Agricultural production, irrigation, climate change, and water scarcity in India

By

Farzad Taheripour, Thomas W. Hertel, Badri Narayanan Gopalakrishnan, Sebnem Sahin, and Jorge J. Escurra

Introduction

It is frequently acknowledged that the economy of India and in particular its agricultural sectors will face serious water challenges over the coming decades (e.g. Rosegrant et al., 2013 and Rodriguez et al., 2013). Population growth coupled with economic growth of nearly 7% per year to 2035 will translate into strong growth in food demand, crop production, and demand for water for irrigation. Growing demand for irrigation, when coupled with industrial, residential, and commercial demands for water, is projected to result in intense competition for water in India. However, the intensity of this competition will not be uniform across different Agro Ecological Zones (AEZs) of this country. In particular, the impact of climate change on irrigation is likely to be differentially felt across AEZs. Hence, while irrigation adoption is commonly suggested as an important alternative response to climate change, changes in water scarcity can change the extent that this policy can be implemented. This paper develops and uses an advanced computable general equilibrium (CGE) model coupled with biophysical data on land and water resources by AEZ at a river basin level to mainly examine: 1) the consequences of the climate change for India's agricultural and food products; 2) the extent to which water scarcity can affect the irrigation adoption and demand for water; and 3) how water scarcity, climate change, and trade jointly alter land use changes across the Indian subcontinent.

Literature review and contributions

Many papers have studied the impacts of climate change on crop yields and food security (e.g. Lobell et al., 2007 and Nelson et al., 2010). These studies demonstrate how changes in climate variables and CO_2 concentration in atmosphere affect food security across the world. However, they do not provide a clear picture on the interactions between climate change, crop yield, and water scarcity. More recent papers (e.g. Willis et al., 2014 and Marshal et al. 2014) have taken into account these interactions and show that while climate change can induce incentives for irrigation, water scarcity may limit the extent that irrigation adoption can be implemented. While these papers and the earlier work in this area provide valuable economic and biophysical analyses of the impacts of climate change for crop production and food security, they ignore the interplay between climate change and international trade. Some papers have examined the interaction between trade and climate change. For example, Reilly et al. (2002) have shown that trade can improve food security in regions which their crop production will be negatively affected by climate change factors. This paper and its successors usually ignore water scarcity induced by climate change and or economic factors. Recently, Liu et al. (2014) have shown that trade can mitigate the consequences of future irrigation short falls in regions where water scarcity threaten their food security as well. However, this paper ignores the impacts climate change on crop yield in the presence of water scarcity. This paper aims to enhance the existing literature by developing an analytical framework which allows us to examine the nexus between climate change, crop yield, water scarcity, and trade.

Research methodology

We use the GTAP-BIO-W model documented in Taheripour et al. (2013) and used in a recent published paper (Liu et al. 2014). This model traces demands for and supplies of a wide range of commodities including biofuels, primary sources of energy and electricity at the global scale by region. It divides crop producers into rainfed and irrigated and traces water and land resources and their demands at the river basin & agro-ecological zones in each country/region. In this model water can move across its alternative uses within a river basin with limited movement across AEZs and takes into account global trade for goods and services. We couple this model with the results obtained from crop models under the AgMIP project (Rosenzweig et al.

(2014 and Villoria et al. 2014) to achieve the goals of this paper. Unlike the earlier CGE works in this area, in this paper for the first time we take into account the difference between the rainfed and irrigated crop yields over time as an incentive for expansion in demand for irrigation. The data base used in this paper is an enhanced version of the GTAP data version 8. We use this model and data base to highlight the impacts of climate change for economy of India in 2035 under alternative climate and water scarcity.

Results

Here are some key findings. Climate change affects crops yields in different ways and its impacts vary from one AEZ to another one. For example, while climate change improves rainfed and irrigated rice yields in many AEZs in India, it has negative impacts on irrigated and rainfed corn yields across many AEZs. While the impacts of climate change on crop yields vary by crop, AEZ, year, and irrigation type, we observed significant positive (but volatile) differences between the irrigated and rainfed yields over time in particular for higher temperature cases. For example, in a moderate climate scenario the average of yield differences for rice, wheat, corn, and soybeans in AEZ 3 (with 42% share in rainfed harvested area of India) are expected to be about 0.28, 3.33, 0.18, and 0.34 metric ton per hectare for the time period of 2008-2035, respectively. We learned that when we ignore water scarcity (assuming water price is fixed), expansion in irrigated areas grows rapidly as we move to higher temperatures. When we include water scarcity, competition for water increases and that largely reduces the demand for irrigation. For example, in a moderate climate scenario, when we assume total available water supply is fixed, demand for irrigation drops by about 10% in response to climate change. Our results indicates that while changes in crop yields due to climate change moderately hurt food security in India in future years, as water scarcity grows, mainly due to expansion in demand for water in other sectors, climate change hurts the Indian economy even more. In all of these cases, trade plays an important role in reducing the negative side effects of water scarcity and climate impacts on crop yields.

Resources

- IGES, (2013) “Water availability for sustainable energy policy: Assessing cases in South and South Asia,” Institute for Global Environmental Strategies, Hayama, Japan.
- Liu et al. (2014) “International trade buffers the impact of future irrigation shortfalls,” *Global Environmental Change*, Vol. 29: p 22-31
- Lobell et al. (2007) “Prioritizing Climate Change Adaptation Needs for Food Security in 2030.” *Science*, 319: p 607-610.
- Marshal et al. (2014) “Agricultural production under climate change: The potential impacts of shifting regional water balances in the U.S.,” AAEA Annual Meeting, Minneapolis, MN, 2014.
- Nelson et al. (2010) “Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options,” International Food Policy Research Institute, Washington, D.C., USA.
- Rodriguez et al. (2013) “Thirsty Energy,” Water Partnership Program, World Bank, Washington DC.
- Rosegrant et al. (2013) “Water and food in the bioeconomy: Challenges and opportunities for development,” *Agricultural Economics*, Vol. 44 (s1): p 139-150.
- Rosenzweig et al. (2014) “Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison,” *Proceedings of the National Academy of Sciences, 111*(9), 3268–3273.
- Reilly et al. (2002) “Changing Climate and Changing Agriculture,” New York, NY: Cambridge University Press.
- Taheripour et al. (2013). Introducing Water by River Basin into GTAP Model, GTAP Working Paper 77. Center for Global Trade Analysis, Purdue University, USA
- Villoria et al . (2014) “The AgMIP Tool: A GEOSHARE Tool for Aggregating Outputs from the AgMIPs Global Gridded Crop Model Intercomparison Project,” Purdue University, West Lafayette, IN.
- Willis et al., (2014) “Projecting the economic impact and level of groundwater use in the Southern High Plains under alternative climate change forecasts using a coupled economic and hydrologic model,” AAEA Annual Meeting, Minneapolis, MN, 2014.