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Rainfall and Economic Growth and Poverty: Evidence from Senegal and Burkina Faso

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Abstract

This paper assesses the effects of rainfall shocks on poverty in Burkina Faso and Senegal using a computable general equilibrium model. An index quantifying effects of rainfall fluctuations shows that, due to a predicted increase in annual rainfall, Senegal will experience a decline in poverty, while Burkina Faso will experience an increase in its poverty rate in conjunction with a trend of declining rainfall. The implementation of mitigating policies in Burkina Faso can affect the rate of increase in poverty, but future rainfall trends are expected to have positive effects on poverty in Senegal and negative effects in Burkina Faso.

Key worlds: climate change, rainfall, agriculture, poverty, CGE.

JEL Classification: Q1, O13, I3, C6.

Résumé

L'objectif de ce papier est d'évaluer l'impact des fluctuations pluviométriques sur la pauvreté au Burkina Faso et au Sénégal. L'analyse est menée à l'aide d'un modèle d'équilibre général calculable dynamique dans lequel les fluctuations pluviométrique sont captées par un indice pluviométrique. Les résultats des simulations montrent qu'en raison d'une tendance à la hausse prévue des précipitations, le Sénégal pourrait expérimenter une baisse de la pauvreté. En revanche, le Burkina Faso pourrait connaître une augmentation de l'incidence de la pauvreté en raison d'une tendance à la baisse des précipitations attendue. Toutefois, la hausse de l'incidence de la pauvreté au Burkina Faso pourrait être atténuée lorsque des politiques d'adaptation sont mises en place. Au total, les prévisions futures de précipitations devraient avoir des effets positifs sur la pauvreté au Sénégal et négatifs au Burkina Faso.

Mots clés : changements climatiques, agriculture, pauvreté, modèle EGC.

Classification JEL : Q1, O13, I3, C6

1. Introduction

While poverty has declined in south and east Asia in recent decades, it has increased in sub-Saharan Africa, particularly in rural areas (World Bank, 2000). Low agricultural productivity is a key factor in the region's high poverty rate; from 1965-1998, Africa was the only region in the world in which agricultural production increased at a rate below that of population growth (Kydd et al., 2004). Declines in per capita cereal consumption were particularly significant during the severe droughts seen in 1968 to 1973 and 1981 to 1984 (World Bank, 1991). In addition to cereal deficits, the region also faces chronic water scarcity. Although Senegal and Burkina Faso have significant potentially arable land, agricultural activity is mainly rainfed; hence, agriculture in those two countries is highly vulnerable to rainfall shocks and pressure on natural resources.

After independence, no specific environmental legislation was enacted in either country. However, severe drought during the 1970s and the resulting hunger and rural exodus to cities convinced policymakers of the need to take vigorous measures against natural resource degradation (République du Sénégal, 1998). Since the second decade after its independence, Senegal has addressed environmental issues through the Office of Environment, established in 1975 within the Ministry of Industrial and Environmental Development. Burkina Faso also created a ministry devoted to environmental issues in 1976, and the Rio conference in 1992 gave further opportunity for both countries to set environmental issues at the core of their economic and social development policy process.

Since Rio, environmental factors have been more visible in both countries' development strategies. In 1996, the government of Burkina Faso initiated an in-depth discussion that led to the adoption in 1998 of a Strategic Orientation Document (DOS) for the agriculture and livestock sectors. The Strategic Document for Rural Development (DSDR) is the basic framework for all interventions in rural areas until 2015 and is designed to promote investments and higher agricultural yields, sustainable and rational management of natural resources, and equal access to land. Under this initiative, a program for building small dams to support irrigation has been continued and production of improved seed varieties has been reinforced. The government also supplies producers with free seed and heavily subsidized fertilizer, tractors, and pumps for irrigation. Senegal's tenth Orientation Plan for Economic and Social Development (PODES) also focuses on the rational management of natural resources, specifically the fight against desertification, the protection of humid areas, and the improvement of coastal management. A national action plan for the environment was implemented in 1994 in Burkina Faso and in 1997 in Senegal, and a forestry plan was set in place in 1993 in Senegal and in 1997 in Burkina Faso (République du Sénégal, 2011; Burkina Faso, 2006, 2010).

These programs were followed by the implementation of the Comprehensive Africa Agriculture Development Program, which aims to boost agricultural growth to 6 percent and halve poverty by 2015. One of CAADP's key measures calls for countries to allocate at least 10 percent of their budgetary resources to their agricultural sectors; to date, Burkina Faso is one of the few countries that have met this commitment. While CAADP was conceived as a strategy based on agricultural intensification, it also works to ensure coherent policies and programs for the agricultural sector. The National Agricultural Investment Plan (PNIA) of Senegal and Burkina Faso is a set of prioritized projects derived from the CAADP process.

Despite all of these efforts, however, rainfall shocks remain a significant threat to agricultural production in Senegal and Burkina Faso and are the main obstacles to meeting CAADP goals. While Sub-Saharan Africa has seen renewed growth following the 2008 global economic crisis, optimistic forecasts for the region do not take into account the issue of rainfall. Due to frequent shortages in rainfall, which expose farmers to significant risks, a clear understanding of the impact of rainfall shocks on economic growth is of critical importance. According to the IPPC (2007), in some countries where agriculture is highly dependent on rainfall, cropping periods will be shorter and yields could be halved by 2020. Therefore, the optimistic predictions of growth in Africa depend on several endogenous and exogenous factors, including climate.

Regarding endogenous growth, human capital, public expenditures, institutional quality, and macroeconomic framework are quite crucial to take into account (Acemoglu D. et al., 2002, Barro R. et al., 1995, Aghion Ph. et al., 1992, Mankiw N. G. et al., 1992). However, growth also depends on some exogenous factors, including external aid allocation (Burnside and Dollar, 1997) and the lack of diversification in Africa's exports (Sachs and Warner, 1997). Landlocked geography and tropical climates also pose challenges for many African nations (Bloom and Sachs, 1998). Since 1960, rainfall has generally declined in the region (Nicholson, 1994; Barrios et al., 2010), and this decline has had severe consequences on economic growth (Nicholson, 1994; Collier and Gunning, 1999; O'Connell and NDulu, 2000; Bloom and Sachs, 1998). The effects of climatic change are increasingly visible and a growing number of studies are taking place in order to produce further and more robust empirical evidence about the effects of climate change on economic growth.

Using new cross-country panel climatic data in an empirical economic growth framework, Barrios et al. (2008; 2010) examine the role of rainfall trends on poor growth performance in Sub-Saharan African nations relative to other developing countries. Their results show that rainfall has been a significant determinant of poor economic growth for African nations, but not for countries in other regions. A scenario of no decline in rainfall would have resulted in a reduction of between approximately 15 percent and 40 percent of the existing gap in African GDP per capita relative to the rest of the developing world (Barrios et al., 2010). Benson (1994) shows that the major drought that occurred in 1992 over much of southern

Africa led to a decline in GDP of 9 percent, 8 percent, and 3 percent in Zambia, Zimbabwe, and South Africa, respectively. Trends in Zimbabwe's economic growth in particular have been linked to rainfall variability, despite the fact that the country's recent decline in growth could be impacted by other factors such as land reform policies enacted in 2000 (United Nations Statistics Division, 2006).

An advance warning system for drought risk and seasonal rainfall prospects would improve Africa's economic growth potential and would provide additional security for food and water supplies (Jury, 2002). According to the World Bank (1991), the decline in per capita food consumption was more pronounced during the major drought episodes observed from 1968 to 1973 and 1981 to 1984, suggesting the impact of drought on food productivity (Tarhule, 2007). This strong link between rainfall and growth in Africa is due to several factors: the prevalence of rainfed agriculture in the region; input-output linkages between agriculture and other economic sectors; the proportion of the population engaged in agricultural activities; and the prevalence of subsistence agriculture.

A shock such as a drought can thus have significant, economy-wide effects. Three main indices are used for identifying periods of drought: the rainfall anomaly index (RAI), the Bhalme and Mooley drought index (BMDI), and the Palmer drought index (PDI). Using data from the state of Nebraska as an example, Oladipo tries to examine these indices' comparative performance in depicting periods of drought of differing intensities (1985). The results of his analysis suggest that rainfall is the most important climatic element as an input into meteorological drought. The Palmer index has been used and enhanced in the case of Canadian prairies to determine that drought is the single most limiting factor for crop yield (Akinremi, McGinn, and Barr, 1996). NKome and Gomes (2006) also attempt to assess the effects of water shortages caused by climate change on millet production in the Gambia. This work relies on a spatial nonlinear dynamic programming model, specifically a hydro-economic model similar to the one developed by Hurd et al. (1999; 2004). The major finding of this study is that at a macroeconomic level, irrigation generates substantial profits; while at a microeconomic level, revenues from irrigated agriculture do not seem to cover the costs of irrigation, a condition that presupposes the introduction of subsidized irrigation policies for Gambian farmers.

Several studies have evaluated the effects of rainfall fluctuation on sectoral and economic growth using partial equilibrium models to estimate the residual damages of climate change on different agricultural sub-sectors in the US (Adams et al., 1998; Reilly et al., 1994; Perez-Garcia, 1994). Integrated evaluation models (IEM) have also been used to take into account several variables related to greenhouse gas emissions and the carbon cycle and atmospheric chemistry. Weyant (1997) identified 23 types of EIM that can be grouped into three categories: models for policy evaluation, models for policy optimization, and models of uncertainty decisions. These models attempt to link all the relevant variables of a system so that the effects of climate change on ecosystems and human activities are captured. Barrios et al. (2008) examine the impact of rainfall trends on the poor growth performance of Sub-Saharan Africa (SSA) economies compared to non-Sub-Sahara Africa (NSSA) developing countries using a new cross-country panel climatic dataset in an agricultural production framework. Their results show that climate, measured as changes in countrywide rainfall and temperature, is a major determinant of agricultural production in SSA. By contrast, NSSA countries appear not to be affected by climate in the same manner. Simulations done using the estimates suggest that the detrimental changes in climate seen since the 1960s can account for a substantial portion of the gap in agricultural production between SSA and the rest of the developing world.

Recently, the literature has been enriched by several environmental studies based on computable general equilibrium models (CGEs). Several studies have used this framework to assess the costs attributable to climate change, in particular the cost in terms of production shortfalls in the US (Mark Douglas, 1997; Stuart et al., 1997; Parry et al., 1988; Rosenberg, 1993). These studies find that when farmers have limited financial resources and little capacity to adopt new technology, relatively small changes in the agro-ecological system can have quite a substantial effect on households.

