International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:02, Issue:02

CLIMATE CHANGE, AGRICULTURAL OUTPUT AND POLICIES IN SENEGAL

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ABSTRACT

The Senegalese agricultural sector shows low production level over the last decades. . This study assesses the impact of climate change on crop production and also tests policies instruments through a national static computable general equilibrium (CGE) model. Our main results show that the local impacts of climate change (through declining yields) are likely to affect Senegal beyond the agricultural sector and farmers. The results show also after testing different policies instruments in the worst climate scenario for Senegal that decreasing the rice import tariff by 20% and subsidizing fertilizers are the most suitable policies instrument that can help to mitigate the negative effects that climate change has on agricultural food markets in Senegal. A global action plan to evaluate and improve policy instruments can mitigate the negative effects of climate change, enhance the overall resilience of the farming system and strengthen the capacity of local markets to absorb shocks.

Keywords: Climate change, Agriculture output, Agriculture policies.

TABLES

ISSN: 2455-6939

Volume:02, Issue:02

FIGURES

ABBREVIATIONS

ANSD: National Agency of Statistics and Demography

BSD: Senegalese Development Bank

CGE: Computable General Equilibrium

CFA: Communauté Financière Africaine

CNCR: National Council for Dialogue and Rural Cooperation

CPI: Consumer Price Index

DARC: Regional Centers of Development Assistance

DSRP: Document de Stratégie de Réduction de la Pauvreté

ECOWAS: Economic Community of West African States

GDP: Gross Domestic Product

GOANA: Great Agricultural Offensive for Food and Abundance

IPCC: Intergovernmental Panel on Climate Change

LOASP : Loi d'Orientation Agro Sylvo-Pastorale

LPDA: Letter for Agricultural Development Policy

LPDRD: Letter of Decentralized Rural Development Policy

LPI: Institutional Development Policy Letter

NEPAD: New Partnership for Africa's Development

NOVASEN

ISSN: 2455-6939

Volume:02, Issue:02

NPA: New Agricultural Policy

OCAS: Office of the Senegal Agricultural Marketing

ONCAD: National Office for Cooperation and Development Assistance

PAFS: Forestry Action Plan of Senegal

PASA: Policy of Agricultural Sector Adjustment

PDDAA: Program for the Development of Agriculture in Africa

PNDA: National Agriculture Development Program

PNDE: National Program for Livestock Development

PNIA: National Agricultural Investment Program

REVA: Return to Agriculture

SAED: National Development Corporation and Exploitation of the Senegal River Delta land and Faleme

SNDES: National Strategy for Economic and Social Development

SNFAR: National Strategy for Agricultural and Rural Training

SONACOS: National Company of commercialization Oilseeds of Senegal oleaginous

INTRODUCTION

The scientific community acknowledges that climate changes in recent decades are largely connected to human activities which generate emissions leading to greenhouse effects. In its Third Assessment Report, the Intergovernmental Panel on Climate Change (IPCC, 2001) stated that, during the 20th century, the average temperature of the planet has increased by 0.2° C to 0.6 ° C. The transformation of the global environment is due to many factors, including depletion of the ozone layer, the destruction of tropical forests, acid deposition and concentration of greenhouse gases. These factors lead to an overall increase in temperature.

Environmental changes on a global scale are linked to complex social, economic, political and scientific factors. Even if we cannot attribute climate change solely to human activity, there is no

ISSN: 2455-6939

Volume:02, Issue:02

doubt that natural climate fluctuations have a significant effect on the ecology and economic world (Silver 1992). The greatest damage of climate change is expected to affect agriculture in sub-Saharan Africa. Agriculture is expected to be particularly vulnerable in this region because it already endures high heat and low rainfall, because it is a very big part of the economy, and because it relies on relatively basic technologies (McCarthy et al. 2001). However, despite these forecasts, relatively few economic studies have attempted to quantify the damage to agriculture in Africa using African data (Kurukulasuriya & Rosenthal 2003).

Climate change has been attributed to greater inconsistencies in agricultural conditions, ranging from more-erratic flood and drought cycles to longer growing seasons in typically colder climates. While the increase in Earth's temperature is making some places wetter, it is also drying out already arid farming regions close to the Equator. This year's Intergovernmental Panel on Climate Change (IPCC) assessment report states that "increases in the frequency of droughts and floods are projected to affect local production negatively, especially in subsistence sectors at low latitudes." The decline in production in the face of growing demand can drive up prices in markets that may lack the technology to fight environmental hazards to overall production.

By FAO estimates, the developing world will spend $52 billion between 2007 and 2008 on imports of wheat, corn, and other cereal crops. If current trends persist, these countries will also be worst affected by climate change's pressure on food production and pricing, while experiencing the effects of more varied and more severe environmental conditions. Advances in technology make it unlikely that overall world food production will decline due to climate change, but agricultural capacity in large parts of Africa and Asia is expected to shift dramatically. Climate-related changes in agricultural conditions will likely only increase developing countries' dependence on imported food, a pricey prospect considering rising global transportation costs.

In Senegal, it is clear that climate change such as extreme weather events, increased incidence of droughts and floods, variability in rainfall and degradation of marginal lands will affect the agricultural sector and its many workers. The productions of cereals (rice, maize, millet, sorghum, groundnuts, beans etc.) for example, are particularly sensitive to changes in temperature and precipitation. Crop distribution and performance of agricultural activity are closely related to high rainfall variability. Rice millet and maize are the main food crops. They occupy more than 80% of cultivated land of the country. Yields levels are low because of the levels of investment and a sharp increase in rainfall and soil degradation. Cereals production per rural capita declined by 40% since 1960. This food shortage affects the northern regions most exposed to rainfall deficit and the poor suffer from this phenomenon. This deficit is made up with imports and food aid (Martin 1988).

The objective of this paper is to assess the impact of climate change on the production volume of some crops in Senegal and to test alternative policies instrument that can help to mitigate fluctuations of quantities through a national static computable general equilibrium (CGE) model. The rest of the paper is organized as follows: section 2 discusses the climate situation and the context of agriculture in Senegal; section 3 reviews the literature relative to climate change and general equilibrium model. In section 4, I present the model, the data and calibration issues; the climate scenarios and the different simulations are dealt with in section 5 and finally, the results are presented and discussed in section 6.

I. CLIMATE SITUATION AND CONTEXT OF AGRICULTURE IN SENEGAL

I.1. Climate situation

Senegal lies in the westernmost point of the African continent and is a country that belongs to the Sahel group. Senegal has a Sudanic and Sahelian climate dominated by two very distinct seasons: a dry season from November to June and a rainy season from July to October. The climate is governed by the dynamics of strong winds. The duration of the rainy season and the intensity of seasonal distribution of precipitations vary from north to south, the annual heights of rains estimated to be between 1200 mm and 200 mm in the north.

Climate-related disaster trends and impacts

Like most of Sahelian West Africa, the climate of Senegal is characterized by high spatial and temporal variability in precipitation. On average, most of the annual precipitation falls between June and September, in a typical monsoonal pattern of alternation of wet and distinctly dry seasons. Annual mean precipitation decreases from south to north, from ~1000 to 200 mm/year. This spatial distribution of rainfall partly explains patterns in livelihood activities: agro-forestry and cash crops are mostly grown in the south; agro-pastoralism is mostly practiced in central Senegal; and pastoralism is mostly practiced in the north (FEWS NET, 2012a).

Rainfall is better distributed during the rainy season in the southern parts (especially in Kédougou) and more irregular in the north-western parts of the country (Thiès, Louga, Saint-Louis), this rainfall pattern exacerbates flood risk along the north-western coast of Senegal.

There is a decline in annual precipitation between 1960 and the mid-1980s, followed by an increase in rainfall after 1995. The frequency of floods has increased significantly between 1990 and the present. Between 1990 and 2000, only one flood with humanitarian implications was registered, whereas between 2000 and 2010, 6 floods were reported. Since 2000, the majority of

ISSN: 2455-6939

Volume:02, Issue:02

these have been linked to intra-seasonal variability during the monsoon, which could be potentially linked to long-term climate change (Roudier et al., 2011). Focus group discussions with at-risk populations in Kaffrine further show that rainfall variability, extreme rainfall events, and long dry spells are the key climatic factors affecting crop production and food prices (Mertz et al., 2009).

