International Center for Climate Governance

OPPORTUNITIES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT THROUGH CONSERVATION

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Opportunities for Sustainable Agricultural Development Through Conservation

by Patrick Ward (ICCG)

Abstract

Climate change is expected to place additional stress on agricultural production, since many crops in many developing countries have already exceeded their heat tolerance. Additional warming may result in lower agricultural productivity, which, given projections of future population, may have significant effects on food security, especially in developing countries. In this brief, we review several strategies of conservation agriculture: a series of agricultural practices that promote increased agricultural productivity while reducing or eliminating deleterious environmental impacts that would otherwise arise from agricultural intensification or extensification. These practices present a promising approach to sustainable agricultural development to meet future food needs, providing agricultural, environmental, and economic benefits.

Introduction

In this short brief, we consider the possibility of climate-sensitive agricultural production practices as a means of increasing global agricultural production, increasing food security in developing regions of the world, and raising agricultural profits in many of these areas. In most developing countries, households are very dependent upon agriculture as a source of their very livelihoods. Tragically, it is often also in these parts of the world that climate change is expected to have the most severe negative impacts on agricultural yields. Given constraints on converting land into agricultural use, increasing yields and the pace of yield growth many be the only means by which global agricultural production can be increased to meet the demands of a growing global population. Production practices which enhance yields without detrimentally affecting the environment or without depleting already fragile natural resource stocks may present the greatest opportunity for sustainable agricultural development to increase food security.

Climate Change Impacts on Agricultural Production

The agricultural sector is inherently dependent upon climate. Just as land, labor, and machinery are necessary inputs into crop production, so too are climatological variables such as temperature and precipitation. And like with these other inputs, production responses are nonlinear, generally following a hill-shaped pattern. Such nonlinearities imply an optimal temperature or level of precipitation, holding other inputs constant. In many developing countries, many crops are already approaching or have already exceeded their temperature thresholds, suggesting that continued warming beyond that already observed will have negative impacts on either yield levels or the pace of yield growth. Indeed, while globally yields for most crop types have continued to grow despite rising global average temperatures and changing patterns of precipitation, studies suggest that changing climate conditions have slowed the pace of yield growth for several crops.[1]

When one considers the potential impacts of climate change on the agricultural sector, the issue of global food security is a particularly relevant concern. The United Nations estimates that the global population will rise to approximately 9 billion people by the year 2050,[2] and changing climate conditions may make it more difficult to feed all of these people. There are four dimensions of food security: (1) availability of food (both through food production as well as trade); (2) stability of food supplies; (3) access to food supplies; and (4) utilization of food supplies. Though food security depends on more than just climate, it should be noted that climate change is expected to impact all four of these dimensions.[3] Climate change impacts on food production are expected to be mixed and vary regionally. Expected patterns of warming should lead to increased production in upper latitudes in the northern hemisphere, while warming in the tropics—where temperatures are in many cases exceeding the temperature thresholds for many crop types—is expected to lower production. Assuming that the same agricultural practices continue into the future, some studies estimate that moderate warming (1-3º C) may have a small positive impact on global food crop production, but warming beyond this level is almost certainly going to have a negative effect on global production.[4] Figure 1 illustrates the expected changes in global crop yields for a variety of 11 major crops (wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed) from 2046-2055 (compared with 1996-2005). While yields are expected to increase in some high latitude regions, it is important to note that yields are predicted to fall in many areas that are heavily dependent upon agriculture—both as a source of national income as well as employment—including most of Africa, India, and much of southeast Asia.

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[1] Lobell, D., W. Schlenker and J. Costa-Roberts (2011). "Climate trends and global crop production since 1980."
[2] United Nations (2004). *World Population to 2300*.
[3] FAO (2003). "Impact of climate change on food security and implications for sustainable food production committee on world food supply."
[4] Easterling et al. (2007). "Food, fibre and forest products."

