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A general equilibrium assessment of climate change–induced loss of agricultural productivity in Nepal

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ABSTRACT

The impact of climate change on agriculture has been one of the most discussed topics in the literature on climate change. Multi-regional computable general equilibrium (CGE) models have frequently been used to examine the impact of climate change on agriculture. However, these studies do not focus on country-specific issues related to the link between climate change and agriculture. This paper aims to address this gap by investigating the economy-wide impacts of climate change on Nepalese agriculture. Nepal makes an interesting case study as it has one of the most vulnerable agricultural economies in South Asia. This paper develops a comparative static multi-household CGE model to trace the direct and indirect impacts of climate change in Nepal. The results suggest that climate change has a significant negative impact on the overall Nepalese economy due to the induced loss of agricultural productivity. The results further reveal that rural households in Nepal, whose livelihoods primarily depend on subsistence farming, will face additional climate change–induced stresses due to already overstrained poverty and a weak social welfare system. The results indicate an urgent need to mainstream adaptation strategies to lessen the negative impacts of any climate change–induced loss of agricultural productivity in Nepal.

1. Introduction

A substantial volume of the literature on climate change brings attention to two major issues. First, human-induced climate change is unavoidable and is predicted to have a significant negative impact on many developing economies. Besides having consequences on the environment, climate change affects the resources that human life depends on. Importantly, the current and future impacts of climate change directly affect the welfare of the poor and vulnerable by damaging physical resources such as shelter and infrastructure through the increased frequency of flooding, storms and climate-related disasters (Garnaut, 2013; Nelson and Shively, 2014).

Second, agricultural systems are heavily affected by negative impacts of climate variability, such as rises in annual temperature, erratic rainfall patterns and dimmed solar radiation, resulting in a decline in agricultural productivity. Extreme events, especially floods and droughts, have significant negative impacts on South Asian crop productivity and food supply (Bandara and Cai, 2014, p. 452), which ultimately imposes upward pressure on food prices. The inclusion of food security features in the Paris Agreement as a part of a global climate change accord (UNFCCC, 2015, p. 20) not only confirms climate change impacts on food productivity but also presents challenge for maintaining food supply and demand in this over-populated part of the world (UNFCCC, 2015, Article 2b, p. 21).

Recent studies (eg., Cai, Bandara, and Newth, 2016; Chhetri, Chaudhary, Tiwari, and Yadaw, 2012; World Bank, 2012) agree that agriculture in South Asia is in a poor state due to anomalous floods, prolonged droughts, large-scale landslides and frequent and severe thunderstorms. Given the important contribution of agriculture to employment and people's livelihoods in South Asian countries, the loss of agricultural productivity due to climate change is of social and economic concern. Many other economic sectors besides agriculture are likely to experience the impacts of climate change, with negative effects on households' income and consumption. As a consequence of these threats, climate change imposes additional stresses to the social and economic challenges that the poorest households already face (IPCC, 2013). This situation accelerates their vulnerabilities as their livelihoods depend on climate-sensitive natural resources and their social welfare systems are weak. As a result, climate change increases their chances of falling into a cycle of poverty from which it is difficult to escape.

Of the countries in South Asia, Nepal is expected to be one of places

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most vulnerable to climate change. With regard to climate change parameters in Nepal, the regional climate-model projections show temperature increases of 1.6°C–2 °C by 2030, 2.3°C–2.9 °C by 2050, and 3.4°C–5.0 °C by 2080 (Ahmed and Suphachalasai, 2014). If, as expected, agricultural productivity is significantly affected, this could have severe negative impacts on the Nepalese economy due to the crucial role of agriculture in household income and consumption. Agriculture generates around 74% of total employment in Nepal, contributing an average of 36% of gross domestic product (GDP) and at least 30% of exports (CBS, 2014).

Although there is clear evidence that Nepal is highly vulnerable to climate change, few detailed studies have examined the effects of climate change on agricultural productivity in Nepal within a partial equilibrium modelling framework (eg., Chalise, Maraseni, and Maroulis, 2015; Joshi, Maharjan, and Piya, 2011; Poudel and Kotani, 2013). Of those that have, it has been found that agricultural productivity in Nepal is likely to be severely affected by climate change. However, these studies have three important limitations. First, their results are skewed towards individual perceptions and practices, and the uncertainty and long timeframes associated with climate change limit the findings. Second, most of these studies emphasize crop production as a major factor in partial equilibrium analysis (Elbehri and Burfisher, 2015), and disregard the direct and indirect linkages with the overall economy. Third, none of these studies look at climate change in relation to disparities between households in terms of income and expenditure.