Recent climate trends and climate change projections

Mean annual temperature has increased by almost half a degree Centigrade between 1960 and 2006, with the most rapid increase in the post-monsoon months (October-December). Temperature variations also follow a clear spatial pattern: coastal areas are cooler due to the mitigating effect of the Atlantic Ocean, whereas inland areas tend to be warmer (Fall et al., 2006).

The data show a clear increase in temperature during the period 1960 to 2006. However, as remarked in the previous sub-section, it is the high rainfall variability at seasonal, inter-annual and multi-decadal scales that characterizes climate change in Senegal. Variability at inter-annual and multi-decadal time scales, in Senegal, as across the Sahel, is known to be largely the effect of the oceans' influence warming of the tropical oceans, and reduced warming of the North Atlantic compared to the South Atlantic, and explains persistent late-20th century drought. Conversely, the more recent recovery of precipitation can be ascribed to a reversal to warming in the North Atlantic, partly explained by a reduction in sulphate aerosol loading consequent to pollution control measures taken in North America and Europe (Chang et al 2011; Booth et al 2012), the upward trend in temperature is consistent with the simultaneous drying up to the 1980s. Thereafter, temperature and precipitation trends seem to have decoupled, with temperatures continuing to rise despite the partial recovery of precipitation (Famine Early Warning Systems (FEWS) 2012c).

II.2. Stylized facts in the Senegalese agriculture and review of agricultural development strategies

II.2.1. Stylized facts in the Senegalese agriculture

Analysis of agricultural growth

Senegalese agriculture is mainly composed of cash crops (groundnuts, cotton, sugar cane), food crops (rice, maize, millet, sorghum, cowpea, cassava) and horticulture (fruits and vegetables). The income activity is largely dominated by the cultivation of groundnuts. Food agriculture products, mainly consisting of cereals, make up a large part of the food consumption of households.

Despite considerable efforts by public authorities (see graph 13) to promote Senegalese agriculture, the sector is taking time to take off. In general, the agricultural growth rate is on average relatively weak and erratic, making the sector vulnerable. Compared to the secondary and tertiary sectors, the agricultural sector shows a lower average growth rate as shown in the following table 4.

Table 1: Performance of the agricultural sector (2000-2011)

Sectors	Agriculture	Manufacturing	Service
Average growth rate	2.5%	4.1%	4.6%

Source: Fall and al, 2013

Furthermore, it should be noted that agricultural growth remains well below its medium- long term goal (7%), as defined in the National Strategy for Economic and Social Development (SNDES).

Evolution of the agricultural sector growth rate (1997-2011)

After a decline in 1997, the agricultural value added growth was positive and this was maintained until 2000, before declining in 2001 and further deteriorated to a record level of 34.5 % in 2002. Indeed the year 2002 coincided with the reduction of agricultural production, due in large part to the rain out of season and flooding along the Gambia River.

As usual, after a drastic decline, the agricultural value added has returned to growth in 2003, also supported by good rainfall and implementation of programs, especially for maize.

In 2004, the year of adoption of the LOASP ('Loi d'Orientation Agro Sylvo Pastorale'), there has been a slight increase in agricultural value added growth (4.1%), driven by industrial agriculture (25.8 %), despite a decline in food crops (-5%). Exogenous factors, including the locust threat and rainfall deficit, have in fact characterized the 2004/2005 crop year, causing the decline of food crops. Thus grain production declined by 25.3 %, while groundnut production rose by 36.7 % 9.

ISSN: 2455-6939

Volume:02, Issue:02

Agricultural value added grew by 16% in 2005. This performance can be explained by a good distribution of rainfall in time and space, the renewal of agricultural equipment, the availability of subsidized good quality fertilizer and good phytosanitary monitoring.

However, agricultural growth was negative for the years 2006 and 2007. The underperformance is mainly due to lower cultivated areas and yields, the late implementation of fertilizers and seeds, to unfavorable climatic and phytosanitary conditions and difficulties related to previous commercialization campaigns.

In 2008, strong growth was recorded, due to what may be called the "green revolution." This revolution has materialized in the creation of the Great Agricultural Offensive for Food and Abundance (GOANA). However, the various Senegalese agriculture stimulus plans did not allow a continuation of agricultural performance. Indeed, from 2009, the sector has gradually deteriorated, bottoming out at a negative growth rate of 27.8 % in 2011. This decrease is equivalent to a loss of 113 billion CFA of value added in 2011 compared to 2010.

a). The agricultural sector volatility

The evolution of agricultural value added was previously analyzed (see graph 13) and showed high volatility. This can be both an impediment to private investment and cause productivity problems. Table 5 compares the volatility of the agricultural sector to those of the manufacturing and service sectors over the period 1997-2011.

Table 2: The value added of the agricultural sector (1997-2011)

Sectors	Subsistence agriculture	Industrial agriculture	Manufacturing sector	Service sector
Volatility	17.5%	32%	2.5%	1.6%

Source: Fall and al, 2013

Industrial agriculture is more volatile (32 %) than subsistence farming (17.5%). Indeed, groundnut, which is the main speculative industrial crop, is heavily dependent on rainfall. However, Senegal has suffered severe climatic irregularities during the fifteen years considered.

b). Evolution of the share of the agricultural sector

Despite the fact that 30.6% of the population work in the agricultural environment, its share in GDP remains low, at up to 8.68% on average over the period 1997-2011 .

Table 6 shows the evolution of the share of agriculture compared to other sectors of the Senegalese economy.

Table 3: Average Share of agriculture in GDP (1997-2011)

Sectors	Agriculture	Primary	Manufacturing	Service
1997-2001	10.10%	19.90%	22.58%	57.50%
2002-2006	8.06%	16.36%	23.10%	60.52%
2007-2011	7.86%	15.76%	22.00%	62.26%

Source: ANSD

It follows a gradual decline in the share of agriculture in the GDP. On average, it rose from 10.10% between 1997 and 2001 to 7.86 % between 2007 and 2011. This situation prevailed, despite the adoption of the LOASP and PNIA (National Agricultural Investment Program) on one hand, and the implementation of the REVA plan and GOANA on the other.

Contribution of the agricultural sector to growth

In the period under review, contributions to GDP growth of the branches "subsistence farming" and "industrial agriculture" were low. If the contribution of food production to growth has been fairly stable (0.1%) that of industrial agriculture has remained erratic.

Table 4: Contribution of the agricultural sector to growth (1997-2011)

Sectors	1997-2001	2002-2006	2007-2011	1997-2011
Subsistence agriculture	**0.1%**	**0.1%**	**0.1%**	**0.1%**
Industrial agriculture	**0.3%**	**-0.3%**	**0.0%**	**0.0%**
Primary	0.5%	-0.1%	0.5%	0.3%
Manufacturing	0.9%	0.8%	0.7%	0.8%
Services	2.4%	3.1%	2.1%	2.5%

Source: ANSD

ISSN: 2455-6939

Volume:02, Issue:02

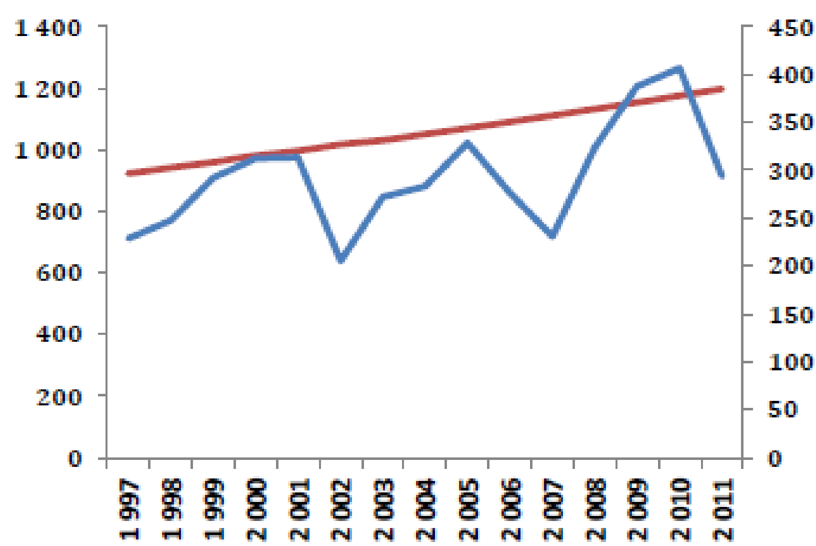
The negative contribution noted for industrial agriculture, during the second period (2002-2006) is mainly due to the bad performances of 2002 previously analyzed. Also the sector has not experienced the expected recovery in the following years, with zero contribution. Between 2007 and 2011, the overall contribution of agriculture was extremely low (0.1%), while the primary sector as a whole contributed nearly 0.5% to GDP growth.