In Senegal and Burkina Faso, agriculture is mainly rainfed; therefore, rainfall shocks can have wide distributive effects on households and individuals. A growing number of studies are taking place in order to produce further and more robust empirical evidence about the effects of rainfall shocks on economic growth. However, these studies are generally based on a partial equilibrium framework; assessing this phenomenon using on a general equilibrium framework and exploring the linkages with poverty is less common. The aim of this research is to assess the effects of rainfall changes on growth and poverty using a case study from two Sahelian countries and to determine how CAADP can help to mitigate the adverse effects of rainfall shocks in the region.

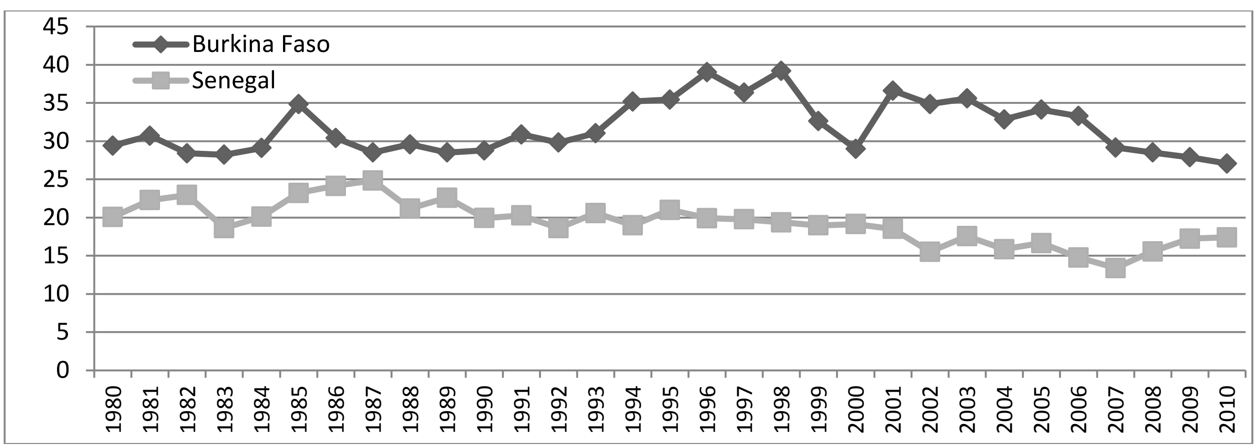
2. Background

Senegal and Burkina Faso are the two West African countries examined in this case study. Senegal has an area of 197161 km^2 and an estimated population of 12 million, mainly concentrated in cities. Senegal's rate of population growth is 2.7 percent, while its rate of economic growth is four percent (République du Sénégal, 2010). Burkina Faso has an area of 274.200 km^2 area and a population estimated at 13 million. Its rate of population growth of population is also 2.7 percent, while its rate of economic growth is 5.6 percent (IMF, 2008).

The agricultural sectors of both countries are mainly rainfed and therefore highly dependent on rainfall, characterized in this region by sharp fluctuations. Large rainfall fluctuations expose farming activities to significant uncertainties; the level of uncertainty differs depending on each country's growth performance and the contribution of the rainfed agricultural sector to overall GDP.

From 1980 to 2010, the share of agriculture in overall GDP in Burkina Faso was at least 27 percent and reached as much as 40 percent (Graph 1). In Senegal, its share varied between 20 and 25 percent (Graph 2). The pattern of the contribution of agriculture to overall GDP also differs in those two countries. During the recent global economic crisis, the contribution of agriculture to GDP has declined in Burkina Faso and slightly increased in Senegal due to differences in each country's policy response to cereal shocks.

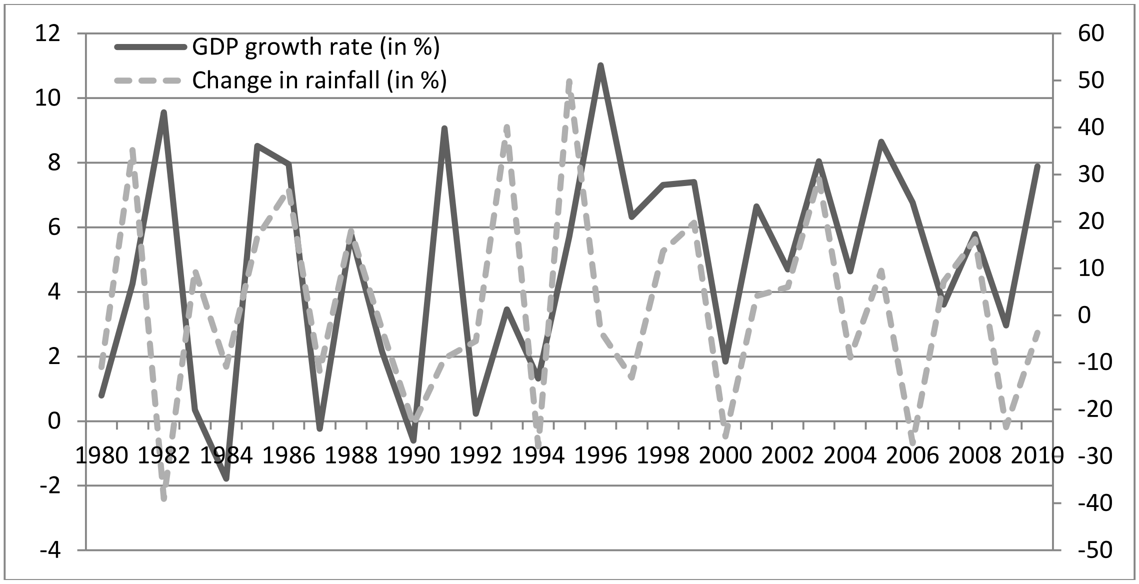
Graph 1: Contribution of agricultural sector to total GDP, 1980-2010 (in %)



Source: World Development Indicators, World Bank (2012)

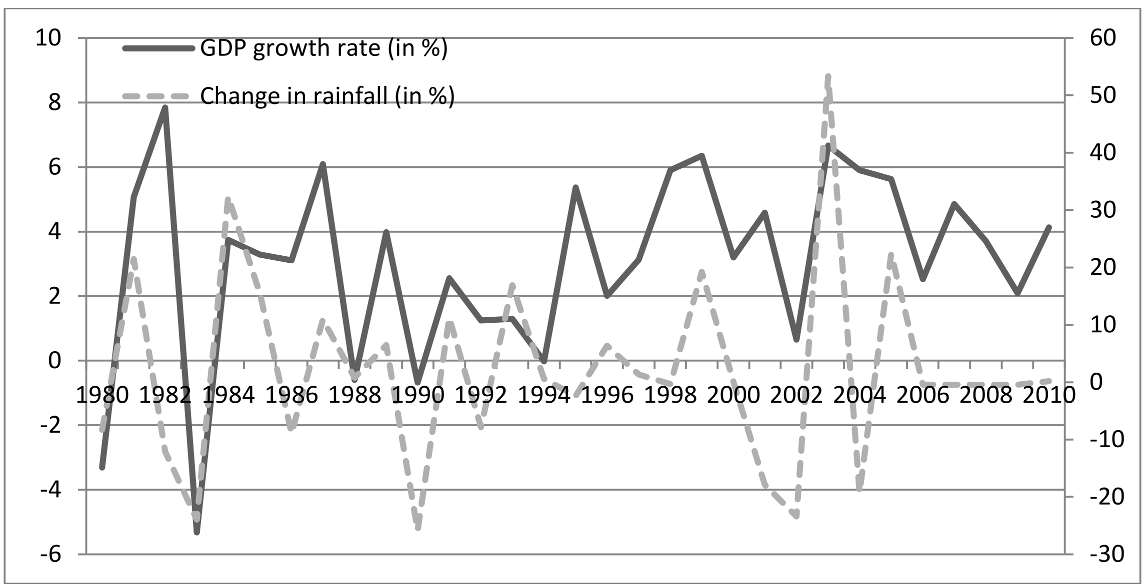
Rain quantity is relatively low in this region. During the 1980s and 1990s, the average amount of rainfall was 617 mm in Senegal and 748 mm in Burkina Faso. GDP growth trends show that Burkina Faso's growth during the three last decades was more substantial and higher than the Senegal's, with the exception of a few periods (Graphs 2 and 3). However, the pattern of growth is still volatile for both economies and seems to follow rainfall patterns.

Graph 2: GDP growth compared to rainfall in Burkina Faso, 1980-2010 (in %)



Source: World Development Indicators, World Bank (2012)

Graph 3: GDP growth compared to rainfall in Senegal, 1980-2010 (in %)



Source: World Development Indicators, World Bank (2012).

Crops that are more dependent on rainfall, such as cereals, are more important in Burkina Faso than in Senegal, where oil crops are more important (Table 1).

Table 1: Cereals and Oil Crops Area Harvested and Production in Senegal and Burkina Faso

	Area harvested (1000 ha)					Production (1000 tons)				
	1999-2001	2003-2005	2007	2008	2009	1999-2001	2003-2005	2007	2008	2009
Cereals										
- **Burkina Faso**	2944	3300	3321	4179	4179	2698	3372	3109	4326	4326
- **Senegal**	1243	1202	1069	1482	1647	1060	1313	772	1740	1869
Oil crops										
- **Burkina Faso**	603	939	882	978	933	125	159	131	171	163
- **Senegal**	1023	780	681	912	1116	308	199	116	238	325

Source: FAO Statistical Yearbook (2010).

Poverty is largely a rural phenomenon in Senegal and Burkina Faso, and a large share of both countries' workforce is employed in the agricultural sector. In Burkina Faso, the poverty headcount is equal to 46 percent at the national level. However, 52 percent of persons are poor in rural areas versus 20 percent in urban areas (Ebcvm, 2003). The same trend can be seen in Senegal, whose poverty headcount is equal to 51 percent at the national level (Esps, 2005); 35 percent of urban persons are poor, compared to 62 percent of rural persons.

Cereals (excluding beer) and vegetable oils seem to be the most important products in the basket of consumption in Senegal and Burkina Faso during 2005 to 2007 (Table 2).

