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By

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Abstract

Based on a Computable General Equilibrium (CGE) model, the study examines the impact of land degradation on agricultural production and food security using three policy approaches: irrigation schemes, subsidies for agricultural inputs and equipment, and rural infrastructure development (roads and rural markets). These agricultural investment policies are funded through a combination of direct taxes and assistance from technical and financial partners. The results show that land degradation in Burkina Faso lowers Real Gross Domestic Product. Indeed, the agricultural policies that have been implemented have effectively reversed the negative effects of land degradation on the agricultural sector. However, agricultural policies such as improving the rural road network, expanding irrigation capacities and reducing costs of acquiring chemical fertilizers and farm equipment are cost-effective measures for farmers. The results show that in the face of production supply constraints emanating from the declining land productivity, the government could, in the short and medium term, focus on extending irrigation schemes and subsidizing agricultural inputs and equipment.

Key Words: Agricultural policies, Land productivity loss, Agriculture, Food security, Computable General Equilibrium model, Burkina Faso

JEL Code: C68, Q24, Q54, O13

1. Introduction

Burkina Faso is a landlocked country in West Africa. There has been considerable growth in the economy over the last decade, with an average annual growth rate of more than 6% between 2000 and 2012 (FAO, 2014). Agriculture, livestock, forestry and mining are the main economic activities. The agricultural sector employs more than 86.0% of the population and represents about 35.3% of the Gross Domestic Product (GDP) and accounts for more than 37.0% of national exports (Monitoring and Analyzing Food and Agriculture Policies - MAFAP, 2013). With nearly 77% of the population living in rural areas and dependent on agriculture for their livelihoods, agriculture plays a leading role in fostering economic growth, and reducing poverty and food insecurity in the country. The proportion of the population living below the poverty line in Burkina Faso decreased from 44.5% in 1994 to 40.1% in 2014, with a poverty incidence of around 47.5% in rural areas and 13.7% in urban areas for the year 2014 (INSD, 2017). Despite a decline in poverty and an increase in total agricultural production, existing data show that nearly 20% of households experience food insecurity (USAID, 2014). In addition, Burkina Faso is in a precarious situation, with a hunger index of 22.2, placing it the 65th among 78 countries (Garrido and Sanchez, 2015), but the dominance of agriculture has also decreased over the years, with its contribution to GDP declining from 37% in 2008 to about 30% in 2015 (World Bank, 2018).

Most farmers in Burkina Faso are small-scale producers, with about 72% of them relying on less than 5 hectares of land (MAFAP, 2013). Cereal crop productivity is still very low, averaging only 1.14 t/ha between 2010 and 2015 (World Bank, 2019). In addition, only 15% of the country's agricultural land is irrigated, thus making agriculture largely susceptible to rainfall variability (Herrera and Ilboudo, 2012). The low agricultural productivity could be attributed to many factors, including land degradation, small farm size and low technology use. Land degradation is mainly related to two broad categories of processes; one associated with climate change and the other linked to human activities, mainly change in land use (crop expansion, agricultural intensification, overgrazing and over-exploitation of timber plantations) (Rasmussen et al., 2014; Pimentel et al., 2004).

Recent empirical evidence shows that there is considerable uncertainty about the economic impact of land degradation (Nkonya et al., 2016). The cost of land degradation in West Africa is estimated at US$ 18.9 billion (Nkonya et al. 2016). The loss of cereal yield induced by soil erosion is estimated at between 5 and 20 million tons per year in Burkina Faso (ELD initiative and UNEP, 2015). More than two decades earlier, Lal, (1995) estimated the reduction in maize yield at between 47.48 and 63% for a soil erosion of 5.1 and 20 centimetres in Ouagadougou, Burkina Faso. More recently, Niemeijer and Mazzucato (2002) found that soil erosion and degradation leads to a decrease in agricultural production of 0.5 to 1% in Burkina Faso. In addition, estimates of the direct effects of soil erosion using a biophysical model by Sartori et al., (2019), show a decline in agricultural production of 3.832 million tons in Burkina Faso. It is worth mentioning that land degradation affects 34% of cultivated land in Burkina Faso (Hien and CILSS, 2015).

Soil erosion is known to have severe consequences on populations (Panagos et al., 2018). At the international level, soil erosion is one of the main sources of land degradation, according to Article 1 of the United Nations Convention on Combating Desertification of 2017. The Government of Burkina Faso, like other countries in the world, recognizes, in the face of continuing land degradation, the need for a stronger commitment to increase the performance of production systems, responding to the food needs of the population, improving farmers' incomes and ensuring sustainable management of land, livestock and fishery resources. Since 2003, Burkina Faso has made efforts to promote agricultural development and reduce food insecurity by developing the Rural Development Strategy (SDR), which was implemented in the period 2003-2010 through the Sub-Sector Action Plan and implemented in the period 2011-2015 by the National Rural Sector Programme (NRSP). The NRSP also considered the rural component in the Accelerated Growth and Sustainable Development Strategy (SCADD), the Comprehensive Africa Agriculture Development Programme (CAADP), the Agricultural Policy of the West African Economic and Monetary Union (WAEMU) and the Regional Agricultural Policy for West Africa. However, the implementation results of the SDR for the period 2003-2010 indicate that actions undertaken have been hampered by weak sector policies and insufficient budgetary programming instruments.