Contribution of agricultural labor

The role of the agricultural labor must be underlined, which simultaneously raises questions about its productivity. Indeed, the agricultural population is very important and made up30.6% of the working population in 2011. The graph below shows the evolution of labor parallel to that of the added value.

The growth of agricultural labor in the last fifteen years (1.9%) has been slow, compared to that of the working population (3%). Indeed, labor migration has become a reality in Senegal, with the exodus of the rural farm population to urban areas.

Graph 1: Value added and labor in the agricultural sector (1997-2011)



Source: ANSD

In the left side there is the population (in thousands) and in the right side the value added (in billion CFA). The red line represents the agricultural working population and the blue one is the value added.

ISSN: 2455-6939

Volume:02, Issue:02

These movements are due among other things to the scarcity of resources and rural drought. This situation is related to a slightly positive growth in agricultural labor productivity. Indeed, all things being equal, the agricultural value added growth (3.2%), combined with weak agricultural labor growth, suggests an increase in agricultural labor productivity.

Analysis of key sectors

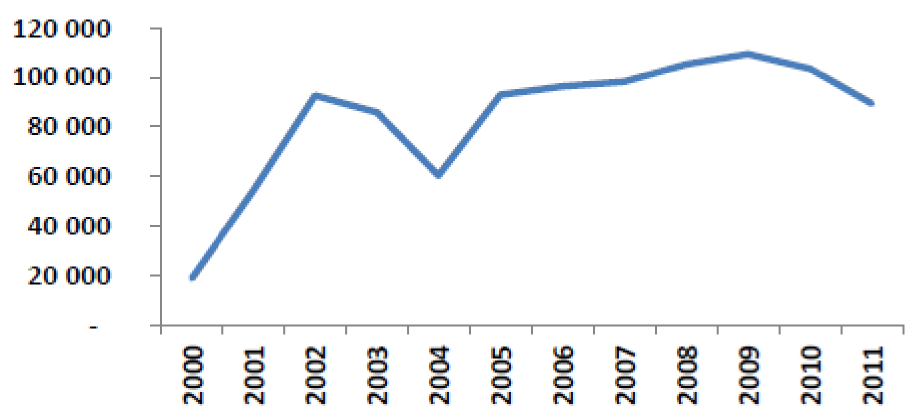
Maize sector

Maize became in 2003 the second grain specialization after millet thanks to the special program launched by the Senegalese Government which achieved a growth rate of 39.9 % from 2002 to 2003. However, performance waned from 2006 on, when production fell by 54.6 %. Despite a substantial recovery observed in 2008 (151.1 %), with the establishment of the GOANA, production decreased again after 2010.

Difficulties in the sector are mainly related to low price incentives, the decline of soil fertility, climatic hazards and dilapidated farm equipment. These constraints pose damaging productivity problems in the sector. They lead to the failure of the industry to satisfy local demand, leading to a rise in imports.

The volume of maize imports has consistently increased. However, periods of decline were recorded in 2004, due to the maize program, as well as in 2009 and 2010, after the launch of GOANA. (See graph below)

Graph 2: Maize Imports (tons)



Source: ANSD

ISSN: 2455-6939

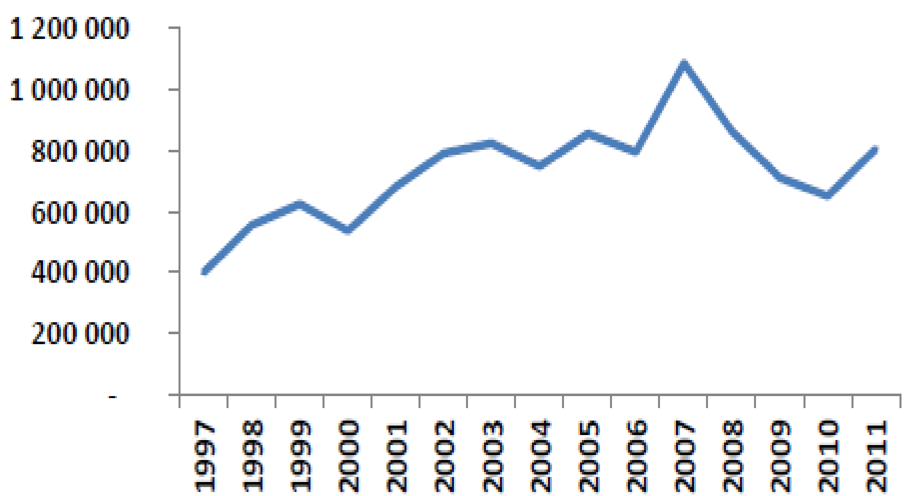
Volume:02, Issue:02

Rice sector

Rice is the staple food in Senegal. However, a huge gap exists between domestic demand and local production. The government, keen to develop the rice sector, created in 1965 the National Development Corporation and Exploitation of the Senegal River Delta land and Faleme (SAED) in 1965.

This company was tasked with the adaptation and management of irrigated zones and also provided inputs and agricultural advice. The rice sector was liberalized in 1996. This liberalization has affected rice imports because domestic rice production only covered between 20 and 30% of the national demand. However, in 2008, the national rice self-sufficiency program (PNAR) was launched in order to reduce dependency on the outside. The constraints of rice in Senegal are related to significant bird invasions, especially in the Senegal River Valley, the dilapidated processing plants, difficulties in their commercialization of local rice, the low level of use of mineral fertilizers and quality seeds, delays in accesing inputs, credit access difficulties and land issues. The high and growing amount of rice imports add to the various constraints in the sector, as indicated in the chart below.

Graph 3: broken rice imports (in tons)



Source: ANSD

Rice imports were on average 729,021 tons between 1997 to 2011, as opposed to 288,497 tons which were produced. However, they dropped after 2008 due to the increase in local rice

ISSN: 2455-6939

Volume:02, Issue:02

production triggered by the REVA plan and GOANA. Unfortunately, like maize, rice imports have recovered in 2011.

Groundnut sector

Groundnut is the main source of income for the rural world. This crop is also one of Senegal top four export products, along with fishery products, phosphates and tourism. The groundnut production activity in Senegal has a significant effect on other sectors (harvesting, industrial processing and product commercialization).

However, the groundnut sector faces the constraints of climate disruptions, degradation of soils, deficiencies in the supply of inputs, especially seeds, lack of renewal and maintenance of equipment parks, the lack of support / advice to producers and access to credit. To this are added the difficulties of groundnut commercialization.

In 2013, Chinese merchants arrived on the Senegalese groundnuts market, proposing a producer price which approximates 250 FCFA a kilo, significantly higher than the official price of 190 FCFA. The arrival of China on the groundnut market brought a financial windfall for producers who think that they can make a decent living from selling their produce at this price. However, this situation is detrimental to local mills (SUNEOR, NOVASEN), who are likely to suffer from a lack of supplies.

II.2.2. Review of agricultural development strategies in Senegal

During the first two decades after Senegal's independence, the state conducted an interventionist agricultural policy, intensified and diversified agricultural production. Management structures such as the Office of the Senegal Agricultural Marketing (OCAS), were created to support farmers and disseminate methods and farming techniques. The OCAS had the privilege of disposing over the purchasing monopoly on groundnut production from agricultural cooperatives and a limited number of approved private traders. The Office sold the harvest to processing industries operating in Senegal or to companies who organized the export of groundnuts for its treatment in France.

