan plain, China", *Climate Risk Management*, Vol. 26, p. 100199, doi: 10.1016/j.crm.2019.100199.

Vermeulen, S.J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J., . . . Wollenberg, E. (2012), "Options for support to agriculture and food security under climate change", *Environmental Science and Policy*, Vol. 15 No. 1, pp. 136-144, doi: 10.1016/j.envsci.2011.09.003.

Wang, Y. and Yao, Y. (2003), Sources of China's economic growth 1952-1999: incorporating human capital accumulation, *China Economic Review*, Vol. 14 No. 1, pp. 32-52, doi: 10.1016/S1043-951X(02)00084-6.

Wang, X., Tong, Q., Qiu, F. and Zhang, J. (2023), "Predicting residents' adoption of living environment improvement practices toward sustainable development: the role of internet use", *Journal of Environmental Planning and Management*, Vol. 66 No. 3, pp. 1-21, doi: 10.1080/09640568.2021.2000373.

Wang, Y., Xin, L., Zhang, H. and Li, Y. (2019), "An estimation of the extent of rent-free farmland transfer and its driving forces in rural China: a multilevel logit model analysis", *Sustainability*, Vol. 11 No. 11, p. 3161, doi: 10.3390/su11113161.

Yamane, T. (1967), *Statistics: An Introductory Analysis*, 2nd ed., Harper and Row, New York, NY.

Zeng, Y., Jia, F., Wan, L. and Guo, H. (2017), "E-commerce in Agri-food sector: a systematic literature review", *International Food and Agribusiness Management Review*, Vol. 20 No. 4, pp. 439-459, doi: 10.22434/IFAMR2016.0156.

Zhang, Y., Wang, L. and Duan, Y. (2016), "Agricultural information dissemination using ICTs: a review and analysis of information dissemination models in China", *Information Processing in Agriculture*, Vol. 3 No. 1, pp. 17-29, doi: 10.1016/j.inpa.2015.11.002.

Zheng, H. and Ma, W. (2021), "Smartphone-based information acquisition and wheat farm performance: insights from a doubly robust IPWRA estimator", *Electronic Commerce Research*, Vol. 23 No. 2, pp. 1-26, doi: 10.1007/s10660-021-09481-0.

Zou, B., Mishra, A.K. and Luo, B. (2018), "Aging population, farm succession, and farmland usage: Evidence from rural China", *Land Use Policy*, Vol. 77, pp. 437-445, doi: 10.1016/j.landusepol.2018.06.001.

Further reading

Muench, S., Bavorova, M. and Pradhan, P. (2021), "Climate change adaptation by smallholder tea farmers: a case study of Nepal", *Environmental Science and Policy*, Vol. 116, pp. 136-146, doi: 10.1016/j.envsci.2020.10.012.

Corresponding author
Qingmeng Tong can be contacted at: qingmeng@ccnu.edu.cn