Table 2: Share of Dietary Components in Total Energetic Consumption in Senegal and Burkina Faso (2005-2007)

	Cereals (excl. beer)	Vegetable Oils	Sugar & Sweetener	Meat & Offals	Roots & Tubers	Milk, Eggs & Fish	Fruits (excl. wine & vegetables)	Animal Fats	Pulses	Other
Burkina Faso	72,8	5,2	2,1	3,5	0,6	1,6	0,7	0,5	4,8	8,2
Senegal	60,3	14,7	5,8	2,9	2,6	4,5	2,6	0,6	1,7	4,3

Source: FAO Statistical Yearbook (2010).

3. Methodology

Changes in rainfall can have adverse effects on the productivity of different crops, as highlighted by the IPCC (2007). Since agriculture is linked to the other sectors of the economy, variations in rainfall will affect farming activities and then the rest of the economy through inter-sectoral relations. As a result, a shock such as lack of rainfall or a drought will have important effects on agricultural supply and on the demand for input factors such as fertilizers. This in turn produces feedback effects on growth and, therefore, incomes and consumption prices. The present study uses a dynamic CGE to assess the effects of a rainfall shock, as well as of shock mitigation policies, on the sectoral reallocation of resources and growth.

3.1 Model Description

The dynamic model of the Senegalese economy used here was developed from the Exter model (Decaluwe, Martens, Savard, 2001). This model applies to a small open economy for which world prices are given and is designed as a set of simultaneous linear and non-linear equations, which define economic agents' behavior as well as the economic environment in which these agents operate. This environment is represented by market equilibrium conditions and macroeconomic balances. As rainfall shocks can induce wide effects over the long term, we use a dynamic recursive model.

For this study, a number of features were added to the Exter model: an endogenous function of total factor productivity, the inclusion of public capital, land factors, and dynamic updating equations. The resulting model belongs to the strand of dynamic recursive CGE literature, which implies that agents' behavior is based on adaptive projections rather than on the forward-looking projections that underlie alternative inter-temporal optimization models. Since a recursive model is treated one period at a time, it is possible to separate the *within-period* component from the *between-period* component, where the latter dictates the model's dynamics. The following sections present an overview of the model's structure.

Within Period

The within-period component describes a one-period static CGE model. The model integrates four production factors: labor, private agricultural capital, private non-agricultural capital, and public capital and land. The institutions selected are households in Dakar, households in other urban centers, rural firms, the country, and the rest of the world. The added value of the agricultural sector is expressed as a Constant Elasticity Substitution (CES) function of land and a composite factor aggregating labor, private agricultural capital, and public capital, where labor is specified as a CES function of qualified and unqualified labor and where the composite capital is expressed as a Leontief function specifying fixed shares of public and private capital (private agricultural capital, private non-agricultural capital). The added value of the non-agricultural sector is instead expressed as a CES function of labor and non-agricultural capital. Moreover, a function of export demand with a finite elasticity is introduced to take into account the constraints faced by Senegalese producers in the world market.

Between Period

While the static model described above is detailed in its representation of the Senegalese economy within a particular time period, its inability to account for second-period considerations limits its assessment of the full effect of policy and non-policy changes. In order to take into account the dynamics underlying the impact of rainfall changes, such as the inter-temporal changes in investments and the rate of capital accumulation, the static model is therefore extended to a recursive dynamic model in which selected parameters are updated based on results from previous periods and inter-temporal behaviors. The introduction of dynamic updating equations can better explain the linkages between rainfall changes, factor accumulation, and productivity changes. Current economic conditions, such as the availability of capital, are endogenously influenced by past economic conditions but remain unaffected by forward-looking expectations. The dynamic model is also exogenously updated to reflect demographic changes that are based on observed or inferred projected trends. The process of capital accumulation is endogenous.

The dynamic model is treated as a series of equilibria, each one representing a single year. In other words, the model takes into account dynamic adjustments in simulating the economic growth under rainfall shocks and a counterfactual scenario (steady, average rainfall). The difference between the economic pattern under rainfall shocks and the counterfactual scenario are interpreted as the economy-wide impact of climatic events.

Specific Features

The stock of sectoral private capital at the period is equal to the stock in the previous period minus capital depreciation, plus the capital accumulated during that period. Private capital accumulated during a period depends on the ratio between the return to capital and the cost of this factor. Agricultural private capital is distinguished from non-agricultural private capital, as the first goes specifically to rural households whereas the latter is supposed to be received by all categories of households. For the given sector *j*, the stock of public capital at the period is also equal to the stock of the previous period *t* minus capital depreciation, plus the volume of investment accumulated. Public investment is a complement of private investment. This relation links public capital and private capital in the tradable sector. In the public sector, the investment at period *t* depends on the available income.

The model directly integrates rainfall through the level of rainfall and a rainfall index (ipluv). The rainfall index is computed using data from the Meteorological Services. The calculation of this index is based on the spirit of the Palmer (1965) drought severity index. The rainfall index is given by the ratio of the value of rainfall at period *t* and its reference value:

$$ipluv^t = \frac{pluv^t}{pluvo} \quad (1)$$

The benchmark index is given by the average rainfall during a cycle of at least 30 years. The index takes the value 1 when the amount of rain collected is equal to the average. Below this value, the index is between 0 and 1 and reflects a rainfall deficit. Above the value 1, the index reflects surplus rainfall.

The total factor productivity (TFP) in agricultural sectors (A^t_{tra}) at period *t* is a function of rainfall quantity (Smadhi and Zella, 2012; Chebil and Mtimet, 2011; Subash, Singha, and Priyaa, 2011; Arega, 2010)[1]. TFP increases with the latter but can also decrease when there is excess rainfall; thus, even if the correlation between TFP and rainfall is positive, it can be inverted beyond a certain threshold. One way to take into account this specific functional form is to assume that the TFP is as a quadratic function of the rainfall:

$$A^t_{tra} = h^1_{tra} * (pluv^t_{tra})^2 + h^2_{tra} * (pluv^t_{tra}) \quad (2)$$

Land market equilibrium is characterized by the existence of underemployed land (Logfren, 1999). Land supply is supposed to be affected by rainfall shocks[2]. In Senegal, for instance, just 60 percent of the agricultural land stock is effectively used, so increasing rainfall leads to pressure on land demand. By contrast, when rainfall decreases, it induces an underutilization of land. Thus land supply in period *t* ($TOTLAND$) is equal to land demand ($LAND$) in t plus the underutilized part of the land supply. This latter is equal to the unused portion of land supply ($TOTLAND * beta\_l$) adjusted by the changes in land stock due to rainfall fluctuations:

$$TOTLAND_i^t * \left[1 + (1 - ipluv^t)\right] = \sum_{tra} LAND^t_{tra} + TOTLAND^t * beta\_l_i \quad (3)$$

$$TOTLAND = \sum_{tra} LAND^t_{tra} + TOTLAND * beta\_l * \left[1 + (1 - tpuv)\right] \quad (3')$$

In the labor market, labor supply (*FS*) by households *H* by type *L* is equal to the sum of sectors *j* demand (*FD*) by type of labour:

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[1] This functional form is close to the one that underlies the results of Chébil and Mtimet (2011). In their findings, they showed that increased rainfall from November to December and from March to April positively affects crop yields. However, the coefficients of second-order of variables "rainfall" are negative, which shows that an increase in rainfall during the same period negatively affect those returns. For instance, flood is supposed to have an adverse effect on crops. In their study, Chébil and Mtimet (2011) used a semi-log function to estimate changes in yields based on rainfall, temperature, and the time trend. These results are not far from that of Subasha, Singha, and Priyaa (2011), who found that rice productivity showed a degree polynomial technological trend and a steady increase in all their areas of survey except one. The authors found that extreme rainfall events create a severe threat to agricultural productivity, particularly for rice in different agro-ecological zones in India. They used a Mann-Kendall test to detect trends and the method of least square linear fitting to determine the slope of the trend lines. The vulnerability of extreme rainfall indices on productivity is analyzed using simple correlations. Based on principal component analysis, Smadhi and Zella (2012) also analyzed the relation between productivity and rainfall for several crops in Tunisia (durum wheat, beard wheat, barley). They found that rainfall is one of the key drivers of production and yields. Arega (2010) from USDA-ERS also found rainfall is one of the main determinants of TFP in African agriculture.

[2] Logfren (1999) assumes that for irrigated agriculture, two regimes are possible: full employment with market-clearance price or unemployment with the utilization level as the clearing variable. He assesses that, in practice, a factor of this type would be unemployed at any given point in time. Therefore, land market analysis is based on the labor market equilibrium model. In this type of market, the total labor supply in the economy is equal to the sum of labor demand from sectors plus the volume of unemployment. Similarly, we assume that there is a stock of unused land in the economy, like unemployment in the case of the labor market (land remained fallow which we have estimated from the property sheet). Therefore, the rate of land underemployment is assumed to increase during years of rainfall deficit (due to extreme drought which makes land barren) and decrease in years of good rainfall.

$$\sum_{H} FS^{t}_{H,L} = \sum_{j} FD^{t}_{L,J} \quad (4)$$

3.2 The Poverty Module

The standard CGE model generally covers a limited number of categories of households, thus restricting its use in the analysis of poverty and revenue distribution. More and more analysts are choosing to establish a link between the CGE model and data from a nationally representative household survey to analyze the microeconomic impacts of macroeconomic policies and shocks.[3] The present analysis is based on an intermediate micro-accounting approach that proves more appropriate in the case of this study, given the difficulty in reconciling micro-household data with data from the SAMs. First the monetary poverty profile for the base year is replicated, while taking into consideration the national poverty line. After the simulation, the change in consumption expenditures is computed from the CGE model and used to estimate new expenditures of real households in the survey. The poverty line is also updated through a change in consumer price indices generated from the CGE model. Then, new poverty rates are estimated for the simulation.

Poverty analysis is done based on the Foster, Greer and Thorbecke (1984) Pα index:

$$P_\alpha = \frac{1}{n} * \sum_{i=1}^{p} \left(\frac{z-y_i}{z}\right)^\alpha$$

where z is the poverty line, yi the mean expenditure of the household i, α is a coefficient expressing the level of aversion against poverty, n the total number of individuals, and p the total number of poor within the population. The poverty index is computed based on the following variable of interest: *expenditure per equivalent-adult*. For Senegal at the base year (2005), the poverty line defined by the statistical office[4] based on the household survey (ESPS, 2005) is 923.71 for Dakar FCFA/day/equivalent-adult, for cities others than Dakar, , 661.76 FCFA/day/equivalent-adult and for rural area, 561.22 FCFA/day/equivalent-adult.At national level, the poverty line at national level is equal to 82 672 FCFA/year/equivalent-adult in For Burkina Faso (EBCVM, 2003).