To address these situations, the SDR was reviewed in 2016 and includes four strategic pillars with specific objectives and action points that are translated into a National Rural Sector Programme (NRSP) for the period 2016-2020. The NRSP has a rural component within the National Plan for Economic and Social Development (PNDES). Within the implementation framework of the NRSP, three sector policies have been developed: agro-forestry-pastoral production sector policy; environment, water and sanitation sector policy; and research and innovation sector policy that runs up to 2025. The objective of the NRSP is to ensure food and nutritional security through sustainable development of productive and resilient agro-forestry-pastoral, fisheries and wildlife sectors that are more market-oriented. Thus, the sector policy for agro-forestry-pastoral production for the period 2018-2027 is designed to sustainably increase agro-forestry-pastoral, fisheries and wildlife production and productivity. The specific objectives of the sector policies are to:

(i) increase production and productivity in the agricultural sector;

(ii) improve food and nutritional security;

(iii) increase irrigation production;

(iv) improve producers' access to agricultural risk management tools; and

(v) strengthen the livelihoods of vulnerable households. To achieve these objectives, the government intends to invest 10% of public expenditure in the agro-forestry-pastoral sector.

Therefore, what would be the impact of loss of land productivity and agricultural investment options regarding agro-forestry-pastoral production policy on agricultural production and food security in Burkina Faso?

The overall objective of this study is to assess the impact of land productivity loss and subsequent policy interventions; that is, the agro-forestry-pastoral production policy on agricultural production and food security in Burkina Faso. More specifically, this study first assesses the impact of land productivity loss and then the impact of public investments in irrigation, agricultural inputs and equipment and investments in rural infrastructure (roads and rural markets) on agricultural production and food security. Considering that policies are designed to counteract the negative effects of land degradation, this paper combines both a soil degradation model and a Computable General Equilibrium (CGE) model. As this type of policy can generate significant general equilibrium effects, the CGE model is the most appropriate tool given that it is able to reconcile the complex general equilibrium effects of decline in agricultural productivity due to land degradation and the agricultural investment policy of the government of Burkina Faso. CGE models are comprehensive tools capable of determining the correlations between economic activities and economic operators with given macroeconomic constraints. The analysis uses Burkina Faso's 2013 Social Accounting Matrix (SAM). This study contributes to and informs discussions on the impact of development policies in developing countries. In addition, to our knowledge, there is no study that fully captures these structural impacts of land productivity losses due to land degradation in Burkina Faso.

The subsequent sections present the situation of the agricultural sector and food security in Burkina Faso. Section 3 provides literature review, section 4 presents the methodology and data, and section 5 describes the simulation hypotheses. Section 6 provides the conclusion and policy implications.

2. Agricultural policy and food security in Burkina Faso

Like most developing countries, the majority of the population of Burkina Faso lives in rural areas and relies on subsistence farming. GDP per capita is one of the lowest in Africa and more than 40.1% of the population lives below the poverty line (INSD, 2017). Although the agricultural sector, which is key to overall economic performance and poverty reduction, has grown in recent years, poverty and food security remain critical challenges for Burkina Faso's economic expansion. Agriculture remains largely characterized by low inputs and low-yield agricultural systems dependent on rainfall in which droughts periodically reverse performance gains with devastating effects on household food security. Since the 1970s, food and nutrition security has been a major challenge in Burkina Faso. The drought seasons of 1970-1973, 1983-1984, 1991, 1994, 1998 and 2004 led to loss of livestock and human life, and prompted rural exodus. All these factors contributed to the severity of the famine. Recurrent drought has also led to further degradation of agricultural land. In fact, 34% of the production land is degraded, with a degradation progression that went sequentially from 113,000 ha/year between 1983 and 1992, to 360,000 ha/year between 1992 and 2000, to 469,000 ha/year between 2002 and 2013 (MAAH, 2018). In addition, the country's agriculture is characterized by small extensive family farms that occupy 70% of the cultivated areas and provides basic food for the majority of the population. However, inflation in food prices has been high since 2008 and has affected access to food.

Famine susceptibility has continued due to inter-community conflicts and prolonged droughts in many parts of the country. Burkina Faso is gradually emerging from a difficult food situation caused by the 2011 drought, which affected 3.5 million people and forced the government to declare a state of national crisis in 2012 (WFP/FEWS-NET/Burkina Faso, 2014). Food prices have remained high since the 2008 food crisis and have contributed to keeping populations insecure in terms of food and subsequently putting them in a precarious situation (Kibora, 2014). As a result, Burkina Faso has become one of the main beneficiaries of international food aid. Although the country has made progress in terms of food and nutritional security, food shortages continue to be a recurrent phenomenon. Thus, at the national level, 19% of households are food insecure, including 1% in a severe situation in 2014 (WFP/FEWS-NET/Burkina Faso, 2014). According to the 2015 SMART survey, the prevalence rate of undernourishment and stunted growth among children under five years of age are 21% and 30%, respectively, in 2015 (MOH, 2015) and the proportion of poor cereal-growing households in structurally deprived areas remains high at 56.6% for the same period. The economy loses about 7.7% of GDP each year as a result of long-term effects of malnutrition among children (FIAN Burkina Faso, 2016). Despite a reduction in poverty rate over recent years, which fell from 46.1% in 2009 to 40.1% in 2014, the severity of poverty remains very high at 3.3% of the population (INSD, 2016).

For the purposes of sustainably increasing agricultural production and national food security, the Government of Burkina Faso has put in place the Agro-forestry-Pastoral Production Sector Policy (PS-PASP, 2018-2027), which outlines three thematic areas of intervention, each with its own strategic objectives and investment plans. These thematic areas of intervention are:

(i) increasing agricultural production and productivity in a sustainable manner;

(ii) improving competitiveness of agricultural commodity chains; and

(iii) sustainable management of natural resources.

The first strategic area is aimed at achieving a sustainable increase in agricultural productivity by providing subsidized agricultural inputs and equipment. Irrigation development is also a major priority for the government, with a view to increasing agricultural production and productivity. Furthermore, improving the competitiveness of agricultural products will help farmers move from subsistence farming to cash crop farming, mainly by improving rural market infrastructure, rural roads and marketing systems.