An ambitious program of agricultural modernization was set up, funded by the BSD (Senegalese Development Bank), later BNDS (National Bank of Senegal Development); it was supervised by the DARC (Regional Centers of Development Assistance) and accessible to farmers through cooperatives which guaranteed borrowings, based on groundnut sales of their members. Between 1966 and 1967 the CRAD and OCAS were dissolved and their functions transferred to the

ISSN: 2455-6939

Volume:02, Issue:02

National Office for Cooperation and Development Assistance (ONCAD), a newly created structure.

Faced with the persistent imbalances that affected the Senegalese economy in the late 1970s and the vulnerability of public finances, the state was obliged to adopt adjustment measures in the agricultural sector. Consequently, it implemented the stabilization program in 1979, and the economic and financial recovery program between 1980 and 1984. ONCAD was dissolved in 1980 and its activities acquired by the National Company of Commercialization of Oilseeds of Senegal Oleaginous (SONACOS). The disengagement of the state has been strengthened by the official end of the agricultural program and fertilizer credit. Instead, the state tried to establish a restraint on groundnut sales (the refund) for the repayment of fertilizer loans in 1984. In the same year, the state adopted the New Agricultural Policy (NPA) which further reduced its interventionist action in the agricultural sector. The NPA sought to create vital conditions of production in a framework that promotes effective participation and empowerment of the rural world.

However, following the devaluation of the CFA and in order to correct the dysfunctions observed in the implementation of the NPA, the state implemented the Policy of Agricultural Sector Adjustment (PASA), which was executed via the Letter for Agricultural Development Policy (LPDA) in April 1995. The withdrawal of the state, first initiated in 1979, has been strongly supported by the LPDA.

The willingness of the government to develop the agricultural sector can also be seen through the elaboration and approval of the various sectoral policy documents, including the Institutional Development Policy Letter for the agricultural sector (LPI 1998), the Letter of Decentralized Rural Development Policy (LPDRD, 1999) and the Development Policy Letter for the groundnut sector (2003).

The liberalization of the agricultural sector became more effective in 1997, but the results are inconclusive. In addition, the integration of the liberalized Senegalese agricultural sector in the world market and the greater autonomy of farmers, suffer from a lack of training for agricultural professionals. From 1999, the National Strategy for Agricultural and Rural Training (SNFAR) was set up with objectives to be achieved by 2015.

From the 2000s on, there is still a non - performance of the agricultural sector, forcing the political authorities to implement a new more global approach to agricultural issues, putting agriculture at the heart of the strategy for strong and durable growth. In particular, professional agricultural organizations, including the National Council for Dialogue and Rural Cooperation (CNCR), requested a new agricultural law. Thus, the Agro-Silvo-Pastoral Orientation Law

(LOASP) of 2004 was enacted to give an overall strategic direction to Senegalese agriculture over a period of 20 years, based on the strengthening of family farms. This law is the basis for operational development programs in the medium-term, such as the National Agriculture Development Program (PNDA), the National Program for Livestock Development (PNDE) and the Forestry Action Plan of Senegal (PAFS). LOASP has therefore replaced all sectoral agricultural policies in Senegal. It is supposed to be made operational by the agricultural component of the DSRP, which later became the DPES, then the SNDES.

The inventory reveals an agricultural policy which has been designed by several strategic documents, which, however, make its execution difficult. Indeed, apart from the programs launched under the LOASP, the Government launched, in 2006, the Plan for Return to Agriculture (REVA) to deal with illegal immigration flows to Europe. This program has two major objectives: re-launch agriculture and enable young emigrants to return to Senegal, investing in agriculture. Finally in 2008, the state launched the Great Agricultural Offensive for Food and Abundance (GOANA) in response to the global food crisis of 2007-2008. Its aim was to meet the challenge of food sovereignty, to avoid any risk of famine or starvation, and produce for export.

Parallel and in a spirit of coordination of national policies, sub-regional and regional, African countries adopted the New Partnership for Africa's Development (NEPAD), for which the agricultural component is supported by the Comprehensive Program for the Development of Agriculture in Africa (PDDAA). This is implemented in West Africa through the Agricultural Program of ECOWAS (ECOWAP) and nationally by the National Agricultural Investment Program (PNIA). Note finally that the objectives of the LOASP are supposed to be harmonized with those of the ECOWAP / PDDAA.

In conclusion, the agricultural policy of Senegal is defined in many strategies formulated at regional, sub-regional and national levels. Given the multiplicity of the agricultural policy documents, it is convenient to focus on the projects and agricultural programs which are in the National Agricultural Investment Program (PNIA). Then, for this study we focus on some policy types which are in this program namely: the adjustment of import taxes for agricultural products and increase in investment in capital and subsidies for fertilizers.

III. LITERATURE RELATED TO THE ECONOMIC EFFECTS OF CLIMATE CHANGE IN AFRICA

In this section we will review the studies using computable general equilibrium (CGE) models to see the impacts of climate change on African economy, particularly on the agricultural sector since this later constitutes the main source of food and income for developing countries. Several studies have been already done for this issue.

In 2010, Bezabih and al. used a CGE model to estimate the effects of climate change on Total Factor Productivity in the Tanzanian Economy. They found that in all four scenarios that they used, total factor productivity growth mattered considerably more than climate change for the outcomes during the entire period. The opportunity for substitution, both between crops and between land and capital, meant that almost the entire effect of climate change itself can be offset. In the low TFP scenarios, however, per capita income remained low and, at the end of the study period, was projected to have risen by only about 110%, regardless of whether climate change took place or not. Agriculture declined in importance in all four scenarios, but far more in the high-TFP scenarios. By the end of the study period, agriculture accounted for less than 2% of GDP in the high-TFP scenarios, compared to about 14% in the low-TFP scenarios.

In their paper on implications of Climate Change for Ghana's Economy Arndt and al in 2014 used a computable general equilibrium model, informed by detailed sector studies, to estimate the economy-wide impacts of climate change under four climate projections. The results show that in no climate change scenario, GDP in the dynamic model grows at just under five percent per year until 2050. The share of agriculture in total GDP falls by a third from 35.1 percent in 2007 to 20.1 percent in 2050. In contrast, the share of services GDP rose from 34.4 percent to 47.0 percent over the same period. With climate change scenarios there is a decline in agricultural GDP by 1.9 percent in 2050 compared to a "no climate change" base. Some of the largest economic losses occur in the major export crop sector, particularly cocoa. In contrast, positive crop yield variations associated with "local wet" scenario leads to an increase in agricultural GDP of 0.1 percent.

Parry and al. in 2004 used a general equilibrium approach to analyze the global consequences to crop yields, production, and risk of hunger of linked socio-economic and climate scenarios. They first estimate the responses of crop yields to greenhouse gas inducing climate change, and second, they simulate the agro-economic consequences of these potential changes in crop yields, changes in regional productivity, fluctuations in global commodity prices and resultant impact on the total number of people considered at risk of hunger in the world. The potential impacts of climate change are estimated by climate scenarios developed from the HadCM3 climate model under the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) A1FI, A2, B1, and B2. Projected changes yield are calculated using the transfer functions from crop model simulations with observed data and climate scenarios projected climate change. The base system (BLS) is used to evaluate the resulting changes in world cereal production, cereal prices and the number of people at risk of hunger. They found that the largest amounts of climate change tested in the A1 and A2 of the SRES scenarios, climate change may increase disparities in cereal yield between developed and developing countries in a more significant way than what has been found in previous studies. When the crop yield results are fed into the model of global food trade system BLS, the combined model and experience scenarios show that the world, for the most part seems to be able to continue to feed in the SRES scenarios for the rest of this century. However, this is achieved through production in developed countries (most of which benefit from climate change) to offset the expected decline, mostly from developing countries. While global production appears stable, regional differences in agricultural production are likely to strengthen over time, leading to a significant polarization effects, with substantial increases in prices and risk of hunger among the poorest nations, especially in scenarios with greater inequality (A1FI and A2).

