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RESEARCH ARTICLE

Household and Community Assets and Farmers' Adaptation to Extreme Weather Event: the Case of Drought in China

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Abstract

Under climate change, rising frequency and serious extreme weather events have challenged agricultural production. Designing appropriate adaptation measures to the extreme weather events require rigorous and empirical analysis. The overall goals of this study are to understand physical adaptation measures taken by farmers and the impacts of household and community assets on farmers' adaptation when they face drought. The analyses are based on a unique data set collected from a household survey in three provinces in China. The survey results show that though not common on annual basis, some farmers did use physical adaptation measures to fight drought. Regression analysis reveals that both household and community assets significantly affect farmers' adaptation behaviors. Improving households' social capital and wealth, communities' network and access to government's anti-drought service can facilitate farmers' adaptation to drought. Results indicate that community's irrigation infrastructure and physical adaptation taken by farmers can substitute each other. Further analysis shows that the households taking adaptation measures have higher crop yields than those without taking these measures. The paper concludes with several policy implications.

Key words: drought, physical adaptation measure, household, community, asset, agriculture

INTRODUCTION

In recent years, extreme weather events have received increasing concerns due to their significant impacts on economy, society and environment (Easterling *et al.* 2000; Changnon *et al.* 2001; IPCC 2012). In particular, the severe drought, because of its long-lasting and wide area coverage, can have devastating effects on agricultural and other natural resource-dependent households in the developing world (Shen *et al.* 2007; Liu *et al.* 2013). Recent studies showed that the global droughts increased remarkably since the late 1970s under global warming (Dai *et al.* 2004; Dai 2013). Like the rest of the world, China has also experienced frequent and severe drought during the second half of the 20th century (Qian *et al.* 2012; Ye *et al.* 2012). The area covered by drought reached about 24 million ha annually and showed a rising trend in 1990-2010 (NBSC 2012). Correspondingly, annual grain production losses attributed to drought have also increased from 21 million t in the 1990s to 35 million t in the 2000s (MWR 2012). Over the 21st century, it is projected that the probability of drought event will

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increase in China (Liu *et al.* 2012).

In face of increasingly serious challenge of drought, the question of how to adapt to it through appropriate measures has attracted great attention from policy makers and researchers. 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 the increasingly extreme events in developing country (Mendelsohn *et al.* 2006; Seo and Mendelsohn 2008). In recent years, China's government has also given top priority to formulate and implement 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 China's white paper on national policies and actions against climate change thereafter.

However, the current level of knowledge is not sufficient to support the implementation of national plan on adaptation to climate change at local and farm levels. At local or farm level, while there are studies about the farmer's adaptation in response to long term change of climate in agricultural production (Seo *et al.* 2005; Maddison 2007; Nhemachena and Hassan 2007; Thomas *et al.* 2007; Wang *et al.* 2008, 2010; Deressa *et al.* 2009), there is little empirical study that seeks to understand the ability of farmers adapted to the extreme weather events and factors affecting their adaptation capacity.

In the literatures, while the links between human capital or local community services and technology adoption have been well documented (e.g., Wozniak 1984, 1987; Goodwin and Schroeder 1994; Koundouri *et al.* 2006; Cosar 2011), little evidences are available on the role of human capital on farmer's adaption to drought. Nelson and Phelps (1966) suggested that the role of human capital in development may go beyond its role as a mere factor of production. Dulal *et al.* (2010) also suggested that human capital may also play a crucial role in determining the livelihood options available for adaptation to extreme weather events such as drought. Previous studies also found that local community assets such as rural infrastructure and public service could facilitate farmers' technology adoption in agriculture (Yaron 1992; World Bank 2006; Genius *et al.* 2013). However, whether these community assets could also play important roles on farmers' adaptations to drought and other extreme events is an interesting research issue as it will have important policy implications on incorporating climate change adaptation into national and local development plans.

