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Analysis

Economywide impacts of climate change on agriculture in Sub-Saharan Africa

Alvaro Calzadilla [a,*], Tingju Zhu [b], Katrin Rehdanz [a,c], Richard S.J. Tol [d,e,f], Claudia Ringler [b]

[a] Kiel Institute for the World Economy, Hindenburgufer 66, 24105 Kiel, Germany
[b] International Food Policy Research Institute, 2033K Street, NW, Washington, DC 20006-1002, USA
[c] Christian-Albrechts-University of Kiel, Department of Economics, Olshausenstraße 40, 24118 Kiel, Germany
[d] Department of Economics, University of Sussex, Falmer, Brighton, BN1 9SL, United Kingdom
[e] Institute for Environmental Studies, Vrije Universiteit, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands
[f] Department of Spatial Economics, Vrije Universiteit, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

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ABSTRACT

Two possible adaptation scenarios to climate change for Sub-Saharan Africa are analyzed under the SRES B2 scenario. The first scenario doubles the irrigated area in Sub-Saharan Africa by 2050, compared to the baseline, but keeps total crop area constant. The second scenario increases both rainfed and irrigated crop yields by 25% for all Sub-Saharan African countries. The two adaptation scenarios are analyzed with IMPACT, a partial equilibrium agricultural sector model combined with a water simulation module, and with GTAP-W, a general equilibrium model including water resources. The methodology combines the advantages of a partial equilibrium approach, which considers detailed water-agriculture linkages, with a general equilibrium approach, which takes into account linkages between agriculture and nonagricultural sectors and includes a full treatment of factor markets. The efficacy of the two scenarios as adaptation measures to cope with climate change is discussed. Due to the limited initial irrigated area in the region, an increase in agricultural productivity achieves better outcomes than an expansion of irrigated area. Even though Sub-Saharan Africa is not a key contributor to global food production (rainfed, irrigated or total), both scenarios help lower world food prices, stimulating national and international food markets.

1. Introduction

Agriculture is of great importance to most Sub-Saharan African economies, supporting between 70 and 80% of employment and contributing an average of 30% of gross domestic product (GDP) and at least 40% of exports (Commission for Africa, 2005). However, specific agro-ecological features, small farm sizes, poor access to services and knowledge, and low investment in infrastructure and irrigation schemes have limited agricultural development in Sub-Saharan Africa (Faurès and Santini, 2008).

Rainfed farming dominates agricultural production in Sub-Saharan Africa, covering around 97% of total cropland, and exposes agricultural production to high seasonal rainfall variability. Although irrigation systems have been promoted in the region, the impact has not been as expected. Reasons include a lack of demand for irrigated products, poor market access, low incentives for agricultural intensification, unfavorable topography, low-quality soils, and inadequate policy environments (Burke et al., 2006; Faurès and Santini, 2008). Although the cost of irrigation projects implemented in developing countries has generally decreased over the last four decades, and performance of irrigation projects has improved (Inocencio et al., 2007), the situation in Sub-Saharan Africa is different. This region has higher costs than other regions in terms of simple averages. However, some projects have been implemented successfully with lower costs compared to other regions.

Agriculture in Sub-Saharan Africa is characterized by comparably low yields. While Asia experienced a rapid increase in food production and yields during the Green Revolution in the late 1970s and early 1980s, in Sub-Saharan Africa per capita food production and yields have stagnated. The failure of agriculture to take off in Sub-Saharan Africa has been attributed to the dependence on rainfed agriculture; low population densities; the lack of infrastructure, markets, and supporting institutions; the agro-ecological complexities and heterogeneity of the region; low use of fertilizers; and degraded soils (Johnson et al., 2003; World Bank, 2007).

In Sub-Saharan Africa, rural poverty accounts for 90% of total poverty in the region, and approximately 80% of the poor still depend on agriculture or farm labor for their livelihoods (Dixon et al., 2001).

* Corresponding author. Tel.: +49 431 8814 401; fax: +49 431 8814 500.
E-mail address: alvaro.calzadilla@ifw-kiel.de (A. Calzadilla).

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High population growth rates, especially in rural areas, increase the challenge of poverty reduction and raise pressure on agricultural production and natural resources. According to the Food and Agriculture Organization of the United Nations (FAO, 2006), the population in Sub-Saharan Africa could double by 2050, increasing agricultural consumption by 2.8% annually until 2030, and by 2.0% annually from 2030 to 2050. During these same periods, agricultural production is projected to increase by 2.7 and 1.9% per year, respectively. As a consequence, net food imports are expected to rise.

The *World Development Report 2008* (World Bank, 2007) suggests that the key policy challenge in agriculture-based economies such as those in Sub-Saharan Africa is to help agriculture play its role as an engine of growth and poverty reduction. Development of irrigation and improvements in agricultural productivity have proven to be effective in this regard. Hussain and Hanjra (2004) identify three main pathways through which irrigation can impact poverty. Irrigation, in the micro-pathway, increases returns to the physical, human, and social capital of poor households and enables smallholders to achieve higher yields and revenues from crop production. The meso-pathway includes new employment opportunities on irrigated farms or higher wages on rainfed farms. Lower food prices are also expected, as irrigation enables farmers to obtain more output per unit of input. In the macro-pathway, or growth path, gains in agricultural productivity through irrigation can stimulate national and international markets, improving economic growth and creating second-generation positive externalities. In a similar way, Lipton et al. (2003) analyze the conditions under which irrigation has positive effects on poverty reduction and classify them into direct and indirect effects.