3.3 Collection and Processing of Statistical Data

The dynamic general equilibrium models are built based on a 2005 social accounting matrix (SAM) of the Senegalese economy and a 2008 SAM of that of Burkina Faso. The SAM includes 13 sectors for Senegal (millet/sorghum, maize, rice, groundnut, vegetables, fruits, livestock, fishery, other types of agriculture,

[3] Davies (2009) provides an exhaustive review of the literature regarding the techniques of reconciling macro-modeling with poverty and inequality analysis.
[4] Direction de la Prévision et des Statistiques

industry, tradable services, and non-tradable services) and 12 for Burkina Faso[5] (millet/sorghum, maize, rice, vegetables, fruits, livestock, fishery, other types of agriculture, industry, tradable services, and non-tradable services). Both SAMs integrate two types of labor (skilled and unskilled) and three types of capital (agricultural private capital, non-agricultural private capital, and public capital). Data on rainfall has been collected from the Agricultural Ministries of the two countries and data on household surveys is taken from national statistics offices.

4. Simulations and Results

Three categories of simulations have been performed to assess the effects of further changes in rainfall on growth and poverty in Burkina Faso and Senegal (Table 3). The first category of simulation is based on deviations from the predicted rainfall trend that has been deemed "normal[6]" based on past trends. For Senegal, two "normal" periods, 1945 to 1974 and 1975 to 2004, are cumulated as one robust past trend. For Burkina Faso, one normal period (1963 to 1992) and one half period (1993 to 2007)[7] are cumulated to build a robust past trend. The average amount of rain recorded by Senegal from 1945 to 2004 was 732 mm, while Burkina Faso's recording for 1963 to 2007 was 669 mm. The simulated average deviation from these past cumulated norms are 1.037 from 2005 to 2020 for Senegal (Sim. 1a), and 0.776 from 2008 to 2020 (Sim. 1b) for Burkina Faso.

The second category of simulation enables experimentation with alternative rainfall trends. It is based on deviations from "normal" during 30 years of rainfall, from 1975 to 2004 for Senegal and from 1993 to 2007 for Burkina Faso. The average amount of rainfall for those "normal" periods was 652 mm for Senegal and 640 mn for Burkina Faso. The simulated expected deviations were 1.163 for Senegal (Sim. 2a) and 0.811 for Burkina Faso (Sim. 2b).

A third category of simulation addressed Burkina Faso only, where rainfall patterns are predicted to decrease. This simulation was coupled with a growth in TFP in rainfed agricultural sectors of 50 percent (Sim. 3a and Sim. 3b). The adoption of high-yield varieties as a mitigation policy is expected to come from the CAADP package.

[5] Groundnut is not a common crop in Burkina Faso.
[6] A "normal" is defined by a period of 30 years that is consistent with a reference path of rainfall patterns. In this exercise, a robust cumulated "normal" is built based on two "normal" periods in Senegal and one "normal" and one half period for Burkina Faso, aside from a "normal" of 30 years for the two countries.
[7] Due to data issues for rainfall in Burkina Faso.

Table 3: Simulations

	Senegal	Burkina Faso
Simulations 1a (deviations from the past cumulated "normal," 1945-2004)	increase in rainfall by **+3.7%**	
Simulations 1b (deviations from the past cumulated "normal," 1963-2007)		decrease in rainfall by **- 22.4%**
Simulations 2a (deviations from the past "normal," 1975-2004)	increase in rainfall by **+16.3%**	
Simulations 2b (deviations from the past "normal," 1993-2007)		decrease in rainfall by **- 18.9%**
Simulations 3a (deviations from the past cumulated "normal," 1963-2007, coupled with a growth by +50% of the TFP)		decrease in rainfall by **- 22.4%** plus increase by +50% of the TFP
Simulations 3b (deviations from the past "normal," 1993-2007, coupled with a growth by +50% of the TFP)		decrease in rainfall by **- 18.9%** plus increase by +50% of the TFP

For each simulation, the assumption is the business as usual (BAU) scenario is driven by the path given by the average rainfall recorded during past "normal" periods. The baseline period, given the SAM availability, is respectively 2005 for Senegal and 2008 for Burkina Faso. The macroeconomic, sectoral, and poverty effects of the expected rainfall deviations are analyzed in the following sub-sections. We thus assume that the effects of any further changes in rainfall on sectors, factors, and economic growth will pass through yields and the changes in factor stocks, such as the availability of cultivated land. In this model, we emphasize the effects of rainfall on economic growth and poverty, which pass through changes in total factor productivity8 and the equilibrium of the land market. The most direct effects of rainfall fluctuations on economic growth are changes that pass through returns to factor distributed by rainfed agricultural sectors. The indirect effects will pass through changes induced by spillover effects of rainfed agriculture on the rest of the economy. The agricultural sector is inter-linked with the other sectors of the economy, as per the input-output matrix. Changes in rainfall will indirectly affect non-agricultural sectors depending on the intensity of the inter-relations that they have with the agricultural sector. They will also affect key services along agri-food chains, such as transportation. The results of the simulations are analyzed following this scheme: from its sectoral effects, shocks are supposed to affect value-added and hence GDP. Shocks induce effects on factors' demand and hence rate of return. Nominal income and price effects that will follow will then drive poverty effects.

8 Even though it is an important phenomenon, we do not analyze the issue of flooding in this paper.

The following results have been observed:

Sectors are positively affected in Senegal and negatively affected in Burkina Faso.

Senegal is supposed to experiment an increase in value-added in all sectors. The most important increases were observed in maize, rice, vegetables, and the composite "other type of agriculture" sector (Tables S1 and S2 in Appendix). Value-added livestock also increases due to the widespread practice of extensive livestock rearing (free-range), whose performance is closely related to the quantity and quality of rainfed pastures. Other food industries and tradable services are also quite sensitive to the effects of climatic shocks on agriculture; the tradable services and industrial sector also experiences a significant increase in activities because of their linkages with the agricultural sector.

For Burkina Faso, value-added deeply decreases. The main drops in value-added are seen in the "other types of agriculture" sector, millet/sorghum, maize, rice, vegetables, and fruits. Other sectors of the economy, like tradable services, also experience a significant decrease in their value-added (Table B1 and B2).

As sectors react differently to a rainfall shock, effects on sectoral value-added and overall GDP will differ.

Recession is expected in Burkina Faso, while Senegalese GDP growth is positive.

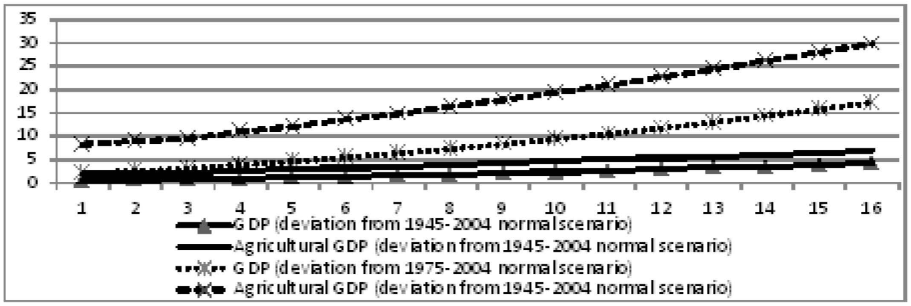
In Senegal, due to the expected rainfall trend, changes in GDP growth with respect to the baseline for the period 2005 to 2020 range from +0.5 to +4.3 percentage points for the first scenario based on deviation from the two past "normal" periods, 1945 to 2004 (Sim. 1a) (Graph 4). Changes in GDP range from +2.1 to +17.2 percentage points for the second scenario based on deviation from the past "normal" of 1975-2004 (Sim. 2a). Accordingly, changes in agricultural GDP with respect to the baseline that occur for the first scenario (Sim. 1a) will go from +1.9 to +7.0 percentage points for the period 2005 to 2020. As for the second scenario, changes in agricultural GDP with respect to the baseline (Sim. 2a) vary from +8.3 to +29.8 percentage points. Good future rainfall seems to have a positive effect on GDP growth, but this is sensitive to the choice of the reference "normal." Cumulating two "normal" periods gives more robustness and consistency to the past rainfall trends from which further deviations are calculated (Graph 4).

In Burkina Faso, expected changes in GDP growth with respect to the baseline for the period 2008-2020 range from -6.1 to -46.5 percentage points for the first scenario based on a deviation from the two past "normal" periods, 1963 to 2007, without mitigation policy (Sim. 2a) (Graph 5a). The range of the changes in GDP goes from -5.1 to -38.9 percentage points for the second scenario based on deviation from the past "normal" of 1993 to 2007, without mitigation policy (Sim. 2b). With a mitigation policy based on TFP increase of 50 percent due to an implementation of high-yield varieties to enhance productivity, changes in GDP growth with respect to the baseline will be in a range of -4.9 to -40.2 percentage points in the case of a deviation from the two past "normal" periods, 1963 to 2007 (Sim. 3a) (Graph 5a). The range of changes in GDP growth will go from -3.9 to -32.7 percentage points with a deviation from the two past "normal" periods, 1993 to 2007 (Sim. 3b).

Accordingly, changes in agricultural GDP with respect to the baseline that occur for the first scenario, without mitigation policy, vary from -17.7 to -72.3 percentage for the period 2008-2020 in Burkina Faso (Sim. 2a) (Graph 5a). As for the second scenario, without mitigation policy changes in agricultural GDP with respect to the baseline vary from -14.8 to -60.8 percentage points (Sim. 2b) (Graph 5a). With the mitigation policy, changes in agricultural GDP growth will range from -13.8 to -59.8 percentage points for a deviation from the two past "normal" periods, 1963 to 2007 (Sim. 3a), and from -11.1 to -48.7 percentage points for a deviation from the two past "normal" periods, 1993 to 2007 (Sim. 3b) (Graph 5a).

