Potential impacts of climate change on agriculture

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Abstract

This study is primarily aimed at reviewing the impacts of climate change on Indian agricultural sustainability and poverty where poverty and agriculture are both salient, and that climate change is likely to reduce agricultural yields significantly, and that this damage could be severe unless adaptation to higher temperatures is rapid and complete. The study also summarizes the existing literature on the causes and characteristics of expected climate changes in India over the coming years, especially in the agricultural sector, and discusses the ways in which these changes might affect the lives of the poor. The study also throws light on the nexus between agricultural productivity and poverty eradication.

Keywords: Indian agricultural sustainability, climate changes, agricultural productivity, poverty eradication

Introduction

Poverty reduction is now one of the main goals of development. yet progress against poverty stalled in many countries during the late 1990s and early 2000s. Global warming and climate change are causing natural calamities of floods and droughts, and rain-fed agriculture is becoming most unpredictable. India is no exception. Increasing poverty and food insecurity have become large threats, despite Millennium Development Goals to reduce the numbers below the poverty line by half and eliminate hunger, by 2015. India's poverty reduction through the anti-poverty and employment generation programmes along with overall economic growth planning efforts has helped to reduce the poverty ratio in the country. But despite considerable success in reducing poverty, India today still has more than 456 million (42% of the total Indian population) live under the global poverty line of $1.25 per day (PPP). This means that a third of the global poor now reside in India (World Bank, 2006). So developing a national strategy to prevent further increases is more urgent than ever here comes the role of agriculture. Agriculture is critical to achieving global poverty reduction targets, especially in countries where the share of agriculture in overall employment is large. It is still the single most important productive sector in most low-income countries, often in terms of its share of Gross Domestic Product and almost always in terms of the number of people it employs. Agriculture in India makes up roughly 20% of GDP and provides nearly 52% of employment (as compared to 1% of GDP and 2% of employment for the US), with the majority of agricultural workers drawn from poorer segments of the population (FAO, 2006).

Agriculture & poverty alleviation

The debate on the role of agricultural research in poverty alleviation dates back to the green revolution in South Asia and Mexico in the late 1960s (Pinstrup-Andersen and Hazell, 1985). A general consensus has emerged that not only did research-led technology prevent widespread starvation; it also contributed to significant national economic growth and saved huge areas of forest, hillsides and other environmentally fragile lands from conversion to agriculture. For example, the green revolution contributed to more than a doubling of the aggregate food supply in Asia over a 25-year period. More importantly, it achieved this output increase with only a 4 percent increase in the net cropped area (Rosegrant and Hazell, 2000). The WDR projects that India will surpass China in population by 2030. To meet the demand for food for this growing population, the country's farmer need to produce 50% more grains by 2030. WDR also highlights the importance of agriculture by stating that GDP from agriculture will be 4 times effective than GDP from industry to reduce poverty (WDR, 2008). Fan *et al.* (2000) were the first to directly link agricultural research to rural poverty reduction. Their results for rural India indicate that agricultural research has the largest productivity impact of all kinds of government investments included in their study. This growth impact has also trickled down to the rural poor. In fact, agricultural research has the second largest impact on rural poverty reduction in India, second only to investments in rural roads. In summary, whenever there is higher growth in agricultural production and productivity, both rural and urban poverty declined. This is evident from the fact that during Green revolution period 1970's, India achieved self sufficiency in the food grains production. At that time India showed significant growth in rural economy with increase in rural wages and reduction in rural poverty. On the contrary, from 1990 onwards waning of Indian agricultural growth was experienced and has become major cause for the rural poverty (Subramaniam and Subramaniam).

Since the late 1980s high food production achieved during the 70's world over, raised new threat due to depletion of environmental and natural resources and

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land degradation (United Nations, 1997). Considering these facts, the concept of sustainable agricultural development and international food security has got priority especially after the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. There is no universal definition for the concept of sustainable agriculture among economists and practitioners. The concept of sustainable agriculture is still evolving. The waning of Indian agriculture can also be attributed to our agricultural research system which has tended to focus mostly on increasing the yield potential by more intensive use of water and bio- chemical inputs. Far too little attention has been given to the long-term environmental impact or on methods and practices for the efficient use of these inputs for sustainable agriculture. Poverty reduction and food security can emerge only from a thriving agriculture supported by improved productivity that can stimulate economic growth (Sarala Gopalan).