Achieving the various thematic areas of intervention and strategic objectives requires efficient allocation of public resources and appropriate implementation of investments. Additionally, in recent years, the bulk of support to the agricultural sector has been directed towards agriculture-specific expenditures for the improvement of production, productivity and food security. Table 1 shows the evolution of public expenditure on agriculture between 2008 and 2016. Data from Yameogo et al. (2017) indicate that agriculture-specific expenditure increased between 2008 and 2016, with a fluctuation between years (Table 1). Nevertheless, spending on agriculture has declined from its 2008 level. For the year 2013, Table 1 indicates that 67.2% of public support to agriculture goes to agriculture-specific expenditures (payments to employees in the agricultural sector and general support to agricultural sector) and 32.8% is directed to expenditures in promoting agriculture (such as rural infrastructure, health or rural education). In 2013, development of rural infrastructure accounted for 85% of agricultural expenditure.

Table 1: Evolution of public expenditure (%) on agriculture between 2008-2016

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Specific expenditures on agriculture	51.0	48.2	59.3	74.9	69.6	67.2	74.5	79.8	71.7
Payments to employees in the agricultural sector	60.9	57.7	47.4	42.7	57.3	64.8	56.2	61.5	60.1
General support to the sector	39.1	42.3	52.6	57.3	42.7	35.2	43.8	38.5	39.9
Spending on agriculture	49.0	51.8	40.7	25.1	30.4	32.8	25.5	20.2	28.3
Rural infrastructure	32.3	41.5	45.4	79.4	85.9	85.0	59.8	55.3	60.7
Other support to the rural sector	67.7	58.5	54.6	20.6	14.1	15.0	40.2	44.7	39.3

Source: Yameogo et al. (2017)

Specific expenditures on agriculture include payments to agricultural employees (including producers and consumers) and general support to the agricultural sector, including agricultural research, technical assistance, training, extension services and agricultural infrastructure (irrigation, access roads, etc). For the year 2013, payments to agricultural employees represented 64.8% of specific agricultural expenditure, while activities such as agricultural research, technical assistance, training, extension and agricultural infrastructure consumed 35.2% of this expenditure heading. Producers receive payments in the form of input subsidies (seeds, fertilizers, agricultural capital, technical assistance and extension services), which account for 85.1% of the total payment to staff in the agricultural sector.

There are two main sources of funding for public expenditure in the agricultural sector: donor aid and domestic resources. Donor aid is an important source of Burkina Faso's budget. In the last ten years, capital expenditure has been largely supported by external aid (loans and grants), accounting for 53% between 2006 and 2015 (Yaméogo et al., 2017). Between 2014 and 2015, donor-financed public expenditure was low at 12% and 18%, respectively. Between 2008 and 2013, external aid financed an average of 62% of public agricultural investment expenditure (Yaméogo et al., 2017). Moreover, between 2012 and 2015, external aid accounted for 25% of agriculture-specific expenditure and 40% of spending on agriculture. External aid is much more oriented towards spending on agriculture, particularly on rural education and rural infrastructure such as rural roads, rural energy, water and sanitation, among others. The proportion of public spending on rural health covered by external aid rose from an average of 10% between 2006 and 2008 to 46% between 2012 and 2015 (Yaméogo et al., 2017). Expenditure on marketing and storage promotion is largely financed domestically.

3. Literature review

Land degradation is a serious problem for the agricultural sector in the literature (Pimentel et al., 1995; Scherr and Yadav, 1996). Soil erosion due to water or land degradation due to drought destroys arable land and makes it unproductive (Pimentel et al., 1995). Specifically, soil erosion changes the physical, chemical and biological characteristics of soils, leading to a reduction in agricultural productivity and posing a food security challenge, especially in developing countries (Pimentel, 2007; Graves et al., 2015; FAO, 2015). Panagos et al. (2018) present a review of the literature on land degradation (erosion) and assessment methods used.

Analysis of the effects of land degradation on economies and on the agricultural sector is less developed in the existing literature (Panagos et al., 2018; Sartori et al., 2019). Garcia-Ruiz et al. (2017) acknowledged that it is still difficult to assess the economic consequences of the effects of land loss due to erosion. In addition, an assessment on the costs of losses in agricultural production, gross domestic product and food security due to soil erosion was not sufficiently developed in the literature. The European Union Soil Thematic Strategy has raised the awareness of policy makers on the need to protect soil, develop forward-looking measures to mitigate soil degradation and include soil erosion as a key priority for action (Kibblewhite et al., 2012). The significance of impact assessment is acknowledged and has increased considerably in developing and developed countries in relation to agricultural and environmental policies (UNCCD, 2017). In the literature, two types of methods have been used for assessing the impact of land degradation and agricultural adaptation policies. With the exception of Panagos et al. (2018) and Sartori et al. (2019), the above-mentioned studies are generally based on a cost assessment exercise focusing on agricultural production losses (Martínez-Casasnovas and Ramos, 2006; Erkossa et al., 2015; and Hein, 2007). Specifically, the economic value of loss of land productivity is calculated as the direct loss of production from crops affected by erosion, multiplied by their respective average market prices.

To fill the gaps in the literature, recent studies have attempted to develop macroeconomic methods in conjunction with biophysical models to determine both the direct and indirect effects of soil erosion (Panagos et al., 2018; Sartori et al., 2019; Alfsen et al., 1997; Grepperud and Wiig, 1999; and Diao and Sarpong, 2011). Thus, Panagos et al. (2018) combined a biophysical model and a macroeconomic model to estimate the cost of agricultural productivity loss due to soil erosion by water in

European Union countries. The biophysical model is used to estimate the direct effects of erosion on land productivity. The estimated land productivity losses are used as inputs into the Computable General Equilibrium (CGE) model to capture the effects of soil erosion on the economy. However, they do not explicitly analyze food security in their research. They conclude from the effects on prices and agricultural production that soil erosion is not a threat to food security in the EU, but rather leads to particularly high costs for the agricultural sector. Sartori et al. (2019) also incorporate the biophysical model into a global CGE model to estimate the economic impacts of water-induced soil erosion on the world economy. They integrate food security analysis, and the measurement of food security is carried out through the production and prices of agricultural products. Results show that soil erosion leads to food insecurity as agricultural production decreases and agricultural commodity prices increase.

