Global climate change and vulnerability of African agriculture: implications for resilience and sustained productive capacity

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Abstract

Despite noticeable improvements in recent socio-economic performance in Africa, variations exist across countries and performance is constrained by plethora of factors that inhibit the attainment of Africa's optimum production potential. Changing climate and environmental factors have contributed to increased transactions costs, lower productivity of factors of production, increased bottlenecks in the production process and investment challenges, especially for small and medium scale farmers in varying degrees across the continent. This paper reviews the impact of climate change on farming activities in Africa. Four countries across the continent are studied, viz. Burkina Faso, Egypt, Kenya and South Africa. We examine how long-term profitability of 4,000 farms vary with local climate, such as temperature and precipitation. To better ascertain the impact of climate variables, the marginal impacts of unit changes in temperatures and precipitation on crop farming activities are studied. Using selected climate scenarios, predictions are made on the extent to which projected climate changes will affect net revenues by the year 2050 and 2100. The findings suggest that climate affects agricultural returns in the four countries. The results further show that there is a non-linear relationship between temperature and crop revenue on the one hand and between precipitation and crop revenue on the other. Overall, the temperature elasticity suggests that global warming is harmful for agriculture across all the countries. These have profound implications for the policy requirements to address the productive capacity and resilience of the agricultural sector. Effort will be required to enhance adaptation at farm, regional and national levels. Policy adjustments will in addition require increased liberalization of the financial system and an implementation of agriculture civil service reforms for better performance of the extension service. This

may have further implications for state budgeting and agriculture sector expenditures which will without doubt require new shifts.

Keywords: Africa, climate change, agriculture, vulnerability, resilience, productive capacity
JEL: C32, D81, Q11

1. Introduction

Current climatic variation has significant impacts on agricultural production, constraining agricultural income and forcing farmers to adopt new agricultural practices in response to altered conditions. The risks of future climatic changes such as higher temperatures, changes in precipitation and increased climate variability can result in significant impacts on agriculture and rural areas, and attendant macroeconomic consequences for nation states (ROSENZWEIG and PARRY, 1993; MENDELSOHN and WILLIAMS, 2004; KURUKULASURIYA et al., 2006; IPCC, 2007). For countries with significant proportion of agrarian economies climate change is expected to have significant microeconomic and macro-consequences (MENDELSOHN and DINAR, 2003; DERESA et al., 2005; GBETIBOUO and HASSAN, 2005).

Africa is one of the world's largest continents, covering over 35 million km^2 and including about 48 countries. Sub-Saharan Africa counts a total land area of 2,455 million ha, of which 173 million ha (about one quarter of the potentially arable area) are under annual cultivation or permanent crops (FAO, 2002). African economies depend on semi-subsistence agriculture. Agriculture accounts for 20% of the continent's GDP (WORLD BANK, 2000a), employs 67% of the total labour force and is the main source of livelihood (DIXON et al., 2001). Over 90% of farms are small, farming less than 5 ha, with about two-thirds having less than 1.5 ha (SPENCER, 2001). These small-scale farms account for over 80% of agricultural production and support the food and fibre needs of about 600 million people in the continent. The continent's environment is closely linked with its climate such that climatic constraints are a major force in the development of vegetation, soils, agriculture, economic development and general livelihood.

Actual revenue increases for the agricultural sector in most African countries as a result of increases in global commodity prices and opening up of some export markets has masked the stagnating per capita production. Per capita agricultural production has stagnated primarily due to unfavorable weather for the rainfed crop production. Some important questions that this paper seeks to answer include: how vulnerable is African agriculture to a changed climate? What are the consequences on current and future macroeconomic policy? Primarily, the goal of this paper is to review and put in perspective the extent to which the productive capacity of selected countries: Burkina Faso, Egypt, Kenya and South Africa are vulnerable to climate change.

2. Mounting evidence of global warming and climate change

The IPCC reports in its Fourth Assessment Report that the earth's climate is changing, and the rate of change is accelerating with man's economic activity having a discernible effect on the climate. The best judgement of the Intergovernmental Panel on Climate Change (IPCC, 2007) is that if emissions of greenhouse gases (GHG) continue to grow as currently projected the global mean temperature will increase over the current century. These changes in greenhouse gases may not only lead to changes in temperature, precipitation and other climate variables, but may also result to global changes in soil moisture and increase in global mean sea level, and prospects for more severe extreme temperature events, flood and droughts in some places.