There are a few studies on the economy-wide impacts of climate change on agriculture. For example, Hertel, Burke, and Lobell (2010) employed a Global Trade Analysis Project (GTAP) model to evaluate the climate change–poverty nexus on a global scale. They found that the economic inefficiencies that are likely to be induced by climate change will impose extra trade imbalances in South Asian countries. Similarly, Bandara and Cai (2014) and Cai et al. (2016) attempted to evaluate the impacts of climate change on food crop productivity and provided a framework for an integrated assessment of food production economies in South Asia. Both studies claimed that unfavourable climate change is likely to exert upward pressure on food prices, which ultimately threatens food security in South Asia. Although the above mentioned studies attempted to assess climate change impacts on agriculture using global general equilibrium frameworks, the results are generalized for all South Asian countries. As such, they do not address country-specific climate change issues and impacts. More country-specific climate change studies are needed to investigate climate change–induced effects on agriculture and income distribution in vulnerable developing countries such as Nepal. There is clearly a gap in current literature for a specific study on Nepalese agriculture.

To this end, the main objective of this paper is to examine the economy-wide impacts of climate change–induced productivity loss in Nepalese crops. The rest of the paper is organized as follows: Section 2 provides a brief literature review on climate change and agricultural productivity in Nepal; Section 3 outlines the methodology, including the empirical model and framework; Section 4 presents the simulation results; and Section 5 discusses policy implications and offers some concluding remarks.

2. Climate change and agricultural productivity in Nepal: a brief overview of literature

Understanding climate status and its relationship with agricultural productivity is central to assessing the impacts of climate change on a particular crop. Moreover, it assists with the design of a framework of overall impacts on the Nepalese economy. Since agricultural productivity in Nepal primarily depends on seasonal rainfall patterns (the system of rain-fed farming dominates, at around 85%), precipitation is a major factor that influences crop yields. Monsoons, in particular, provide around 80% of the annual rainfall (CBS, 2014). Although mean annual precipitation varies within the country and there is no definite trend in aggregate precipitation, there is evidence of extreme precipitation in Nepal. For example, in 2006, the mid-western lowlands (Terai) experienced heavy rains with flash floods, which damaged standing crops and reduced production by 30% (Pokhrel and Thapa, 2007). At the same time, the eastern part of Nepal faced extreme drought, which led to a decrease in rice production of 30% and a reduced crop production of 12.5% on a national basis (Malla, 2008). As a late or erratic monsoon quickly turns into crop damages and subsequent food insecurity, climate change influences large- and small-scale farming systems and brings about significant changes in crop-growing seasons, crop-growth cycles and cropping patterns.

Another important cause of productivity loss is temperature rise, as heat waves impact the physiology of plants. Moreover, scientists have confirmed that an increase in temperature plays a great role in changing precipitation. Temperature records of Nepal from 1977 to 2009 show a general warming trend, with a 0.06 °C increase in average annual temperature (Chalise, 2012). Some models predict an increase in temperature over Nepal that ranges from 0.5 °C to 2.0 °C in 2030 (NCVST, 2009). NAPA (2010) also suggests that days and nights are likely to become warmer than in the past. Specifically, the results of global circulation models (GCMs) suggest that the number of extremely hot days per annum (based on the hottest 5% of days for the period 1970–1999) will increase by up to 55% by the 2060 s and 70% by the 2090 s (NCVST, 2009). Cline (2007) has projected temperature and daily precipitation in Nepal for 2080. The projections reveal that the daily temperature and daily precipitation in the monsoon months (June, July and August) is expected to increase markedly. This is likely to result in flash floods and landslides which will damage the agricultural system in Nepal.

Table 1 summarises a comprehensive literature survey on climate change impacts on Nepalese agriculture. According to Joshi et al. (2011), a time series regression analysis of 1977–2008 (see Table 1)

Table 1
Comprehensive literature survey on climate change impacts in Nepalese agriculture.
Source: Chalise and Naranpanawa (2016)

Source	Methodology	Crop	Productivity change (%)		
Kumar and Parikh (2001)	Regression on net farm revenue	All	-8.4 (Projection in Indian crops- as of +2^{o}C)		
Cline (2007)	Integrating all models	All	Without carbon fertilization = -17.3 With carbon fertilization and adaptation = -4.8		
Iglesias and Rosensweig (2010)	Crop simulations on the basis of carbon dioxide emission scenarios[a]		2020	2050	2080
		Rice	-2.23	+2.70	+6.67
		Wheat	-7.55	+9.58	+9.37
		Maize	-7.75	-10.91	-4.98
Hertel et al. (2010)	General equilibrium analysis based on GTAP		Low	Medium	High
		Rice	-15	-5	+4
		Wheat	-10	-3	+4
		Maize	-17	-10	-3
Joshi et al. (2011)	Time Series Regression (1977-2008 as of +2^{0}C)	Rice	+1.7		
		Wheat	+2.32		
		Maize	+1.49		
Knox et al. (2011)	Crop models		2020	2050	2080
		Rice	-2		32
		Wheat	-60 (Indian crops)		
		Maize	+10 (other South Asian countries)		
Bandara and Cai (2014) and Cai et al. (2016)	Systematic literature review on all models	Rice	-2		
		Wheat	-13.7		
		Maize	-17(2030 projection)		

[a] The data are available for different CO_2 emission scenarios of SRES (IPCC, 2000). The A2 scenario is employed for this study.