Science of the Total Environment 550 (2016) 192–199

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

How rural land use management facilitates drought risk adaptation in a changing climate — A case study in arid northern China

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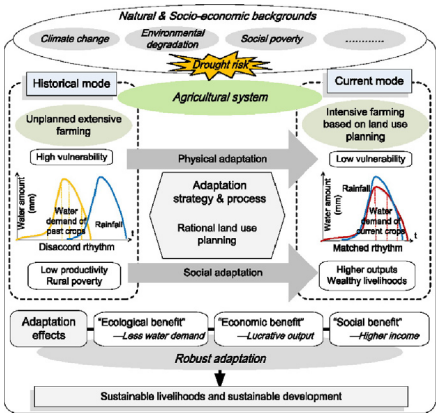
HIGHLIGHTS

- We provide an empirical farm-level case study with a set of feasible methodologies.
- Rational land use planning can be an effective adaptive strategy to agro-droughts.
- A robust adaptation should balance the ecological and economic benefits with social interests for agricultural sustainability.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 July 2015
Received in revised form 15 January 2016
Accepted 15 January 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Climate change
Drought risk
Land use management
Adaptation
Agricultural sustainability

ABSTRACT

Under a warming climate, frequent drought and water scarcity in northern China have severely disrupted agricultural production and posed a substantial threat to farmers' livelihoods. Based on first-hand data collected through in-depth interviews with local managers and farmer households, this study evaluated the effectiveness of rural land use management in mitigating drought risk, ensuring food security and improving farmers' livelihoods. Our findings indicate that a) reforestation on low-yield cropland not only can improve the eco-environment but can also prominently mitigate the production risk to local farmers; b) replacing the traditional border irrigation with sprinkler irrigation has substantially curbed agricultural water usage and increased the per unit of output; and c) in recent years, instead of planting water-intensive grain crops, local farmers cultivated more forage crops to raise animals, which greatly diversified their income sources and reduced the drought risk of agricultural production. By performing an empirical case study in drought-prone Inner Mongolia, this study provides decision-makers with insights into how to strategically adapt to drought risk and reduce rural poverty within the broader context of climate change.

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http://dx.doi.org/10.1016/j.scitotenv.2016.01.098
0048-9697/

1. Introduction

In the context of climate change, frequent drought and water shortage have been global concerns for many years. While the human population and associated demands for freshwater resources are increasing, intractable drought can put global food security at risk (Dai, 2011; Mu et al., 2013). Even worse, it is very likely that the noticeably warming climate in recent decades may increase the possibility and intensity of drought (IPCC, 2007). In northern China, which has a dense population and a vulnerable natural environment, recurrent droughts have severely afflicted rural residents (Ye et al., 2012) and threatened regional food security (Liu et al., 2008; Lei et al., 2011). Additionally, drought can directly or indirectly affect social and economic sustainability (Alam et al., 2012). For example, drought may cause crop damage, low productivity and high production cost, which lead to income losses for farmers and increased poverty (Siwar et al., 2009; Alam et al., 2011). Thus, it is essential to explore solutions that effectively address drought risk mitigation and rural poverty reduction for agricultural sustainable development.

Recently, specific adaptation strategies that aim to mitigate the impacts of climate change and drought on agriculture have been explored. In particular, the role of land use management in drought risk mitigation has been widely discussed in the literature. Some studies indicated that under a certain level of meteorological drought, inappropriate land use practice may aggravate the drought impact on local agriculture (UN/ISDR, 2011), whereas rational land use management can play a positive role in reducing disaster losses (Tang et al., 2008; Fu et al., 2013). In Malaysia, long-term land use management was required to cope with climate change (Alam et al., 2012). In South Africa, farmers' adaptation strategies to climate change and drought have included the introduction of better-adapted crop varieties (Deressa et al., 2009), altered planting dates, and changed farming types (Bryan et al., 2009). A case study in China (Zhou et al., 2014) revealed that over the past decade, the government tried to adapt to climate change and drought by implementing a nationwide reforesting project, which has produced noticeable environmental benefits.

