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Policy support, social capital, and farmers' adaptation to drought in China

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ABSTRACT

Increasingly severe drought has not only threatened food security but also resulted in massive socio-economic losses. In the face of increasingly serious drought conditions, the question of how to mitigate its impacts through appropriate measures has received great attention. The overall goal of this study is to examine the influence of policies and social capital on farmers' decisions to adopt adaptation measures against drought. The study is based on a large-scale household and village survey conducted in six provinces nationwide. The survey results show that 86% of rural households have taken adaptive measures to protect crop production against drought, most of which are non-engineering measures. In the case of non-engineering measures, changing agricultural production inputs and adjusting seeding or harvesting dates are two popular options. A multivariate regression analysis reveals that government policy support against drought such as releasing early warning information and post-disaster services, technical assistance, financial and physical supports have significantly improved farmers' ability to adapt to drought. However, since only 5% of villages benefited from such supports, the government in China still has significant room to implement these assistances. Moreover, having a higher level of social capital in a farm household significantly increases their adaptation capacity against drought. Therefore, the government should pay particular attention to the farming communities, and farmers within a community who have a low level of social capital. Finally, farmers' ability to adapt to drought is also associated with the characteristics of their households and local communities. The results of this study also have implications for national adaptation plans for agriculture under climate change in other developing countries.

1. Introduction

There is growing concern about global climate change. Over the past 100 years, the average global surface temperature has increased by 0.74 °C (IPCC, 2007). From 1961 to 2011, the annual average surface temperature in China rose by 0.29 °C every 10 years (NCC of CMA, 2011). In addition, from 1961 to 2011, 6 of the 10 major river basins in China recorded a declining trend in total surface water, indicating significant shifts in precipitation patterns. Of these six river basins, the total surface water of the Haihe River, Yellow River and Liaohe River has been decreasing by 3.64%, 2.26%, and 1.66% per decade, respectively (NCC of CMA, 2011).

Drought is an increasing problem and becoming more severe in many regions in the world, including China. It is forecasted that the total area suffering from drought in the world will expand by 15–44% from now until the end of 21st century (IPCC, 2012). In China, from the 1950s to the beginning of this century, the annual average crop area suffering from drought has expanded from 11.6 million hectares to 25.1 million hectares, an increase of 116%. Over the same period, the proportion of crop area hit by drought increased from 8% to 16% (NBSC, 2010; MWR, 2010). Moreover, the share of seriously damaged area (a yield loss of at least 30%) to drought-hit area (a yield loss of at least 10%) increased from 34% in the 1950s to 46% in the 1990s, and 58% in the first ten years of the 21st century.

Increasingly severe drought has not only threatened food security but also resulted in massive socio-economic losses. Drought is known to be one of the most severe natural disasters threatening food security (UNDP, 2004). For example, as a result of serious drought, the grain yield fell by 59% and grain exports decreased by 19% in Australia in 2002 (Karoly et al., 2003). In 2010, Russia encountered its most severe drought in 130 years and declared a temporary ban on the export of wheat and other

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agricultural products, which is considered one of the major causes of the global food price hikes in 2010 (Wegren, 2011; Dronin and Kirilenko, 2011). Over the past two decades, drought has resulted in an annual grain production loss of more than 27 million tons in China. In 2000, drought caused the largest grain production loss (60 million tons) and made it difficult for 28 million people and 22 million heads of livestock to obtain drinking water (MWR, 2010). In 2007 and 2009, drought resulted in direct economic losses of over RMB 100 billion Yuan in China (MCA, 2010).

In the face of increasingly serious drought conditions, the question of how to mitigate its impacts through appropriate measures has received great attention. The international community has called for national development plans to incorporate climate change adaptation (Adger et al., 2007; World Bank, 2010). In recent years, the Chinese government has also given top priority to formulate and implement adaptation policies (NPC, 2011). Indeed, a national plan responding to climate change was issued in 2007, which was followed by a publication of China's white paper on national policies and actions against climate change in 2012 (NDRC, 2007, 2012).

However, the current level of knowledge is not sufficient to support the implementation of China's national plan on adaptation to drought and other extreme weather events. The major problem is that most existing studies focusing on China are based on a qualitative analysis. In addition, most of the publications are based on local case studies, seldom drawing on a larger sample survey covering more than one province. Despite the rich information provided by the qualitative studies, it is difficult to provide robust evidence to support the adaptation policies in China. For example, Wang et al. (2013) developed an analytical framework to examine climate change adaptation for saline agriculture in Jiangsu province. Based on descriptive analysis, scholars have focused either on farmers' adaptation strategies in coping with drought in certain regions (Liu et al., 2008; Ju et al., 2008; Sun et al., 2012; Su et al., 2012; Sjögersten et al., 2013) or on macro-level adaptation strategies to deal with the long-term effects of climate change (e.g., Pan and Zheng, 2010; Xia et al., 2008). Until now, according to our knowledge, only two studies have applied quantitative approach to analyze adaptation issues. Wang et al. (2008) applied a simulation model to explore adaptation options to water scarcity in the Haihe River Basin. Wang et al. (2010) applied an econometric model to analyze farmers' choices on crop structures and irrigation methods in different climatic conditions.

With the rising significance of drought, several questions need to be answered to increase adaptation capacity. How have farmers responded to drought? What major adaptation measures have been adopted? Why are some farmers able to respond to drought while others are not? Has any policy supported farmers when they face serious drought? If yes, how effective have these policies been in helping farmers to adopt adaptation measures? Then, as has been found in other countries (Deressa et al., 2009; Katungi, 2007), is adaptation closely related to farmers' social capital in China? Answering these questions is critical, not only to better understand farmers' responses to extreme weather events, but also to provide empirical evidence for policy makers to help them formulate adaptation plans and policies.