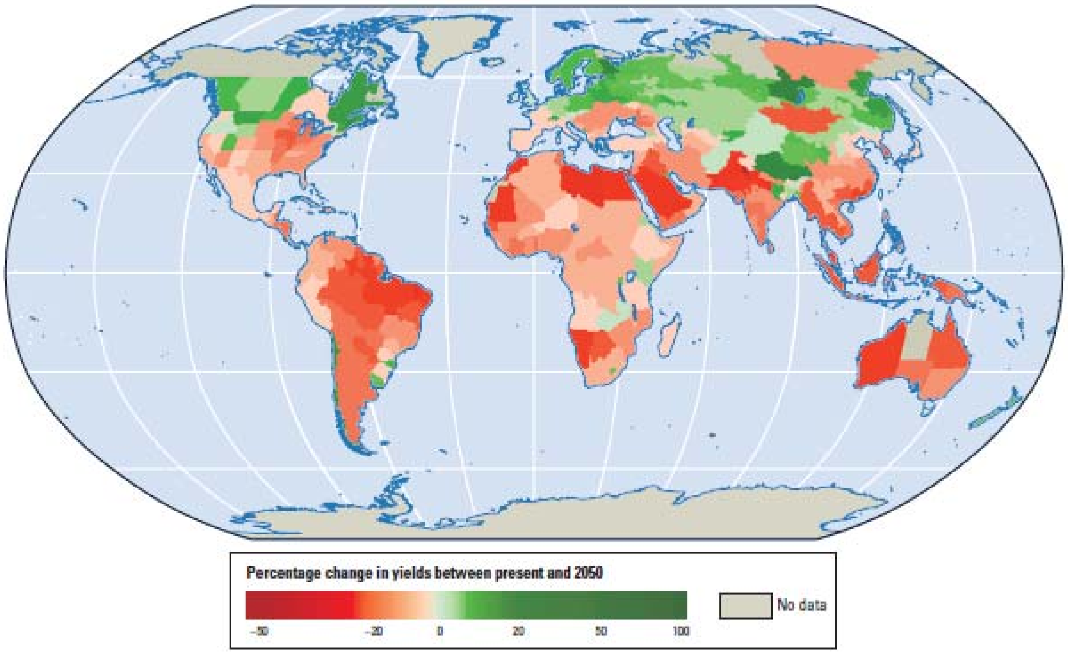

Figure 1: Climate change impacts on global crop yields

Source: World Bank (2010), based on Müller et al. (2010).
Note: The figures shown represent the averages from three emission scenarios across five global crop models, assuming no carbon fertilization effects.

Given that, for temperature increases above 3º C, climate change is expected to lower global agricultural productivity, total agricultural output might be increased through either increased intensive agriculture (involving the heavy usage of chemical pesticides and fertilizers) or increased extensive agriculture (increasing the total area under cultivation). Intensification of agriculture can be damaging to the natural environmental-ecological system, since fertilizer runoff can contribute to the formation of low-oxygen dead zones, while intensive irrigation can lead to salt build-ups in the soil, lowering soil fertility. Furthermore, fertilizer use contributes 64% of global nitrous oxide emissions, a greenhouse gas that increases radiative forcing.[5] Expansion of agricultural lands may not be a feasible response either. One study suggests that the total area of land suitable for agricultural production may be the same in 2080 as it is today, with roughly 2.6 billion hectares worldwide moderately suitable for cultivation.[6,7] The distribution of this suitable land area is expected to be vastly different from the present, however, with new suitable areas becoming available in Russia, the Ukraine, Central Asia, East Asia and North America (due to the removal of cold-temperature constraints), while Northern Africa and Southern Africa are each expected to lose considerable areas of formerly suitable land for agricultural cultivation.[8] Extensification usually comes at the expense of forested areas (often through slash-and-burn practices), which has significant environmental implications of its own.

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[5] FAO (2001). *Global Estimates of Gaseous Emissions of NH_3, NO, and N_2O from Agricultural Land.*
[6] Fischer,G., M. Shah, and H. van Velthuizen (2002). *Climate Change and Agricultural Vulnerability.*
[7] These figures are derived from simulations conducted on the Hadley Center coupled atmospheric-oceanic general circulation model (AOGCM), version 3 (HadCM3), based on IPCC SRES emissions scenario A1FI, which is a particularly fossil fuel intensive development scenario. The roughly 2.6 billion hectares referred to here include those lands that are prime, good, and moderately suitable for agriculture. Of these, only about 2 billion hectares are prime or good agricultural lands. Roughly the same area is expected to be prime or good agricultural land in 2080.
[8] Suitable land in Russia is expected to increase 64% above the average of 1961-1990. On the other hand, Northern Africa's and Southern Africa's suitable land area is expected to decrease by 75% and 46%, respectively, relative to the same baseline period.

It remains, therefore, that productivity will almost certainly have to increase if global food production is to be sufficient to meet future global food demand. One study suggests that with climate change yields will need to grow roughly 1.8% over the next fifty years in order to meet demand—roughly twice the yield growth that would be needed without climate change.[9] Meeting this needed growth rate in agricultural productivity is a challenge, one that is made more difficult by the fact that much of this increase in yield growth is going to have to come from developing countries, since many major crop producing developed countries are already near their maximum yields under current technologies.[10]

Conservation Agriculture and Sustainable Agricultural Development

Conservation agriculture (hereafter, CA) presents significant opportunities for sustainable agricultural development. In short, CA is an application of modern agricultural technologies and practices to improve production while protecting and enhancing the land resources on which production depends.[11] Rather than the intensive use of fertilizers and irrigation as a means of maximizing yields, CA aims to optimize yields and profits to attain a balance of agricultural, economic, and environmental benefits. There are several CA technologies and practices that are currently being implemented around the world, including zero- or minimum-tillage systems, agroforestry, precision land levelling, contour farming, integrated pest management, and crop and pasture rotations. Many of these practices present "win-win" scenarios, since they result in higher productivity, lower production costs, better management of finite natural resources, and the production of valuable by-products.[12] CA practices are already practiced on more than 100 million hectares of land worldwide, but given its potential to increase total production in an environmentally-responsible way, the expansion of CA into more of the world may be an important strategy by which to meet future food demands. Below we briefly review three of these practices and some of their most important resulting benefits.