The overall goals of this study are to better understand adaptation measures taken by farmers and the roles of both household and community assets on farmers' adaptation when they face drought. On adaptation, this study focuses on physical measures against drought that include major irrigation infrastructure such as lateral or sub-lateral canals, pumps, tubewells, cisterns, and ponds. These physical measures against drought distinguish with the others that usually related to farm management measures (e.g., changing planting or harvesting dates, adjusting cropping patterns and changing crops varieties) and other non-physical adaption measures (e.g., crop insurance) and not examined in this study. To meet the above goals, the rest of paper is organized as follows. The next section briefly describes the dataset used in this study. Section 3 discusses status of drought, physical adaptation measures taken by farmers and its likely relationship with assets of household and community. Multivariate analyses on the farmers' adaptation are presented in section 4. Section 5 describes the relationship between adaptation and crop yields. The final section concludes.

DATA

The data used in this study are from a primary household survey conducted in three provinces in China in November and December, 2011. These three provinces include Guangdong in South China and Shaanxi and Qinghai in Northwest China. When selecting provinces for field survey, not only have we taken into account the differences in climate and water resources between northern and southern regions, but also diversified economic development. For example, Shaanxi and Qinghai have less precipitation, belonging to semi-arid and arid regions, respectively, while Guangdong has more abundant precipitation and water resources (MWR 2012). These regions also represent high (Guangdong) and middle to low (Shaanxi and Qinghai) levels of economic development (NBSC 2012).

In each province, we applied the stratified random sampling approach to select samples. First, we selected 8-10 counties that experienced the most serious drought in at least one year in the past 3 yr (2009-2011) in each province. The total number of counties in Shaanxi, Qinghai and Guangdong is 107, 43 and 121, respectively. Second, three counties from each of Shaanxi and Qinghai (serious drought region) and two counties from Guangdong (only part of the province experienced serious drought and the rest of province usually faced flood problem) were selected from these counties that also experienced one normal year in 2009-2011. The normal year is the year when the impacts of weather on crop yields are moderate. This sampling approach allows us to examine differences in the two distinct years (disaster year and normal year) on farmers' responses and actual adaptation measures as well as the impacts of drought at farm level. Second, within each of eight counties selected, three townships and two communities (villages) from each township were randomly selected. Finally, the total sample includes 50 villages (12 villages in Guangdong, 18 villages in Shaanxi, and 20 villages in Qinghai).

In each community, we conducted two surveys: community and household surveys. In the community survey, main respondents were village leaders (e.g., village party secretary, village head and accountant). The questionnaire mainly covered the information on communities' physical assets (e.g., the residential area characteristics and the irrigation infrastructure) and public services (or non-physical assets such as accesses to government technology service for dealing with drought).

Within each community, we randomly selected 10 households for face-to-face interview. In total there were 500 households from 50 villages in 8 counties. In each household we further gathered detailed crop production information in disaster year and normal year. While the household survey covered a wide range of issues, our analysis used only those data related to this study. Especially, the following data are used: farmer's perceptions on drought, drought situations, physical adaptation measures on crop production by farmers, household's assets (e.g., education, social capital, farm land, and durable consumption assets), and community assets (e.g., accessing to public technical service and infrastructure). In this study, the assets include both physical and non-physical assets that may be valuable for farmers in their adaptation to extreme weather event. In the final analysis, we used 499 households as one household was excluded due to incomplete record of data.

DROUGHT, ADAPTATIONS AND ASSETS OF HOUSEHOLDS AND COMMUNITIES

Farmers' perceptions of drought

The survey results show that majority of farmers perceived an increasing frequency of drought over time. In our samples, 67.4% farmers perceived rising frequency of drought in their villages in the past 10 yr (column 1, Table 1). Percentage of farmers who perceived a rising frequency of flood (14.1%) and frost (13.4%) were much lesser than that for drought.