The overall goal of this study is to examine the influence of major factors, particularly policies and social capital, on farmers' decisions to adopt adaptation measures against drought in China. To achieve this goal, we have the following two specific objectives. The first is to gain a better understanding of current adaptation measures taken by farmers against drought. To do so, we conducted a large-scale household and village survey in six provinces across China. The second objective is to conduct both descriptive and econometric analyses to identify and quantify the influence of policy support, farmers' social capital, and other factors on their decisions to adopt adaptation measures against drought.

The rest of paper is organized as follows. In the next section, we briefly introduce the data used in this study. Section 3 discusses the current situation in terms of adaptation measures used by farmers. Section 4 presents the relationship between farmers' responses to drought and policy support, and between their responses and their households' social capital. Section 5 presents multivariate analyses on the determinants of farmers' adaptation. The final section concludes the paper.

2. Data

The data used in this study are collected from one large-scale field survey conducted in six provinces in China. These six provinces are Hebei in the Haihe River Basin (RB), Jilin in the Songliao RB, Anhui in the Huaihe RB, Sichuan in the Yangtze RB, Yunnan in the Southwest RB, and Zhejiang in the Southeast RB (see Fig. 1). When selecting provinces for the field survey, we considered differences in climate and water resources between the northern and southern regions, as well as the diverse economic development in these regions. For example, the survey samples cover three river basins (Songliao, Haihe, and Huaihe RBs), which are characterized by less precipitation and more frequent drought conditions, especially in Haihe RB. During the period 1950–2000, precipitation in these RBs declined by 50–120 mm (ECSNCCA, 2011) and drought has become more serious (Wang et al., 2007). In contrast, the other two river basins (the Yangtze and Southeast RBs) have more abundant precipitation and water resources, and have witnessed an increase in annual precipitation of 60–130 mm over the same period (ECSNCCA, 2011), although with no significant change in drought conditions (Wang et al., 2007). These six regions also represent high (Zhejiang Province), middle (Jilin and Hebei Provinces), and low (Anhui, Sichuan, and Yunnan Provinces) levels of economic development (NBSC, 2010).

Stratified random sampling was used in each province to select the study areas. First, we divided all counties in each province into three quantiles according to the per capita annual net income of rural residents in 2009. In each quantile, we randomly selected one county for the survey. Then, we randomly selected two townships in each county and three villages in each township for field surveys. As a result, the survey samples included 108 villages, 36 townships, and 18 counties across the six provinces.

In each village, we conducted two surveys, namely village and household surveys. In the village survey, the main respondents were the village leaders, such as the village party secretary, the village head, and accountants. The questionnaire mainly covered two major issues: (1) policy support for dealing with drought, including whether the government provided early drought warning and prevention information services, as well as technical, financial, and physical assistance to farmers; (2) physical and socio-economic conditions, such as water supply reliability, soil type, transportation infrastructure, economic development, and personal characteristics of the village leaders. Table 1 provides the descriptive statistics for the major information collected from the village surveys.

Within each village, we randomly selected 10 farm households and then selected those households whose crop production had suffered as a result of drought in the past five years to be our study samples. Here, drought is measured based on by a farmer's own judgment or self-report. If a farmer said that his/her agricultural production was seriously influenced by drought, we define this to mean that drought occurred or that the farmer experienced a drought. Specifically, during our survey, we first asked farmers if their agricultural production had been affected by drought in the past five years (2006–2010). If a farmer answered "Yes" then we

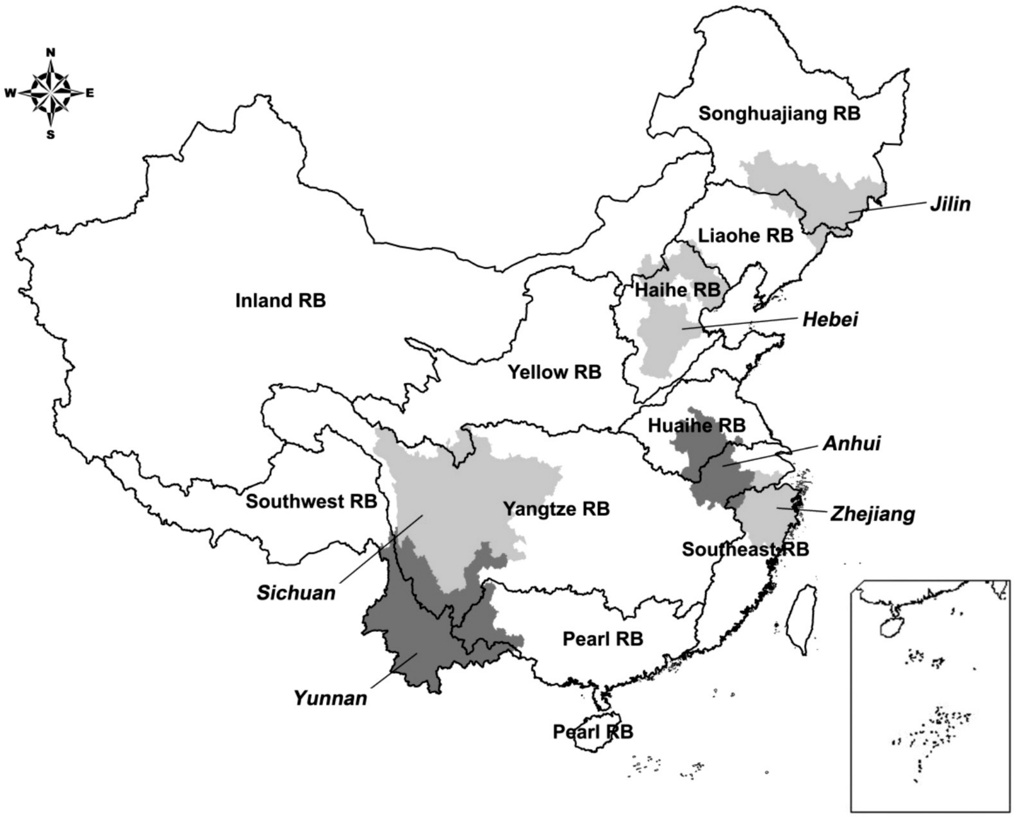

Fig. 1. Locations of six provinces and river basins in China.