- Traditional agricultural practices involve tilling up soils to remove weeds, shape the soils into rows for planting, and creating furrows for irrigation. Tilling the soil has adverse effects such as contributing to soil erosion, soil compaction, the loss of organic matter (including the release of carbon into the atmosphere), and the degradation of soil aggregates. Under zero- or minimum-tillage systems function, farmers plant their seeds directly into the undisturbed soil. Organic materials are retained in the soil and can have a fertilizing effect on the crops that are planted. In addition to the obvious environmental benefits of zero- or minimum-till systems, there are also significant economic benefits, as studies have shown that such systems lead to savings in fuel, labor, irrigation, water, production costs, and other energy costs.[13]
- Agroforestry involves using trees in agricultural landscapes as a means of reducing soil erosion, maintaining or even increasing soil fertility, increasing water efficiency, watershed protection, increased biodiversity, and carbon sequestration. In addition to these environmental and productivity benefits, agroforestry also offers benefits to smallholder farm households by providing environmentally-friendly fertilizers, fruits for consumption, medicines, livestock fodder, timber and fuelwood. Fertilizer trees (trees that provide nitrogen fixation services) have been used quite extensively in southern Africa and have shown remarkable success. The use of such trees on maize farms increases maize yield approximately two

[9] Lotze-Campen, H., A. Popp, J.P. Dietrich, and M. Krause (2009). "Competition for land between food, bioenergy, and conservation."
[10] Cassman, K.G. (1999). "Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture." It is possible that technologies (e.g., genetically-modified crop varieties, etc.) could faciliate increased yields in many developed countries.
[11] Dumanski, J., R. Peiretti, J.R. Benites, D. McGarry, and C. Pieri (2006). "The paradigm of conservation agriculture."
[12] World Bank (2010). *World Development Report 2010: Development and Climate Change*.
[13] Jat, M.L., S.K. Sharma and K.K. Singh (2006). "Conservation agriculture for sustainable farming in India."

times more than farmers' usual practice of continuous (i.e., no fallow) cultivation without chemical fertilization.[14,15]

- Precision land levelling (increasingly through the use of laser technology) has been identified as one of the two most important developments in soil and crop management practice and farming operations.[16] These practices redistribute soil from high spots of the field to low spots of the field. Unevenness of the soil surface can have significant negative effects on the productivity of the field. Such unevenness can result in water pooling in some areas of the field while other areas are dry. And while moisture is an important agricultural input in its own right, the soil moisture also affects the effectiveness of the other inputs (e.g., fertilizers). Uneven fields also increase soil erosion and runoff (including fertilizer runoff). A study on conservation agriculture practices in India finds that levelling of the land can result in a more even distribution of water, which increases the efficiency of water application (by over 50%, resulting in a 25-30% savings in irrigation water), increases the water productivity of crops, increases crop yields (by 15-25%), increases nutrient use efficiency (by 15-25%) and improves the uniformity of crop maturity (which can lower labor costs).[17] In addition, when combined with zero- or minimum-till practices, the benefits can be enhanced due to better seed placement, germination, and the uniform distribution of irrigation water.
- Integrated pest management (IPM) is a science-based decision-making process that provides guidance for farmers in addressing pest management. IPM is typically viewed as a multi-step process of setting thresholds, monitoring pest activity, taking preventative measures to reduce pest problems before they begin, and controlling pests in the event that the previous steps indicate a pest problem.[18] A cornerstone of IPM is that it utilizes current, scientific information about particular pests and the potential for infestation and what the impacts of such infestation are likely to be. Rather than liberally applying chemical pesticides, IPM promotes the ex ante prevention of pest infestations and permits the judicious use of pesticides only once the threshold for action has been surpassed.

Conclusions

Many CA practices present a promising avenue for agricultural development and environmentally friendly strategies for increasing agricultural production. In this research brief we have demonstrated that temperature changes in excess of 3°C are likely to result in a decline in global average crop yields, assuming similar agricultural practices and technologies in the future. These lower yields on roughly the same area of land suitable for cultivation may make it difficult for food production to meet the higher food demands of a larger and wealthier future global population. Conservation agriculture practices provide the potential for increasing agricultural yields and raising profits for farmers, especially those in developing countries that currently have yields far below potential. We have briefly reviewed several CA practices, and have shown a sample of the agricultural, environmental, and economic benefits. The increased adoption of these practices may provide greater hope for the future and for food security around the globe.

[14] Kwesiga et al. (2003). "Agroforestry research and development in southern Africa during the 1990s: Review and challenges ahead."
[15] Akinnefesi et al. (2008). "Contributions of agroforestry research to livelihood of smallholder farmers in southern Africa: Part 1—Taking stock of the adaptation, adoption and impacts of fertilizer tree options."
[16] Jat et al. (2006), Op. cit.
[17] Ibid.
[18] U.S. Environmental Protection Agency (2012). "Integrated pest management (IPM) principles."

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