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RESEARCH ARTICLE

Crop Diversification in Coping with Extreme Weather Events in China

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Abstract

Apart from the long-term effects of climate change, the frequency and severity of extreme weather events have been increasing. Given the risks posed by climate change, particularly the changes in extreme weather events, the question of how to adapt to these changes and mitigate their negative impacts has received great attention from policy makers. The overall goals of this study are to examine whether farmers adapt to extreme weather events through crop diversification and which factors influence farmers' decisions on crop diversification against extreme weather events in China. To limit the scope of this study, we focus on drought and flood events only. Based on a unique large-scale household survey in nine provinces, this study finds that farmers respond to extreme weather events by increasing crop diversification. Their decision to diversify crops is significantly influenced by their experiences of extreme weather events in the previous year. Such results are understandable because farmers' behaviors are normally based on their expectations. Moreover, household characteristics also affect farmers' decisions on crop diversification strategy, and their effects differ by farmers' age and gender. This paper concludes with several policy implications.

Key words: adaptation, extreme weather event, climate change, crop diversification, farmer

INTRODUCTION

The world, including China, has experienced and will continue to experience long-term climate change. In the past 100 yr (1906 to 2005), the global average surface temperature has increased by 0.74°C (IPCC 2007). Similar to the global trend, China has also experienced a warming trend. From 1951 to 2009, the average annual temperature rose by 1.38°C (ECSNCCA 2011). By the end of the 21st century, the global air surface temperature will have increased by 1.8 to 4°C, and China's temperature will increase by 2.5-4.6°C (IPCC 2007; ECSNCCA 2011). Additionally, precipitation changes have presented obvious regional trends. On the global scale, precipitation has tended to increase in the high-latitude regions of the northern hemisphere and in the tropical regions, while in the semi-tropical regions, precipitation decreased over the past several decades (IPCC 2007; Dai 2011). In China, drier regions in the northeast have received less precipitation in summer and autumn, while the wetter regions in the south have experienced more rainfall during both summer and winter (Piao *et al*. 2010).

Apart from long-term climate change, the frequency and severity of extreme weather events (e.g., drought and flood) have also increased. Since the 1950s, the

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occurrence of extreme weather events in the world has presented an increased trend, and, on average, the annual economic losses resulting from these events reached US$67 billion (Guha-Sapir *et al*. 2004). The total area suffering from drought throughout the world is forecasted to expand by 15 to 44% by the end of the 21st century (IPCC 2012). In China, the annual average crop area suffering from drought increased from 11.6 to 25.1 million ha, with an increase of 116% from the 1950s to the beginning of this century (Ministry of Water Resources 2010). During the same period, the annual average crop area suffering from flooding increased by more than 50%, from 7.4 to 11.2 million ha.

Importantly, although there is some uncertainty about the long-term impacts of climate change, the potential negative impacts of extreme weather events cannot be ignored. Depending on regional conditions and other factors, long-term climate change may have mixed effects on agriculture. For example, increased temperature has shown to be harmful to rain-fed farms, but beneficial to irrigated farms in China (Wang *et al*. 2009). If the CO_2 fertilization effect could be realized, the negative impacts of climate change on agriculture would become positive (Xiong *et al*. 2009). However, increasingly severe extreme weather events can result in massive socio-economic losses in China. For example, in the past 60 yr, drought caused an annual grain production loss of more than 27 milliont in China (Ministry of Water Resources 2010). In the drought year of 2000, China suffered a loss of 60 million t of its grain harvest, and 28 million people and 22 million heads of livestock had difficulty obtaining drinking water (Ministry of Water Resources 2010). The great flood of 1998 inundated 21 million ha of land and destroyed five million houses in the Yangtze Basin, causing an economic loss of over US$20 billion (Zong and Chen 2000).

