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Analysis

Farmers' Adaptation to Climate Change, Its Determinants and Impacts on Rice Yield in Nepal

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ABSTRACT

This paper explores the factors that influence farmers' decision-making in adopting climate change adaptation strategies and how these adaptations impact on farm yields. We employ a simultaneous equations model to investigate the differential effects of adaptation on adapters and non-adapters. An endogenous switching mechanism is employed to account for selectivity bias. Based on a survey of 422 rice farmers in Nepal, our results show that farmers' education, access to credit and extension services, experience with climate change impacts such as drought and flood, information on climate change issues, belief in climate change and the need to adapt all variously determine their decision-making. We find that the adaptation strategies employed by farmers significantly increase rice yields. Furthermore, results indicate that both adapters and non-adapters would benefit from the adaptation of the identified strategies. This study, therefore, provides supportive evidence for policy makers to take into consideration farmers' existing knowledge and skills in adapting to climate change. The findings show that it is imperative to involve farmers in climate change adaptation planning processes if the full benefits of such policy action are to be realized.

1. Introduction

There is a growing consensus that the impact of climate change has a highly negative effect on the agriculture sector and that farmers in least developed and developing countries are the hardest hit (Bandara and Cai, 2014; Kahsay and Hansen, 2016; Parry et al., 2004; Schellnhuber et al., 2013; Wheeler and Von Braun, 2013). Studies indicate that even moderate increases in temperature will have negative impacts on the major cereal crops including rice, maize and wheat (Knox et al., 2012; Morton, 2007; Sarker et al., 2014). Also, the literature indicates the crucial need to enhance farmers' adaptive capacity (Huq et al., 2004; Seo, 2011) which requires a better understanding of adaptation strategies and the implications of such adaptations in farm productivity (Di Falco and Veronesi, 2013). While a significant body of research exists to assess the impact of climate change on agriculture and adaptation strategies, further research is needed to understand whether farmers' adaptation strategies support farm productivity.

While climate-induced yield loss in agriculture is becoming a serious concern, some studies indicate that agriculture might benefit from future climate change if suitable adaptations are implemented (Di Falco et al., 2011; Dixon et al., 2003; Kabir et al., 2017; Kahsay and Hansen, 2016; Reid et al., 2007; Tingem and Rivington, 2009). Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Adaptations are categorized according to various criteria, including the planning horizon (short-term or long-term), timing (reactive or anticipatory), form (technical, institutional, legal, behavioral or educational), and actors involved (private or public) (Füssel, 2007; Smit and Skinner, 2002). Adaptations are further distinguished between autonomous adaptations - which occur in a system as a matter of course - and planned adaptations which require or result from deliberate policy decisions (Smith et al., 2000). Stage (2010) distinguishes between autonomous adaptation-decisions made by private firms and households and planned adaptation where decisions are made by government bodies.

Smallholder farmers in many least developed and developing countries have been making adjustments in their management practices in response to climate change impacts. These adaptations are of an autonomous nature, defined as the ongoing implementation of existing knowledge and technology by farmers themselves, in response to experienced changes in climate (Leclère et al., 2013). From the viewpoint of food security, it is important to investigate whether such autonomous adaptations enhance farm productivity.

A number of studies have analyzed the benefits of adaptation on crop yield. However, many of them took into account only a few

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adaptation strategies (Waha et al., 2013) and were focused on the global, regional or national level (Challinor et al., 2014). Such studies have been crucial to planning adaptation strategies at a macro level. However, studies focusing on community, household and farm level are necessary to identify and design effective adaptation strategies at the local level. Moreover, few studies have assessed the impact of adaptation on farm productivity taking into account the actual adaptations adopted by farmers (Di Falco et al., 2011; Huang et al., 2015). Di Falco et al. (2011) examined the impact of adaptation on farm household food productivity in Ethiopia finding that adaptation increases food productivity and that the farm households that did not adapt would benefit the most from adaptation. Huang et al. (2015) found that adaptation to extreme weather events through adjustments in farmers' management practices significantly increases rice yield in China.

There exists ample literature on farmers' adaptation to climate change in developing countries (Alam et al., 2016; Alauddin and Sarker, 2014; Kabir et al., 2017; Ngigi et al., 2017). However, one of the challenges in studying adaptations in small scale farming is the identification of true adaptation, as many changes in agricultural management and technology do not necessarily represent this (Huang et al., 2015; Lobell, 2014). As well, adaptation in agriculture varies across countries. Farmers practice different adaptation strategies depending on the varying climatic, social, economic and institutional factors (Below et al., 2012; Deressa et al., 2009). For these reasons information on the implications of actual adaptation used by farmers on crop yields will be useful for effective adaptation planning.