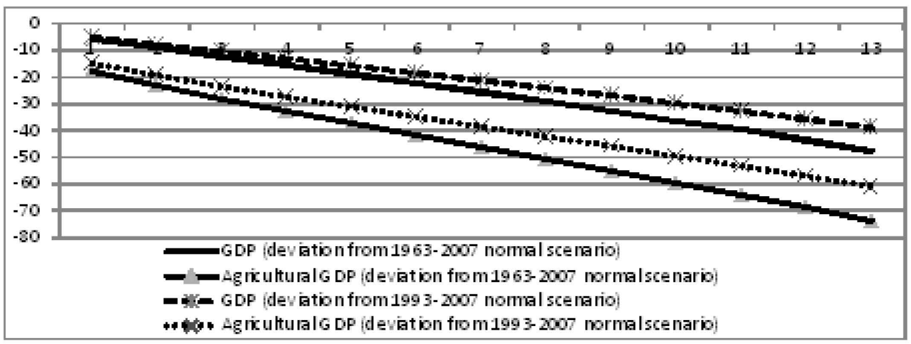
As factor intensity is different from one sector to another, the effect on factor demand and, hence, the rate of return to each type of factor will be different.

Graph 4: Changes in economic and agricultural GDP growth w. r. t. the baseline for Senegal (in %)



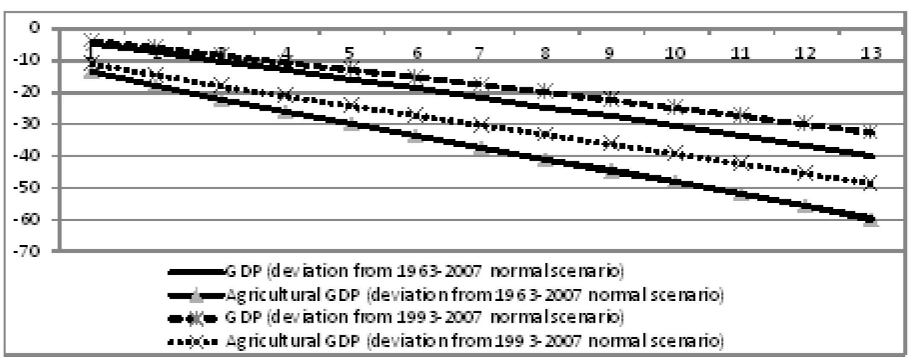
Source: calculations of authors based on simulation results.

Graph 5a: Changes in economic and agricultural GDP growth w. r. t. the baseline for Burkina Faso, without a mitigation policy (in %)



Source: calculations of authors based on simulation results.

Graph 5b: Changes in economic and agricultural GDP growth w. r. t. the baseline for Burkina Faso, with a mitigation policy (in %)

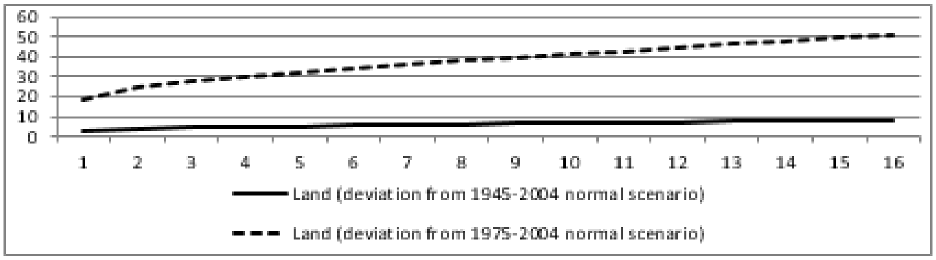


Source: calculations of authors based on simulation results.

Overall increase in the rate of returns in Senegal contrasts with declining rates in Burkina Faso.

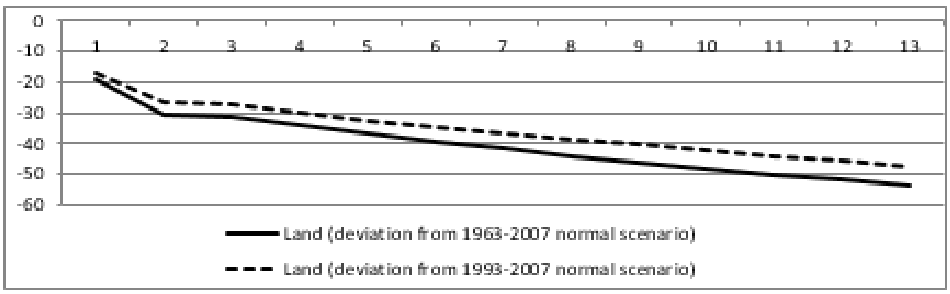
Factor demand and returns will depend on sectors' technology use and on reactions to rainfall patterns. Senegal's expected future positive rainfall trend will induce pressure on land demand and will lead to an increase in its rate of return (Graph 6). By contrast, Burkina Faso will experience a decrease in the rate of return to land due to its decreasing pattern of rainfall (Graph 7a). The rate of decrease will be lessened when mitigating policies, like implementing high-yield varieties to enhance productivity, are in place (Graph 7b).

Graph 6: Changes in the return to land w. r. t. the baseline, for Senegal (in %)



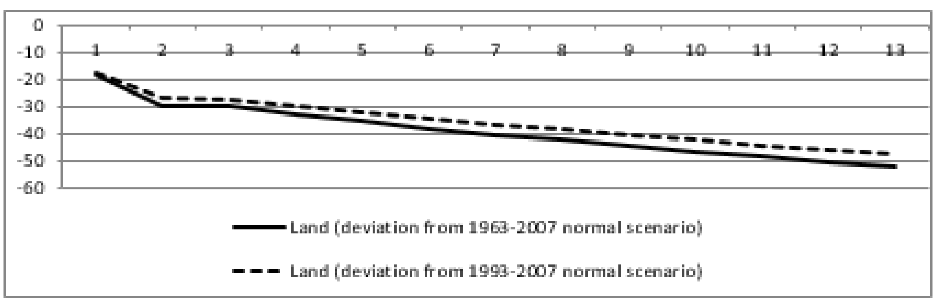
Source: calculations of authors based on simulation results.

Graph 7a: Changes in the return to land w. r. t. the baseline for Burkina Faso, without a mitigation policy (in %)



Source: calculations of authors based on simulation results.

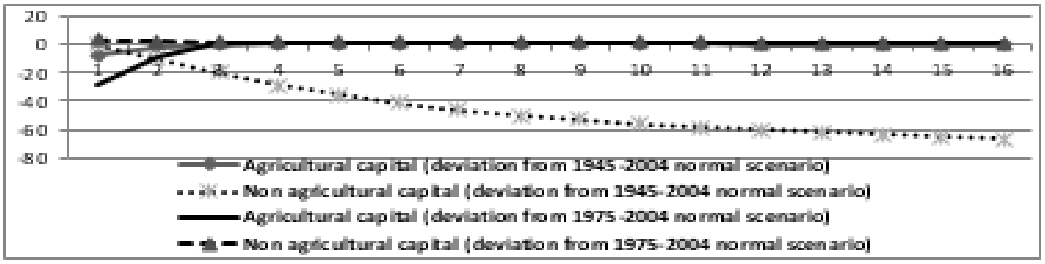
Graph 7b: Changes in the return to land w. r. t. the baseline for Burkina Faso, with a mitigation policy (in %)



Source: calculations of authors based on simulation results.

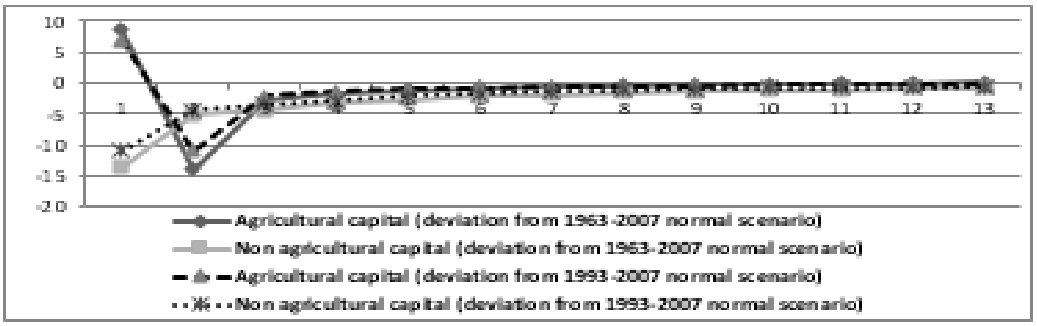
Increasing demand for agricultural capital coincides with the positive rainfall trend in Senegal, and the rate of return to agricultural capital experiences a slight increase over the period, while non-agricultural capital tends to be more abundant. Therefore, its rate of return declines sharply (Graph 8). In Burkina Faso, the rate of return to agricultural capital sharply decreased at the beginning of the period. It still remains negative, as does the rate of return to non-agricultural capital throughout the entire period (Graph 9a and 9b).

Graph 8: Changes in returns to agricultural and non agricultural capital w. r. t. the baseline, for Senegal (in %)



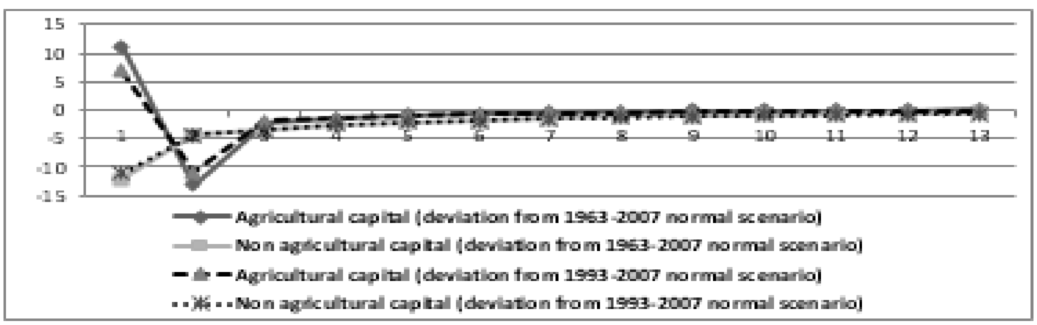
Source: calculations of authors based on simulation results.

Graph 9a: Changes in returns to agricultural and non agricultural capital w. r. t. the baseline, for Burkina Faso, without a mitigation policy (in %)



Source: calculations of authors based on simulation results.