IV. DESCRIPTION OF THE MODEL, DATA AND CALIBRATION

To highlight the effects of climate change on the volume of production in Senegal and to test alternative policies instruments, the methodology used in this study is based on a static computable general equilibrium (CGE) because it has the ability to analyze the interactions among different sectors. For example, agriculture, manufacturing, and services operate through commodity and factor markets. In their conventional usage, CGE models are flexible price models used to examine the impact of relative price changes on allocations of goods and factors across a range of economic agents. Thus, in addition to providing insights into the economy-wide general equilibrium effects of policy changes, CGE models allow examination of key inter-industry linkages.

In this study, the model has four agents (government, firms, households and the rest of the world), two factors of production (labor and capital) and fourteen branches. The model structure is based on five blocks of equations describing the production, income and savings, demand, prices and trade with the outside; the balance is achieved in factor markets and commodity markets. Equality between savings and investment is realized.

The Representative Household

Households aim to maximize their utility function under the constraint of their budget. Their income consists of the remuneration received from their supply of production factors namely labor and capital. In addition, households receive transfers from the Government and the rest of the world. The revenue thus formed is first used to pay taxes and to consume and save. Household preferences regarding their demand for consumer goods are represented using a linear expenditure system from the maximization of a Stone-Geary (SG) utility function.

This specification of household preferences are such that they first use their income to meet their minimum or incompressible consumption of each type of good i. Residual income or super cash is then divided between the non-compressible consumption and savings. The maximization program of the household h utility is as follows:

Max $\Pi(C_{i,h,t} - C^{MIN}_{i,h,t})^{yi,h}$

$$\sum_i Pci,h,t\ Ci,h,t = Rht$$

With the following restrictions:

$C^{MIN}_{i,h,t} < C_{i,h,t}$ **and** $\sum_i Pmci,h,t = 1$

$Pmc_{i,h,t}$ is the marginal consumption of good i.

$C^{MIN}_{i,h,t}$ is the minimal consumption (in volume) of good i by the household h at time t.

The production process

Production activities are represented by branches of the national accounts system whose organization is based on the NAEMAS nomenclature. In the basic model, each activity j (j = 1, .., J) is the production of a single good noted i (i = 1, .., I). The model assumes that each producer maximizes its profits, subject to a constraint production technology available.. The technology is such that the production is a Leontief function of value added and a composite measure of inputs. Value added is, in turn, specified as a Cobb-Douglas function of labor and capital in non-agricultural sectors, while in the agricultural sector, it aggregates a composite of the primary factors that are labor and capital.

As for the composite measure of inputs, it includes disaggregated intermediate consumption of the activity, according to a Leontief function. The factors of production are labor and capital. It is assumed that there is a perfect segmentation of the labor market. In this market the supply of labor will be assumed exogenous while the wage rate will adjust to clear the market in response to changes in the demand for labor. The supply of capital is supposed to be specific to sectors. The annual change in the capital stock is endogenous and determined by the following equation:

$$KD_{jt} = (1 - \delta(j))\ KD_{jt-1} + INV_{jt-1}$$

KD_{jt} is the capital stock of the sector j at time t ; $\delta(j)$ is the depreciation rate of capital of the sector j and INV_{jt} represents the investment volume of sector j at period t.

The Final Demand

Final demand for each commodity i is formed by the sum of domestic and import demand of this commodity. Once incorporated, the final demand for any good i is the sum of final consumption, government consumption, investment and intermediate goods industries, following the traditional script of the equilibrium equation on goods and services.

Trade

The **foreign trade block** comes from export activities and the import of goods. World prices of imports and exports will be assumed exogenous in that the analysis is conducted in the context of a small open economy. In general, for each product, export supply will be determined by arbitration between exports and supply on the domestic market, through a constant elasticity of transformation function (CET). In contrast, imports will come from the arbitration between the demand for locally produced goods and those addressed to the "rest of the world," according to a constant elasticity of substitution function (CES) or Armington function. (Equations are in annex).

Government

The function of government is to collect indirect taxes on production, the components of final demand, direct taxes on incomes of households and enterprises and, finally customs duties and taxes on exports. It receives transfers from the "rest of world" and conducts itself in transfers to households, as well as subsidies to enterprises. Moreover, the government has resources in respect of capital remuneration. Its income thus formed is then used for its spending. Public resources are intended, first, for the consumption of goods (public consumption) and, on the other hand for investment (public investment). The difference between the state resources and its expenditures (current and investment) constitute the budgetary balance.

The market equilibrium, the model assumptions and mechanisms of closure

In terms of **macroeconomic closure of the model**, foreign savings will be assumed to be exogenous. The balance of the external account will be realized on the basis of the assumption of exogeneity of the trade balance and therefore, the adjustment process will be achieved through the real exchange rate. The meaning of this assumption is that the Senegalese economy cannot adjust to the external debt to cover internal imbalances, but should generate sufficient export earnings to proceed to the purchase of imported goods and services. In other words, any increase in imports of certain goods will be systematically offset by lower imports of other goods or by an

ISSN: 2455-6939

Volume:02, Issue:02

equivalent increase in exports, to meet the constraint. In general, the prices of different goods adjust to balance the relevant markets. (Equations are in annexe)

Data and Calibration

The model is calibrated using the 2010 agricultural accounting matrix for Senegal (DPEE, 2010). First, the social accounting matrix (SAM) is a summary table that outlines the structure of production in an economy through the use of production and operating accounts and the interactions between the economic agents.

For this agricultural accounting matrix, the matrix which was built during the training seminar on CGE in Ottawa in November 2011 has served as the basis. It uses data from 2010.

The main idea is to disaggregate the sectors "subsistence agriculture" and industrial agriculture "and fill the SAM according to specific structures. The products used in food crops (maize, millet, sorghum, paddy rice and other products of the sector) and those of industrial agriculture (peanut, tomato, cotton, sugarcane, other products of the sector) were identified following the reading of the National Agricultural Investment Program (PNIA), which is a strategic document showing the outline of the Senegalese agricultural policy. The national accounts are the main source of data and the different manipulations were made so that the numbers of the initial SAM were calculated.

To study the Senegalese rice market specifically, the sector "Work grain, manufacturing products" has also been disaggregated into "Work grain relating to rice" and "Work grain relating to other products". Indeed, the sector "husked rice" is not part of "Subsistence Agriculture" which includes only the production of unhusked paddy rice.

For each sector, the intermediate consumption (IC) should logically be broken down according to the intensity of use of the products in its production structure. Unable to find information that can help spread these intermediate consumptions, the value of production of each speculation is the repartition key which was finally adopted. The structures corresponding to the final consumption, the imports, the exports were created from the national accounts. The final consumption of households was divided between the products through "Equilibrium

Resource - Use" of local production and imports which identify the uses done as intermediate consumption and final consumption.

After the disaggregation of sectors, it was necessary to balance the rows and columns. To do this, the imbalances of sectors resulting from the disaggregation were distributed in the intermediate consumption, based on the weight of each product. At the end, the public and private investments should match the total savings, which is the closure of the matrix.

The elasticities of demand for revenues are estimated for each product from the temporal series of ANSD. The transformation elasticity of the CET function according to the destination of the product (local sales or exportations) is calibrated to reflect the possibility for the local producers to increase their foreign sales in case of a contraction of domestic sales. The elasticities of substitution between primary factors serve in the CES aggregation of capital and labor. The elasticities of substitution between commodities by households are from the GTAP African database.

V. DESCRIPTION OF CLIMATE AND BIOPHYSICAL SCENARIOS

For this study we will use the climate scenarios described by Khouma and al, 2012 which show projected precipitation changes in Senegal in the four downscaled general circulation models (GCMs) (CNRM-CM3, MIROC 3.2 medium-resolution, CSIRO Mark 3, and ECHAM 5) from the IPCC AR4 in the A1B scenario.

All models show rainfall more or less unchanged in most of Senegal, in the range of –50 to +50 millimeters. However, both CNRM-CM3 and MIROC 3.2 medium-resolution GCMs show increased precipitation (in the range of 50 to 100 millimeters) in the Casamance Region, especially MIROC 3.2. On the other hand, ECHAM 5 shows a severe reduction in rainfall (range –50 to –200) for eastern Senegal.