asked questions to establish which year(s) was (were) relatively normal, and the year in which they experienced the most serious drought (i.e., their agricultural production was seriously hit by drought). We recorded the answer to the latter question as "the most serious drought year." The household survey was conducted through face-to-face interviews. The results showed that about 53% of households (569 of 1080 households from 91 villages) had suffered from drought during the period 2006–2010. Therefore, these 569 rural households were used as the final samples for this study. In the rest of this paper, both the descriptive statistical analysis and econometric analysis refer to this, sample of 569 households from 91 villages. We then asked a series of questions on whether or not each of these farmers applied any adaptation measures in response to the drought. In addition, we collected basic characteristics of the households and their farms (e.g., social capital, cropping structure, farmland, family wealth, and characteristics of the household head), as these may influence farmers' behavior when adopting adaptation measures. The descriptive statistics of the major information collected from the household survey are also summarized in Table 1.

Table 1
Descriptive statistics of village and household's characteristics.

	Mean	Std. Dev.
Villages (sample = 91):		
Received early drought warning and prevention information from the governments (1 = Yes; 0 = No)	0.57	0.50
Received technical, financial and physical supports against drought from government (1 = Yes; 0 = No)	0.05	0.23
Surface water reliability (ratio of number of years with reliable surface water supply over 5, the past five years)	0.58	0.43
Groundwater reliability (ratio of number of years with reliable groundwater supply over 5, the past five years)	0.14	0.34
Sandy soil (1 = Yes; 0 = No)	0.34	0.48
Loam soil (1 = Yes; 0 = No)	0.36	0.48
Clay soil (1 = Yes; 0 = No)	0.30	0.46
Distance from township government office (km)	6.79	5.58
Number of enterprises in the village	2.16	4.83
Age of village leaders (years)	47.57	7.18
Education of village leaders (years)	6.60	3.01
Households (samples = 569):		
Received early drought warning and prevention information from the villages (1 = Yes; 0 = No)	0.38	0.49
Received technical, financial and physical supports against drought from villages (1 = Yes; 0 = No)	0.09	0.29
Social capital (number of relatives in government within 3 generations)	0.25	0.57
Crop type (1 = Grain; 0 = Cash crop)	0.87	0.33
Ratio of hilly, slopes and terraces over total cultivate land	0.45	0.39
Wealth (value of durable consumption goods) (10,000 RMB)	7.01	9.86
Population (number)	3.75	1.55
Age of household head (years)	50.74	10.27

Source: Authors' survey.

3. Adaptation measures against drought by farm households

There are many definitions of the adaptation options. Since we collected information on how farmers have actually responded to drought, our analysis is about adaptation practices rather than potential adaptation options. As summarized by the IPCC report released in 2007 (Adger et al., 2007), adaptation practices can be differentiated along several dimensions, for example, by type of action (physical, technological, investment, regulatory, market), by actor (national or local government, international donors, private sector, NGOs, local communities, individuals), by spatial scale (local, regional, national), among others. Based on our pretests and experience during the field survey, we found that classifying the adaptation options as either engineering (e.g., investment or maintenance options) or non-engineering (e.g., technological, regulatory, or market options) types, farmers and local policy makers find them easier to understand. Therefore, we chose to define our adaptation options "by type of action." Based on our field survey, engineering measures predominantly comprise constructing wells, building cisterns, excavating channels, and updating pump equipment. Non-engineering measures are characterized by the nature of their technical, institutional, and legal aspects. Therefore, we found that non-engineering measures in our study areas mainly included changing crop production inputs, adjusting planting or/and harvesting time, adjusting crop irrigation, changing cropping patterns, and purchasing crop insurance. The adaptation measures adopted by farmers could be adopted before a drought (anticipatory) or after a drought (reactive). However, since we did not ask farmers precisely when (e.g., which month) they adopted their drought adaptation measures, we have no way of differentiating between these two kinds of adaptation measures in this study.

The field surveys showed that most households took some sorts of action to protect crop production in response to drought. For example, of the 569 households who faced drought during the study period, 86% adopted an adaptation measure, most of which were non-engineering measures (see Table 2, row 3). Only 10% of the households applied both engineering and non-engineering measures (row 6). This is understandable, as non-engineering measures are more convenient, less costly and more easily implemented in the short term.

For those farmers who were able to apply engineering measures in the face of drought, further analyses indicate that they did so both to increase the amount of irrigation water and, to improve the reliability of the water used in irrigation. Of the households that applied engineering measures, 33% invested in wells to access groundwater resources and 25% chose to build cisterns to collect rainfall (see Fig. 2). In addition, 15% of these households purchased pumps to draw water from a nearby river or lake for irrigation. In summary, 73% (33 + 25 + 15) of the households that adopted engineering measures did so to increase their irrigation water supply capacity. The remaining 27% of households invested in water saving facilities to improve water supply reliability and water delivery efficiency. This group was further divided between those who invested in surface pipe or sprinkler irrigation facilities to improve their drought adaptation ability (14%), and those who made an effort to maintain canals to reduce canal water leakage and water delivery losses (13%).