Given the risks posed by climate change, the question of how to mitigate the negative impacts has received a great deal of attention from policy makers. The international community has called for incorporating climate change adaptation into national development plans (IPCC 2007; World Bank 2010). This is especially urgent and important for farmers who have been suffering from increasingly extreme events in developing countries (Mendelsohn *et al*. 2006; Seo and Mendelsohn 2008). In recent years, China's government has also given top priority to formulating and implementing adaptation policy (NDRC 2007, 2012). A national plan responding to climate change was issued in 2007, which was followed by a series of publications of white papers on national policies and actions against climate change.

In recent years, exploring suitable adaptation measures has become an important research topic. According to their nature and attributes, adaptation measures can differ along several dimensions such as intent (spontaneous versus planned), timing (reactive, concurrent or anticipatory), duration (short versus long term), spatial extent (localized or widespread), and agent responsibility (e.g., government, producers, etc.) (Bradshaw *et al*. 2004). Smit and Skinner (2002) systematically summarized the major adaptation measures adopted in the agricultural sector. According to their summary, there are several categories of adaptations at the farm level, including the modification of resource management, improving farm management, purchasing crop insurance, and the diversification of production activities. They indicated that diversification has the potential to reduce exposure to climate-related risks and increase the flexibility of farm production to changing climatic conditions.

Even though crop diversification has been recognized as an effective adaptation option for farmers for risk mitigation (Gebrehiwot and van der Veen 2013), little empirical analysis has been conducted to determine how extreme weather events influence farmers' decisions on diversifying their crops. From a literature review, we find that crop diversification has often been examined as a tool to stabilize crop revenue and farm income (Zentner *et al*. 2002; Orindi and Eriksen 2005; Chen 2007). Many scholars have analyzed the influence of farm and farmers' characteristics on crop diversification (Pope and Prescott 1980; Mishra and El-Osta 2002; Culas and Mahendrarajah 2005; McNamara and Weiss 2005). However, to our knowledge, there is little empirical study that has quantified the relationship between the occurrence of extreme weather events and farmers' crop diversification behavior.

Given the severity of extreme weather events and the potential role of crop diversification in mitigating risks, several questions are raised. Do farmers adapt to climate change, especially extreme weather events, through crop diversification? If so, how do farmers diversify their crops? Why do some farmers respond to extreme weather events by increasing crop diversification while others do not? Answers to these questions are critical not only for a better understanding of farmers' responses to extreme weather events, but also for providing empirical evidence for policy makers in the formulation of their adaptation plans and policies.

The overall goals of this study are to examine whether farmers adapt to extreme weather events through crop diversification and to determine which factors influence farmers' decisions on crop diversification against extreme weather events in China. To limit the scope of this study, we focus on drought and flood events only. To achieve the above goal, we have the following two specific objectives. The first is to gain a better understanding of current crop diversification based on a large-scale household survey conducted in nine provinces across China. The second is to identify the relationship between the occurrence of extreme weather events and crop diversification and to examine the impacts of socio-economic factors on farmers' decisions to diversify their crops to cope with extreme weather events.

To meet the above objectives, the rest of this paper is organized as follows. In the next section, we briefly introduce the data used in this study. Section 3 discusses the current crop diversification situation and the statistical relationship between crop diversification, extreme weather events, and other socio-economic factors. Section 4 presents the econometric models of farmers' crop diversification behaviors in response to extreme weather events and the estimation results. The final section concludes the paper.

DATA

The data used in this study are based on a large-scale household survey conducted in nine provinces in China from the end of 2012 to early 2013. These nine provinces include Hebei, Henan, Shandong, Jilin, and Anhui in northern China and Jiangxi, Guangdong, Yunnan, and Jiangsu in southern China. In selecting provinces for the field survey, we have taken into account the differences in climate and water resources between the northern and southern regions as well as the different income levels. For example, the five provinces in northern China have less precipitation and belong to semi-arid or arid regions, while the four provinces in southern China have more abundant precipitation and water resources (Ministry of Water Resources 2012). These regions also represent income ranging from high (Jiangsu and Guangdong) to middle (Shandong, Jilin, Hebei, and Henan) to low (Jiangxi, Anhui and Yunnan) levels (National Bureau of Statistics of China 2012).