Most of farmers also reported that their crop production was affected by drought during 2009-2011. The results presented in Table 1 indicate that 83.3% of farmers' crop production was affected by drought at least once during the past 3 yr (the last column). At the same period, the share of households whose crop

Table 1 Farmers' perceptions on extreme weather events in the past 10 yr and percentage of households whose crop production affected by the events in 2009-2011 (%)[1)]

Extreme weather events	Percentage of farmers perceived extreme weather events in the past 10 yr				Percentage of households whose crop production was affected at least once in 2009-2011
	Rising	Declining	No change	Unknown	
Droughts	67.4	13.4	16.4	2.8	83.3
Floods	14.1	13.4	53.9	18.6	27.7
Frosts	13.4	23.4	49.6	13.6	6.3

[1)] The sample includes 499 observations. Source: Authors' surveys in 2011. The same as below.

production was influenced by flood and frost events was much lower than that by drought.

Households' adaptation measures against drought

The physical adaptation measures taken in normal year are considered as prevention measures, while the same measures taken in disaster year should be interpreted as both prevention (the measure ahead droughts) and actual response (the measure after the droughts) to the current drought. Therefore the higher adoption rate for physical adaptations observed in disaster is expected. Ideally, we should separate the adaptation measures before and after the drought occurred. Unfortunately, we did not distinguish these two kinds of measures during our survey.

In response to rising trend of drought, farmers may take different measures, including physical and non-physical adaptation measures. This study specifically focuses on the physical adaptation measures because they generally are much more costly than non-physical measures (e.g., changing crop planting and harvesting time, adjusting irrigation water use, and changing other farm management) and are big decisions for farmers to make. Based on field survey in our study area, physical measures include investments and maintenances of irrigation facilities such as canal, tubewell, cistern, pond, and pump equipment. These physical adaptation measures are similar to the other findings in the climate change adaptation literatures (e.g., Nhemachena and Hassan 2007).

Table 2 shows the percentages of households taken physical adaptation measures in the study areas. On the average, 10.3% of households applied physical adaptation measures. The adoption rate of adaptation was higher in disaster year (11.6%) than that in normal year (9.0%) (column 1, Table 2). The physical adaptation measures taken in normal year are considered as prevention measures, while the same measures taken in disaster year should be interpreted as both prevention and actual response to the current drought. Therefore the higher adoption rate for physical adaptations observed in disaster is expected.

Further analyses indicate that the main purpose of taking physical adaptation measures was to improve

Table 2 Percentages of households taken physical adaptation measures in normal year and disaster year (%)[1)]

	Total	Lateral or sub-lateral canal	Pump	Tubewell	Others
Average	10.3	4.7	3.3	1.9	0.4
Normal year	9.0	4.0	2.8	1.8	0.4
Disaster year	11.6	5.4	3.8	2.0	0.4

[1)] Sample includes 499 observations in both normal and disaster years. Others includes cisterns and ponds.

the irrigation capacity. As shown in Table 2, among various physical measures, investing and maintaining lateral or sub-lateral canal was more common (4.7%). In rural China, the investment in canal system is usually made by government. The communities or households also invest in lower level of canal system (e.g., lateral or sub-lateral canal), they are more responsive for maintenance of various canals within the village. In addition, to improve irrigation facilities, some households also purchased pumps (3.3%) or invested in tubewells (1.9%) and others (e.g., cisterns and ponds, 0.4%). In general, there was also higher adoption rate for adaptations observed in disaster year than that in normal year.

Physical adaptations and assets of households and communities

Before quantitatively examining the impacts of household and community assets on farmers' adaptation to drought, we firstly provide descriptive analysis on the relationship between the adaptation and assets based on the survey data. In this study, we use four indicators to represent the assets at household level. They are education of household head (measured as years of formal education), social capital, land per capita (ha) and household's wealth. We follow the approach used in Deressa *et al.* (2009); social capital is measured by the number of relatives within three generations. Here more relatives could imply the larger social network and more information service and financial aid, and therefore higher social capital. Household's wealth is measured by total value of durable consumption assets, which include any durable consumption assets more than 500 CNY. The community assets include whether or not the village accesses to government's technical service on drought, whether or not residential areas is concentrated and continued within the village, and number of lateral canals in the village. Government's technical services on drought (e.g., advices on technology, management and investment to prevent and mitigate the losses) are provided mainly through village's broadcast, drought warming and advice message sent to farmers' cellphone, and/or direct advice from local officials. If residential areas is concentrated and continued (not spatially scattered) within a village, we consider the farmers have more communication and better social network within the village. More irrigation canals in a village imply a better initial condition against drought.