Diao and Sarpong (2011) developed a CGE mode for Ghana, which they combined with an erosion model. They examined the effect of land degradation on economic growth and poverty in Ghana. Unlike previous works, they integrated analysis on sustainable agricultural practices as an adaptation policy. Results show that adoption of modern land management techniques has reversed the decline in productivity induced by erosion and significantly reduced poverty in three regions of northern Ghana. Alfsen et al. (1997) developed a CGE model with a soil productivity model for Ghana. They calculated the adverse effects of soil extraction and soil erosion on the Ghanaian economy and illustrated the effects of different policies aimed at reducing these environmental problems. They point to the subsidization of fertilizers and pesticides and to direct taxes and taxes on agricultural products as policy strategies to overcome land degradation. Wiig et al. (2001) incorporate a nitrogen cycle model endogenously into the CGE model of the Tanzanian economy to establish a dual link between environment and economy. For a given level of soil productivity, farmers maximize their profit by choosing the amount of inputs, and thus production volumes, which influence soil productivity through nitrogen recycling. The model is used to simulate the effects of typical structural adjustment policies, such as a reduction in agrochemical subsidies, or a reduction in the implicit export tax rate. The implemented policy provides an increase in GDP. All these past studies have not paid adequate attention to food security as the focus of their analysis. They were more interested in the impact of land degradation on growth or the economic cost of soil erosion.

A few studies have addressed the issue of food security in the literature. A comprehensive review is provided by IOB (2011) and Mariano and Giesecke (2014). CGE models, with their potential for disaggregated modeling of agricultural commodities, provide a logical methodological framework for a number of studies (Mariano and Giesecke, 2014). Assessing the impacts of agricultural trade policy on food security has been a focus for many of these studies (Aragie et al., 2018, Tanaka and Hosoe, 2011; Cororaton et al., 2009; Cororaton and Cockburn, 2007 and Rae and Josling, 2003). Studies on public interventions in domestic markets for agricultural products are less common (Mariano and Giesecke, 2014; Mariano et al., 2015; and Liu et al., 1996). Government food aid, such as cash and in-kind transfers to households, has also been the subject of several studies in CGE (Gelan, 2006; Lips, 2005 and Arndt and Tarp, 2001), as have strategies to support agricultural growth (investment in infrastructure, extension services, research and development, input subsidies) on food security (Pauw and Thurlow, 2011; Giesecke et al., 2013; Arndt et al., 2016; Caria et al., 2011; Boulanger et al., 2018; Kirstkova et al., 2017). All these studies use different measures of food security, such as agricultural production, household consumption, and domestic food prices that capture the dimensions of food security such as availability, access, use and stability. Mariano et al. (2015), Mariano and Giesecke (2014) and Giesecke et al. (2013) integrate four measures of food security into the CGE model:

1 - the household food coverage index. The index is a measure of the capacity of households to meet their food needs with current income, calculated as the ratio of total household expenditures to the value of their expenditures for all food and beverages;

2 - the food self-sufficiency index, which measures the share of domestic food consumption covered by national food production;

3 - the food trade balance index, which measures the country's financial capacity to meet its national food needs through its export earnings (Ecker et al., 2010); and

4 - the household calorie intake index, which measures changes in household calorie intake associated with price-induced changes in the quantity of food consumed by households.

4. Methodology, data and simulations

Measuring the loss of agricultural productivity due to land degradation

The methodology developed for measuring crop loss estimates crop outputs measured in terms of tons per hectare (t/ha) productivity for maize, millet, sorghum, beans and rice, and estimates the likely loss of productivity of these crops. Statistics on crop productivity are extracted from FAOSTAT (FAOSTAT, 2018) for the period 2012-2016. These data give us the cultivated area, the cultivated production and the crop production in tons per hectare. The crops under consideration are: maize (including both grain and green maize), rice, millet, beans and sorghum. The area covered by these crops represents about 80% of Burkina Faso's cultivated land and about 65% of agricultural production. The market value of each crop is based on the producer's price (extracted from the Food and Agriculture Organization of the United Nations (FAO) statistics (FAOSTAT, 2018)) as the average price for the period 2012-2016.

Numerous studies have shown that soil erosion has a serious impact on agricultural production. However, it is difficult to quantify the loss per piece of land on agricultural yield due to lack of a clear relationship between erosion and productivity (Diao and Sarpong, 2011). Moreover, soil is only one of the factors affecting productivity, as the returns from agricultural speculation are a function of several variables (Perrens and Trustum, 1984). According to the study by Roose et al. (1976 and 2004), the crop management factor coefficient for maize, millet and sorghum is 0.4. According to Biggelaar et al. (2004), reduction in crop yield in Africa as a result of soil erosion is between 2% and 40%, with an average loss of 8.2%. For these authors, the average loss of maize yield per year as a result of soil erosion is 0.49%. Based on reliable literature findings, this study assumes that an 8% loss in crop productivity is recorded in highly cultivated fields, where erosion rates are high (above 17 tons per ha per year). The literature review considers the experimental evidence of crop productivity loss due to erosion in Africa and particularly in Sub-Saharan Africa. Therefore, to determine the level of loss of land productivity due to soil erosion, we follow the methodology of Panagos et al. (2018). Then, the rate of loss of land productivity is estimated as follows:

$$PPT = \frac{SEA}{TAA} * SEC \qquad (1)$$

Where PPT is the indicator of loss of land productivity in percentage; SEA is cultivated land affected by soil erosion (ha); TAA is total cultivated land (ha); and SEC is the soil erosion coefficient.