Within each province, the following sampling strategies were used to select study areas. First, three counties in each province except for Jiangxi (10 counties) and Guangdong (6 counties) were randomly selected from those counties that met the following two conditions in the past 3 yr (2010, 2011, and 2012): 1) had experienced a serious drought or flood and 2) had experienced a normal weather year. Jiangxi and Guangdong had more counties included because we had funding from two projects that allowed us to expand the survey samples. By collecting data for both extreme weather and normal years, we can identify the impact of extreme weather and any differences in adaptation between the extreme weather year and the normal year. The selection of these counties are possible because there are about 100 counties in each province, and at least 20% of these counties experienced a serious drought or flood in the past 3 yr.

Within each county, the townships were divided into three groups based on the local irrigation and drainage infrastructure (good, medium, and bad infrastructure), and one township from each group was randomly selected. Irrigation and drainage infrastructure represent the local adaptation capacity to deal with extreme weather events. Therefore, this sampling approach allows us to examine the actual range of adaptation measures that have been adopted by farmers among these three different categories of townships.

Finally, within each township, three villages and 10 households from each village were randomly selected. In total, the samples include 37 counties, 111 townships, 333 villages, and 3330 households in nine provinces in China. Because some key information is missing, the final samples used in our analysis include 3306 households.

While the household survey covered a wide range of issues, our analysis used only those data that are relevant to this study. This includes the following data. 1) Planted crops in the past 3 yr. We asked farmers what kind of crops they planted in their plots in the past 3 yr (2010-2012). Based on this information, we can generate a variable to represent crop diversification; this is the key variable used in this study. Specifically, we use the number of crops planted by farmers in each year to represent crop diversification. 2) Household characteristics, including the age, years of education, and gender (male or female) of the household head, the number of family members, and farm size (total cultivated land area). In the survey, we collected data for 3 yr (2010-2012) for all these household characteristics.

CROP DIVERSIFICATION

Extreme weather events and crop diversification

The survey indicated that in the past 3 yr, 1 yr experienced more serious extreme weather events than the other 2 yr, which confirms our sampling design. As shown in Table 1, the most serious extreme weather events occurred in 2011. In 2011, more than 70% of sample households located in the counties encountered serious extreme weather events (e.g., drought or flood or both). Drought and flooding were not as severe in the other years, as in 2010 and 2012, only 16.2 and 13.6%, respectively, of sample households belonged to the counties that suffered from drought or flooding.

Table 1 Number and percentage of households affected by extreme weather events (drought or flood) in 2010-2012[1)]

Year	No. of households affected	No. of households not affected	Percentage of households affected (%)
2010	537	2769	16.2
2011	2320	986	70.2
2012	449	2857	13.6

1) The sample size in each year is 3306. Source: Authors' survey. The same as below.

When examining crop diversification, we found that crops were not more diversified in 2011, when the most serious extreme weather events occurred (Table 1, last column); however, crop diversification in this year (2.827) was slightly lower than in 2012 (2.861) (Table 2, column 1). It is likely that drought and flooding occurred after the planting season and that farmers thus had difficulty deciding whether to plant more or fewer crops during the extreme weather year. As adaptive expectation, farmers may have learned from the drought/flood events and decided to change the number of crops in the forthcoming year to mitigate the risks caused by natural hazards.

Table 2 Status and distribution of crop diversification in 2010-2012[1)]

	2010	2011	2012
Average number of crops planted	2.798	2.827	2.861
Percentage of households by the number of crops (%)			
1 crop	9.5	8.9	8.8
2 crops	43.1	42.8	41.5
3 crops	24.7	24.8	25.6
4 crops	12.6	13.1	13.2
⩾5 crops	10.2	10.4	10.9

1) The major crops in the study areas are rice, wheat, maize, rapeseed, sweet potato, and peanut.