As shown in Table 3, we firstly find that there appears to be a correlation between farmers' adaptation and household assets. For example, the education level of household's head (rows 1-2), social capital (rows 3-5), and household's durable consumption assets (rows 9-11) are positively associated with farmers' adaptation to drought. Indeed, Maddison (2007) also found that there is a positive relationship between human or social capital of a household and the adaptation to climate change. More wealth of a household, more likely to take the physical adaptation measures in the face of drought. This is what we should expect because of less capital constraint in taking the household's adaptation decision. However, land per capita is found to have negative relationship with farmer's decision to take physical adaptation measures. This may be explained by the following possible reasons. First, the physical adaptation measures are costly. The households with more land need more capital investment if they decide to take any physical adaptation measure. Second, the household with more land can mitigate drought risk through diversifying their crop production. The last but not least, the larger farm may have better initial production conditions so that they do not need to take more physical measures in the current year. Unfortunately, this paper is not able to test these hypotheses given the data we have.

Table 3 demonstrates that there also exists an obvious relationship between community assets and farmers' adaptation to drought. For instance, government's technical service on drought is positively related to the adaptation of farmers to drought. Farmers who can access to the government's technical service on drought, compared with those who cannot access to such service, are more likely to take the physical adaptation measures against drought. In addition, positive relationship is also found between

Table 3 Relationship between households taking physical adaptation measures and household and community assets

Household and community assets	Percentages of households taken physical adaptation measures (%)		
	Average	Normal year	Disaster year
Household asset			
Education of household head (yr)			
6 or less	4.9	4.2	5.6
More than 6	5.4	4.8	6.0
Number of relatives within 3 generations			
11 or less	2.4	2.0	2.8
11-16	3.2	2.6	3.8
More than 16	4.7	4.4	5.0
Land per capita (ha)			
0.1 or less	4.6	3.8	5.4
0.1-0.2	3.7	3.4	4.0
More than 0.2	2.0	1.8	2.2
Durable consumption assets (1 000 CNY)			
4 or less	1.5	1.2	1.8
4-10	3.8	3.0	4.6
More than 10	5.0	4.8	5.2
Community asset			
Access to government's technical service on drought			
No	3.9	3.4	4.4
Yes	6.4	5.6	7.2
Concentrated continuous residential areas			
No	2.6	1.8	3.4
Yes	7.7	7.2	8.2
Number of lateral canals			
1 or less	5.9	5.4	6.4
1-3	2.6	2.0	3.2
More than 3	1.8	1.6	2.0

the adaptation measures taken by household and the villages with concentrated continuous residential areas. However, there seems to be a negative correlation between the number of lateral canals and farmers' adaptation (the last 3 rows, Table 3). This suggests that farmers may need less effort in taking adaptation measures to drought if their villages have better irrigation infrastructures.

ECONOMETRIC MODEL AND ESTIMATION RESULTS

Econometric model

An econometric model is developed to examine the impacts of assets of households and communities on farmers' adaptation measures in facing drought. As discussed in introduction section, previous studies have showed that the important role of farmer's human assets or capital in the adoption technologies (e.g., Saha *et al.* 1994; Koundouri *et al.* 2006). The descriptive analysis of this study also found that there are positive relationships between assets of households and communities and adaptation measures taken by farmers. According to human capital theory, these assets are associated with the resource allocation skills of farmers (Nelson and Phelps 1966; Huffman 1977). Therefore we specify the following empirical model of farmers' adaptation to drought:

$$A_{ijcs}=\gamma_0+\gamma_1 H_{ijcs}+\gamma_2 C_{jcs}+\gamma_3 P_s+\gamma_4 D_{cs}+\varepsilon_{ijcs} \quad (1)$$