While prioritizing the sustainable agriculture, it was found that climate change played a major role in determining crop performance. Climate change is one of the major potential threats to national food security and sustainable agriculture for a country. Impacts on agriculture due to climate change have received considerable attention in India as they are closely linked to the food security and poverty status of a vast majority of the population. Dr. Cline's report to World Bank further accentuated the situation. According to Dr. Cline, "India is among the most adversely affected with losses of 30-40% (in agriculture productivity) depending upon whether higher carbon dioxide provides a significant fertilization effect (WBR, 2009). Hence credible estimates of the impact of climate change on agriculture is valuable in understanding the distributional effects of climate change as well as the potential benefits of policies to reduce its magnitude or promote adaptation. An attempt has been made in this regard through this write up.

Agriculture & climate change

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Most agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change, not so much by gradual trends in climate. If change is gradual, there may be enough time for biota adjustment. Rapid climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions, because there is less time for optimum natural selection and adaption. Some argue that increasing CO_2 fertilisation could make a major contribution to solving the problems created by climate change for agriculture, however others feel this contribution may be overestimated. It is worth noting the differential impacts of CO_2 fertilisation, with crops such as wheat, rice and soybeans [known as C3 crops] responding positively to increased CO_2, whilst other major staples, such as maize, sorghum, sugarcane and millet [C4 crops] do not benefit. As C4 crops are those grown in the tropics, this factor alone shows the possibility of differential climate change effects and points to the fact that only agricultural production in more temperate zones, will be partially compensated by the beneficial effects of CO_2 enrichment.

Several factors directly connect climate change and agricultural productivity: Increase in average temperature; change in rainfall amount and patterns; rising atmospheric concentrations of CO_2 ; pollution levels such as tropospheric ozone; change in climatic variability and extreme events.

Average temperature increase: An increase in average temperature can lengthen the growing season in regions with a relatively cool spring and fall; adversely affect crops in regions where summer heat already limits production, increase soil evaporation rates, and increase the chances of severe droughts. Change in rainfall amount and patterns: Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. The IPCC predicts that precipitation will increase in high latitudes, and decrease in most subtropical land regions—some by as much as about 20 percent. While regional precipitation will vary the number of extreme precipitation events is predicted to increase rising atmospheric concentrations of CO_2: Carbon dioxide is essential to plant growth. Rising CO_2 concentration in the atmosphere can have both positive and negative consequences. Increased CO_2 is expected to have positive physiological effects by increasing the rate of photosynthesis. Currently, the amount of carbon dioxide in the atmosphere is 380 parts per million. In comparison, the amount of oxygen is 210,000 ppm. This means that often plants may be starved of carbon dioxide, being outnumbered by the photosynthetic pollutant oxygen. The effects of an increase in carbon dioxide would be higher on C3 crops (such as wheat) than on C4 crops (such as maize), because the former is more susceptible to carbon dioxide shortage. Under optimum conditions of temperature and humidity, the yield increase could reach 36%, if the levels of carbon dioxide are doubled. Pollution levels such as tropospheric ozone: Higher levels of ground level ozone limit the growth of crops. Since ozone levels in the lower atmosphere are shaped by both emissions and temperature, climate change will most likely increase ozone concentrations. Such changes may offset any beneficial yield effects that result from elevated CO_2 levels.

Change in climatic variability and extreme events: Changes in the frequency and severity of heat waves, drought, floods and hurricanes, remain a key uncertainty in future climate change. Such changes are anticipated by global climate models, but regional changes and the potential affects on agriculture are more difficult to forecast. A warmer climate is predicted to bring more extreme weather. The period 1951-2000, has witnessed an increase in the magnitude and frequency of high intensity rains in India and a decrease in the frequency of moderate rains (Goswami *et al.,* 2006).