The field surveys revealed that changing crop production inputs and adjusting crop planting and/or harvesting time are two major non-engineering measures adopted by farmers. According to the field survey results, when shocked by drought the major non-engineering measures chosen by farmers were to change the crop production inputs (e.g., seeds, fertilizer, pesticides, and labor). The share of households changing crop production inputs accounted for 35% (Fig. 3). Moreover, 24% of households preferred to adjust when they planted or harvested their crops to reduce or prevent loss caused by drought. To mitigate the potential negative impacts of drought, some households (18%) also chose to enhance irrigation intensity by changing irrigation times or volumes. Changing crop varieties or planting drought-resistant crops were other non-engineering adaptation measures adopted (14% of households). Finally, buying crop insurance against more frequent extreme weather events has also become a new option for farmers to mitigate the impacts of drought on their income. According to our field survey data, of those households who adopted non-engineering measures, 8% bought crop insurance.

Table 2
Adaptation measures against drought for households suffering drought.

	Number of households	Share of households (%)
Total samples	569	100
Without adaptations measures	82	14
With adaptation measures	487	86
(1) Only engineering measures	0	0
(2) Only non-engineering measures	432	76
(3) Both types of adaptation measures	55	10

Source: Authors' survey.

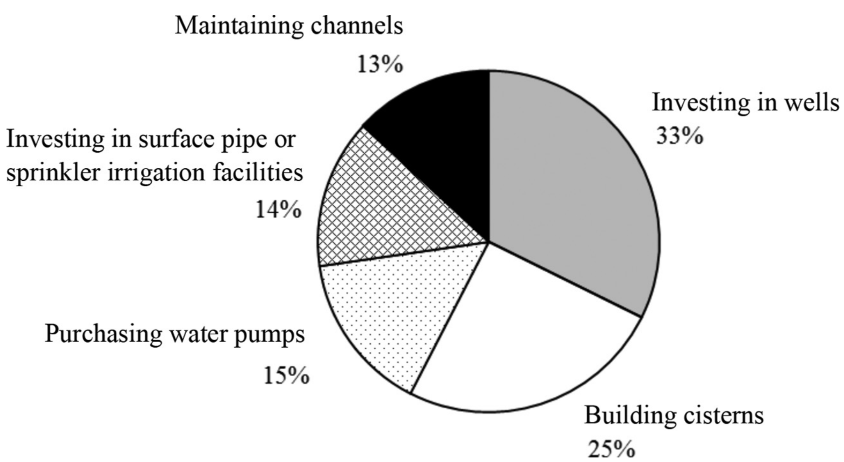

Fig. 2. Engineering adaptation measures adopted by farmers for resisting drought.

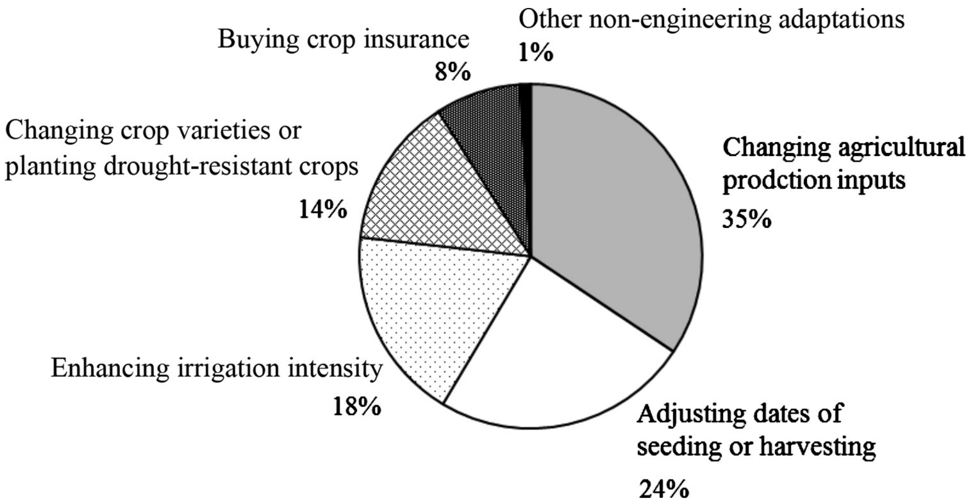

Fig. 3. Non-engineering adaptation measures taken by farmers for resisting drought.

4. Policy support, social capital, and farmers' adaptation to drought

4.1. Policy support and farmers' adaptation to drought

In general, when local governments at different levels (e.g., provincial, county and township) assist farmers against drought, there are two major approaches. The first approach is to provide farmers early warning and prevention information against drought, and the second is to provide farmers technical, financial, or physical support. Early warning and prevention information released to farmers often occurs through farmers' meetings organized by village leaders or township officials, broadcasts and other media managed by the local governments, texting message to farmers' cell phones, and issuing urgent disaster documents from the higher to the lower levels of government, and from there to the village community. Information provided before a drought occurs, mainly it emphasizes how to prevent potential losses by telling farmers the possible duration and seriousness of the forecasted drought, and by reminding farmers that they should take appropriate adaptation measures (e.g., storing water or adjusting crop planting patterns) to reduce losses. In addition to informing farmers of the characteristics and intensity of a drought, information provided during a drought is mainly to help farmers use remedial measures to minimize losses (e.g., exploring other possible water resources, adjusting the input of crop production, or changing the cropping system).

On the other hand, with regards to technical, financial and physical policy support, local governments often help farmers more directly. For example, local governments often send extension staff to the fields to advise farmers on how to adopt engineering or non-engineering measures (e.g., teaching farmers how to build or maintain their infrastructure, how to adopt water saving technology, and how to adjust production inputs). Financial support provides subsidies to farmers through drought relief funds and subsidized loans. The financial subsidy can relax the financial constraints on farmers to help them to adopt adaptation measures or can directly reduce their losses from the disaster. The local governments also provide farmers with materials (e.g., water-saving facilities, drought-resistant seeds, fertilizer, pesticide or some other production inputs) to help their fight against drought.