Where, i and j represent the ith household and the jth village, c represents county and s represents province. The dependent variable, A_{ijcs}, is whether or not the household i took physical adaptation measures, it is a dummy variable with a value of 1 if the household took any of the physical adaptation measures presented in Table 2 in response to drought and 0 otherwise. The first set of explanatory variables, H_{ijcs}, is a vector of variables used to reflect the household assets as we discussed above, which includes: 1) education of household head (yr); 2) the social capital status of household i, measured by the number of household's relatives (within three generations); 3) land per capita in a household (ha); and 4) family wealth, measured by the value of household's durable consumption assets (1 000 CNY). The second set of explanatory variables, C_{jcs}, is a vector of variables reflecting assets at village level, which includes: 1) access to government's technical service on drought, which is a dummy variable with a value of 1 if received the government's service and 0 otherwise; 2) concentrated and continuous residential areas, also a dummy variable with a value of 1 if the village's residential areas are concentrated and continuous, and 0 otherwise; and 3) the number of lateral canals within the village, denoting the initial condition of community irrigation infrastructure.

Because farmers' adaptation behaviors may also be affected by other factors such as the occurrence of disaster and other unobserved factors such as locations (Maddison 2007; Bryan *et al.* 2009; Deressa *et al.* 2009), therefore, to better quantify the impacts of these factors, in the empirical model we also include the following variables. The first is a set of provincial dummy variables (Shaanxi and Qinghai), P_s. The basis for comparison is Guangdong Province. Including the province dummies is to control for the impact of regional unobservable characteristics (e.g., cropping pattern, geographic location and other natural and economic conditions, etc.) that may potentially affect farmers' adaptation decisions. The other variable is disaster dummy variable, D_{cs}, which is measured at county level. It equals 1 if the county experienced a serious drought shock in that year and equals 0 if the county experienced a relatively normal year. Details see the discussions in data section (section 2). The term ε_{ijcs} is the household specific error term and are assumed to be subjected to independent identical distribution.

In above equation, γ_k (k=1, …, 4) are the coefficients to be estimated, which captures the impact of different explanatory variables on the probability of taken adaptation measures by farmers. We are in particular interested in the coefficients γ_1 and γ_2, which respectively captures the impacts of household assets and community assets on farmers' adaptation to drought. Summary statistics of the dependent and independent variables are in Appendix.

Estimation results

Given the nature of dependent variable (1 or 0), Probit model (a binary response model) is used to estimated

Table 4 Marginal effects on the determinants of farmers' physical adaptation to drought (Probit model)[1)]

Explanatory variables	Adoption of physical adaptation measures (1=yes; 0=no)
Household assets	
Education of household head (yr)	0.004
	(1.502)
Number of relatives within 3 generations	0.003**
	(2.121)
Land per capita (ha)	-0.175***
	(-3.211)
Durable consumption assets (1 000 CNY)	0.001**
	(2.361)
Community assets	
Access to government's technical service on drought (1=yes; 0=no)	0.034*
	(1.872)
Concentrated continuous residential areas (1=yes; 0=no)	0.078***
	(4.449)
Number of lateral canals	-0.005***
	(-3.096)
Province dummies (base is Guangdong):	
Shaanxi Province (1=yes; 0=no)	0.114***
	(2.702)
Qinghai Province (1=yes; 0=no)	0.169***
	(4.053)
Disaster dummy (1=disaster; 0=normal)	0.022***
	(3.411)
Observations	998
LR chi-squared	65.54
Pseudo R-squared	0.17

[1)] All numbers in parentheses are robust z-statistics.
***, ** and * represent statistically significant at 1, 5 and 10%, respectively. The same as below.

eq. (1) by pooling data from 2 yr. The estimated results of marginal effects are presented in Table 4.