To further explore the relationship between the occurrence of extreme weather events and farmers' crop diversification, we plot the number of crops in the current year against the number of crops in the previous year for farmers who were affected by drought/flood in the previous year (Fig. 1). The number of crops planted in the previous year is chosen as the baseline for comparison. Farmers who suffered from extreme weather events in the previous year are targeted since we are interested in whether their behavior changed in the current year. We also draw a 45-degree line from the original point as the baseline in Fig. 1. All of the observations or dots on the 45-degree line indicate that these farmers did not change their number of crops. The dots above the 45-degree line indicate that farmers planted more crops in the current year than in the previous year, while the dots below the 45-degree line mean that farmers planted fewer crops in the current year than the previous year. The results show that more dots are located above the 45-degree than below (Fig. 1), which implies that relatively more farmers tended to increase the number of crops planted

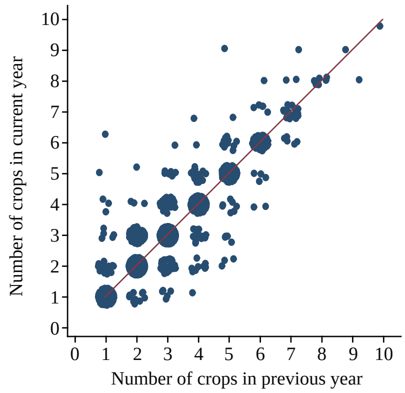

Fig. 1 Number of crops in the previous year and the current year for farmers that experienced extreme weather events in the previous year.

in the current year than in the previous year when they experienced extreme weather events in the previous year. More precisely, when we counted the actual numbers of plots, we found that 9.5% of farmers changed the number of crops from 2011 to 2012, and 6.2% of them grew more crops in 2012 than in 2011, which was larger than the percentage of farmers (3.3%) who planted fewer crops. This is consistent with our expectation: farmers are more likely to diversify their crops after they experienced serious extreme weather events in the previous year.

Household characteristics and crop diversification

Further analysis indicates that not all farmers chose the same strategy of crop diversification. In our study areas, major field crops include rice, wheat, maize, rapeseed, sweet potato, and peanut. Within a given year, while the average household planted nearly three crops (Table 2, row 1), the number of crops planted by farmers ranged from one crop to more than five crops per household (Table 2). Fewer than 10% of farmers planted one crop in a year; most farmers planted two or more crops. Over 40% of households planted two crops, while 25% planted three and 23% planted more than three.

Farmers' different crop diversification strategies are possibly related to the characteristics of the farm households. First, a larger farm size is likely associated with more diversified crops. While all farm sizes were small, larger farms tended to have relatively more crops (Table 3, rows 1-2). Second, the survey data indicates that crop diversification choices were likely related to farmers' age. Younger farmers tended to plant more crops. This is consistent with our expectations. Older farmers usually have more farming experience, and they may have more options for coping with risks, such as better field management. Older farmers may also be more likely to follow traditional planting methods and may lack the flexibility to change crops. Third, surprisingly, the survey data show that the average number of crops planted in a male-headed household is larger than that in a female-headed household (Table 3, rows 5-6). Usually, males are more willing to take risks than females, so that they are less likely to use crop diversification to mitigate risk. Fourth, better-educated farmers seem more likely to plant more types of crops than those with fewer years of education.

The above descriptive analysis did not control for the influence of other factors, so it is hard to isolate the impact of each household characteristic on farmers' crop diversification decisions. The econometric analysis presented in the next section will provide a more rigorous examination of the relationship between household characteristics and crop diversification.