Crop plants have an inherent relationship with climate and the environment. Global environmental changes in atmospheric carbon dioxide, land transformation and anthropogenic nitrogen fixation, affect plant photosynthesis, respiration and decomposition, thus leading to changes in plant carbon dioxide fixation and the carbon stocks in vegetation and soils (MELILLO et al., 1993; SCHIMEL et al., 1994; VITOUSEK et al., 1997). Thus, the risks of changing weather conditions in relation to higher temperatures, changes in precipitation, increased climate variability and extreme weather events can result in strong significant impacts on agriculture, forestry and rural areas (ADAMS et al., 1990; MENDELSOHN et al., 1994; EASTERLING et al., 1993; LANG, 2001).

As a consequence of its vast size and opportunity and that Africa sits astride the equator, this results in a more or less symmetrical distribution of climate about the equator (THOMPSON, 1965), which is modified by regional factors such as topography and large water bodies. In other words, Africa experiences a wide variety of climate regimes, ranging from deserts to tropical rainforests (see KRISHNAMURTI and OGALLO, 1989). As a result of its latitudinal span (27° N to 34.5° S), there is a zonal distribution of climate from the meteorological equator northwards and southwards (OLAGO, 2001). The equatorial zone experiences the confluence of airflow from the northern to southern hemispheres, and the confluence zone migrates northward to about 15° to 24° N in June to August, and southward to about 8° N to 16° S in December to February giving rise to humid climate with a double rainfall maximum, flanked on the north and south by broad belts of monsoon climates characterised by summer rains and winter drought (STREET-PERROTT and PERROTT, 1993). The monsoon climate belts are flanked to the north by the arid Sahara and to the south by semi-arid and savanna regions. The temperate northern and southern extremities of the continent, which project into the belts of the mid-latitude westerlies, experience westerly cyclonic disturbances which give rise to high winter precipitation (STREET-PERROTT and PERROTT, 1993). Across the Kalahari and Sahara desert regions, precipitation is inhibited by sinking motion virtually throughout the year. In contrast to the equatorial and tropical regions which are characterised by abundant precipitation concentrated along the Inter-Tropical Convergence Zone (ITCZ) (SEMAZZI and SONG, 2001). Since the movement of the ITCZ trails the position of maximum surface heating associated with the north/south displacement of the overhead position of the sun, the equatorial region have two rainy seasons while most of the other regions of the continent have only one distinct rainy period during the year (*ibid*.).

Despite the relative dearth of quantitative records prior to 1900, adequate historical information has been put together to produce reliable picture of climate variability throughout the 19th century (HASTENRATH, 2001; NICHOLSON, 1978) using proxy material dealing with such phenomena as drought, goods and harvests, and various hydrological indicators. According to NICHOLSON (2001) and HASTENRATH (2001) climate and environmental conditions that prevailed over Africa long ago were quite unlike those of today. Table 1 presents the magnitude of the rainfall anomalies for the 1970s and 1980s in Africa. In the arid region of West Africa, rainfall was about half a standard deviation (SD) below the long-term mean of the 1970s, but approximately 0.8 SDs in the 1980s. The change in the more humid Guinean regions was more moderate but was also greater in the 1980s. In east Africa the averages for the two decades were 0.04 and 0.15 SD above normal, respectively. In southern Africa, the increase in the 1970s, up to 0.56 SDs, was almost equivalent to the decrease in the rainfall in the 1980s. In summary, rainfall was below normal throughout most of Africa during the 1980s, and this pattern generally prevailed in the 1990s (NICHOLSON, 2001). NICHOLSON (2001) further indicates that dry conditions were frequent during the 1840s, 1850s and early 1860s in all four regions (Sahel, Eastern Africa, Southern Africa-N and Southern Africa-S), analogous to the 1980 decade. This was a continuation of the drier conditions that occurred during the first few decades of the century (1900-1920). In the 1960s, however, rainfall increased over much of the equatorial region, associated with increase in the level of the Rift Valley lakes (see NICHOLSON and YIN, 2000). By the early 1970s, increased aridity was wide spread, with southern Africa observing relatively wet regimes. By the 1980s, rainfall was below the long-term mean over most of Africa. This trend continued into the 1990s. In the last 3 to 4 decades (1960-2000), rainfall was predominantly above average on all the regions but East Africa, a pattern quite similar to the 1950s.