Additionally, the loss of productivity is identically distributed across all crops and the variability between them is attributable to different percentages of severely eroded land and total agricultural area. The loss of productivity of different crops is calculated as follows:

$$PPC_i = PPT * TC_i * PC_i \tag{2}$$

Where PPC_i is the productivity loss per crop i; TC_i is the area of each crop i in ha and PC_i_i is the yield per crop i in t/ha. The estimated loss of land productivity is the basis for determining the macroeconomic impact of soil erosion on the agricultural sector, food security and GDP.

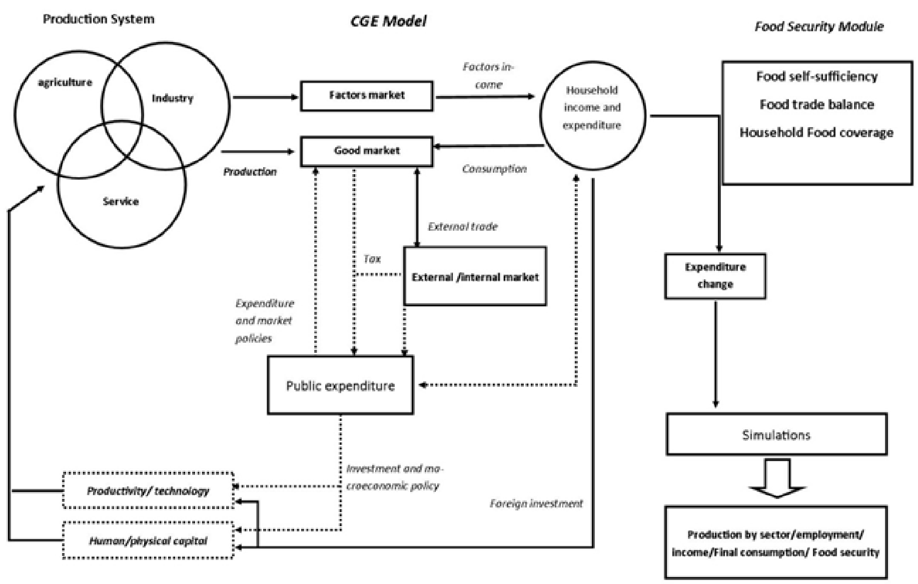
Computable general equilibrium model

Conceptual framework

CGE models provide a means of identifying the linkages between sector and national economic growth, and household income and food security (Figure 1). Direct and indirect transmission channels linking agricultural or national sector growth to food security are determined by Burkina Faso's economic structure. Food security is achieved at the individual, household, national, regional and global levels when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). There are four components of food security: availability, access, utilization and stability (Berry et al., 2015). Availability refers to food production, access is linked to the purchasing power (income and price level) of household food items, utilization is determined by access to water and sanitation, and finally, stability is measured by dependence on food imports (Berry et al., 2015; FAO-WFP-IFAD, 2013). Food production and consumption form the basis for defining the four components related to food security.

The effect of agricultural policy on production is determined by the use of technologies (factors of production) within the agricultural sectors. Consequently, when farmers ask for intermediate inputs, this influences the output of both the agricultural and non-agricultural sectors. The increase in agricultural production stimulates the use of intermediate inputs and means of transport, which leads to an increase in non-agricultural production. The more intensive the sector is in intermediate consumption, the stronger its linkages with other sectors. Conversely, the projected output of the agricultural sector corresponds to the input supply of downstream industries. Moreover, an increase in agricultural production leads to an increase in the supply of agricultural products to the agri-food industries, which also leads to an increase in non-agricultural production. An increase in agricultural and agri-food production increases the availability of food commodities in the domestic market.

Figure 1: Computable General Equilibrium model conceptual framework



Source: Author Illustration

The impact of public investment on consumption occurs when household income is used to purchase goods and services. When agricultural production increases, it increases farmers' incomes through the remuneration they receive for their factors of production. Households use their income to purchase agricultural and non-agricultural goods. The magnitude of impact on consumption depends on the share of income derived from factors distributed to households, the composition of the consumption basket and the share of goods supplied by the domestic market in relation to consumer demand.

The CGE model helps to identify the linkage between production and consumption when evaluating agricultural policy. The model includes production functions for each sector. To produce, the farmer uses a production technology that determines their linkages with other sectors. The production functions combine factors of production (e.g., land, labour and capital) generating income for factors and households. As with producers, the model differentiates between groups of households, and the distribution of income from factors depends on households' endowment factor.

Households consume products according to their preferences and utility functions. This general equilibrium structure allows us to trace the contribution of sector output to national economic growth and household incomes and expenditures through both product and market factors.

The model also considers the public sector and the rest of the world. The government derives its income from direct and indirect taxes that it uses to finance public consumption, and this generates demand for goods and services from producers. Government revenue is also used to finance social subsidies and make capital investments. In addition to taxes, the government may receive financial assistance from the rest of the world in the form of grants or loans. Foreign markets are a source of demand for exports and a supplier of imports. The export intensity and import penetration ratios of different sectors, especially the agricultural and agro-industrial sectors, determine the size of growth multiplier effects. A country with high export intensity faces fewer domestic supply constraints; however, higher import penetration translates into increased competition from foreign producers. Finally, a food trade deficit results in the country's inability to obtain food products on the international market, and thus makes food security volatile.

Model specification

In terms of modeling, we use the standard static PEP 1-1 model by Decaluwé, et al (2013). Although the model is described in detail in Decaluwé et al. (2013), we provide its main features and present changes introduced to better illustrate the context of Burkina Faso. It is a model that considers consumer and producer behaviours and describes the relationships between economic operators using linear and non-linear equations. In the CGE model, demand and supply occur in a competitive context.