In this study, we assess the actual adaptations adopted by farmers in rice farms and examine the impacts on rice yields. More specifically, we assess the strategies that rice farmers adopt to minimize the negative impact of long-term changes in climatic conditions, factors affecting farmers' decision to adapt and investigate the impact of adaptation strategies on rice yield in Nepal. We employ a simultaneous equations model with endogenous switching to take into account selectivity bias and to investigate the differential impact of adaptation on adapters and non-adapters. To identify true climate change adaptations, we link the farmers' adjustment in farm management with particular climate change impacts in rice production. More precisely, we asked farmers whether they have noticed any changes in the local climatic condition, and if yes, what have been the impact of such changes on rice production, and what specific adjustments were made to deal with these changes. Understanding the determinants of farmers' actual adaptation to climate change and implications for crop productivity seem particularly relevant because many least developing countries including Nepal are in the process of designing and implementing climate change adaptations.

2. Background and Data

2.1. Background

Nepal is a small country covering an area of 147,181 km^2, broadly divided into three ecological regions. They are the Terai, the Hill and the Mountain. The Terai constitutes 23% of total land area of which about 38% is cultivated and is of relatively high agricultural potential. This region largely consists of flat land that extends from 60 m above sea level (masl) up to 500 masl. The most important crops grown are rice, wheat, maize and oilseeds. It is relatively better off than the other two regions in terms of social and economic infrastructure development. The Hill region constitutes 42% of total land area of which about 15% is cultivated. The region comprises steeply sloped lands with several small valleys and is in the range of 500 to 2500 masl. Maize and rice based cropping systems are predominant. The rice based cropping system is generally practiced in wetlands and maize based cropping system in drylands. The Mountain constitutes 35% of the total land area of which about 4% is cultivated. The region ranges in altitude from 2500 to 8848 masl and consists of steeply sloped lands and snow covered mountains with few valleys. Barley, buckwheat and potato are the major staple crops with livestock also playing an important role.

In Nepal, agriculture has historically been a dominant sector, contributing about 35% of total gross domestic product and employing 70% of the population (MoAD, 2012). Rice is one of the most important staple crops. It is grown by 76% of agricultural households (Sanogo and Amadou, 2010) and covers about 1.4 million ha which comprises 46% of the cultivated land (MoAD, 2012). Although rice has special significance and economic importance for Nepal, growth in production and productivity have been poor and prone to fluctuations (MoF, 2013). The average rice yield is 3.17 t/ha (MoAD, 2012) which is low compared to other South Asian countries.

Nepalese farmers grow rice under uncertain environments where rain-fed farming accounts for nearly two-thirds of total cultivation (MoAD, 2012). Prolonged droughts and unseasonal rains have a substantial effect on rice farming in Nepal. For example, due to unfavorable weather conditions, nationally the area under rice cultivation and production fell by 7.2% and 11.3% respectively in 2012/13 compared to the previous year (MoF, 2013).The extent of variability is illustrated by the severe drought in 2006 which produced a 13% reduction in the rice area planted (Gumma et al., 2011). A number of studies have indicated that there is significant potential to enhance rice productivity in developing countries (Alauddin and Sharma, 2013; Huang et al., 2015). Thus in view of the critical importance of rice to the Nepalese economy and its sensitiveness to climate change impacts, it is of particular importance to identify and adopt climate change adaptation strategies that could increase rice productivity.

The existing literature on the effects of climate change on Nepal's agriculture sector focuses on three areas. First, a number of studies analyze temperature and rainfall trends (Practical Action, 2009; Shrestha et al., 2000; Shrestha et al., 1999). The second category of studies focus on assessing the impact of climate change on the agriculture sector output (Eriksson et al., 2009; Malla, 2009) and the third area is the identification of adaptation practices (Chhetri et al., 2012; Maraseni, 2012; Nayava, 2010). An important issue that has been largely ignored in the literature is the link between climate change adaptation and farm productivity. Nepal is in the process of planning and implementing local and national adaptation programs and plans. This study is therefore timely in providing data which can assist policy makers in designing and promoting practical and robust adaptation strategies.

2.2. Data

This research was conducted in two major rice producing regions: the Terai and the Hill. Administratively, the country is divided into 75 districts. In this research, two districts from each of the two ecological regions were selected: Kaski and Dhading from the Hill region and Chitwan and Rupandehi from the Terai region. The field study was conducted by means of randomly selecting two village development committees (VDCs)[1] in each district. The unit of analysis is the farming household, which is the decision making unit in the agricultural production process.

The selection of farming households from the VDC involved two steps. First, four wards in each VDC were selected randomly. We obtained a list of households in the selected wards from the office of the VDC. Then we identified households involved in farming in each randomly selected ward. In the next step, we selected farming households from each ward through simple random sampling. We contacted households' heads and asked about their availability and interest in participating in the survey. We selected 15 households from each ward, producing a total sample size of 480. Of these 58 were not involved in

[1] A VDC is an administrative unit in Nepal similar to a municipality which is further divided into nine wards. Each ward constitutes one to several villages.