BOOK REVIEW

Climate Change and Food Production Systems

Tejal Kanitkar*

Intergovernmental Panel on Climate Change (IPCC) (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [Field, C. B., Barros, V. R., Dokken, D. J. Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M.. Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. and White, L. L. (eds.)], Cambridge University Press, Cambridge and New York.The Second Working Group (WG-II) of the Intergovernmental Panel on Climate Change (IPCC) published the approved version of its Fifth Assessment Report (AR5), titled "Climate Change 2014: Impacts, Adaptation, and Vulnerability," in March 2014. The contributors to the report – approximately 300 authors and editors – have been drawn from about 70 different countries. They were, in turn, aided by about 430 contributing authors and 1700 experts and government reviewers.

The Second Working Group (WG-II) of the Intergovernmental Panel on Climate Change (IPCC) published the approved version of its Fifth Assessment Report (AR5), titled "Climate Change 2014: Impacts, Adaptation, and Vulnerability," in March 2014.

In terms of structure and content, there are significant differences between previous Working Group II reports and this one. In terms of structure, new sections have been added to the report. These include separate sections on the impact of climate change in rural and urban areas, and a new section on ocean systems. According to the authors, the literature available for assessing the impact of climate change, adaptation, and vulnerability has more than doubled since the Fourth Assessment Report (AR4) was published. The assessment of the impact of climate change was based on climate model projections discussed in the Special Report on Emission Scenarios (SRES). In AR5, the assessments of impact are based on the SRES scenarios as well as the new Representative Concentration Pathways (RCP). The four RCPs – RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 – describe different levels of emissions (for

* Assistant Professor and Chairperson, Centre for Climate Change and Sustainability Studies, School of Habitat Studies, Tata Institute of Social Sciences, Mumbai, tejal.kanitkar@gmail.com.

different socio-economic scenarios as well as different levels of mitigation), leading to different levels of radiative forcing by the end of the 21st century.[1]

The impact of climate change has been classified in the report under three main categories: (i) the impact on natural (and managed) resources and their uses, (ii) the impact on human settlements, industry, and infrastructure, and (iii) the impact on human health, well-being, and security. The first section discusses the impact of climate change on water systems and resources, coastal and ocean systems, and food production systems. The second section discusses the impact of climate change in urban and rural areas as well as its impact on key economic sectors and services. The third section discusses the impact of climate change on human health and well-being, as well as on poverty, poverty alleviation programmes, and livelihoods. The rest of the report is devoted to discussions on vulnerability, risk assessment, and adaptation, and a detailed analysis of the region-wise impact of climate change. Food production systems and food security has been classified under the first category of "Natural and Managed Resources" and not under "Industry" in the report. The section on rural areas also focuses mainly on the impact of climate change on agriculture and agriculture-related livelihoods. This review will focus on the impact of climate change on food production systems and the relevant means of adaptation discussed in the AR5.

Main Results from Report of Working Group–I

The fifth assessment reports of all the working groups of the IPCC use two methods of describing the reliability of a finding. First, confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence is expressed qualitatively. Levels of confidence are described on a scale of five qualifiers: very low, low, medium, high, and very high. Secondly, the results of statistical analysis are expressed as quantitative measures. These methods (or metrics) are quoted in this review also to convey the certainty of particular findings or results.

The report of Working Group I (WG–I), published in 2013, provides four reference trajectories, each corresponding to a level of emissions and a certain probability of exceeding a temperature rise of 2° Celsius. The probability of exceeding 2° Celsius is below 33 per cent for RCP 2.6 and exceeds 50 per cent for the other three RCPs. The corresponding carbon budget for the period between 2012 and 2100 for RCP 2.6 is 270 gigatonnes of carbon (GtC). Restricting emissions within this global carbon budget will be a very big challenge before all countries, developed and less-developed. Staying within the limits of the other RCPs, which correspond to a carbon budget of 780 GtC in the period 2012 -2100, will be much easier.

[1] Radiative forcing is the difference between the radiant energy of the sun received by the earth and the energy radiated back outside the atmosphere. A positive value of radiative forcing denotes warming while a negative value denotes cooling.

Impact of Climate Change on Major Crops

Information on the impact of high levels of temperature rise on the yields of major crops in all regions has been presented in the report of WG-II. Evidence since AR4 suggests that plant responses to CO_2 depend on whether the plant is of type C3 or C4. C3 plants (e.g., wheat, rice, cotton, soybean) experience a higher negative effect of CO_2 concentration than C4 plants (e.g., corn, sorghum). This is because photosynthesis rates in C4 crops are less responsive to increases in ambient CO_2 (Leakey 2009). Table 1 shows some of the projected effects of climate change on crop yields up to 2050 for a few major crops.