Brief survey of existing literature on India

Most previous studies of the economic effects of climate change (Mall *et al.,* 2006) provide an excellent review of the climate change impact studies on Indian agriculture mainly from a physical impacts point of view) have followed one of two methodologies, commonly known as the production function approach and the Ricardian approach. The production function approach (also known as crop modeling) is based on controlled agricultural experiments. This approach has the advantage of careful control and randomized application of environmental conditions but these laboratory-style outcomes may not reflect the adaptive behaviour of optimizing farmers. In the Indian context, Kumar and Parikh (2001a) have estimated the macro level impacts of climate change using such an approach. They estimate yield changes of rice and wheat crops. They show that under doubled carbon dioxide concentration levels in the latter half of the 21st century the gross domestic product would decline by 1.4 to 3 percentage points under various climate change scenarios, with adverse poverty effects. The Ricardian approach, pioneered by Mendelsohn *et al.* (1994), can account for both the direct impact of climate on specific crops as well farmers adjustment of production techniques, substitutions of different crops and even exit from agriculture. However, the success of the Ricardian approach depends on being able to account fully for all factors correlated with climate and influencing agricultural productivity.

Most research in developing countries has followed the production function approach, finding alarmingly large possible impacts (Cruz *et al.,* 2007). A true Ricardian study would be difficult to carry out in a developing country context, because land markets are less likely to be well-functioning and data on land prices are not generally available. Instead, a semi-Ricardian approach has used data on average products instead The major developing country semi-Ricardian studies, of India and Brazil, found significant negative effects, with a moderate climate change scenario (an increase of 2°C in mean temperature and seven percent increase in precipitation) leading to losses on the order of 10% of agricultural products (Sanghi *et al.,* 1998b, 1997). The Ricardian approach has received widespread attention due to its elegance and the strong assumptions it makes. Several studies in India have followed this approach in the past to assess the climate sensitivity of Indian agriculture (Kumar & Parikh, 2001b; Mendelsohn *et al.,* 2001; Kumar, 2003; Sanghi and Mendelsohn, 2008). Mendelsohn *et al.* (2001) have compared the climate sensitivity of US, Brazilian and Indian agriculture using estimates based on the Ricardian approach and have argued that using the US estimates for assessing climate change impacts on Indian agriculture would lead to an under-estimation of impacts. O'Brien *et al.* (2004) attempted to identify the so-called 'double exposed' districts in India – i.e., the districts that are vulnerable to climate change as well as globalization – with a focus on the agricultural systems. Kumar (2007) provides an overview of all Indian studies in an attempt to put together the available evidence on: (a) the extent of the adverse impacts of climate change on Indian agriculture; (b) the characteristics of relatively more vulnerable regions; and (c) effective adaptation strategies that help to ameliorate the present and future vulnerability of agriculture.

World Bank (2008) analyzed the climate change impacts in the drought- and flood- affected areas of India. Sanghi and Mendelsohn (2008) have compared the climate change impacts on Indian and Brazilian agriculture based on estimates provided by the Ricardian approach. This study follows similar methodology and data as Kumar and Parikh (2001b) and Mendelsohn *et al.* (2001) and reports annual losses varying between 4% and 26% for India under various climate change scenarios (the losses are expressed as a percentage of farm-level net revenue). The climate change scenarios considered cover a temperature increase of 1 to 3.5°C and a precipitation change of -8% to +14%. Under the middle scenario of a 2°C increase in temperature and a 7% increase in precipitation, the authors report an annual loss of 12 percent of farm-level net revenue in India.

More recently, kumar (2009) in his study uses the Ricardian approach to examine the impact of climate change on Indian agriculture. Using panel data over a twenty year period and on 271 districts, he estimated the impact of climate change on farm level net revenue. The key findings reveal that climate change results in a 9% decline in agricultural revenues in the base model but incorporating spatial effects lowers this effect to 3%. It is also pointed out that better dissemination of knowledge among farmers through both market forces and local leadership will help popularize effective adaptation strategies to address climate change impacts. The available evidence shows a significant drop in the yields of important cereal crops like rice and wheat under the changed climate conditions. However, the studies on the biophysical impacts on some important crops like sugarcane, cotton and sunflower are not adequate (kumar, 2009). The above facts emphasize the need to not only study in detail the climate change vulnerability of agriculture but also the methods of improving the adaptive capacity of agriculture to climate variability and extremes.