The structure of the CGE model, illustrated in Figure 1, represents the Social Accounting Matrix (SAM) of Burkina Faso and identifies the production process, which is on the supply side of the model, and the market flows of goods and services, which are on the demand side of the model. Thus, in the SAM, an activity can produce more than one good and service. In the model, the production function is assumed to be at constant output scale and is represented by a three-level production process. At the first level, production is a perfect combination of total intermediate consumption and value added through the Leontief function. At the second level, a constant elasticity of substitution (CES) function is used to represent the substitution between land and the capital-labour composite factor. At the third level, the capital-labour composite factor is a combination of composite labour and physical composite capital based on a CES function. Secondly, composite labour is a CES function between different types of labour (agricultural and non-agricultural labour). Composite capital demand is a combination through a CES function between different types of capital. Finally, demand for land is a CES function, according to the type of land available for agricultural production.

The loss of land productivity induced by soil erosion calculated by equation 1 is the input to our CGE model. Thus, the loss of land productivity is directly converted into a change in the productivity of the land input in the CGE model. In the CGE model, land is a primary input that is used by the farmer in the various agricultural sectors along with labour, capital and intermediate consumption to produce agricultural goods. In the CGE model, land productivity loss is represented by ψ_j where j represents the different crops grown on the land. Loss of land productivity is given by the estimation of equation 1 and is the same for all crops. The loss of land productivity is then used in the crop value added function and affects the land productivity parameter. This takes the form of a constant elasticity of substitution function, which depends on land, capital and labour:

$$VA_j = \Phi_j^{VA} \left[\beta_j^{VA} LAND_j^{-\rho_j^{VA}} + (1 - \beta_j^{VA}) KL_j^{-\rho_j^{VA}} \right]^{-1/\rho_j^{VA}} \tag{3}$$

Where VA_j the value is added by activity sector; $LAND_j$ is the demand for land by sector; KL_j is the composite capital-labour demand; Φ_j^{VA} is the scale parameter of the function; β_j^{VA} is the distribution parameter between land and composite capital-labour factor and ρ_j^{VA} is the elasticity of value added. The parameter β_j^{VA} is modified in the simulation depending on the influence from the loss of land productivity ψ_j. The value added function becomes:

$$VA_j = \Phi_j^{VA} \left[\beta_j^{VA} (1 - \psi_j) LAND_j^{-\rho_j^{VA}} + (1 - \beta_j^{VA}) KL_j^{-\rho_j^{VA}} \right]^{-1/\rho_j^{VA}} \tag{4}$$

To measure the impacts of the chemical fertilizer subsidy on the economy as a whole, we make the price of fertilizer exogenous in the model. Fertilizer demand is endogenous and is determined by the CGE model based on the prevailing price. Fertilizer is used as an intermediate consumption whose demand is linked proportionally to the level of production. In addition, fertilizer can be considered as manure that enriches the land and the demand for fertilizer is related to the demand for land. Indeed, a decrease in the price of fertilizer will lead to an increase in the demand for fertilizer and could improve the yield of the land.

In addition, the model looks at four types of operators or institutions: households, government, businesses, and the rest of the world. Households derive their income from labour and capital compensation and income transfers from the institutional sectors (government, businesses, households and the rest of the world). Households spend their income on consumption of goods and services, pay direct taxes to government and save the rest. On the consumption side, household behaviour is modeled as a linear expenditure system (LES) and is subject to its budgetary constraint.

In addition, second, businesses derive their income mainly from capital income and remittances from other institutions. After payment of income tax and transfers to other institutions, the remaining income forms part of corporate savings. Overall government income includes direct taxes paid by households and enterprises, indirect taxes on domestic sales, import duties, remittances from other institutions and a share of capital income. The government expends its income on consumption of goods and services, including input subsidies, and on remittances to other institutions. The development partners pay part of the total cost of the subsidy and this part of the transfers to government is proportional to the cost of the program. To balance the government budget, we assume that the direct tax rate on production is adjusted through additive increases in the production tax rate to ensure that revenues equal total expenditures minus development partner grants. Government savings are equal to government income minus government consumption and remittances to other economic operators; the rest of the world receives income from capital income, export income, and remittances from Burkina Faso.

To relate Burkina Faso with the rest of the world, we use the traditional small country hypothesis, which means that Burkina Faso has no influence on world prices. We also assume that producers in Burkina Faso cannot sell as much as they want on international markets. To sell more on these markets and increase market share, producers must be more competitive than other producers. Therefore, export supply is limited by export demand, which is assumed to have a finite elasticity, indicating the competitiveness of local producers on the international market. Finally, supply in the domestic market comes from two sources: domestic production and imports with imperfect substitution between the two, which shows differences in quality and origin.

For Burkina Faso's context, we modify the assumption of the PEP 1-1 model to consider the context of Burkina Faso. Contrary to PEP.1-1 model of Decaluwé et al. (2013), we assume that the family labour market is underemployed and we assume that the nominal wage rate for this labour market is fixed. In addition, in this work, we assume that both the agricultural wage labour market and the non-agricultural labour market are bound by real wage rigidity. The introduction of real wage rate rigidity is possible by taking into account the occurrence of unemployment in both markets. The existence of involuntary unemployment can only be rationalized by the existence of real wage rigidities that prevent wages from falling to their market equilibrium level. Several theories have been developed to explain wage rigidity. Following Blanchflower and Oswald (1995), we assume that there is an equilibrium wage rate associated with unemployment rate. The authors show the existence of an empirical relationship linking wage rate and unemployment rate, also called the "wage curve". The relationship shows a negative slope between unemployment rates and wage rates. Thus, we use the following specification:

$$LS_l = \sum_j LD_{l,j} + UN_l \times LS_l \qquad (5)$$

Where LS_l the labour supply is for each type l of work; $LD_{l,j}$ is labour demand for each type l and sector j. UN_l is the unemployment rate for each category of work. The wage curve is modeled as follows:

$$W_l = A\_W_l \times UN_l^{\varepsilon_l} \quad (6)$$

with W_l the wage rate for each type l of work, A_W_l the scale parameter of the wage curve for each type of work l and ε_l is the wage elasticity for each type of work l. Following the work of Decaluwé et al. (2011), we use the value -0.1 for the wage elasticity for Burkina Faso.