Table 3 Household characteristics and crop diversification in 2010-2012

	Average number of crops planted			
	Average	2010	2011	2012
Farm size				
Less than or equal to 0.53 ha	2.699	2.685	2.695	2.716
Over 0.53 ha	2.962	2.916	2.963	3.005
Age of household head				
Under 60 yr old	2.849	2.812	2.845	2.890
Over 61 yr old	2.768	2.758	2.773	2.774
Gender of household head				
Female	2.671	2.630	2.644	2.740
Male	2.832	2.802	2.831	2.864
Education of household head				
Primary school or below	2.800	2.771	2.795	2.836
Junior high school or higher	2.852	2.821	2.854	2.882

ECONOMETRIC MODELS AND ESTIMATION RESULTS

Model specifications

To more rigorously examine whether farmers adapt to extreme weather events by planting more crops and to identify the influence of household characteristics on farmers' crop diversification strategies, we set up a simple OLS model and a fixed effect (FE) model with and without cross-terms. The mathematical form of the OLS model is expressed as follows:

$$y_{i,t}=\alpha_0+\alpha_1 D_{i,t\text{-}1}+\alpha_2 S_{i,t}+\alpha_3 A_{i,t}+\alpha_4 G_{i,t}+\alpha_5 E_{i,t}+\varepsilon_{i,t} \quad (1)$$

The dependent variable $y_{i,t}$ represents crop diversification strategy, measuring the number of crops planted by farmer *i* in year *t*. $\varepsilon_{i,t}$ is the error term and all α_s are the coefficients to be estimated. Farmers' decisions on the number of crops vary across regions based mainly on weather conditions and irrigation systems. Therefore, to control for heterogeneity across regions, we normalize the number of crops in each year by calculating the relative value based on data for the first year (2010).

We include several independent variables to analyze their impacts on crop diversification. As discussed in the last section, farmers may diversify the crops in the current year in response to extreme weather events in the previous year. Therefore, we include a lag dummy variable $D_{i,t\text{-}1}$ in the model. It represents whether farmer *i* experienced extreme weather events (e.g., drought and/or flood) in year *t*-1, with 1 for such events and 0 otherwise. To compare crop diversification across households, we also include some variables that represent the household characteristics. The variable $S_{i,t}$ is the farm size of household *i* in year *t*. The variable $A_{i,t}$ is the age of the household head. $G_{i,t}$ is the gender of the household head, with 1 representing males and 0 for females. The variable $E_{i,t}$ is years of education received by the household head.

Even though we control for some factors that represent household characteristics, there might be some unobservable characteristics that affect crop diversification behavior. To eliminate the unobservable effects between households and explore the relationship between extreme weather events and crop diversification more rigorously, a household FE model is used to measure the net effect of the extreme weather events in the previous year by removing the effects of time-invariant variables such as regional, local, and household characteristics. The specifications of the FE model are given as follows:

$$Y_{i,t}=\beta_0+\beta_1 D_{i,t\text{-}1}+\beta_2 S_{i,t}+\gamma_i+u_{i,t} \quad (2)$$

Where, γ_i is the unknown intercept for each farm, $u_{i,t}$ is the error term, all β_s are the coefficients to be estimated, and $Y_{i,t}$ is the actual number of crops planted by household *i* in year *t*. We do not need to normalize the dependent variable in eq. (2) because the household FE model already controls for the initial conditions of all households in the estimation. $D_{i,t\text{-}1}$ and $S_{i,t}$ have the same meaning as in eq. (1).

The FE model has an advantage over the OLS model in which it controls for all household characteristics, but it fails to identify the effects of household characteristics such as age and education. However, the FE model with the interaction term can separate the impacts of the key household characteristics on crop diversification when extreme weather events occur. This means that it can determine whether farmers with different characteristics react differently when disaster occurs in terms of changing the number of crops. Therefore, we set up a household FE model with the interaction terms of a lagged disaster (or extreme weather event) dummy variable and household characteristics as follows:

$$Y_{i,t}=\delta_0+\delta_1 D_{i,t\text{-}1}+\delta_2 S_{i,t}+\delta_3 D_{i,t\text{-}1}A_{i,t}+ \delta_4 D_{i,t\text{-}1}G_{i,t}+\delta_5 D_{i,t\text{-}1}E_{i,t}+e_{i,t} \quad (3)$$

Where, $e_{i,t}$ is the error term, all δ_s are the coefficients to be estimated, and all other variables have the same meanings as in eqs. (1) and (2).

