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How smallholder farmers adapt to agricultural drought in a changing climate: A case study in southern China

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ABSTRACT

Although the adaptation strategies of smallholder farmers to climate change and its attendant hazards have attracted widespread attention, the quantitative detection and evaluation of their adaptive behaviors remains a difficult task that deserves further study. This article describes an empirical case study performed in southern China to examine the adaptation strategies of paddy farmers to agricultural drought. We collected first-hand data through household questionnaires, in-depth interviews with local managers, and farm-level land-use surveys. The effectiveness of the adaptation approaches of the farmers was assessed in terms of the ecological, economic, and social benefits. Our findings indicate that over the past three decades, when confronted with recurrent seasonal drought in a warming climate, farmers have gradually abandoned the double-cropping rice production and transformed their cropping patterns into a new diversified mode of "Rice-Cole, rice, cotton, seedling nursery, and coarse cereals". Current farming practice reduces the vulnerability of local agriculture to drought, and allows farmers to diversify and improve their incomes, which contributes to enhanced resilience and adaptability to drought. However, the autonomous adaptation of farmers may primarily serve their interests of minimizing drought risk and maximizing economic profits but could also undermine the social benefits, such as regional grain security. A robust adaptation strategy should balance the ecological and economic benefits with social interests to maintain agricultural sustainability.

1. Introduction

Agriculture, owing to its inherent exposure, is highly sensitive to climate change, particularly to climatic extremes such as drought. A changing climate may increase the possibility and intensity of drought (IPCC, 2012), thus elevating the potential risk to agricultural production. Given that even the most rigorous mitigation efforts cannot forestall the additional impacts from climate change (IPCC, 2007; Esham and Garforth, 2013), it is critical to identify and evaluate possible adaptation options to both climate change and its attendant droughts in the coming decades (Smit and Skinner, 2002; Howden et al., 2007). When drought occurs, the agricultural sector is usually the first to be affected. The economic costs of drought can be enormous, and the adverse impact can last for months or even years (Pandey and Bhandari, 2009; Conway and Schipper, 2011). Drought can cause crop failure, reduce yield, and increase the cost of production (Lei et al., 2011), leading to income shortfalls for farmers and aggravating rural poverty (Siwar et al., 2009). Therefore, exploring adaptation strategies to the expected increase in droughts has become a critical issue for poverty reduction and agricultural sustainability.

In recent years, the adaptation strategies of farmers to both climate change and drought have been explored in many ways. For example, farmers use a variety of drought adaptation strategies, including the choice of cropping patterns (Pandey et al., 2007) and diversifying crop varieties (Howden et al., 2007; Anik and Khan, 2012). In Ethiopia and South Africa, farmers adapted to climate change by adopting new crop varieties (Deressa et al., 2009), altering planting dates, and migrating seasonally (Bryan et al., 2009). In Europe, farmers were inclined to redesign their cropping systems to cope with climate-induced drought, such as introducing new crops with higher water use efficiency (Huntjens et al., 2010) and reducing water consumption through crop rotation (Willaume

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et al., 2014). Farmers can also adapt to climate change and drought by adjusting their livelihood activities. For example, a case study in China (Sun et al., 2012) suggested that the drought impact on farmers can be alleviated through diversifying both on- and off-farm activities. Another empirical research showed that, in Africa, farmers responded to climatic change by disconnecting their sources of income from climate-dependent activities, and relying more on non-farm income (Ifejika Speranza and Scholz, 2013).

These studies indicate that the impacts of climate change and drought on the agricultural sector could be reduced if farmers take appropriate adaptation strategies. However, little is known about what type of adaptation is appropriate and feasible for farmers. Or rather, what are the possible principles or criteria to assess the effectiveness of the methods of adaptation to drought used by farmers? Although there have been efforts to evaluate the adaptive capacity of farmers to climate variability and change (Benegas et al., 2009; Marshall et al., 2009) and to explore the factors affecting the adaptation choices to climate change that farmers make (Deressa et al., 2009; Raymond and Robinson, 2013), there are relatively few studies that quantitatively detect the adaptive process of farmers and evaluate its effectiveness. To address these knowledge gaps, more empirical studies, particularly at the rural community level, are required.