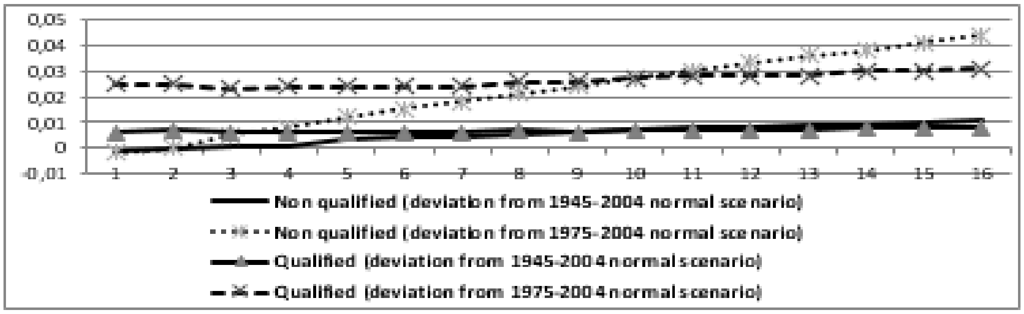
Graph 9b: Changes in returns to agricultural and non agricultural capital w. r. t. the baseline, for Burkina Faso, with a mitigation policy (in %)



Source: calculations of authors based on simulation results.

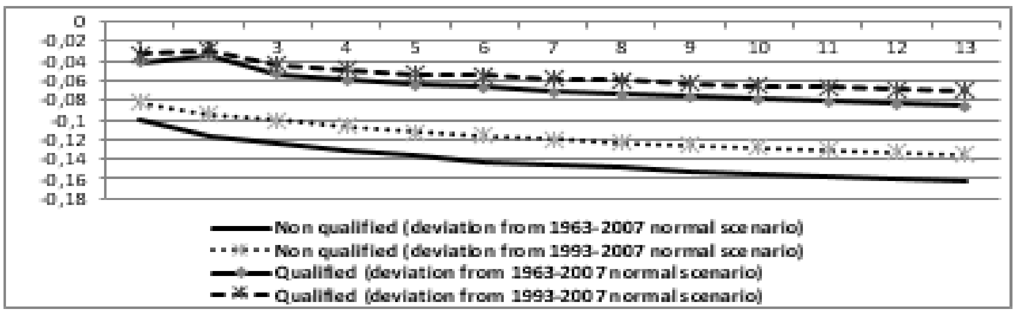
In Senegal, periods of positive rainfall are also characterized by an increase in wage rates for non-qualified labor, as this type of labor is more intensively used in rainfed agricultural sectors (Graph 10). Non-agricultural sectors that are directly linked to agriculture also tend to expand in periods of good rainfall and therefore need skilled labor; thus, the wage rates for skilled labor also increase, but less than those of unskilled labor. In Burkina Faso, wage rates decrease as the rainfall pattern decreases, with the unskilled labor force more intensively used in agriculture experiencing greater wage rate decrease than skilled laborers. This decrease is less when the mitigating policy is implemented (Graph 11a and 11b).

Graph 10: Changes in qualified and non qualified wage rate w. r. t. the baseline, for Senegal (in %)



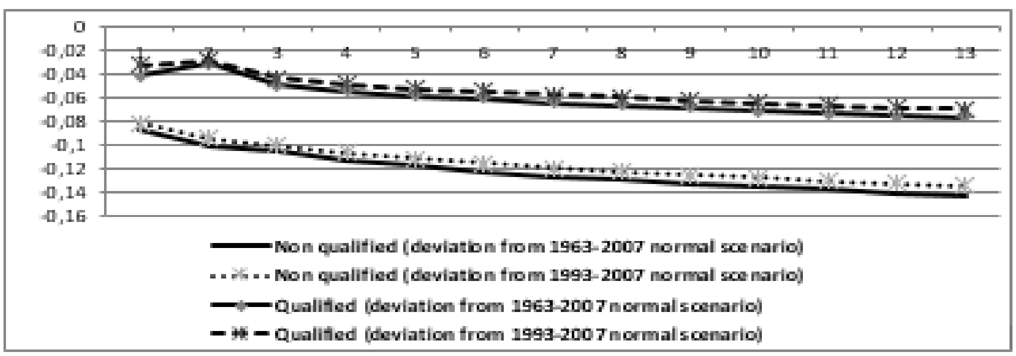
Source: calculations of authors based on simulation results.

Graph 11a: Changes in qualified and non qualified wage rate w. r. t. the baseline, for Burkina Faso, without mitigation policy (in %)



Source: calculations of authors based on simulation results.

Graph 11b: Changes in qualified and non qualified wage rate w. r. t. the baseline, for Burkina Faso, with a mitigation policy (in %)



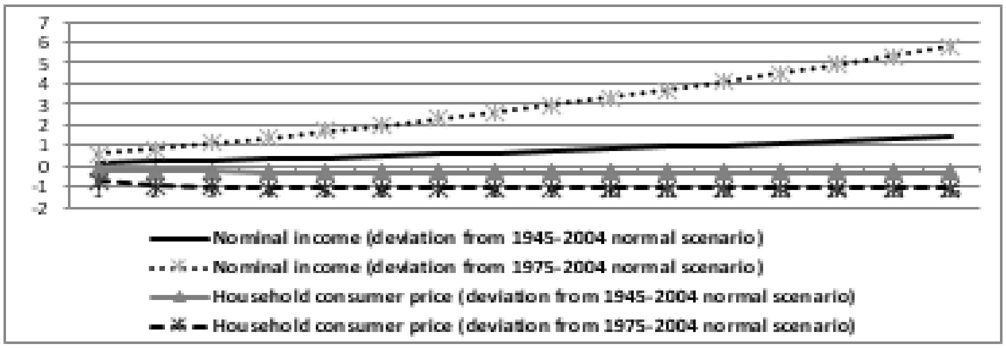
Source: calculations of authors based on simulation results.

The income of each category of individual will change depending on the individual's factor endowment. Price effects will also determine real income following changes in supply and demand for tradable goods and services.

Nominal income increases and consumption prices decrease in Senegal, while the converse holds true in Burkina Faso.

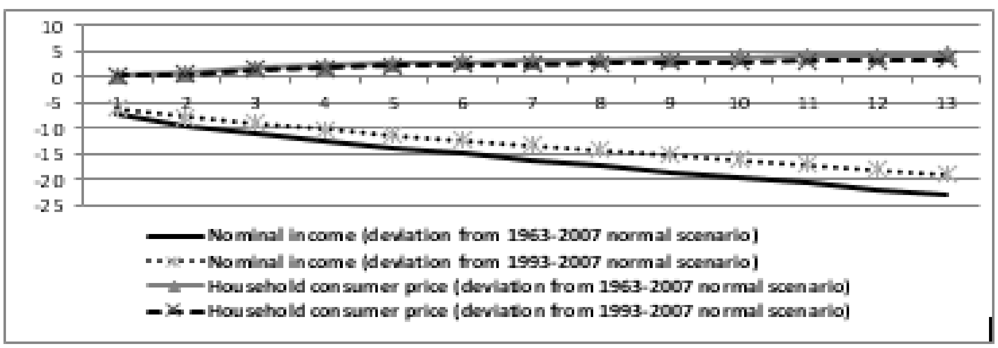
Changes in the rate of return affect nominal incomes and consumer prices. In Senegal, compared to the baseline, nominal revenues increase while consumer prices decrease for all simulations (Graph 12). For Burkina Faso, prices tend to increase while nominal incomes decrease due to the negative effects of declining rainfall. However, the decrease in nominal incomes is lessened when the mitigating policy is simultaneously implemented (Graph 13a and 13b).

Graph 12: Senegal: household revenues and prices change w.r.t to the baseline scenario



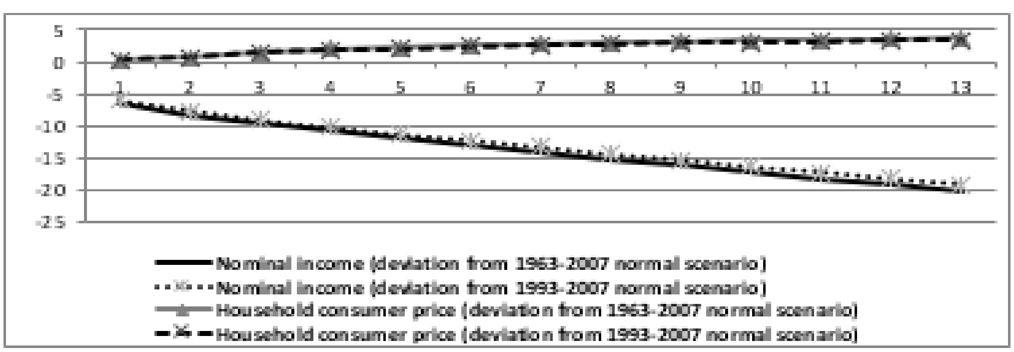
Source: calculations of authors based on simulation results.

Graph 13a: Burkina Faso: household revenues and prices change w.r.t to the baseline scenario, without a mitigation policy



Source: calculations of authors based on simulation results.

Graph 13b: Burkina Faso: household revenues and prices change w.r.t to the baseline scenario, with a mitigation policy



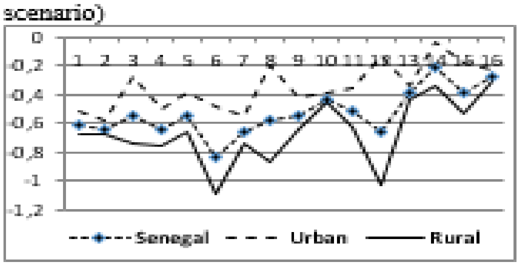
Source: calculations of authors based on simulation results.

Poverty reduction is expected for Senegal, but not for Burkina Faso.

Price and revenue effects are also reflected through poverty outcomes. Income and price effects lead to declining poverty trends in Senegal. The incidence of poverty declines at the national level and for both urban and rural groups; this decline is deeper for rural areas than for urban ones (graph 14a and 14b).

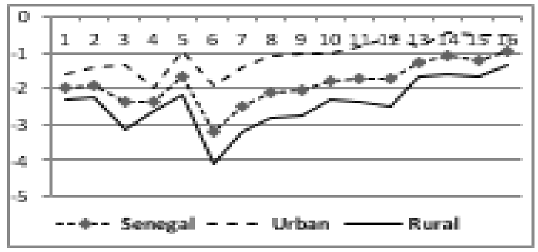
In Burkina Faso, by contrast, predicted declining rainfall leads poverty to increase at the national level and for all groups. Rural groups will suffer more with a higher increase in the incidence of poverty (graph 15a and 15b); but adopting mitigating policies such as a diffusion of high-yield varieties will help to dampen the increase in poverty (graph 15c and 15d).