Faurès and Santini (2008) suggests that improvements in agricultural productivity can provide a pathway out of poverty for rural households in several ways. Poor households that own land benefit from improvements in crop and livestock yields through greater output and higher incomes. Households that do not own land but provide farm labor benefit from higher demand for farm labor and wages. Households that do not own land or provide farm labor benefit from a greater supply of agricultural products and lower food prices. Improvements in agricultural productivity can also benefit nonagricultural rural households and urban households through greater demand for food and other products (stimulated by higher agricultural incomes and higher net incomes in nonagricultural households). Food processing and marketing activities can also be promoted in urban areas. When agricultural productivity improves by means of water management, the incremental productivity of complementary inputs raises and expands the demand for these inputs, which in turn stimulates nonagricultural economic activities.

However, the effectiveness of irrigation and agricultural productivity in reducing poverty and promoting economic growth is affected by the availability of affordable complementary inputs, the development of human capital, access to markets and expansion of markets to achieve economies of scale, and institutional arrangements that promote farm-level investments in land and water resources (CA, 2007; Faurès and Santini, 2008).

Sub-Saharan Africa has the potential for expanding irrigation and increasing agricultural productivity. The *World Development Report 2008* (World Bank, 2007) points out that the new generation of better-designed irrigation projects and the large untapped water resources generate opportunities to invest in irrigation in Sub-Saharan Africa. New investments in irrigation need complementary investments in roads, extension services, and access to markets. The Comprehensive Assessment of Water Management in Agriculture (CA, 2007) suggests that where yields are already high and the exploitable gap is small, projected growth rates are low, whereas low yields present a large potential for improvement. In Sub-Saharan Africa, observed yields are less than one-third of the maximum attainable yields. The potential for productivity enhancement is therefore large, particularly for maize, sorghum, and millet. Although water is often the principal constraint for agricultural productivity, optimal access to complementary inputs and investment in research and development are also necessary.

Future climate change may present an additional challenge for agriculture in Sub-Saharan Africa. According to the Intergovernmental Panel on Climate Change (IPCC) (Watson et al., 1997), Africa is the most vulnerable region to climate change because widespread poverty limits adaptive capacity. The impacts of climate change on agriculture could seriously worsen livelihood conditions for the rural poor and increase food insecurity in the region. The *World Development Report 2008* (World Bank, 2007) identifies five main factors through which climate change will affect agricultural productivity: changes in temperature, changes in precipitation, changes in carbon dioxide (CO_2) fertilization, increased climate variability, and changes in surface water runoff. Increased climate variability and droughts will affect livestock production as well. Crop production is directly influenced by precipitation and temperature. Precipitation co-determines the availability of freshwater and the level of soil moisture, which are critical inputs for crop growth. Based on an econometric analysis for the US agriculture, Reilly et al. (2003) found that higher precipitation leads to a reduction in yield variability. Therefore, higher precipitation will reduce the yield gap between rainfed and irrigated agriculture, but it may also have a negative impact if extreme precipitation causes flooding (Falloon and Betts, 2009).

Temperature and soil moisture determine the length of the growing season and control the crop's development and water requirements. In general, higher temperatures will shorten the frost periods, promoting cultivation in cool-climate marginal croplands. However, in arid and semi arid areas, higher temperatures will shorten the crop cycle and reduce crop yields (IPCC, 2007). A higher atmospheric concentration of carbon dioxide enhances plant growth and increases water use efficiency (CO_2 fertilization) and so affects water availability (e.g. Betts et al., 2007; Gedney et al., 2006; Long et al., 2006).

Climate variability, especially changes in rainfall patterns, is particularly important for rainfed agriculture. Soil moisture limitations reduce crop productivity and increase the risk of rainfed farming systems. Although the risk of climate variability is reduced by the use of irrigation, irrigated farming systems are dependent on reliable water resources; therefore, they may be exposed to changes in the spatial and temporal distribution of river flow (CA, 2007).

In Southern Africa, climate change is already having an adverse impact on food security especially in the least developing countries with large rural population dependent on rainfed agriculture (FAO, 2011). Farmers need and started to adapt (i.e. Dinar et al., 2008; FAO, 2007, 2011; Ngigi, 2009; Paavola and Adger, 2006). The adaptation to climate change is expected to be autonomous or anticipatory. Autonomous adaptation is the reaction of an agent in response to climate change after the fact (ex-post), that is, changing crop types or using different harvest and planting dates when they observed changes in precipitation patterns. Its effectiveness depends on the availability of resources to cope with this unexpected event. Anticipatory adaptation is a planned (ex-ante) strategy to climate change. It is formulated as a public policy based on robustness, flexibility and net benefits (Dinar et al., 2008).

The adaptation strategies need to incorporate relevant and specific hydrologic, agronomic, economic, social, and environmental processes, thus they vary across different spatial scales (i.e. farm, basin, national, regional and global) but they also require a cross-scale interaction (Paavola and Adger, 2006; Ringler, 2008). In most cases, adaptation actions take place at the farm and basin level, where most decisions are made and interactions are strongest. Most common adaptation strategies at these levels are: crop and livestock selection, crop diversification, changing/improving cropping and grazing patterns, investing in irrigation technology, changing/improving agricultural practices (e.g. enhancing input use efficiency, better use of fertilizers) and soil and water conservation (e.g. small-scale water harvesting and management).