Table 1. Magnitude of rainfall anomalies in Africa for the period 1970-1979 and 1980-1989

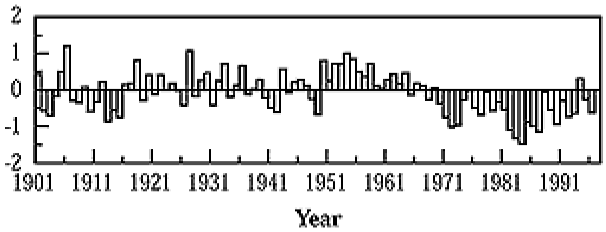
Sub-Region	1979-79		1980-89	
	%	% σ	%	% σ
Sahelo-Sahara	-31	-47	-24	-35
Sahel	-22	-55	-31	-82
Sudan Savanna	-13	-53	-20	-85
Sudano-Guinean Zone	-5	-36	-8	-56
Guinea Coast	-6	-31	-7	-35
Eastern Africa	0	4	2	15
South Africa-North	6	20	-5	-21
South Africa-South	10	34	-7	-27
South Africa-West	26	56	-12	-25

Note: Regionally averaged rainfall is expressed as a percent departure from the long-term mean and as a standardised departure [ratio of the departure from the mean to the standard deviation (SD)].
Source: NICHOLSON (2001)

According to NICHOLSON (2001) one of the most significant climatic variations has been the persistent decline in rainfall in the Sahel since the late 1960s. Mean rainfall decreased by 20-40% in the Sahel between the periods 1931-1960 and 1968-1997 and generally 5-10% across the rest of the continent (see figure 1). The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest of the past 30 years and was thought to perhaps indicate the end of the drought. However, dry conditions returned after 1994 (IPCC, 2001). Linear regression of 1901-1990 rainfall data from 24 stations in the west African Sahel yields a negative slope amounting to a fall of 1.9 standard deviations in the period 1950-1985 (NICHOLSON and PALAO, 1993). For the years ahead, HEWITSON (1997) simulates precipitation to increase over much of the African continent by the year 2050. Similarly, HERNES et al. (1995) constructed climate change scenarios for the African continent that showed land areas over the Sahara and semi-arid parts of southern Africa warming by 2050s by as much as 1.6 ^{o}C and the equatorial African countries warming at a slightly slower rate of about 1.4 ^{o}C.

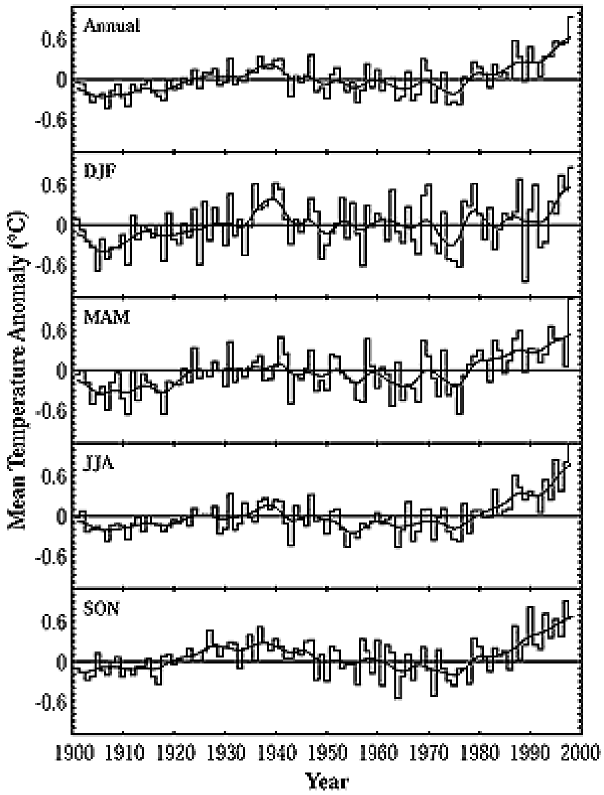
In effect, records show that the continent of Africa is warmer than it was 100 years ago (HULME et al., 2001) and warming through the 20th century has been at the rate of about 0.05 °C per decade, with slightly larger warming in the June, July, August (JJA) and September-November seasons than in December, January, February (DJF) and March-May (HULME et al., 2001). The five warmest years in Africa have all occurred since 1988, with 1988 and 1995 the two warmest years (figure 2). This rate of warming is not dissimilar to that experienced globally. Comparing data, the periods of most rapid warming (the 1910s to 1930s and the post-1970s) occur simultaneously in Africa and the world. The climate of Africa has experienced wetter and drier intervals during the past 2 centuries. The most pronounced periods were during the 20th century.

Figure 1. Rainfall fluctuations, 1901-1998, expressed as regionally averaged standard deviation (departure from long-term mean divided by standard deviation) for the Sahel



Source: IPCC (2001)

Figure 2. Annual temperatures in Africa[1]



Source: HULME et al. (2001)

1 Mean surface air temperature anomalies for the African continent, 1901-1998, expressed with respect to 1961-1990 average, annual and four seasons (DJF, MAM, JJA, SON).