Graph 14a: Senegal: changes in poverty effects in main areas for further deviations from 1945-2004 normal trend (in % w.r.t to the baseline scenario)



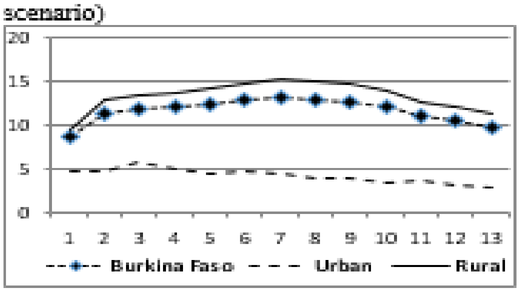
Source: calculations of authors based on simulation results.

Graph 14b: Senegal: change in poverty effects in main areas for further deviations from 1975-2004 normal trend (in % w.r.t to the baseline scenario)



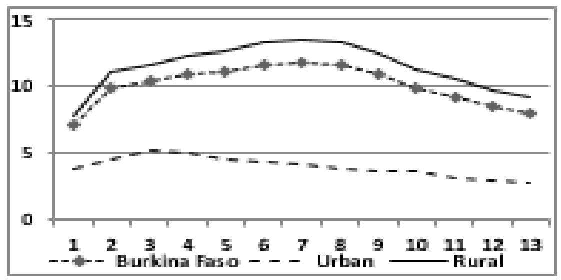
Source: calculations of authors based on simulation results.

Graph 15a: Burkina Faso: changes in poverty effects in main areas for further deviations from 1963-2007 normal trend and without a mitigation policy (in % w.r.t to the baseline scenario)



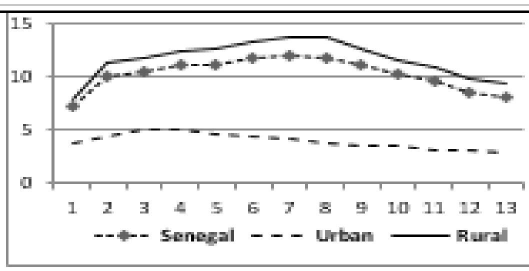
Source: calculations of authors based on simulation results.

Graph 15b: Burkina Faso: changes in poverty effects in main areas for further deviations from 1993-2007 normal trend and without a mitigation policy (in % w.r.t to the baseline scenario)



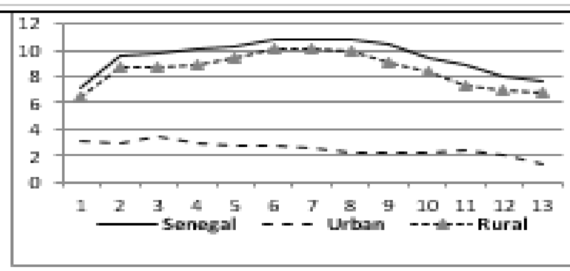
Source: calculations of authors based on simulation results.

Graph 15c: Burkina Faso: changes in poverty effects in main areas for further deviations from 1963-2007 normal trend and with a mitigation policy (in % w.r.t to the baseline scenario)



Source: calculations of authors based on simulation results.

Graph 15d: Burkina Faso: changes in poverty effects in main areas for further deviations from 1978-2007 normal trend and with a mitigation policy (in % w.r.t to the baseline scenario)



Source: calculations of authors based on simulation results.

5. Conclusion and Policy Lessons

For Sahelian countries like Burkina Faso and Senegal, where agriculture is largely rainfed, rainfall has a strong effect on agricultural growth, GDP growth, and poverty. Rainfall shocks are the main climatic risk faced by both countries' economies, particularly their agricultural sectors. In this paper, we first build a dynamic general equilibrium model in which we introduce an index that captures rainfall fluctuations and link it to total factor productivity and land markets. We then simulate and evaluate the impact of predicted rainfall trends on sectors, factors remuneration, and GDP and poverty. For Burkina Faso, which is expected to experience decreasing rainfalls, the supposition is that mitigating policies, like the adoption of high-yield crop varieties, will be implemented.

The results obtained show that Senegal will experience a decline in poverty due to a predicted increase in future rainfall trends. By contrast, Burkina Faso will experience an increase in its poverty rate, as future rainfall is predicted to decline. However, mitigating policies tend to reduce the rate of this decrease. To sum up, future rainfall trends are expected to have positive effects on poverty in Senegal and negative effects in Burkina Faso.

Future rainfall patterns will largely determine the path of growth for many Sahelian countries. The good news is that for countries in which rainfall is expected to increase, the performance of rainfed agricultural sectors can increase. However, to be sure that their growth path will not be so volatile, Sahelian economies facing decreasing rainfall patterns will need to set in place strong mitigating policies that will protect their growth from climatic events such as rainfall shocks.

Bibliography

Acemoglu, D., P. Aghion, and F. Zilibotti. 2002. "Distance to Frontier, Selection and Economic Growth." NBER Working Paper 9066. Cambridge, MA: The National Bureau of Economic Research.

Adams et al. 1998. "The Economic Effects of Climate Change on US Agricultural." In *The Impact of Climate Change on the US Economy*. Cambridge, UK: Cambridge University Press.

Aghion, P. and P. Howitt. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60(2): 323-351.

Akinremi, O. O., S. M. McGinn, and A. G. Barr. 1996. "Evaluation of the Palmer Drought Index on the Canadian Prairies." *Journal of Climate* 9: 897–905.

ANSD. 2005. "Enquête de suivi de la pauvreté au Sénégal." Ministère de l'économie et des Finances, République du Sénégal.

Alene, A. D. 2010. "Total Factor Productivity: Measures and Determinants." Ibadan, Nigeria: International Institute of Tropical Agriculture.

Barro, R. and X. Sala-i-Martin. 1995. *La Croissance Economique*. New York City, NH: McGraw Hill.

Barrios, S., L. Bertinelli, and E. Strobl. 2010. "Trends in Rainfall and Economic Growth in Africa: A Neglected Cause of the African Growth Tragedy." *The Review of Economics and Statistics* 92(2): 350- 366.

Barrios S., B. Ouattara, and E. Strobl. 2008. "The Impact of Climatic Change on Agricultural Production: Is It Different for Africa?" *Food policy* 33(4): 287-298.

Benson, C. 1994. "Drought and Macroeconomic Performance: A Comparative Analysis of Six Sub-Saharan African Economies." Mimeo. London: Overseas Development Institute.

Bloom, D. E. et al.. 1998. "Geography, Demography and Economic Growth in Africa." *Brooking Papers on Economic Activity* 1998(2): 207-295.

Burnside, A. C. and D. Dollar. 1997. "Aid, Policies and Growth." World Bank Policy Research Working Paper No. 569252. Washington DC: World Bank.

Chebil, A. and N. Mtimet. 2011. "Impact du Changement Climatique Sur la Productivité des Cultures Céréalières Dans la Région de Béja (Tunisie)'.' *AfJARE* 6(2).

Collier P. and J.W. 1999a. "Why Has Africa Grown Slowly?" *Journal of Economic Perspective* 13(3).

Collier, P. and J.W. Gunning. 1999b. "Explaining African Economic Performance." *Journal of Economic Literature* 37: 64-111.

Decaluwe, B., A. Martens, and L. Savard. 2001. "La Politique Economique du Développement et les Modèles D'équilibre Général Calculable." Presse de l'Université de Montréal, AUPELF/UREF.

Foster J., J. Greer, and E. Thorbecke. 1984. "A Class of Decomposable Poverty Measures." *Econometrica* 52(3): 761-766.

IMF. 2008. "IMF_GDP_Estimates." Available at www.imf.org.

INS. 2003. "Enquête burkinabé sur les conditions de vie des ménages."

IPCC. 2007. "La Fonte des Glaces de l'Himalaya Est Virtuellement Sûre D'augmenter les Inondations, les Chutes de Rochers Se Décrochant des Pentes et la Perturbation des Ressources en Eau." OMM/PNUE.

Hurd et al. 1998. "The Economic Effects of Climate Change on US Water Resources." In *The Impact of Climate Change on the US Economy*. Cambridge, UK: Cambridge University Press.

Jury, M.R. 2002. "Economic Impacts of Climate Variability in South Africa and Development of Resource Prediction Model." *Journal of Applied Meteorology* 41: 46-55.

Kydd, J., A. Dorwrd, J. Morrison, and G. Cadisch. 2004. "Agricultural Development and Pro-Poor Economic Growth in Sub-Saharan Africa: Potential and Policy." *Oxford Development Studies* 32(1).

Logfren, H. 1999. "Trade reform and the poor in Marocco: a rural-urban general equilibrium analysis of reduced protection." IFPRI Discussion Paper No. 38. Washington DC: International Food Policy Research Institute.

Mankiw, N.G., D. Romer, and D. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107(2): 407-436.

McDouglas. 1997. "Global Trade Assistance and Protection: The GTAP 3 Data Base." West Lafayette, Indiana: Center for Global Trade Analysis, Purdue University.

Nicholson, S. E. 1994. "Recent Rainfall Fluctuations in Africa and Their Relationship to Past Conditions over the Continent." *The Holocene* 4: 121-131.

NKome, J.C. and B. Gomes. 2006. "Estimating and Comparing Costs and Benefits of Adaptation Project: Case Studies in South Africa and The Gambia." AIACC Project N° AF 47.

O'Connell, S.A. and B. J. NDulu. 2000. "Africa's Growth Experience." Mimeo.

Palmer, W.C. 1965. "Meteorological Drought." Research Paper No. 45. Washington DC: U.S. Department of Commerce Weather Bureau.

Parry, M.L. et al. 1990. "Agriculture and Forestry." In: *Climate Change: The IPCC Impacts Assessment.* W.J. McTegart, G.W. Sheldon, and D.C. Griffiths (eds.). Canberra: Australian Government Printing Office.

Perez-Garcia. 1994. "Global Forestry Impacts of Reducing Softwood Supplies in North America." Working Paper 43. Seattle, WA: Center for international trade in forest products, University of Washington.

République du Sénégal. 2010. "Note d'analyse des comptes nationaux du Sénégal. Dakar: ANSD/MEFP.

Sachs, J. D. and Warner, A. M. 1997. "Sources of Slow Growth in African Economies." *Journal of African Economies* 6(3).