Estimation results

The estimation results for the OLS model and the FE model with and without the interaction terms are presented in Table 4. The *F*-statistics for all three models are high enough to imply statistical significance for a combination of all explanatory variables. The signs of the estimated coefficients are also consistent with our expectations. This evidence indicates that all three models perform well.

The estimation results confirm the findings from our descriptive statistical analysis that farmers do tend to adopt crop diversification as a tool to mitigate risk from extreme weather events. In other words, farmers are more likely to grow more crops in the current year if they were affected by extreme weather events in the previous year. In the OLS model, the coefficient associated with the dummy variable representing the occurrence of a disaster in the previous year is positive and statistically significant (Table 4, column 1). Although the coefficient is small, it is statistically significant at the 1% level. Another indicator that supports our conclusion is that the results are consistent across all three models.

Household characteristics also affect the level of farmers' crop diversification. First, farmers with larger farms are more likely to diversify their crop types. The coefficient of farm size is positive and statistically significant in all three models (Table 4). A household with more land is expected to plant more crops for several reasons. First, more arable land is available in large farms, better enabling them to plant more crops. Second, large farms may be exposed to greater risk because the larger the farm is, the larger the loss from a failed harvest will be. Our results are consistent with the findings of Bradshaw *et al*. (2004) that large farms grow more crops than small farms.

Second, older farmers are less likely to adopt crop diversification than younger farmers. The coefficient of age is negative and statistically significant (Table 4). Young farmers usually have less farming experience and are more likely to use crop diversification to avoid production risks (Pope and Prescott 1980). This is consistent with the findings of McNamara and Weiss (2005). Another possible explanation is that younger people are more willing to try new crops.

Third, farmers with a lower level of education are more likely to use crop diversification as a tool to mitigate the effects of an extreme weather event. Farmers with less education are more vulnerable when extreme weather events occur (Haddad 2005) and have been shown to be more risk averse (Rosen *et al*. 2003). Therefore, crop diversification is an effective strategy for them to mitigate risk. This is also consistent with the previous findings (Sonka and Patrick 1984; Knutson *et al*. 1998; Bradshaw *et al*. 2004; di Falco and Perrings 2005).

The FE model has an advantage over the OLS model in that it controls for household characteristics and characteristics related to specific local conditions (e.g., cropping patterns, climate, infrastructure, etc.), and it can therefore better capture the impact of extreme weather events on farmers' crop diversification behavior. The estimated results further enhance our findings on farmers' response to extreme weather events though crop diversification. For example, in the FE model, the estimated coefficient of extreme weather events is 0.023, which is statistically significant at the 1% level. This implies that on average, when farmers experienced an extreme weather event in the previous year, they raised the

Table 4 Estimation results for the determinants of crop diversification[1)]

Independent variables	Dependent variable: crop diversification (number of crops planted)		
	(1)	(2)	(3)
	OLS	Fixed effect (FE)	FE with interaction terms
Previous year extreme weather events	0.020***	0.023***	0.314***
(1=yes, 0=no)	(0.006)	(0.008)	(0.066)
Farm size	0.004***	0.029**	0.028**
	(0.002)	(0.012)	(0.012)
Age of household head	-0.002***		
	(0.000)		
Gender of household head	-0.019		
(1=male, 0=female)	(0.022)		
Education of household head	-0.002**		
	(0.001)		
Previous year disaster×Age of household head			-0.004***
			(0.001)
Previous year disaster×Gender of household head			-0.081**
			(0.040)
Previous year disaster×Education of household head			-0.003
			(0.003)
Constant	1.151***	2.800***	2.801***
	(0.033)	(0.015)	(0.0148)
R^2	0.010	0.007	0.012
F-statistic	8.47	6.73	6.53
Observations	6612	6612	6612

[1)] All numbers in parentheses are robust standard errors.