There is a change in average daily maximum temperature in Senegal for the warmest month based on the A1B scenario, presenting results for various GCMs. All four models show an increase in temperature of at least 1.0°C–1.5°C all over the country. Three of the models CNRM-CM3, CSIRO Mark 3, and ECHAM 5 show temperatures increasing from west to east, with higher positive anomalies for CNRM-CM3 (1.5°C–2.0°C) and ECHAM 5 (1.5°C–3.0°C). CSIRO Mark 3 and MIROC 3.2 indicate the lowest increase in temperature. ECHAM 5 seems to be more in accordance with the current vertical stratification of annual maximum temperatures.
Notes:

A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources;

CNRM-CM3 = National Meteorological Research Center–Climate Model 3;

CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation;

ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg);

GCM = general circulation model;

MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

Crop Physiological Response to Climate Change

Khouma and al 2012 mapped the effect of climate change on key crops in Senegal. The comparison is between the crop yields for 2050 with climate change and the yields with the current (2000) climate. All models show a general yield loss of between 5 and 25 percent for groundnuts, with varying loss in groundnut area at the northern fringes of the groundnut basin, along with some significant areas of yield losses greater than 25 percent in the CNRM-CM3 and ECHAM 5 GCMs. We also note a few small areas of yield gains in the CSIRO and MIROC GCMs.

All models show maize areas with gains in yield of 5–25 percent for virtually the same areas and extent, though no significant yield change is projected for most areas. All models have some areas of yield loss as well. CNRM-CM3 and ECHAM 5 show a greater loss in maize yields than the other two models, and the ECHAM5 GCM shows a relatively greater loss in base area than the other models.

The scenarios for rainfed rice are very similar to those for maize, but with a relatively greater increase in yield. In Senegal, maize and rice seem to be less negatively affected than groundnuts by the scenarios' changing climate conditions.

Agricultural Vulnerability Scenarios (Crop-Specific)

The results from the International Model for Policy Analysis of Agricultural Commodities and Trade associated with key agricultural crops in Senegal according to Khouma and al (2012) show that for millet, total production, area under cultivation, and yield per hectare are all shown to increase in all the models. Groundnut production increases in all the scenarios.

Similar to the production and yield of millet and groundnuts, those of sorghum increase in all the scenarios.

ISSN: 2455-6939

Volume:02, Issue:02

Table 5: Climate change induced yield effects by crop, % change from yield with 2000 climate to yield with 2050 climate

	Productivity change ECHAM 5 GCM and CSIRO Mark 3 GCM	Productivity change CNRM-CM3 and MIROC 3.2 medium-resolution GCM
Maize	-5% to -25%	5% to 25%
Groundnut	-5% to -25%	-5% to -25%
Millet	5% to 25%	5% to 25%
Sorghum	5% to 25%	5% to 25%

Source: Khouma and al 2011

We will run the CGE model with these different scenarios using minimum, mean and maximum of the ranges.

5%= minimum 15%= mean 25%= maximum

The prices are in FCFA and the production in tons

V. RESULTS AND DISCUSSION

In ECHAM 5 GCM and CSIRO Mark 3 GCM models, maize production decreases by 34.7%, groundnut production decreases too by 30%, whereas millet and sorghum production increases by 20%. So in these models the farmer has an advantage in cultivating groundnut because he benefits more than from maize, millet and sorghum. The increase in price for maize and groundnut leads to a decrease in household demand. This is also explained by the decrease in household income in these models. The household demand for millet and sorghum increases about 40% due to the decrease in price. This is good for the household because it affects positively its welfare. In ECHAM 5 GCM and CSIRO Mark 3 GCM models, a gain in production for millet and sorghum causes a loss in production for maize and groundnut.

In CNRM-CM3 GCM and MIROC 3.2 medium-resolution GCM models the production of maize, millet and sorghum increases, compared to groundnut production which decreases. The value added of the maize sector rises by 0.17%, but the value added of millet and sorghum sector decreases and this can be due to the lower price. The value added of the groundnut sector increases by 0.0 7% due to the higher price. Growing groundnut and maize is good for the farmer because it allows him to earn more because of the increasing value added in these sectors. The household demand for groundnut decreases by 40% due to its higher price, unlike the demand for maize millet and sorghum which increases. The household income decreases. In CNRM-CM3 GCM and MIROC 3.2 medium-resolution GCM models a gain in production for maize millet and sorghum causes a loss in production for groundnut.

In the CNRM-CM3 and MIROC 3.2 medium-resolution GCM models, the consumer benefits more compared with ECHAM 5 GCM and CSIRO Mark 3 GCM models. This is because the price of most of the crop decreases when there is more rainfall due to a higher volume of production. This decrease in prices alleviates the food expenses of the urban household. Productions of maize and groundnut decrease in the models where rainfall decrease (ECHAM 5 GCM and CSIRO Mark 3 GCM models), while the production of millet and sorghum increases. Nonetheless, in the CNRM-CM3 and MIROC 3.2 medium-resolution GCM models with an increase in rainfall, the production of maize, millet and sorghum increases while the groundnut production decreases.

In the CNRM-CM3 and MIROC 3.2 medium-resolution GCM models the farmer earns more compared with the ECHAM 5 GCM and CSIRO Mark 3 GCM models. Most of the production of the crops increases when rainfall increases and also the value added of the agricultural sector increases by 0.22%.

In conclusion, we can say that it is good for the Senegalese farming system to be in the CNRM-CM3 and MIROC 3.2 medium-resolution GCM models (where rainfalls increase) because the farming system makes more over profits (increasing of the value added by 0.22%). This increasing of value added can allow the employment of more workers in the agricultural sector. In these models, the production volume of the main Senegalese crops increase and this lead to a decrease in the volume of imports.

For the policies we tested four policies that are components of the National Agricultural Investment Program (PNIA). The results for these four policies follow:

Decrease in the rice import tariff by 20%

In the worsened climate scenario for Senegal a decrease in rice import tariff by 20% leads to an increase in agricultural value added by 0.21%. Productions of maize, millet and sorghum are

ISSN: 2455-6939

Volume:02, Issue:02

intensified and this leads to prices lowering. In Senegal the agricultural sector occupies 70% of the working population. More value added can allow more workers to be employed in the agricultural sector. This can be helpful for rural households who rely on agriculture as their main source of food and income. This policy contributes to the drop in demand for imports of maize (12%), millet (22%), sorghum (22%) and groundnut. This drop of demand for imports correlates with the greater popularity of domestic products. The lower demand for imported agricultural goods will be maintained in the long term because of the sustained increase in economic activity. With such a policy the Senegalese farming system would benefit, because the lower rice import tariff compensates for the loss of value added that we have in the baseline scenario without this policy action.

On the consumer side, the dropping prices encourage greater household demand for maize, millet, sorghum and groundnut. However there is a fall in household income by 0.2%, which can be compensated by the lower prices.

Senegal is a country already open to imports, especially to rice imports. The decrease in the rice import tariff means an open economy. As we know, Senegal is a country that imports a lot of rice and which has opened his frontier for the rice imports. Although this reduction of rice imports tariff does not help local producers, but it can help to reduce the negative effects of climate change on production and prices. In addition, the rice occupies a major place in the Senegalese imports and Senegalese people prefer imported rice to local rice because of the quality that they think better. According to Fall, 2005, we import much quantities of rice as we produce cereals (millet, sorghum, maize, rice etc). The opening of the country to rice market generates an agricultural value added that compensates for the losses caused by climate change. Rice imports positively affect the production volume and prices of millet, maize and sorghum. So the decrease in the price of imported rice is spread on the prices of other agricultural products namely millet, maize and sorghum.

Thus, the liberalization of agricultural markets has historically been presented and justified, in the 1980s, as a readjustment between the interests of urban consumers and farmers, the first benefiting from regulatory policies which aim to keep the food price lower to the detriment of the revenues of the latter (Bates, 1981). For Senegal, the reduction of rice import tariffs can be a good policy instrument to reduce the impacts of climate change on production volume and prices.