In general, the signs of the estimated coefficients demonstrate that the dataset was producing results that are consistent with the descriptive results discussed earlier. After controlled for the effects of other factors, the household assets variables have statistically significant impacts on farmers' adaptation decisions (Table 4). For example, higher level of education of households' head increases the probability of taking physical adaptation measures to drought though the estimated coefficient is not statistically significant (row 1). The estimated marginal effect (0.004) indicates that with 1 yr more education for farmers the probability of taking physical adaptation measures to drought can increase by 0.4%.

Moreover, other household assets such as social capital and wealth significantly affect farmer's adaptation decision. No matter in normal/disaster year or using pooled data from 2 yr, all estimated coefficients (marginal effects) of social capital (row 2) and wealth (represented by durable consumption assets, row 4) are statistically significant and positive. More social capital (or relatives) is associated with larger social network, which may help farmers receive more help and information services so that they are more likely to take adaptation measures. The estimated marginal effect (0.001) of durable consumption assets indicates that an increase of 1 000 CNY in household wealth raises the probability of taking physical adaptation measures to drought by 0.1% (row 4). These suggest that the poor may be more vulnerable in face of climatic shocks because they cannot afford to the costly physical adaptation measures.

The estimated marginal effect of land per capita is statistically significant but negative (row 3, Table 4). This implies that households with more land per capita are less likely to take adaptation measures. As we explained earlier, this is possible if one would consider the costly physical adaptation measures, more alternative risk management methods, and possible better initial production conditions of the larger farms. Of course, the mechanism of the above effects is an issue that needs further study.

The estimated results presented in Table 4 also show that the assets at community (or village) level also have significant effects on farmers' adaptation decision. For example, having access to government's technology service on drought increases the probability of taking adaptation measures against drought by more than 3% (row 5). This result implies that the capacity building for famers can enhance their ability to against climatic shocks. Additionally, we find that farmers in the community with concentrated continuous residential areas are more likely to take adaptation to drought (row 6). This could be because that residential concentration (community network), compared to those with largely dispersed residents, is more beneficial for disaster related information exchange among farmers. Interestingly, Table 4 also shows that having better irrigation infrastructure such as lateral canals in community is found to have significantly negative effects on the probability of households to take physical adaptation measures (row 7). Possibly there could be a substitution effect between measures taken at household and village level. For example, for the villages that have already owned better irrigation infrastructure, the farmers there would not need again to invest the physical adaptation measures in canal and other infrastructure by themselves.

As expected, the farmers' adaptation behaviors have great difference across different regions. For instance, farming in Shaanxi and Qinghai has higher probability of taking adaptation measures by farmers than that in Guangdong. As we have explained, Qinghai and Shaanxi locate in the Northwest China, having relatively more vulnerable farmland production conditions compared to Guangdong which locates in China's developed regions of Pearl River Delta. This would imply that the local vulnerability can force farmers to make different adjustments to cope with climatic risks such as drought.

The econometrical result also shows that farmers are more responsive to drought in disaster year than that in normal year, which is what we should expected. The estimated marginal effect for disaster dummy variable is positive (0.022) and statistically significant (bottom of Table 4) suggests that, on average, the probability of adapting physical measures against drought is about 2.2% higher in drought year than in normal year. That is, farmers are more responsive to taking adaptation measures when they do face drought. The above results support other studies which find that households in Africa in higher annual mean temperature and decreasing precipitation were more likely to adapt to climate change through the different adaptation practices (Deressa *et al.* 2009).

PHYSICAL ADAPTATIONS AND CROP YIELDS

It is worth to note that taking costly physical adaptation measures does not imply that farmers are effectively adapting to climate risks. In this section, while we are not able to conduct cost and benefit analysis of adaptation, our survey data do allow us to compare crop yields between two groups of households, taking or not taking physical adaptation measures. The results of these comparisons for wheat, maize and rice are summarized in Table 5.