The survey results demonstrate that policy support differs largely among villages, which provides good empirical data for us to examine the relationship between policy support and farmers' adaptation to drought. For example, among the studied villages, 57% received early drought warnings and prevention information from local governments (Table 3, row 3, column 2). This group was divided as follows: 15% received the information before the drought occurred (row 4), 9%received the information during the drought, and 33% received information both before and during the drought (row 6).

Only 5% of villages enjoyed technical, financial, and physical policy support from their local government (see Table 3, last row), which was a much lower percentage than those that received drought warning and prevention information. That is, during a drought, most villages could not get policy support from their local government on technical, financial, or physical aspects. Therefore farmers in most of these villages (95%) have to depend on their own experience, labor, materials, or funds to face the drought and reduce the possible economic losses.

Does providing information and policy support play a positive role in helping farmers to adopt adaptation measures against drought? As shown in Table 4, both information provision and policy support are positively related to farmers' adaptations. For example, in the villages that received the early warning and prevention information, on average, 88% of farmers adopted adaptation measures, which was higher than the corresponding number in the villages that did not receive such information (Table 4, rows 1 and 5, column 1). Even when information was only provided before or during a drought, the percentage of households with adaptation measures (90% or 86%) was higher than those that did not receive any information (81%, row 5, column 1). Similarly, when the local governments offered technical, financial, or physical support to farmers, 96% of households took adaptation measures (row 6). If such policy support was not offered, the

Table 3
Provision of early warning and prevention information, policy supports against drought.

	Number of villages	Share of villages (%)
All villages	91	100
Villages not received information	39	43
Villages received information	52	57
Before drought only	14	15
During drought only	8	9
Both before and during drought	30	33
Villages not provided policy supports	86	95
Villages provided policy supports	5	5

Source: Authors' survey.

Table 4
Relationship between the provision of early warning and prevention information, policy supports and the adoption of adaptation measures by farmers.

	Share of households with adaptation measures (%)	Of which:	
		Only non-engineering measures (%)	Both types of measures (%)
Villages received information	88**	74*	14***
Before drought only	90*	86*	4
During drought only	86	77	9**
Both before and during drought	89**	70	19***
Villages not received information	81	78	3
Villages provided policy supports	96**	59	37***
Villages not provided policy supports	85	78	7

Source: Authors' survey.
Note: The superscripts are t statistical test results. For rows 1 to 4, their comparing base is row 5 (Villages not received information). For row 6, its comparing base is row 7 (Villages not provided policy supports).
* Statistically significant at 10%.
** Statistically significant at 5%.
*** Statistically significant at 1%.

percentage of households taking adaptation measures dropped to 85% (last row). The above analysis implies that, if local governments provide early warning and prevention information or directly give technical, financial, or physical support to farmers, the probability of farmers adopting adaptation measures is likely to increase and the adaptation capacity of farmers against drought risks is likely to be enhanced.

What kinds of adaptation measures are more likely to be taken by farmers when information and policy support are available? As shown in Table 4, when policy support is available, farmers are more likely to adopt both engineering and non-engineering measures. For example, if early drought warning and prevention information to farmers is not provided to farmers in the villages, only 3% of households adopted both types of adaptation measures (engineering and non-engineering measures) (column 3), which was significantly lower than the 14% of farmers that did so in the villages that did receive the information. In addition, when technical, financial, or physical policy support were offered by the local governments to the villages, the share of households adopting both types of measures reached 37%, more than five times higher than those villages that did not receive policy support (7%). However, if we check the relationship between the policy support and the adoption of non-engineering adaptation measures only, it is difficult to find a consistent story given the simple descriptive statistical data (column 2).

4.2. Social capital and farmers' response to drought

In recent years, the influence of social capital on the adoption of adaptation measures has captured the attention of scholars. Social capital is an aggregate of actual or potential resources which are linked to the possession of a durable network of more or less institutionalized relationships of mutual acquaintances (Bourdieu, 1985). With the development of social capital theory in recent years, some scholars have studied the relationship between farmers' social capital and their adoption of agricultural production technologies (Wu and Pretty, 2004). These studies have recognized that social capital can be treated as one channel for acquiring information and helping farmers reduce necessary credit when applying for a loan (Katungi, 2007). Another potential advantage of social capital is to promote the adoption of new technologies, since the externality of new technologies can be internalized if farmers within the social network work together to overcome difficulties. As a result of its importance, social capital has become the focus of studies on adopting adaptation measures. For example, Deressa et al. (2009) found that social capital can significantly increase the adoption possibilities of adaptation measures by African farmers.

Social capital can be measured in two ways. The first is as a network resource, and the second is a Guanxi resource (Zhang, 2003). In China, one family's Guanxi resource is closely related to the number of relatives working in the government (Luo, 1997). Based on a case study, Yan (1996) found that farmers who have relatives working within the government find it easier to solve problems that occur in the villages (Yan, 1996). Park and Luo (2001) found that Chinese firms can benefit through their personal connections with government officials. Considering the important role of "Guanxi" in China, scholars analyzing Chinese issues usually use Guanxi to measure social capital (Hwang, 1987; Yang, 1994; Xin and Pearce, 1996; Lin and Si, 2010). Therefore, to study whether social capital drives farmers to adopt measures in China, we collected information on the number of relatives of a household (within three generations) who work in the township government or upper levels of government, which we then used as an indicator for social capital.