Table 1 indicates significant reduction in yields by 2050 even with a temperature increase of 2° Celsius. For higher warming, leading to local mean temperature increases of 3°-4° Celsius, the reduction in yields is projected to be much higher, with "large negative [effects] on agricultural productivity and substantial risks to global food production and security" (IPCC 2014). Tropical countries face higher risks because of reduction in yields as the effects of climate change are expected to be higher in the tropical region. They are also vulnerable because of the higher prevalence of poverty in the tropics than in temperate regions.

There are in general, two classes of models for determining the impact of climate change on crop production. In one class of models, a baseline is first established, where the term "baseline" (in such models) refers to the projection of trends in crop production in the absence of climate change. The future impact of climate change on agriculture in any region is then measured by the deviation from these trends due to climate change, with or without adaptation. However, such "baselines" will also depend on a number of non-climate influences on crop production. For example, the introduction of a new source of irrigation in a region or an increase in the use

Table 1 *Impact of climate change in scenarios of temperature increase of 1-3°C on crop yields for major crops across regions* in per cent

Crop	Change in crop yields (%)	Reference
Wheat	−10 to −13	(Nelson *et al.* 2010)
Maize	−4 to − 12	
Rice	−9.5 to −12	
Sorghum	−11 to −15	(Knox *et al.* 2012)
Barley	−1 to −8	(Lobell *et al.* 2008)
Millets	−10 to −20	(Knox *et al.* 2012; Ben Mohamed 2011)
Beans	−1.5 to +45	(Thornton *et al.* 2009)
Soybean	−14 to −25	(Travasso *et al.* 2008)
Potato	0 to −5	(Lobell *et al.* 2008)
Oilseeds	−50 to +25	(Kulshreshtha 2011)

Source: Table adapted from IPCC WG-II, AR5, Table 7-1.

of fertilizers would affect crop production and consequently have an impact on the trends in crop production irrespective of climate change. Changes in the relationship between climate conditions and crop production can, of course, occur because of changes in farmer behaviour as a result of the introduction of a particular technology (Zhang and Liu 2008; Liu *et al.* 2009; Sakurai, Lizumi, and Yokozawa 2012). Estimates of the impact of climate change on crop production and yields measured as a deviation from this "no-climate-change baseline" provides results with low confidence values.

Another class of models uses statistical methods to estimate the sensitivity of food production to weather and climate. These models use extensive datasets on crop yields together with observed or simulated weather data to determine empirical relationships between crop yields and climate. Such studies help us determine with medium confidence that climate trends will have a negative impact on yields of wheat and maize in many regions.

In general, few studies exist that calculate the direct effect of climate change on crop production, specifically as a consequence of global warming that is of anthropogenic origin. However, there is increased documentation of the attribution of changes in average as well as extreme climate conditions to anthropogenic causes (Min *et al.* 2011). Such studies can be used in the future to better understand the effect of anthropogenic climate change on crop production.

In general, there seems to be high confidence in the finding that food production is most vulnerable to rising temperatures (Wassmann *et al.* 2009). Although there are some crop physiology simulation models that show a positive effect of CO_2 fertilisation, Free Atmosphere Carbon Exchange (FACE) experiments – field experiments undertaken to observe the impact of increased carbon concentration – show that the actual effects of CO_2 fertilisation are typically lower than the modelled results.

Impact of Climate Change on Crop Production in Asia and India

For Asia, model results show, with medium confidence, that many regions will experience a decrease in productivity, most evident in the case of rice production. Most models project a decrease in rice yields due to the shortening of growing periods. The process of rice development accelerates with increased heat stress and reduces the duration of crop growth. Studies indicate that certain regions are already close to the heat stress limits for rice cultivation. In India, south India and eastern India are part of this group of regions.

In the Indo-Gangetic plains of South Asia, heat stress is projected to reduce wheat yields by almost 50 per cent (IPCC 2014, ch. 24). Rice production is expected to be affected by the inundation of low-lying areas because of a rise in sea levels. For India, however, there was no change in the mean rice yield projections. The report quotes the study by Srivastava, Kumar, and Aggarwal (2010) for India, which uses the

InfoCrop-SORGHUM simulation model to analyse the impact of climate change on sorghum production. The yields of monsoon sorghum are estimated to reduce by 2-14 per cent by 2020, worsening further by 2050 and 2080. The studies cited from India are few in number. For other developing countries, China in particular, more studies on the impact of climate change on agriculture have been conducted than in India.

Food Security and Climate Change

This impact of climate change on global food production is expected to affect food security. However, studies for estimating food security in particular are few in number and the uncertainties higher because of the large number of non-climate factors that affect global food prices and, consequently, food security. Some studies have documented recent hikes in food prices that followed extreme climate events of some kind. The increase in food prices may be due to shortages or due to domestic policy responses to extreme events, including prohibitions on food exports (a measure implemented by many countries after 2007) (FAO 2008).