Mitigation and adaptation-Preventive measures policy

Responses to climate change include mitigation of greenhouse gases (GHGs) that contribute to the expected changes in the earth's climate and adaptation to the potential impacts caused by the changing climate. While the first is seen largely as a reactive response to climate change, the second one is a proactive response. Though GHG mitigation policies have dominated overall climate policy so far, adaptation strategies are now coming to the fore in order to formulate a more comprehensive policy response to climate change (kumar, 2009). Developing countries face significant challenges to adapt to and cope with climate change. Poorer nations are disproportionately vulnerable to disasters and hence to the effects of climate change for a number of reasons.

- Firstly, the ability to adapt and cope with weather hazards depends on economic resources, infrastructure, technology, and social safety nets (IPCC, 1995).
- Secondly, for many countries, climate change is only one of the many environment problems they confront. Many are already under pressure from population growth, rapid urbanization and resource depletion (Claire *et al.,* 2002). (London School of Economics, Consultancy project for the overseas development institute).

Within the same country itself there is disproportionate sharing of risk and danger faced by the poor when compared to their rich counterpart. In the 1977 floods in Andhra Pradesh, India the deaths were 23-27% for small farmers and fisherman, and there was a 3% death rate for large farmers and local level officials (Winchester 1986). Lack of insurance, savings or credit make it almost impossible to replace or compensate for the numerous things lost or destroyed, including houses, livestock, food reserves, household items and tools (IPCC 2001, Blaikie 1994). In general developing countries have felt constrained, both with regard to technical capacity and resources, in carrying out detailed impact and vulnerability assessments. With regard to agricultural production, adaptation techniques could include changes in crop types, crop location, irrigation, fertiliser use and infrastructure. Apart from the obvious challenges and costs of such adaptation to a developing country, Reilly *et al.* (1994) point out that in the case of agriculture, adaptation itself may not be the most suitable strategy, given the country's worsening relative position in the global agricultural economy. Subsistence farmers in particular do not have the same adaptation options and are likely to be the most heavily affected by changes in crop yields. It is also important to recognize that no single adaptation strategy can be encouraged, given the uniqueness of each country's situation (UNFCCC, 2002).

At the level of farms, adjustments may include

1. The introduction of later- maturing crop varieties or species,
2. Switching cropping sequences,
3. Sowing earlier,-
4. Adjusting timing of field operations,
5. Conserving soil moisture through appropriate tillage methods, and
6. Improving irrigation efficiency.

Some options such as switching crop varieties may be inexpensive while others, such as introducing irrigation (especially high-efficiency, water-conserving technologies), involve major investments. A major adaptive response will be the breeding of heat- and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Adaptation cannot be taken for granted; improvements in agriculture have always depended upon on the investment that is made in agricultural research and infrastructure. Success in adapting to possible future climate change will depend on a better definition of what changes will occur where, and on prudent investments, made in timely fashion, in adaptation strategies. Here comes the role of agricultural investments. In India there is a decline of public investment in agriculture from 4% of agriculture GDP to 2%, while subsidies increased from 3% (1976-80) to 7% (2001-03). This is evident in Table 1. Public investment on agriculture in countries like India is heavily skewed towards providing subsidies rather than investments. In fact, subsidies are more than four times that of public investments in agriculture (WDR, 2008). Most of the subsidies are on fertilizer, power and irrigation water, and these have actually contributed to the degradation of natural resources. Therefore targeted investments would have to be made to bridge the gaps in agricultural research and technology transfer. Public and

Table 1. Investment in agriculture (Rs in Crore at 1999-2000 price).