***, **, and * indicate statistical significance at 1, 5, and 10%, respectively.

number of crops planted by 0.023. Although the average magnitude of change is not large, some farmers did increase the number of crops to mitigate the risk of extreme weather events.

Controlling for factors that are constant over time using the FE model increases the impact of land area on farmers' crop diversification. The estimated coefficient for farm size increases from 0.004 in the OLS estimation to 0.029 in the FE model estimation (Table 4, row 2). Larger farms tend to be much better able to diversify their crops, which is as expected.

More interestingly, our results from the FE model with the interaction terms between the extreme weather events and household characteristics show that different farmers employ different crop diversification strategies when they suffer from extreme weather events. Although the average impact of the previous year's extreme weather events on crop diversification decisions in the current year is small, the impact becomes much larger when we distinguish among the impacts on different farmers. For example, the estimated coefficient for extreme events increases to 0.3136 and is statistically significant (Table 4, column 3). Moreover, the negative and statistically significant coefficient (-0.004) of the interaction term with the age of the household head indicates that the crop diversification tends to fall as the age of the household head increases when the farmer faces extreme weather events. In addition, while the OLS estimation shows that on average, there is no difference in crop diversification between men and women (the estimated coefficient is not statistically significant; Table 4, column 1), the estimated coefficient (-0.081) for the interaction terms of extreme weather and gender (male=1, female=0) in the FE model shows that there is a large difference in behaviors between men and women. After experience with extreme weather events, women tended to plant 0.081 more crops than men. This may be because women tend to be more risk averse than men and are therefore more likely to plant more crops when they face risks.

CONCLUSION

In this paper, we have sought to determine whether farmers diversify their crops to mitigate the risks of extreme weather events and the factors that influence their decision. The results of a large-scale household survey in nine provinces in China show that farmers do respond to extreme weather events by increasing crop diversification. Moreover, we found that farmers' decisions to diversify crops are mainly influenced by their experience of extreme weather events in the previous year rather than in the current year. Econometric analysis further shows a robust relationship between extreme weather events in the previous year and the current year's crop diversification. Such results are understandable because farmers' behaviors are normally based on their expectations, and the number of crops planted is often determined in the beginning of the crop year. The findings of this study imply that providing early information on extreme weather events will help farmers to make better production decisions and mitigate some potential negative impacts from the shocks of extreme weather events.

In addition to the occurrence of extreme weather events, some household characteristics also affect farmers' decisions on crop diversification strategies. Not surprisingly, farmers with larger farms are more likely to diversify their crops. Younger farmers are generally more likely to plant more types of crops than older farmers; this is even more pronounced after they experience an extreme weather event. Farmers with fewer years of education are more likely to adopt crop diversification as a risk diffusion tool, which implies that these farmers may have difficulties adapting to climate change through other measures. When an extreme weather event occurs, female-headed households are more likely to increase the number of crops to mitigate risk than are male-headed households. These findings imply that the demand or need for capacity building to adapt to an increase in the frequency of extreme weather events because of ongoing climate change differs greatly among farmers. For example, older farmers and farmers with small farms may need more attention.

Crop diversification is a less expensive option than other adaptation measures that may require a higher investment. Of course, it may not be effective if large-scale natural disasters occur. These facts remind us that farmers with less ability to employ adaptation measures may need more external assistance. In addition to households' own ability to adapt to extreme weather events, external support from the government, such as releasing early warning information, will enhance farmers' adaptive capacity to mitigate the negative risks from climate change in general and extreme weather events in particular (Chen *et al*. 2013).

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