The discussion of access to food in AR5 focusses on the channels through which access to food is gained, and the impact of rising prices on these channels. Thus, the report concludes that the impact of climate change on agriculture will affect forest-dependent farmers and other small subsistence farmers (who together constitute a small share of the population), who do not access food from the market less than the rural landless population and the urban population, on whom the negative impact will be substantial. Of other categories of the population, net food sellers will benefit from increases in prices.

The recognition by the Report of only one aspect of food security leads to the strange conclusion that climate change will have a limited impact on subsistence farmers.

Nevertheless, the discussion on food security has serious implications for national food policies, especially in less-developed countries such as India. The IPCC report clearly suggests the need for strengthening existing food security and support programmes.[2]

Vulnerability and Adaptation to Climate Change

AR5 recognizes that vulnerability to climate change is also a function of many non-climatic factors. The report emphasises the role of uneven development processes and pre-existing inequalities with respect to class, gender, ethnicity, age, and disability in exacerbating the vulnerability of populations to climate change. Some of the differential risk can be understood by studying the exposure of different categories of

[2] There are strong indications, however, that domestic policy in India is actually moving in the opposite direction (Swaminathan 2009).

the population to current climate variability. A key point made in the report is that "variability in temperature is a risk factor in its own right over and above the influence of increase in average temperatures" (IPCC 2014, Summary for Policymakers). The report suggests that reducing vulnerability to present climate variability is an important step towards dealing with adaptation to future climate change.

Even as studies regarding the impact of climate change are now less ambiguous and deal with uncertainty statistically, providing usable results, studies that deal with potential adaptation strategies, in general, remain vague and ambiguous. For example, in the chapter on Asia, methods of dealing with climate change that range from local and indigenous methods of climate adaptation to the development of new heat-resistant plant varieties are all presented together in one paragraph, without any discussion of priorities or the relative effectiveness of each adaptation strategy. Although there is a discussion of the role of indigenous knowledge in climate adaptation in the report, no scientifically acceptable evidence is provided in support of such claims. However, the report does discuss the limitations of indigenous knowledge in situations where changes in climate and other conditions have made certain traditional methods of adaptation impossible to implement.

Measurable evidence of benefits is, however, available for some controlled studies of cultivar adjustments, adjustments in planting dates, and a few other adaptation strategies. Table 2 shows the benefits of some adaptation strategies (these benefits vary across agro-climatic regions as well as crops and crop varieties).

Improving cultivar tolerance to high temperatures is the adaptation option that is most commonly advocated for almost all crops, in all regions, since high temperatures are expected to have the most dramatic impact on crop yields and quality. But the report suggests that the benefits of adaptation presented above in Table 2 may be understating the potential for adaptation as the measures considered in the studies cited in the Table are either incremental in nature or within the scope of existing

Table 2 *Benefit in terms of crop yields due to various adaptation strategies* in per cent

Crop management option	Benefit from adaptation (%)*
Cultivar adjustment (56 data points across crops and regions)	23
Planting date adjustment (19 data points across crops and regions)	3
Planting date adjustment and cultivar adjustment (152 data points across crops and regions)	17
Irrigation Optimisation (17 data points across crops and regions)	3.2
Fertilizer Optimisation (10 data points across crops and regions)	1.0

Note: *The benefit is the difference between the yield obtained with and without adaptation in the presence of climate change.
Source: IPCC 2014, Chapter 7.

production systems. "Transformative" adaptation measures (Rickards and Howden 2012), referring to more radical adaptation options, have not been considered while estimating the impact of adaptation techniques on crop yields.

Conclusions

The main conclusion of the Fifth Assessment Report is that the effects of climate change will slow down economic growth, make poverty reduction more difficult and create new poverty traps. Climate change poses a severe threat to food security, and developing countries such as India are especially vulnerable to its impact. Although the report is not as specific about the potential adaptation methods that can be undertaken to reduce the risks of climate change, it does point out some important steps that can be taken to reduce vulnerability. The report clearly states that existing inequalities within the population tend to exacerbate vulnerability to climate change. High levels of poverty and inequality also mean higher risks to current climate variability.

The report suggests that reducing vulnerability to current climate variability is an important step towards dealing with future climate change. The immediate task before governments is, therefore, clear: there have to be better mechanisms through which current risks are handled. These measures may include stronger support and extension mechanisms, improved information dissemination, and increased support in the form of subsidies or concessions to small farmers. They may include transformative measures in the form of changes in the distribution of land. The Fifth Assessment Report of the IPCC lays down the potential impact of climate change very clearly. All countries, especially less-developed countries such as India, will have seriously to consider its findings and re-evaluate action plans to deal with climate change.

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