Increase in the capital stock (10%)

An increase in the capital stock by 10%, as suggested by the PNIA (National Agricultural Investment Program), boosts the value added of the agricultural sector by 8%.This jump is more significant than the changes that occur when the import tariff for rice is decreased. The production volume of maize, millet, sorghum and groundnut rises and prices drop. This leads to a loss of profit for the farmer, except for groundnut which is compensated by its good domestic price. The greater capital stock contributes to alleviating the food expenses of the urban household with these lower prices for the consumer. The export supply for maize, rice, millet and sorghum is also better. The benefit of this policy for the household is that, contrary to what we have in the case of a lower rice import tariff, the household income increases by 0.08% and this can contribute to an improvement in overall welfare.

The downside of an increase in capital stock is that it simultaneously leads to lower labor volume. In fact, the increase in these stocks results in higher prices relative to labor, which in turn leads to lower demand for labor. This substitution effect reduces the expected benefits of the increase in capital stocks.

Subsidize fertilizers by reducing tax on fertilizers by 50%

When the tax on fertilizers is reduced by 50%, the value added of the agricultural sector increases by 0.22% relatively to the baseline scenario. There is an improvement in the value added of the maize sector (16%) and the groundnut sector (7%) however the millet and sorghum sectors benefit less (3%). This growth in the agricultural sector is a direct result of the lower tax rate for fertilizers, as is greater demand for labor in the maize sector (6%) and groundnut sector (8%). The capital demand also increases in these sectors.

Contrary to what we have in the baseline scenario, there is a notable increase in the production of millet (21%), sorghum (21%), maize (45%) and groundnut (27%). As production increases, the demand for imports falls off. Household income drops overall by 0.1% in the scenario. However, prices for millet, sorghum and maize are lower and this is most favorable for Senegalese households, since these crops are the main foods in Senegal. Even if the prices fall the farmers earn 22% more.

We know that in Senegal, the period 1980-2000 has been materialized in the framework of a market economy by its disengagement, including the liberalization of grain markets and agricultural inputs. For fertilizers, the producer's access conditions to the subsidy have become stricter. Moreover the subsidy gradually decreased until it canceled out completely in 1989. The current guidelines are designed to promote private sector participation in the fertilizer trade. For this, theoretically margins incentives are not enough. They must also be practically feasible. This supposes the existence of effective demand which is not identified with a simple expression of need.

The decline in soils fertility today prompted the Senegalese government to resume its fertilizer subsidy policy from 2003/2004. After several years of modest subsidies, GOANA was introduced in 2008 to subsidy chemical fertilizers and equipment. The return of the subsidy on fertilizers may help to fight against the impacts of climate change on crop production.

Increasing the maize import tariff by 50%

Not promoting the maize importation leads to an increase in the productions of maize (49%), millet and sorghum (21%), whereas the production of groundnut decreases by 27%. The prices for maize, millet and sorghum fall and this leads to a rise in the household demand for these products. We notice a higher value added for the agricultural sector by 0.19%. The labor demand increases for all the crops (maize, millet and sorghum) due to the effect that hiking the maize import tariff by 50% has on the value added for the agricultural sector. A negative consequence of this policy is that the household income is reduced by 0.18%, which is not good for the household, but this is compensated by the lower prices for maize, millet and sorghum. This policy also developed the Senegalese farming system by creating more jobs, as in Senegal the agricultural sector is the most important source of revenue and food for poor people.

In Senegal, Maize production is largely important behind, millet, and rice. Populations that consume this cereal are essentially those of Tambacounda, Kolda and Kaolack. But since 2000, the developments of the poultry industry and weakness in cereal production have generated strong demand. The maize production which become insufficient, leads to have recourse to imports in order to satisfy human consumption needs. Despite the efforts expend by the government in recent years to increase maize production, maize is abundantly imported and its low average prices make it more accessible than the local maize.

Even if the price of imported maize is cheaper than the price of local maize, our results show that a closure of the Senegalese economy to maize import can mitigate the negative effects of climate change on the local production of maize, millet and sorghum and even decrease prices of this local maize.

When we compare the financial impact of shocks to government revenues of the different policies by considering the value added contribution of these policies, we notice that:

- A decrease in rice import tariff by 20% leads to an increase in value added by 3.384% million F. CFA.
- The value added rises by 11.081% million F.CFA when the capital stock increases
- Subsidizing fertilizers by decreasing fertilizers taxes by 50% also increases the value added by 8.638% million F. CFA

- An increase in maize import tariff 50% leads to decrease the value added by -9.5% million F. CFA

All these policies bring positive value added for the country except for an increase in maize import tariff for which value added is negative. This positive impact on the economy is much more important for policies about the increase in capital stock (11.081% million F. CFA) and subsidizing fertilizers by decreasing fertilizers taxes by 50% (-0.39% million F. CFA). So the financial implications of the increase in maize import tariffs are not good for the state revenues because this shock leads to a loss of value added which is not favorable for the economy. The increase in capital stock increases the value added but the problem is that it leads to decrease the labor demand.

Finally it appears that **cutting the rice import tariff by 20%** and **subsidizing fertilizers by slashing taxes by 50%** are the most suitable policies instruments that can help to mitigate the negative effects that climate change has on agricultural food markets in Senegal. Cutting rice import tariff by 20% generates agricultural value added (0.21%) that compensates for the loss of value added (0.08%) that we have in the baseline climate scenarios. Subsiding fertilizers by halving fertilizer taxes increases agricultural value added by 0.22% which is still an improvement even with an agricultural value added loss of 0.08%. These two policies, modeled in the worst climate scenarios for Senegal can generate agricultural value added that can compensate for the losses that we have in the baseline climate scenarios.

As in Senegal the agricultural sector employs 70% of the working population, the greater value added can provide more jobs in agricultural sector. This growth of the labor force can lead to an increase in the volume of production in the agricultural sector, which is shown by the positive results that we have for the volume of production for maize, millet and sorghum. Prices for these crops for as a result. The demand for imports of maize, millet and sorghum drops.. The lower demand for imported agricultural goods will be maintained in the long term because of the sustained increase in the economic activity.

If the government applies these two policy instruments, the Senegalese farming system will be strengthened because farmers will benefit in comparison to the baseline scenario. Even if we notice small decline in the household income, the better prices can compensate for this loss. So these two policies contribute to alleviating the food expenses of the urban household with cheaper food and also they can be helpful for rural households who rely on agriculture as their main source of food and income.

ISSN: 2455-6939

Volume:02, Issue:02

CONCLUSION

During the last few decades, the Senegalese farming system faced difficulties related to climate change which caused lower and fluctuating levels of production. Consequently the farming system participated less in the creation of national wealth leading to a massive migration of rural people to urban areas. In Senegal, a large segment of the working population is rural and mainly derives its income from agriculture. Therefore, increasing productivity and agricultural production is a certain way to ensure food security and improve living conditions in rural areas. Similarly, improved agricultural performance helps to ease the food expenditure of urban households through lower commodity prices for basic necessities.

This study aimed to assess the impact of climate change on production volume and to test alternative policies instruments that can help to mitigate fluctuations of quantities. Particularly it focused on some policies that are in the Senegalese National Agricultural Investment Program (PNIA).

The level of production decreased in these last years and this is particularly due to climate change. The difficulties of the agricultural sector are mainly due to low levels of rainfall, degradation of soils, dilapidation of agricultural stock, degradation of the agricultural infrastructure, seed quality etc. Consequently, the production deficit is still critical leading to higher levels of imports for agricultural products.

A static computable general equilibrium model oriented on the agricultural sector has been used to assess the impact of climate change on the level of production and to test alternative policies instrument that can help to reduce the fluctuation of quantities.