Based on an empirical case study in southern China, this article attempts to examine the adaptation process to agricultural drought of paddy farmers and to quantitatively evaluate how their adaptive behaviors facilitate drought risk mitigation and rural socio-economic development. We collected first-hand data through household surveys, in-depth interviews with local managers, and a land-use survey at the farm plot level. We tentatively assessed both the effectiveness and deficiency of the adaptation to drought implemented by farmers in terms of the ecological, economic, and social benefits. Finally, we presented discussions and conclusions on the vulnerability, resilience, and adaptability to agricultural drought of farmers, as well as the policy interventions required to facilitate more robust adaptation strategies. Our findings not only will be of interest to the regional policy makers, but they can also provide useful insights into how to effectively reduce the vulnerability of farmers and to enhance their long-term resilience and adaptability to climatic extremes within the broader context of climate change.

2. Materials and methods

2.1. Study area

In China, frequent and widespread droughts cause serious losses to the agricultural economy almost every year (Lei et al., 2011). Even in a humid zone such as Hunan Province (Fig. 1a) in southern China, which is a primary region of rice production, drought has become a recurrent phenomenon and a dominating constraint on agricultural production. Seasonal drought in this region has frequently disrupted the supply of irrigation water for paddy fields and posed a substantial threat to the livelihoods of farmers (Sun et al., 2012). However, compared with the continuous concerns over drought problems in arid and semi-arid areas, the nature of drought in humid regions, its impact on local agriculture, and the adaptation strategies of farmers have not been adequately studied.

We selected the Nanshan Village as our study area, which is located in the drought-prone Dingcheng County in southern China's Hunan Province (Fig. 1). The rough terrain makes it difficult and costly to construct sizable reservoirs or water collecting facilities, so the performance of local agriculture depends largely on the weather. Despite a relatively high annual rainfall of 1300–1400 mm, the Nanshan Village has historically suffered from frequent droughts, especially in autumn, with deficient rainfall but a high water demand of crops such as paddy rice. Therefore, this village is a good site for performing a case study of investigating the impact of drought and the adaptation strategies of farmers.

Over the past half century (1960–2012), regional climate has experienced a noticeable warming and drying trend (Fig. 2). The amount of precipitation exhibits a distinct annual fluctuation, with a slight rising trend during the 1980s and 1990s, but an obvious downward trend in recent decades. Since the 1970s, there has been a warming trend in the annual average temperature, and the rate of temperature increase has been more striking in recent years. At the same time, the relative humidity has clearly declined, and the annual high temperature has increased.

2.2. Field studies

In April 2013, we conducted a field survey in Nanshan Village and its surrounding areas to examine: a) how a changing climate and the recurrent drought may affect local agriculture and b) how the paddy farmers are likely to adapt to droughts. We collected first-hand information through in-depth interviews with local managers, questionnaire surveys on farmer households, and a land-use survey at the farm plot level.

2.2.1. In-depth interviews with local managers

We performed face-to-face interviews with the current and former village managers to obtain an overall understanding of the village characteristics. We interviewed five of the managers, and three experienced managers were selected as our key informants for more in-depth interviews. The open-ended questions were meant to obtain information about: (1) historical drought, including the frequency, intensity, and impact of drought in past decades; (2) measures taken to resist and recover from the impacts of drought, particularly when confronted with some severe droughts that caused huge yield losses and economic costs; (3) the evolution history of the local agriculture, including changes in land-use, cropping patterns, and crop varieties.

2.2.2. Household surveys

Semi-structured questionnaires were held with farmer households to explore the real impacts of climate change and drought on the local agriculture by collecting first-hand information from the farmers on their agricultural production and adaptation actions to drought. Questions asked were divided into three parts: (1) basic household information, including the demographic information of family members, and economic income from both on- and off-farm activities; (2) detailed information on crop production, particularly the inputs (including seeds, fertilizers, pesticides, irrigation, machinery, etc.) and the outputs (yield and market price) of crops, such as paddy rice, cotton, cole, etc.; (3) the impacts of drought on their crop production and livelihood, and the measures taken to offset the impacts of drought.

2.2.3. Land-use survey at the farm plot level

Detecting and measuring the changes in land-use and cropping patterns, especially at the farm plot level, is an essential approach to understand adaptation processes to drought adopted by the farmers. We used the methods of Participatory Rural Appraisal (PRA) (Overmars and Verburg, 2006; Mertz et al., 2010) and participatory mapping (López-Marrero and Tschakert, 2011) to record the changes in land-use and crop varieties for each piece of farmland in Nanshan Village. A high-resolution satellite image of the village (from Google maps: http://maps.google.com/; recorded in June 2012) was used as our base map.

With the help of village managers, we called together local farmers and asked them to identify and locate their own residential