Table 5 shows that adaptation may matter. For example, when examining crop yield between the

Table 5 Main crop yields (kg ha^{-1}) and adoption of physical adaptation measures based on crop plot data[1)]

Crop	Adopted (1)	Not adopted (2)	Percentage of difference (3)=[(1)-(2)]/(2)×100
Wheat	4630.7	3715.2	24.6***
	(35)	(164)	
Maize	5667.3	4628.0	22.5***
	(30)	(180)	
Rice	6090.0	5572.7	9.3
	(10)	(175)	

[1)] The numbers in the parentheses are plot numbers.

plots with adaptation measures (column 1) and without adaptation measures (column 2), the formal has higher yields than the later (column 3). For example, wheat yield is higher by 24.6%, maize yield is higher by 22.5% and rice yield is higher by 9.3%. The differences are statistically significant in wheat and maize but not in rice. This may be due to the fact that wheat and maize have more serious problem in drought than rice.

In sum, the descriptive statistics in Table 5 may provide empirical evidence of partially effectiveness of taking adaptation measures to cope with drought. While there may be systematic differences in the nature of cultivated lands between two types of plots examined (e.g., soil quality, terrain, irrigation, location, size), it does appear that taking adaptation measures could mitigate the shocks of drought on crop yields. Of course, a fully understanding of effectiveness of adaptation requires much more data (e.g., costs) for conducting the cost and benefit analysis of adaptation measures taken by farmers.

CONCLUSION

Based on a household survey conducted in three provinces in China, this study not only examines farmers' physical adaptation practices to drought in agricultural production, but also identifies the impacts of household and community assets on farmers' adaptation decision to drought. This analysis aims to strengthen understanding about farmers' decision-making process and enable policymakers and other stakeholders to support adaptation against extreme weather events such as drought for crop production.

The results show that there are about 10% of farmers do take some physical adaptation measures to mitigate the impacts of drought on agricultural production. Assets at both household and community levels have significant effects on farmer's decision on taking physical adaptation measures against drought. Higher level of household assets in terms of education, social capital and wealth facilitates farmers to take their adaptation decision. The community assets such as village's access to government's technical service and easiness of communication or information flow also can play an important role in facilitating farmers to make their decision to take adaptation measures. The results of this study further show that adaptation does improve (or mitigate loss of) crop yield.

The above findings have several policy and research implications. First, improving farmers' adaptation capacity is important to cope with the rising extreme weather events. A crucial area to improve farmers' adaptation capacity is to improve farmers' education and social capital. Moreover, as the household assets in term of wealth is also an important determinant of taking adaptation measures, it is a challenge to household in those vulnerable and poor regions where most farmers are poor and often lack of sufficient capital to invest in adaptation measures. Enhancing the adaptive capabilities of the poor in vulnerable regions in responding to climate risks should be one of prioritized areas for policy interventions.

Second, the policy to improve community assets also can play an important role for farmers adapted to extreme weather events. The government's technical service related to resistance of drought in the villages should be enhanced since it is of particular importance in facilitating farmers to take adaptation measures for reducing crop loss from drought. There is a great room to play in providing information and service on resistance of extreme weather events to local farmers. Moreover, the investment in village irrigation systems can reduce farmer's investment in the costly physical adaptation measures. If the community has better irrigation infrastructures, farmers can directly access to the irrigation service with lower cost, which diminishes the farmers' vulnerability to climatic shocks. Our results also imply that for regions where households are not closely connected, government services are particularly needed to enhance farmers' adaptive capacity.

Third, we believe that the results of this study also have implications to the national adaptation plan on agriculture under climate change in some other developing countries. Directly providing the technology associated with resistance of extreme weather events to farmers, particular the small-scale farmers, in many developing countries is still not a common activity.

Finally, a great deal of interest also exists in analyzing the effectiveness of adaptation measures to reduce the shocks of drought. To have more policy implications on adaptive investment priority, more research efforts should be made in collecting data on cost of taking each adaptation measure and its effect on crop yield.

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Appendix associated with this paper can be available on http://www.ChinaAgriSci.com/V2/En/appendix.htm

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