According to our survey data, households with stronger social capital are more likely to take adaptive measures. As shown in Table 5, there is a clear, positive correlation between households that adopt adaptive measures and the number of relatives that household has working in the government. For example, households that adopted adaptation measures had an average of 0.27 relatives working in government, which was more than twice as large as those without adaptation measures (0.13). Interestingly, the effort made by farmers to adopt these measures was also positively related to their social capital. Households that only adopted non-engineering measures had an average of 0.25 relatives working in the government, while those households that adopted both engineering and non-engineering measures had 0.47 relatives working in the government.

Table 5
Relationship between social capital and the adoption of adaptation measures by farmers.

	Average number of households' relatives (within 3 generations) worked in the government
Household without adaptation measures	0.13
Household with adaptation measures	0.27**
Of which:	
Only non-engineering measures	0.25*
Both types of measures	0.47***

Source: Authors' survey.
Note: The superscripts are *t* statistical test results. The comparing base is row 1 (Household without adaptation measures).
* Statistically significant at 10%.
** Statistically significant at 5%.
*** Statistically significant at 1%.

5. Econometric model and estimation results

5.1. Specification of econometric models

Since the descriptive statistical analysis did not control for the influence of other factors, it is difficult to separate the influences of early warning and prevention information, policy support, and social capital on farmers' adoption of adaptation measures to cope with drought. In addition, the personal characteristics of households, and the local socio-economic and physical conditions in the villages are likely to influence the adoption of adaptive measures (Deressa et al., 2009; Hassan and Nhemachena, 2008). Therefore, to better quantify the influences of different factors on farmers' decisions to adopt adaptation measures, based on our survey, we specified the following two econometric models:

$$R_{ij} = \alpha + \beta P_j + \partial S_{ij} + \gamma H_{ij} + \mu V_j + \theta D_k + \varepsilon_{ij} \quad (1)$$

$$M_{ij} = \sigma + \varnothing P_j + \rho S_{ij} + \vartheta H_{ij} + \delta V_j + \varphi D_k + \tau_{ij} \quad (2)$$

In model (1), R_{ij} indicates whether household i in village j adopt adaptation measure(s). This is a dummy variable with a value of 1 if a household adopts adaptation measures (either engineering or non-engineering measures), and zero otherwise. Model (2) is similar to model (1), but here the dependent variable is M_{ij}, which can take one of three values. If a household did not adopt any adaptation measures, M_{ij} is set to 1. If a household only adopted non-engineering measures, M_{ij} is set to 2, and if a household adopted both engineering and non-engineering measures, M_{ij} is set to 3.

The independent variables are defined as the follows. P_j is a vector with two policy related variables, the most interesting variables, measured at the village level: (a) whether or not a village received early warning and prevention information (or information service) and (b) whether or not a village received policy support. For (a), we use three dummy variables to measure the information service was information only provided before a drought (1 = yes; 0 = no); was information provided during a drought (1 = yes; 0 = no); and was information provided both before and during a drought (1 = yes; 0 = no). These three variables are compared against the option of no information being provided by the local government. For (b), there is one dummy variable, which is set to 1 if a village received policy support from the local government (e.g., technical, financial, or physical support), and zero otherwise. The variable S_{ji} represents the social capital status of a household, and is one of the interesting variables to be examined in this paper. To measure this variable, as defined in the previous section, we use the number of relatives a household has working within the government (within three generations).

In addition to policy and social capital variables, we include control variables to represent socio-economic and physical conditions for the households and villages, as well as a regional dummy variable that may possibly affect the adoption of adaptation measures by individual households. Here, H_{ij} is a vector of variables used to reflect the socio-economic characteristics of households, comprising the following: (1) crop type 1 for grain and 0 for non-grain crops; (2) farmland topography characteristics, measured as the ratio of hilly, sloped, and terraced to total cultivated land; (3) wealth, measured by the value of a household's durable consumption goods (RMB10,000); (4) family size; and (5) the age of the head of the household (in years). In addition, V_j represents the physical and socio-economic conditions of a village, including: (1) the reliability of the supply of surface water resources, measured as the ratio of the number of years with reliable surface water supply over 5, representing the past five years; (2) the reliability of the supply of groundwater resources, measured as the ratio of the number of years with reliable groundwater supply over 5; (3) soil types, which is either loam (1 = yes; 0 = no) or clay soil (1 = yes; 0 = no), and compared against the amount of sandy soil; (4) the economic development of the village, measured by the number of enterprises in the village; (5) the transportation infrastructure, measured by the distance from the village to the township government office (km); and (6) the characteristics of the village leaders, measured by the age of the village leaders (in years). In addition, we include a provincial dummy variable (D_k) to control for the influences of regional characteristics that do not change over time, but that may affect the adoption of adaptation measures among the provinces (k). In the model, α, β, ∂, γ, μ, θ, σ, $\varnothing$, ρ, δ and φ are parameters to be estimated, and ε_{ij} and τ_{ij} are random error terms, and are assumed to be subjected to independent identical distribution.

5.2. Estimation approach

Given the nature of the dependent variables, we used different estimation methods. As the dependent variable in model (1) is a dummy variable, a logit model is used to run the regression (Wooldridge, 2002). In model (2), the dependent variable measuring the adoption of adaptation measures is made up of three discrete values (1, 2, and 3), which represent three mutually exclusive and independent adaptation options. Considering the nature of this dependent variable, we apply the multinomial logit model (MNL) to estimate model (2). The major advantage of the MNL model is that it allows one to analyze the determinants of various choice possibilities (Wooldridge, 2002). For example, the MNL model has been used to analyze the choice of adaptation measures adopted by Ethiopian farmers in Africa (Deressa et al., 2009).