In terms of the closure of the CGE model, it is assumed that the nominal exchange rate of the model is the model's numeraire. Labour is mobile in all sectors. To consider the long-term effect of agricultural policies, we assume that capital is movable across agricultural sectors. The assumption implies reduced mobility; that is, land is not static only in the agricultural sector. There is an opportunity to grow maize on the land area formerly allocated to sorghum or cotton farming. Under the small country assumption, world export and import prices are exogenous. The current account balance is fixed, and equilibrium in the market for goods and services is achieved by adjusting the prices of goods and services. Product market equilibrium requires that the composite supply of each good is equal to total private and public consumption and investment demand, as well as the sum of intermediate demands. Product market prices adjust to maintain equilibrium. Total investment is equal to the sum of the savings of economic agents. Government expenditure is fixed, as are the tax rates. To ensure that the model reproduces equilibrium conditions, the parameters are calibrated to the 2013 SAM (the baseline data) by ensuring that the number of endogenous variables is equal to the number of equations in the model. Following an exogenous or policy shock, a new counterfactual occurs with a single set of prices due to the equilibrium between supply and demand. Comparison of the counterfactual with the reference situation gives an indication of the impact of the shock on the markets, in terms of prices, output, trade flows and income.

In this study the CGE model PEP-1.1 is used. One of the main advantages is the modular structure of the model, which allows modifications and extensions to answer several research questions. Given this flexibility, the model is used in many contexts, including climate change (e.g. Montaud et al. (2017)), assessment of agricultural public investments (Aragie et al. 2018), food security (Beyene and Engida, 2016) and international trade (Cockburn et al., 2014). Contrary to the standard CGE PEP-1.1 model, our work integrates reduced mobility of agricultural capital and labour rigidity in the non-agricultural labour market. With the assumption of land mobility in the agricultural sector, the supply of land is fixed. The use of additional land in agricultural production is limited to the maximum area available. In this case, the allocation of land between agricultural sectors is the result of an arbitration process that makes the rate of return on land unique for all owners.

Measuring food security and nutrition

There is a wide range of definitions on food security (Babu and Sanyal, 2009; Briones and Galang, 2011; Ecker et al., 2010; and Lovendal, 2007). FAO (2003) provides a general definition: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". According to this definition, the complexity of the concept of food security is apparent in its multidimensional nature (availability, accessibility and stability) and at several levels (e.g., world, country, household and individual).

Within the context of this study, we focus on national and, to some extent, household food security using the following measures:

(i) Food Self-Sufficiency Index (FSSI);

(ii) Food Trade Balance Index (FTBI); and

(iii) Household Food Coverage Index (HFCI). These three indicators are drawn from Giesecke et al. (2013 and Mariano and Giesecke (2014).

These indicators provide an adequate measure for food security situations. Moreover, they can be easily associated with existing variables in the CGE model, particularly those related to production, consumption and trade.

Food Self-Sufficiency Index (FSSI)

Food Self-Sufficiency Index (FSSI) measures the share of national food consumption (foodcons) met by national food production (foodprod). This is given by the following formula:

$$FSSI = \frac{FOODPROD}{FOODCONS} \tag{7}$$

In this regard, a ratio less than (or greater than) 1 means that national food production is insufficient (or sufficient) to meet the country’s food needs (Mariano and Giesecke, 2014). At the same time, a ratio equal to one means that the country’s food production capacity is sufficient to sustain domestic consumption.

Food Trade Balance Index (FTBI)

Food Trade Balance Index (FTBI) is a measure of a country's financial capacity to meet its domestic food needs through export earnings (Ecker et al., 2010). The value of FTBI is calculated using the formula below:

$$FTBI = \frac{VALTOTEXP}{VALFOODIMP} \tag{8}$$

where VALTOTEXP is the nominal value of the total export earnings; and

VALFOODIMP is the nominal value of total food product imports.

Household Food Coverage Index (HFCI)

Household Food Coverage Index (HFCI) measures the ability of households to cover their food expenses with their current income. This index is derived from Giesecke and Tran (2010), Mariano and Giesecke (2014) and Giesecke et al. (2013) and is implemented in the model as the ratio of total household expenditure (CTHT) to the value of household expenditure on all food items and beverages (CTHFOOD):

$$HFCI = \frac{CTHT}{CTHFOOD} \tag{9}$$

Data and structure of the Burkina Faso economy

This study uses Burkina Faso's 2013 Social Accounting Matrix (SAM) developed by Aragie, Angeluci and Demanet (2018). The SAM, as developed, presents in its detailed structure 132 goods and services accounts, 47 of which are agricultural products, and 74 activity accounts. In this paper, the number of activity sectors is aggregated to 18, out of which 11 are agricultural sectors and 7 are non-agricultural sectors. Goods and services are aggregated into 20 products comprising 11 agricultural products and 9 non-agricultural products. The factor accounts are composed of two categories of labour input (agricultural labour and non-agricultural labour) and three types of capital (land, capital equipment and non-agricultural capital). The institutional unit accounts comprise four categories: households (poor rural households, poor urban households, rich rural households, and rich urban households), a government account, a business account, and the

Rest of the World (ROW).

Annex 3 shows the distribution of value addition between different factors of production. Agricultural labour represents, on average, 11.93% of agricultural value-added commodities whereas land represents 61.97%. The non-agricultural sectors are capital intensive, except for the other private and public administration sectors, which are intensive in non-agricultural labour, and it is not surprising that education and health sectors (public administration) generate a lot of labour.

Households derive their income from three main sources: labour income, capital income (land, agricultural equipment, off-farm capital) and remittances (household, government and from the rest of the world). Rural households draw their income from capital (49.73%) followed by labour (31.21%) and remittances (17.42%). Finally, urban households receive 72.82% of their income from capital, 20.72% of their income from labour and 6.46% from remittances (Annex 8). Households spend most of their income on consumption (84.25%) (Annex 4).