Smadhi, D. and I. Zella. 2012. "Variabilité de la Pluviométrie et Son Impact Sur la Production Céréalière au Nord de l'Algérie: Période (1970-2009)." *Sciences & Technologie* June 2012: 55-63.

Stuart et al. 1997. "The Megabare Model and Climate Change Policy: The Role of Research in Policy Development." AIC conferences, government policy conference Sydney, 4-5 August 1997.

Subasha, N., S.S. Singha, and N. Priyaa. 2011. "Extreme Rainfall Indices and Its Impact on Rice Productivity: A Case Study over Sub-Humid Climatic Environment." *Agricultural Water Management* 98: 1373– 1387.

Talhule, A. A. 2007. "Climate Information for Development: An Integrated Dissemination Model." *Africa Development* XXXII (4): 127-138.

United Nations Statistics Division. 2006. "Rainfall Variability and Economic Growth in Zimbabwe."

Weyant. 1997. "Insights from Integrated Assessment." in *Critical Issues in the Economics of Climate Change*. London: IPECA.

World Bank. 1991. "Food Security and Disasters in Africa: A Framework for Action." Washington DC: World Bank, Africa Technical Department.

World Bank. 2000. "Can Africa Claim the 21th Century?" Washington DC: World Bank, African Development Bank, and United Nations Economic Commission for Africa.

Appendix 1

Table S1: Change in value added w. r. t. the baseline for Senegal (in %), (deviation from 1945-2004 normal scenario)

	Milsorg	Mais	Riz	Legum	Fruits	Cot	Autag	Ara	Elev	Peche	Ind	SM
1	1,77	3,09	5,37	5,10	2,59	0,38	3,51	1,39	0,54	0,18	0,22	0,29
2	1,97	2,93	5,63	5,38	2,48	0,50	3,53	1,36	1,00	0,23	0,39	0,45
3	2,11	2,95	6,48	5,88	2,52	0,55	3,78	1,55	0,85	0,32	0,52	0,61
4	2,31	3,27	7,64	6,57	2,71	0,66	4,21	1,80	1,36	0,44	0,70	0,85
5	2,51	3,60	8,88	7,25	2,90	0,71	4,58	2,02	1,26	0,54	0,86	1,07
6	2,77	3,95	10,15	7,98	3,12	0,82	5,04	2,27	1,73	0,67	1,05	1,35
7	3,02	4,30	11,47	8,71	3,33	0,90	5,46	2,51	1,74	0,79	1,23	1,63
8	3,29	4,68	12,82	9,47	3,55	1,01	5,93	2,77	2,14	0,93	1,44	1,96
9	3,57	5,05	14,23	10,23	3,77	1,11	6,39	3,03	2,26	1,07	1,64	2,29
10	3,86	5,45	15,68	11,03	4,00	1,23	6,88	3,30	2,61	1,22	1,87	2,67
11	4,16	5,86	17,18	11,83	4,24	1,35	7,37	3,57	2,82	1,38	2,10	3,06
12	4,46	6,27	18,72	12,65	4,48	1,48	7,88	3,85	3,14	1,55	2,35	3,48
13	4,78	6,71	20,32	13,49	4,73	1,61	8,40	4,14	3,41	1,72	2,60	3,93
14	5,10	7,15	21,96	14,35	4,98	1,75	8,94	4,44	3,73	1,91	2,87	4,41
15	5,44	7,61	23,65	15,23	5,24	1,90	9,49	4,75	4,04	2,09	3,16	4,92
16	5,78	8,09	25,38	16,14	5,50	2,05	10,06	5,06	4,38	2,29	3,45	5,46

Source: Calculations of authors based on simulation results.

Table S2: Change in value added w. r. t. the baseline for Senegal (in %), (deviation from 1975-2004 normal scenario)

	Milsorg	Mais	Riz	Legum	Fruits	Cot	Autag	Ara	Elev	Peche	Ind	SM
1	7,40	13,06	22,98	22,10	10,78	1,50	15,00	6,04	2,13	0,60	0,79	1,08
2	8,29	12,66	24,27	23,45	10,48	1,97	15,14	6,03	3,97	0,81	1,46	1,76
3	8,87	12,45	28,04	25,63	10,57	2,16	16,12	6,58	3,34	1,10	1,97	2,37
4	9,76	13,75	33,24	28,68	11,36	2,59	17,93	7,74	5,38	1,59	2,68	3,29
5	10,61	15,14	38,70	31,67	12,18	2,81	19,53	8,68	5,00	1,97	3,27	4,17
6	11,69	16,66	44,31	34,92	13,11	3,24	21,49	9,76	6,82	2,46	4,01	5,25
7	12,76	18,17	50,11	38,14	14,02	3,53	23,30	10,80	6,90	2,92	4,71	6,35
8	13,95	19,77	56,10	41,50	14,98	3,98	25,32	11,91	8,44	3,46	5,51	7,61
9	15,14	21,39	62,31	44,89	15,95	4,36	27,28	13,02	8,96	3,99	6,31	8,93
10	16,41	23,09	68,71	48,39	16,95	4,84	29,38	14,18	10,31	4,57	7,19	10,39
11	17,69	24,83	75,34	51,95	17,97	5,30	31,48	15,36	11,16	5,18	8,10	11,93
12	19,02	26,63	82,17	55,61	19,01	5,81	33,68	16,59	12,43	5,82	9,07	13,59
13	20,38	28,49	89,21	59,34	20,09	6,33	35,92	17,84	13,51	6,49	10,08	15,35
14	21,79	30,41	96,48	63,16	21,19	6,89	38,23	19,13	14,80	7,19	11,14	17,24
15	23,24	32,38	103,96	67,08	22,31	7,47	40,60	20,45	16,04	7,93	12,25	19,23
16	24,73	34,41	111,66	71,09	23,47	8,07	43,04	21,82	17,39	8,70	13,42	21,34

Source: Calculations of authors based on simulation results.

Table B1: Change in value added w. r. t. the baseline for Burkina Faso (in %), (deviation from 1963-2007 normal scenario)

	Milsorg	Mais	Riz	Legum	Fruits	Cot	Autag	Elev	Peche	Ind	SM	SNM
1	-30,17	-28,97	-29,25	-27,11	-27,00	-1,70	-27,66	-7,05	-1,99	0,75	-3,60	2,14
2	-38,59	-36,16	-36,25	-34,00	-33,82	-1,41	-35,06	-10,54	-4,26	-0,27	-7,72	2,10
3	-43,70	-42,36	-42,36	-40,25	-40,13	-5,74	-43,15	-14,02	-8,08	-3,69	-11,96	3,23
4	-48,28	-47,56	-47,80	-45,75	-45,66	-9,45	-50,44	-17,30	-11,74	-7,12	-15,99	3,84
5	-52,53	-52,31	-52,91	-50,91	-50,83	-13,32	-57,45	-20,58	-15,51	-10,76	-20,03	4,39
6	-56,54	-56,79	-57,81	-55,85	-55,79	-17,38	-64,29	-23,91	-19,40	-14,59	-24,12	4,92
7	-60,39	-61,07	-62,56	-60,64	-60,58	-21,61	-71,03	-27,30	-23,41	-18,60	-28,27	5,43
8	-64,13	-65,23	-67,22	-65,32	-65,28	-26,00	-77,70	-30,75	-27,55	-22,77	-32,50	5,95
9	-67,80	-69,31	-71,81	-69,93	-69,90	-30,54	-84,33	-34,28	-31,80	-27,10	-36,80	6,46
10	-71,44	-73,32	-76,36	-74,50	-74,48	-35,23	-90,96	-37,89	-36,16	-31,57	-41,17	6,97
11	-75,05	-77,31	-80,89	-79,05	-79,03	-40,06	-97,59	-41,57	-40,63	-36,18	-45,62	7,48
12	-78,66	-81,28	-85,42	-83,59	-83,58	-45,01	-104,25	-45,34	-45,22	-40,92	-50,15	8,00
13	-82,28	-85,26	-89,96	-88,14	-88,13	-50,09	-110,94	-49,19	-49,90	-45,79	-54,76	8,52

Source: Calculations of authors based on simulation results.

Table B2: Change in value added w. r. t. the baseline for Burkina Faso (in %), (deviation from 1993-2007 normal scenario)

	Milsorg	Mais	Riz	Legum	Fruits	Cot	Autag	Elev	Peche	Ind	SM	SNM
1	-25,58	-24,56	-24,79	-22,90	-22,81	-1,43	-23,45	-5,63	-1,57	0,63	-2,89	1,72
2	-32,72	-30,72	-30,78	-28,78	-28,64	-1,32	-29,83	-8,51	-3,54	-0,32	-6,35	1,75
3	-37,08	-36,02	-36,00	-34,10	-34,01	-4,91	-36,72	-11,36	-6,68	-3,15	-9,84	2,65
4	-41,01	-40,44	-40,65	-38,79	-38,71	-7,91	-42,91	-14,03	-9,67	-5,96	-13,14	3,12
5	-44,63	-44,50	-45,02	-43,19	-43,12	-11,10	-48,88	-16,72	-12,77	-8,96	-16,46	3,57
6	-48,04	-48,33	-49,21	-47,40	-47,34	-14,46	-54,70	-19,45	-15,98	-12,12	-19,84	4,00
7	-51,32	-51,99	-53,27	-51,48	-51,44	-17,97	-60,44	-22,23	-19,29	-15,44	-23,27	4,43
8	-54,50	-55,54	-57,25	-55,47	-55,44	-21,61	-66,12	-25,07	-22,71	-18,89	-26,76	4,85
9	-57,63	-59,02	-61,18	-59,41	-59,39	-25,38	-71,77	-27,97	-26,23	-22,48	-30,32	5,27
10	-60,72	-62,45	-65,08	-63,31	-63,30	-29,28	-77,42	-30,94	-29,85	-26,20	-33,95	5,69
11	-63,80	-65,86	-68,96	-67,19	-67,18	-33,29	-83,07	-33,98	-33,56	-30,03	-37,64	6,11
12	-66,87	-69,25	-72,83	-71,07	-71,07	-37,42	-88,75	-37,08	-37,37	-33,98	-41,40	6,53
13	-69,96	-72,65	-76,72	-74,95	-74,96	-41,66	-94,45	-40,26	-41,26	-38,03	-45,23	6,96

Source: Calculations of authors based on simulation results.

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