Year	GDP from agriculture	Gross capital formation (GCF) in agriculture			GCF in agriculture as % of GDP from agriculture		
		Pub sec.	Pvt sec.	Total	Pub sec.	Pvt sec.	Total
1980-81 to 1984-1985	239678	12007	13132	25139	5.0	5.5	10.5
1985-86 to 1989-1990	274034	9601	14370	23921	3.5	5.2	8.7
1990-91 to 1994-1995	325957	7915	19348	27263	2.4	5.9	8.4
1995-96 to 1999-2000	383330	7724	22631	30354	2.0	5.9	7.9
2000-01	407176	7155	31872	39027	1.8	7.8	9.6
2001-02	433475	8716	39458	48215	2.0	9.1	11.1
2002-03	398206	7962	38851	46823	2.0	9.8	11.8
2003-04	441360	9376	35457	44833	2.1	8.0	10.2
2004-05	441183	12273	36835	49108	2.8	8.3	11.1
2005-06	468013	15006	39899	54905	3.2	8.5	11.7
2006-07	445939	17749	43013	60762	3.2	8.9	12.5

Source: National accounts statistics 2008(New series), central statistical organization, ministry of statistics and programme implementation, New Delhi.

private investments in the agriculture sector need to increase manifold.

Mitigation

Some researchers have emphasized the need to distinguish between greenhouse gases and particle emissions and shows that the latter are a major source of climate related problems in India. Since these emissions are directly affected by Indian policies and there are some low-cost options for particle emission reductions, it is important that these opportunities not be neglected. Opportunities also exist for obtaining international finance that will help the higher-cost particle emission reductions while also sequestering carbon. So these too should be seized (Somanathan and Somanathan).

Some mitigation options are: Reducing emissions of carbon and methane; encouraging agro-forestry systems; resource conservation technologies; enriching soil organic matter and shifting to Biofuels.

Reducing emissions from cooking fires, the single largest source of smoke, is clearly desirable. About three-quarters of Indian households use wood or other solid biomass fuels (Gangopadhyay *et al*., 2006). If most of these households were to switch to electricity or gas for cooking, they would reduce harvesting pressure on forests that have degraded (Prabhakar *et al*., 2006; Baland *et al.,* 2008). Burning of crop residues will aggravate the brown cloud problem. But bans on agricultural residue burning by farmers have been tried and failed in Punjab, owing to farmers' political power. Emissions from transport and congestion can be reduced through investments in electric rail, public transport, and traffic control. Road-pricing to deal with congestion externalities is now technically feasible and has been implemented in Singapore as well as London and Stockholm.

Conclusion

Emissions of greenhouse gases from agricultural sources are likely to increase in the years ahead, given the necessity to expand food production in order to provide for the world's growing population. This imposes a task upon agricultural researchers to devise ways to continue improving yields while at the same time holding down emissions. Some possible improvements include reducing land- clearing and biomass burning in the tropics; managing rice paddies and livestock so as to reduce methane emissions; and improving fertilizer-use efficiency to reduce the conversion of nitrogen to gaseous N_2O. Much research is still needed to understand the processes by which greenhouse gases are emitted from different agricultural practices. Needed as well are efforts to disseminate the knowledge gained in order to apply it on the farm. Reductions in some gases are likely to be more easily achievable than in others, and appropriate strategies will vary by region. The task of reducing emissions will doubtlessly be complicated by accompanying changes in climate variables such as temperature and wind and precipitation, that interact with the processes through which greenhouse gases are released. The ability of any country to take advantage of the opportunities and to avoid the drawbacks as climate changes will depend on the availability of adequate resources as well as on the quality of the research base. The presently inadequate capacity of agricultural research systems in the tropics and semi-tropics will need to be rectified, and this task can best be achieved through international cooperation. The government has shown little interest in operationalising its own National Action Plan on Climate Change that was released a year ago. There exists a public demand for greenhouse gas emission reduction and carbon sequestration in developed countries. Indian international policy should aim to find ways to use this demand to finance policies that would help the poor while also furthering carbon sequestration and emission reduction. For example, helping poor households switch to modern cooking energy will be expensive, but it will deliver carbon sequestration benefits. Thus we can find finance via taking foreign aid. Finally, in order to achieve the growth rate proposed in the Eleventh Plan of our country, it is the agricultural sector, which has to be liberated. Without according due importance to agriculture, equitable growth could not be achieved. When agriculture fails, it not only impoverishes those who are dependent on it for their livelihood, but also threatens the food security of the nation. Poverty reduction and food security can emerge only from a thriving agriculture supported by improved productivity that can stimulate economic growth. Thus the rejuvenation of the farm sector is the basic prerequisite for reduction of rural poverty.

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