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PERSPECTIVE

Global warming threatens agricultural productivity in Africa and South Asia

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The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC; Christensen *et al* 2007) has, with greater confidence than previous reports, warned the international community that the increase in anthropogenic greenhouse gases emissions will result in global climate change. One of the most direct and threatening impacts it may have on human societies is the potential consequences on global crop production. Indeed agriculture is considered as the most weather-dependent of all human activities (Hansen 2002) since climate is a primary determinant for agricultural productivity. The potential impact of climate change on crop productivity is an additional strain on the global food system which is already facing the difficult challenge of increasing food production to feed a projected 9 billion people by 2050 with changing consumption patterns and growing scarcity of water and land (Beddington 2010). In some regions such as Sub-Saharan Africa or South Asia that are already food insecure and where most of the population increase and economic development will take place, climate change could be the additional stress that pushes systems over the edge. A striking example, if needed, is the work from Collomb (1999) which estimates that by 2050 food needs will more than quintuple in Africa and more than double in Asia. Better knowledge of climate change impacts on crop productivity in those vulnerable regions is crucial to inform policies and to support adaptation strategies that may counteract the adverse effects.

Although there is a growing literature on the impact of climate change on crop productivity in tropical regions, it is difficult to provide a consistent assessment of future yield changes because of large uncertainties in regional climate change projections, in the response of crops to environmental change (rainfall, temperature, CO₂ concentration), in the coupling between climate models and crop productivity functions, and in the adaptation of agricultural systems to progressive climate change (Roudier *et al* 2011, Challinor *et al* 2007). These uncertainties result in a large spread of crop yield projections indicating a low confidence in future yield projections.

A recent study by Knox *et al* (2012) is among the first to provide robust evidence of how climate change will impact productivity of major crops in Africa and South Asia. Using a meta-analysis, which is widely used in epidemiology and medicine and consists in comparing and combining results from different independent published studies, Knox *et al* (2012) show a consistent yield loss by the 2050s of major crops (wheat, maize, sorghum and millet) in both regions. This systematic review and meta-analysis of data in 52 original publications from an initial screen of 1144 studies nicely extend previous works by Müller *et al* (2011) and Roudier *et al* (2011), confirming the threat of negative climate change impacts in Africa but also in South Asia. Knox *et al* (2012) estimate that mean yield change for all crops is −8% by the 2050s with strong variations among crops and regions. For instance evidence of yield reduction up to −40% are detected for some regions of Africa while no mean yield change is detected for



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rice in India. Variations in crop yield projections decrease when considering a large number of climate models confirming the relevance of the expanded use of multi-model ensembles of projections of future climate change adopted in the IPCC Fourth Assessment Report. Conversely, variations in crop yield projections increase with the crop model complexity especially when using process-based crop models over statistical models. Such differences in crop yield variations may be attributed either to the structural differences between crop model approaches or to the spatial scale differences; biophysical crop models operating at finer spatial scales and thus reproducing the higher variability of impacts at these scales.

Such robust evidence of future yield change in Africa and South Asia can be surprising in regards to the diverging projections in a warmer climate of summer monsoon rainfall, the primary driver for rainfed crop productivity in the region, especially in West Africa where some studies make projections of wetter conditions and some predict more frequent droughts (Druryan 2011). This is because of the adverse role of higher temperatures in shortening the crop cycle duration and increasing evapotranspiration demand and thus reducing crop yields, irrespective of rainfall changes (Berg *et al* 2012, Roudier *et al* 2011, Schlenker and Lobell 2010). Potential wetter conditions or elevated CO₂ concentrations hardly counteract the adverse effect of higher temperatures.

Although such systematic reviews and meta-analyses conducted by Knox *et al* (2012), Müller *et al* (2011) or Roudier *et al* (2011) can provide important insights about sign, magnitude and uncertainty of climate change impacts, direct comparison among studies suffers from inevitable limitations. In particular the diversity of the studies selected for the meta-analysis, encompassing a range of different countries, scales, crops and methods (climate models and scenarios, crop models, downscaling technique), makes it difficult to aggregate crop yield projections to provide a consistent and precise impact assessment. A rigorous multi-ensembles approach, with varying climate models, emissions scenarios, crop models, and downscaling techniques, as recommended by Challinor *et al* (2007), would enable a move towards a more complete sampling of uncertainty in crop yield projections. In that sense, coordinated modeling experiments such as the ones conducted throughout the Agricultural Model Intercomparison and Improvement Project (AgMIP; www.agmip.org/) are likely to improve substantially the characterization of the threat of crop yield losses and food insecurity due to climate change.

In spite of the threat of crop yield losses in a warmer climate, it is important to keep in mind, as discussed by Berg *et al* (2012), that developing countries in the tropics have the potential to more than offset such adverse impacts by implementing more intensive agricultural practices and adapting agriculture to climate and environmental change. Indeed Africa and in a lesser extend South Asia are among the only regions of the world where there is an untapped potential for raising agricultural productivity since poor soil fertility and low input levels, combined with extensive agricultural practices, contribute to a large gap between actual and potential yields (Licker *et al* 2010).

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