For both the logit and MNL models, the estimated coefficients reported in Table 6 reflect the direction of the influence of the independent variables on the dependent variable. The magnitude of the influence cannot be indicated by the coefficients. Therefore, based on the coefficient estimation, we computed the marginal effect of the key independent variables in the two models, as shown in Table 7.

5.3. Estimation results

The estimated results for models (1) and (2) show that the models perform well. The likelihood-ratio statistics for the two models are all significant at the 1% level, and passed the Chi square test (see Table 6). The pseudo R^2 is 0.0969 for model (1) and 0.1302 for model (2) (Table 6, row 22). These values are high enough for a multivariate analysis based on cross-sectional data. Furthermore, the sign of many household and village level control variables are consistent with our expectations, as well as being statistically significant. For example, in model (1), the sign of the crop type coefficient is positive and statistically significant. This implies that, after keeping all other factors constant, when grain is shocked by a drought, as compared to cash crops, farmers are more likely to take adaptation measures, particularly non-engineering measures (Table 6, row 6). The finding that grain is more sensitive to drought than cash crops is also consistent with other researchers' findings (Deng et al., 2006). The results also indicate that adaptation measures are more likely to be adopted in non-plain farmlands (such as hilly, slopes, and terraces) than plain farmland because of their higher vulnerability (Table 6, row 7, columns 1 and 2). Some physical and socio-economic conditions in the villages are also correlated with the farmers' decisions to adopt adaptation measures. For example, the coefficient for the groundwater

Table 6
Estimation results on the determinants of adopting adaptation measures by farmers.

		Model (1): Logit model	Model (2): MNL model (Control group: not adopting adaptation measures)	
		Adopting adaptation measures	Only non-engineering measures	Both types of measures
Villages received information				
1	Before drought only (1 = Yes; 0 = No)	0.844 (1.627)	0.838 (1.607)	1.165 (1.267)
2	During drought only (1 = Yes; 0 = No)	0.776 (1.247)	0.787 (1.257)	1.231 (1.207)
3	Both before and during drought (1 = Yes; 0 = No)	0.823* (1.928)	0.739* (1.730)	1.873** (2.410)
Villages provided policy supports				
4	Providing the supports (1 = Yes; 0 = No)	1.967** (2.454)	1.693** (2.083)	2.651*** (3.005)
Farmers' characteristics				
5	Social capital (number of relatives within 3 generations)	0.650** (2.010)	0.602* (1.853)	0.935** (2.435)
6	Crop type (1 = Grain; 0 = Cash crop)	0.720* (1.883)	0.781** (2.018)	0.339 (0.627)
7	Ratio of hilly, slopes and terraces over total cultivate land	0.635* (1.759)	0.627* (1.727)	0.656 (1.197)
8	Wealth (value of durable consumption) (10,000 RMB)	0.00747 (0.482)	0.00733 (0.470)	0.00909 (0.425)
9	Family size (population)	−0.0684 (0.832)	−0.0608 (0.736)	−0.175 (1.298)
10	Age of household head (years)	−0.0152 (1.069)	−0.0164 (1.149)	−0.00241 (0.106)
11	Education of household head (years)	−0.0110 (0.247)	−0.0115 (0.255)	−0.00438 (0.0625)
Villages' characteristics				
12	Surface water reliability	−0.0960 (0.226)	−0.0539 (0.126)	−0.507 (0.770)
13	Ground water reliability	1.514*** (2.825)	1.488*** (2.768)	2.041** (2.400)
14	Loam soil (1 = yes; 0 = no)	0.185 (0.544)	0.199 (0.580)	−0.0412 (0.0818)
15	Clay soil (1 = yes; 0 = no)	−0.0272 (0.0699)	−0.0185 (0.0473)	−0.0995 (0.134)
16	Number of enterprises in villages	0.109 (1.354)	0.114 (1.411)	0.0503 (0.419)
17	Distance from township government office (km)	−0.0471** (2.029)	−0.0497** (2.113)	−0.0272 (0.793)
18	Age of village leader (years)	−0.00463 (0.202)	−0.00246 (0.107)	−0.0288 (0.769)
19	Province dummy	Not reported	Not reported	Not reported
20	Constant	1.931 (1.306)	1.789 (1.207)	−0.656 (0.273)
21	LR chi^2	45.48	105.83	
22	Pseudo R^2	0.0969	0.1302	

Note: (1) Absolute value of z statistic in parentheses; (2) LR chi^2 value is calculated as LR chi^2 (22) in model 1 and LR chi^2 (44) in model; (3) Sample is 569.
* Statistically significant at 10%.
** Statistically significant at 5%.
*** Statistically significant at 1%.

Table 7
Marginal effects of provision of early earning and prevention information, policy supports and social capital on the adoption of drought adaptation measures by farmers.

	Model (1): Logit model	Model (2): MNL model		
	Adopting adaptation measures (Yes = 1; No = 0)	Not adopting measures (Y = 1)	Only non-engineering measures (Y = 2)	Both types of measures (Y = 3)
Villages received information				
Both before and during drought	0.089	−0.092	0.031	0.061
Villages provided policy supports				
Providing the supports	0.166	−0.163	0.114	0.049
Social capital				
Number of relatives within 3 generations	0.093	−0.091	0.079	0.012

Note: Only presents the marginal effects of key variables that are statistically significant.

reliability variable is positive and significant in all models (row 13), demonstrating that, after controlling for the influence of other factors, and increasing reliability of the groundwater supply can significantly enhance farmers' ability to adopt adaptation measures against drought. Moreover, the estimated results in Table 6 also show that the distance from the township is negatively correlated with farmers' ability to adopt adaptation measures (row 17), which may indicate the potential role of a rural infrastructure in adopting drought adaptation measures.