The results show that it is the CNRM-CM3 and MIROC 3.2 medium-resolution GCM where there is greater rainfall ,which benefits the Senegalese farming system, because the level of crop production increases, leading to a lower level of imports for agricultural products. The agricultural value added increases in these models, contrary to what we have in the ECHAM 5 GCM and CSIRO Mark 3 GCM**.** The results show also after testing different policies instrument in the worst climate scenario for Senegal cutting the rice import tariff by 20% and subsidizing fertilizers are the most suitable policies instruments that can help to mitigate the negative effects that climate change has on the production volume in Senegal. With these two policies the level of production rises and the prices fall for the main food crops (maize, millet, sorghum, but not rice and groundnut). Imports of agricultural products shrink. These two policies generate agricultural value added that can compensate for the losses that we have in the baseline climate scenarios.

Finally, cutting the rice import tariff and subsidizing fertilizers can allow Senegal to reach the objectives of the Accelerated Growth Strategy (SCA), which aims to create the conditions for new productivity gains in order to achieve a growth rate of 7% to 8%. Also the improvement of agricultural performance can significantly reduce poverty in urban and rural areas.

Reaching these goals requires seed quantity and seed of good quality; modernization of production techniques, in particular through the training of rural stakeholders, encouraging innovation and research development; strengthening production diversification policies (especially in areas where traditional farming is experiencing a deceleration in production and yield) and improved access to credit for farmers. Emphasis should also be placed on policies that enable the poorest people to carry out and go beyond subsistence agriculture, especially in areas where the severity of poverty is the most significant. Finally, the authorities should improve the transport and telecommunications infrastructure to enable farmers to better sell their products in domestic and international markets.

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ISSN: 2455-6939

Volume:02, Issue:02

ANNEXES

A.1. Declaration of model variables

C(I): Volume of household consumption of commodity i

CH: Household consumption expenditures

DINV(I): Volume of investment demand of commodity i

G(I): Volume of government consumption of commodity i

INT(J): Volume of the index of intermediate inputs used in industry j

K(J): Stock of capital industry j

KTOT: Total stock of capital

KTOTAGR: Total stock of capital in agricultural sector

KTOTNAGR: Total stock of capital in non agricultural sector

LD(J): Labor demand by industry j (volume)

LS: Total labor supply (volume)

PC(I): Sale price of commodity i (without taxes)

PINT(J): Index price of total intermediate inputs used in industry j

PVA(J): Price of value added of industry j

PXTS(J): Output price in industry j (net of production taxes)

PCH(I): Household consumption price (including taxes)

PCINV(I): Purchasing price of investment goods (including taxes)

PCG(I): Government consumption price (including taxes)

PCV(I,J): Intermediate consumption price of commodity i used by industry j

R : Rental rate of capital

RAGR: Rental rate of capital in agricultural sector

RNAGR: Rental rate of capital in non agricultural sector

SAVH : Firm savings

SAVE: Household savings

TOTSAV: Total savings

V(I,J): Volume of commodity i used as intermediate inputs in industry j

VA(J): Volume of value added of industry j

W: Wage rate

XTS(J): Output in industry j

YDH: Household disposable income

YE: Corporate income

YG: Government total revenue

YTH: Household total income

XTD(I) : Volume of total demand of commodity i

M(I) : Import volume of commodity i

EX(I): Export volume of commodity i

XDD(I) : Demand for domestic good i

XDS(I) : SupplY of domestic good i

PM(I) : Sale price of imported commodity i (including duties)

PWM(I) : World price of imported commodity i (without duties)

PEX(I) : Producer price of export commodity i

PWEX(I) : World price of export commodity i

PD(I) : Price of domestic good

ER: Converse between foreign and domestic currencies ('nominal' exchange rate) ($CND per unit of foreign currency)

TRGH: Government transfers to households

SAVG: Government savings

SAVF: Foreign savings

TRROWH: Rest of the world's net transfers to households

WALRAS: Dummy variable to check Walras law

UTC : Uniform consumption tax

VVSTOCK(J): Variation of stock of industry j

TRROWG: Transfer to rest of world

A.2. Equations of the model

Consumer bloc

$C(i,t) = \alpha c(I) * CH(t)/PCH(I,t)$

$CH(t) = [1 - SH] * YDH(t)$

$PCT(t) * CT(t) = CH(t)$

$PCT(t) = \left(\frac{1}{ACT}\right) * \frac{\prod t[PCH(I,t)]}{\alpha c(I)}$

$YDH(t) = (1 - TYH) * YTH(t)$

$YTH(t) = \sum j\, W(j,t) * LS(j,t) + \beta KH * \sum j\, R(j,t) * K(j,t) + \beta LH * \sum j RL(j,t)$

$PHI(t) * PC(t) * CT(t) = WT(t) * (1 - LST(t))$

$SAVH(t) = SH * YDH(t)$

Firm bloc

$PXTS(j,t) * \left(1 - SU(j)\right) = AVA(j) * PVA(j,t) + AINT(j) * PINT(j,t)$

$VA(j,t) = AVA(j) * XTS(j,t)$

$INT(j,t) = AINT(j) * XTS(j,t)$

$PVA(j,t) = \left[\frac{1}{1+}\right]$

$RT(j,t) * KT(j,t) = \alpha Vj * PVA(j,t) * VA(j,t)$

$W(j,t) * LD(j,t) = [1 - \alpha Vj] * PVA(j,t) * VA(j,t)$

Capital and labor

$R(j,t) * K(j,t) = \alpha k(j) * RP(j,t) * KP(j,t)$

$RP(j,t) = R(j,t)$

$KP(j,t) = K(j,t)$

$PINT(j,t) = \sum tAIJ(I,j) * PV(I,j,t)$

$V(I,j,t) = AIJ(I,j) * INT(j,t)$

$YE(t) = \beta KF * \sum jR(j,t) * K(j,t) + \beta LF * \sum jRL(j,t)$

$SAVE(t) = (1 - TYE) * YE(t)$

Government bloc

$YG(t) = TYH * YTH(t) + \sum jSU(t) * PXTS(j,t) * XTS(j,t) + \sum I\, TC(I) * P(I,t)$

Investment demand bloc

$TOTSAV(t) = SAVE(t) + SAVH(t) + SB(t) + ER(t) * SAVF(t)$

$PCINV(I,t) * DINC(I,t) = \beta V(I) * [TOTSAV(t) - \sum j\, P(j,t) * VVSTOCK(j,t)]$

Final demand bloc

$P(I,t) = \frac{1}{AM(I)} * [\alpha M(I)^{\gamma M(I)} * PM(I,t)^{1-\gamma M(I)} + (1 - \alpha M(I)^{\gamma M(I)} * PD(I,t)^{1-\gamma M(I)})]^{1/1-\gamma M(I)}$

$M(I,t) = AM(I)^{\gamma M(I)-1} * XTD(I,t) * [\alpha M(I) * \frac{P(I,t)}{PD(I,t)}]^{\gamma M(I)}$

$P(I,t) = PM(I,t)$

$P(I,t) = PD(I,t)$

$XTD(I,t) = M(I,t)$

$XTD(I,t) = XDD(I,t)$

Prices bloc

$PCH(I,t) = P(I,t) * (1 + TC(I) + Tajust(t))$

$PCINV(I,t) = P(I,t) * (1 + TINV(I))$

$PCG(I,t) = P(I,t) * (1 + TG(I))$

$PV(I,j,t) = P(I,t) * (1 + TINV(I))$

$PCINVG(I,t) = P(I,t) * (1 + TINVG(I))$

$PA(I,t) = P(I,t)$

$PM(I,t) = ER(t) * PWM(I,t) * (1 + TM(I))$

$PEX(I,t) * \left(1 + TEX(I)\right) = ER(t) * PWEX(I,t)$

Budgetary expenses in value

$VG(I,t) = PCG(I,t) * G(I,t)$

$VDINVG(I,t) = PCINVG(I,t) * DINVG(I,t)$

Equilibrium

$XTD(I,t) = C(I,t) + DINV(I,t) + G(I,t)(I) + DINVG(I,t) + \sum jV(I,j,t)$

$XDD(I1,t) = XDS(I1,t)$

$XDD(I2,t) = XDS(I2,t) + WALRAS(t)$

$LS(j,t) = LD(j,t)$

$KS(j,t) = K(j,t)$

$OMEGA = 10$

$$KS(j,t) = K0(j) + (1 - \Delta j) * KS(j,t-1) + IND(j,t-1)$$