However, these adaptation measures (e.g., large-scale reforestation and land use pattern changes) may also trigger some adverse effects, such as economic insecurity, unsustainable livelihood for farmers (Warner et al., 2010) and social problems (Zhou et al., 2014). Additionally, given that previous research has been largely based on theoretical arguments and qualitative evaluations, it is uncertain which adaptation strategies can effectively reduce the vulnerability of agriculture to drought and facilitate rural farmers' livelihoods and social-ecological development. In other words, when confronted with the potentially warmer climate and persistent drought in the future (Lobell et al., 2008; Xiong et al., 2010), which agricultural practices are environmentally friendly, economically feasible, and sustainable in the long-term?

Based on an empirical study of a drought-prone region that is located in arid Inner Mongolia in northern China, this study attempts to examine sustainable farming practices that would facilitate future agricultural policy and decision-making. The remainder of the paper is organized into four sections. In Section 2, we introduce the basic materials and methodologies used in this study. In Section 3, we present the main results and the preliminary analysis of the case study. In Section 4, we discuss possible solutions of linking drought risk adaptation with rural poverty reduction and the broader implications for future agricultural policy options. Section 5 concludes the key findings of the research. We hope that this study provides decision-makers with information on climate change adaptation and drought mitigation actions and it will be beneficial to reduce the vulnerability of local agriculture and enhance farmers' adaptability to climatic extremes within the broader context of climate change.

2. Materials and methods

2.1. Study area

Xinghe County in Inner Mongolia is located in the arid monsoon and non-monsoon division regions in northern China (Fig. 1(a), (b)), which is a typical drought-prone area that is highly sensitive to climate change. The region has an annual average precipitation of 379 mm, whereas the average evaporation is over 2000 mm. Due to its monsoonal climate, the seasonal and inter-annual fluctuations in precipitation are striking. For instance, the historically highest rainfall in the region was 630 mm, whereas the lowest was only 237 mm, which suggests that the area is very sensitive to drought. In this study, we selected Youyi Village in Xinghe County as our study area (Fig. 1(c)) because it is one of the most arid villages. The prolonged droughts have resulted in a degraded environment, uncertain livelihoods and long-lasting poverty for the local farmers.

Over the past half century (1960–2011), the regional climate has experienced a noticeable warming trend (Fig. 2). The precipitation exhibits a slight downward trend with high inter-annual variations, while the annual average temperature exhibits an upward trend, particularly in the last decade, which resulted in high evaporation and recurrent meteorological drought. The frequent droughts have resulted in serious water scarcity, and drought-induced losses persistently threaten regional grain security and local farmers' livelihoods.

To mitigate the prolonged drought and protect the natural environment, the Chinese government launched a nationwide program called "Grain for Green" (GfG) in 2000 (Zhou et al., 2009). Since then, the central and local governments have provided a large amount of subsidies to encourage farmers to plant trees instead of crops in their low-yield sloping farmland. Farmers in Youyi Village actively responded to this program and gradually abandoned their crop production on steep slopes. At the end of 2012, a large area of artificial forests existed in Youyi Village (Fig. 1(d-1)), which greatly improved the ecological environment and alleviated the impact of drought on the local agriculture.

In this region, another measure to deal with drought is the development of water-saving irrigation. This initiative aims to shift drought management from securing reliable water sources to improving irrigation efficiency (Sun et al., 2012). After 2001, farmers in Youyi Village began to introduce sprinkler equipment and developed sprinkler irrigation circles (Fig. 1(d-2)). Recently, the impact of droughts on local agriculture has been significantly alleviated, and the land productivity and farmers' incomes have improved dramatically. However, it is still unclear how these changes in land use and irrigation modes contribute to the alleviation of drought impacts and the improvement in farmers' incomes. The detailed advantages and disadvantages of these changes require more empirical analysis and case studies. This research attempts to address these questions by conducting an in-depth field investigation.

2.2. Field studies

From May to June 2013, we conducted a field survey in Xinghe County, Inner Mongolia to examine: a) how the changing climate and recurrent droughts may affect local agriculture and b) how the government and farmers are likely to cope with droughts. Furthermore, we chose Youyi Village, a drought-prone area, to perform a detailed investigation. We collected first-hand data through in-depth interviews with local managers, questionnaire surveys on farmer households, and farm-level land use surveys.

2.2.1. Personal interviews with local managers

First of all, we performed face-to-face interviews with village managers to obtain an overall understanding of Youyi Village. We visited all the village managers and chose three experienced senior leaders as our key informants. The open-ended questions for the informants