More importantly, the estimation results reveal that providing early drought warnings and prevention information significantly promote the adoption of adaptation measures by farmers. The estimated coefficients of the variables that represent the provision of information, both before and during a drought, are positive and significant in all models (Table 6, row 3). The results of model (1) demonstrate that providing early drought warning and prevention information, both before and during a drought, can play a significant role in helping farmers decide to adopt adaptation measures when facing a drought (column 1). The results of model (2) further show that the information service helps farmers to adopt both non-engineering measures (column 2) and engineering measures (column 3), as the estimated coefficient of the variable (both before and during a drought) is much larger in column 3 than column 2 (Table 6, row 3). According to the calculated results on the marginal effect, if local governments provide information both before and during a drought, the possibility of farmers adopting adaptation measures can increase by 8.9% (Table 7, row 1, column 1). Specifically, the possibility of adopting non-engineering measures rises by 3.1% (column 3), which is lower than the rate of adoption of the two types of measures together (6.1%, column 4).

However, our results also show that if information is provided only before or during a drought, the influence on farmers' adaptation behavior is not statistically significant, although it is still positive in all models (Table 6, rows 1 and 2). Therefore, although policies on providing early warning and drought prevention information can effectively encourage farmers to adopt adaptation measures, when information is only provided before or during the drought, the effectiveness of the information significantly decreases.

Furthermore, the estimate results show that offering technical, financial or physical support policies significantly facilitates farmers in adopting adaptation measures against drought. These policies not only foster farmers' application of non-engineering measures, but also significantly speed up the utilization of both engineering and non-engineering measures. In the estimated results of models (1) and (2), the coefficients of the technical, financial and physical policy support variables are all positive and statistically significant (Table 6, row 4). That is, after controlling for the influence of other variables, implementing technical, financial, or physical policy support significantly increases the possibility that farmers will adopt adaptation measures. Overall, the possibility of adopting these measures can be increased by 16.6%; 11.4% for non-engineering measures alone and 4.9% for both engineering and non-engineering measures together (Table 7, row 2). Therefore, from a policy point of view, governments should provide both early warning and prevention information to farmers and direct technical, financial, or physical support.

We also noted the importance of households' social capital to farmers' decisions to adopt adaptation measures. Based on the estimation results of both models (1) and (2), the coefficients of the social capital variable are positive and statistically significant in all models, implying that there is a positive relationship between social capital and the adoption of adaptation measures (Table 6, row 5). In other words, if households have more relatives working in the village, township or other upper level governments, their extensive social network allows them better communication with outside societies, as well as the possibility of receiving more help or advice on drought resistance. Therefore, they are more likely to adopt adaptation measures. If a household increases the number of such relatives by 1, the possibility for adopting adaptation measures increases by 9.3% (Table 7, row 3, column 1). In particular, the possibility of only adopting non-engineering measures increases by 7.9%.

6. Concluding remarks

Based on large-scale field surveys conducted in six provinces in China, this study examined crop farmers' practices when faced by drought and identified the major factors that affect farmers' decisions on whether or not to adopt adaptation measures against drought. The results show that, when facing a drought, the majority of farmers (86%) in China adopt non-engineering measures, while only 10% of farmers adopted engineering measures. In the case of non-engineering measures, changing agricultural production inputs and adjusting seeding or harvesting dates are two popular options. Some farmers also chose to enhance irrigation intensity, change crop varieties, plant drought resistant crops, or even to purchase crop insurance. Engineering measures adopted by farmers include those that can either increase the supply of irrigation water or improve the reliability or delivery efficiency of irrigation water.

Further analysis indicates that government policy support related to drought resistance can play an important role in help farmers to adapt measures. These supports include providing farmers with early warning and prevention information against drought and assistances in terms of direct technical, financial, or physical support. In addition, having a higher level of social capital in a farm household significantly increases their adaptation capacity against drought. However, it is also worth noting that our study focuses only on farmers' adaptation capacity against drought. We have not examined the impact of improving farmers' adaptation capacity on their crop production and income. The effectiveness and impact of policy support and social capital on farmers' agricultural production and livelihoods after implementing the different adaptation measures are important research issues for future studies.

The results of this study have several potential policy implications. First, there is significant room for the government in China to provide the early drought warning and prevention information to local villages and farmers. For example, in our study area, about two thirds of the rural village farmers have not received this information service. Second, China may need to continue to expand its policy supporting farmers in fighting drought, but it may also be worth examining the costs and benefits of the government direct policy support further, for two reasons. First, there is great potential to expand these activities in China, but this could also be expensive. In the study area, in recent years, only 5% of villages benefited from government assistance in terms of direct technical, financial, or physical support. While we did not have data on the cost of implementing these policies, in the field survey, we were told that the major reason for lower coverage of these supporting policies is budget constraints as direct policy support could be expensive.

Third, improving farmers' social capital is a way to help farmers increase their ability to adopt adaptation measures during droughts, and the government should pay particular attention to the farming communities, and farmers within a community who have a low level of social capital. While this study uses the number of relatives a household has working in the government as a proxy for social capital, the results should have general implications for other measures (e.g., exchanges and communication among farmers and farmers' cooperatives in rural China), which may raise farmers' social capital. The purposes of such measures are to transform the potential social capital into tangible social benefits, to increase the likelihood of adopting adaptation measures, and to improve the capacity of farmers to cope with drought.

Lastly, we believe that the results of this study also have implications for national adaptation plans for agriculture under climate change in other developing countries. Directly providing early disaster warning and prevention information to farmers, particularly small-scale farmers, in many developing countries is still not common. Given the rapid development of communication technology, the wide spread use of cell phones in rural areas, and the cost effectiveness of texting message to individual farmers, disaster information and prevention services in developing countries should be explored in more detail.

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