The bulk of government revenue comes from direct taxes (47.78%), followed by indirect taxes (28.59%) and remittances received from the rest of the world (23.64%). The government spends most of its revenues (47.50%) on the consumption of public goods (public administration, public education, public health), and remits 16.05% of its income to households.

Annex 5 gives us some indications regarding relations between Burkina Faso and the rest of the world. The fifth column of the table shows the breakdown of production (XS), including the share of total production devoted to exports (EX). For example, 99.40% of mining production is exported. The extractive sector (99.40%), export-oriented agriculture (51.62%) and other private services (72.12%) export most of their output. These sectors could be more affected in the event of an external shock. The fourth column shows shares of each exported product (EX) in total exports (EXT). For example, 54.73% of total exports are extraction products, 20.03% of total exports are agricultural export products, 10.34% are "other services" products and 5.10% are products of other services.

The third column refers to import penetration rate; that is, the relationship between Burkina Faso market (Q) and imports (IM). For example, 85.39% of "manufactured products" are imported, as are 70.68% of other services products and 62.07% of other agricultural activities. Given the relatively small size of the manufacturing sector in Burkina Faso, it is not surprising that manufactured products are mainly imported. Under agricultural products, the country imports 73.01% of manufactured products, 11.01% of other private services, and 10.01% of agri-food products. Finally, the second column gives distribution of total imports (TMI) among imported products (IM).

Annex 4 shows the structure of demand between the main components: final consumption (household and public), intermediate consumption and investment (consumption for investment purposes and stock variations). For example, more than 79.85% of maize, 65.23% of rice, 89.42% of millet and 54.43% of sorghum are for household consumption and are therefore highly dependent on household income.

Other agricultural sectors (99.30%), mining (94.50%), export-oriented agriculture (76.87%) and other private services (80.00%), for example, are more dependent on other sectors, with intermediate consumption absorbing most of the market. Unsurprisingly, the public administration sector relies on the investment component (96.38%) and will therefore be sensitive to changes in total investment. Most of the parameters of the CGE model are calibrated from the SAM. The elasticity for calibrating the production, import, export and consumption functions are taken from Cockburn et al. (2013).

Simulation scenarios

Since the onset of droughts in the 1970s, different administrations in Burkina Faso have been resolutely committed to agricultural revolution. Thus, several policies and political commitments have been made to increase agricultural production. Currently, the government's political commitments have been translated into development of PNSR phase two (2016-2020) and made operational by the agro-forestry-pastoral sector policy (2018-2027). Indeed, the government's priority actions through the policy are as follows:

(i) increase the level of use of agricultural inputs and equipment;

(ii) plant protection and packaging of agricultural products;

(iii) research and development, extension services and agricultural advisory support.

Using the CGE model, we analyze the comparative effects of three agricultural policy scenarios. Before evaluating agricultural policies, a baseline scenario is developed to trace the effects of land degradation induced by soil erosion and droughts, thus the soil erosion model estimates land productivity loss. The estimate of land productivity loss given by equation 1 gives a loss of land productivity of about 2%. This loss is used in the CGE model to simulate the effects of loss of land productivity on the economy. The simulation is the land degradation scenario.

Faced with land productivity loss, the strategic orientations of the agro-forestry-pastoral policy are centred on three main areas:

1) food and nutritional security;

2) competitiveness of fish and wildlife agro-forestry-pastoral sectors and access to markets;

3) sustainable management of natural resources.

The actions to be carried out under the policy are to increase investment in rural infrastructure, develop irrigation and subsidize agricultural equipment. Public interest investment to improve rural infrastructure is likely to reduce transaction costs for rural households and facilitate access to markets. Investment in irrigation and subsidies to farmers and agricultural equipment are instruments mainly aimed at improving agricultural productivity.

In this study, we are focusing on the evaluation and comparison of potential effects of agro-forestry-pastoral sector policy on agricultural performance and food security to provide decision-makers with indications on allocation of public funds. The analysis of public funding to the agricultural sector shows an upward trend over the period 2005 to 2015. Indeed, budget allocation increased from FCFA 113.4 billion in 2005 to FCFA 230.5 billion in 2015; that is, an average annual growth rate of 7.78%. In addition, the government is committed to investing 10% of public expenditure per year on the agro-forestry-pastoral sector.

Under the NRSP 2, the government has identified two sources of funding for sector policies; funding from internal resources and contributions from technical and financial partners. Based on Burkina Faso's public finance structure, three realistic sources of financing have been identified. First, we assume that the government redirects its non-productive consumption expenditure towards investments in rural infrastructure, subsidy expenditure in agribusiness and investments in irrigation. Second, we assume that the government can mobilize the amount of funds required to raise the income tax rate. Since the informal sector remains the largest sector of the economy, we assume that the government has the capacity to broaden the income tax base. Finally, we assume that the government will convince the technical and financial partners to finance the agricultural policy. According to the definition regarding the financing of the agricultural policy, 53.9% of own resources and 46.1% of external resources will suffice.

Development of rural infrastructure: Burkina Faso is burdened by a deficit in road infrastructure. The landlocked nature of the country's geographical area increases trade margins and transport costs. Increased investment in rural road infrastructure improves the state of the marketing system. Thus, public investment in rural infrastructure (roads, storage and communication centres) improves the efficiency of marketing infrastructure production and use of extension services. In this way, public interventions aimed at improving the productivity of trade, transport and communication sectors and use of extension or extension services help to reduce transport and trade margins. The objective of improving rural infrastructure in the agro-forestry-pastoral sector policy is in line with the objective of the National Economic and Social Development Plan (PNDES) for 2016-2020. Over this period, the government intends to increase the proportion of rural roads from 27% in 2015 to 43% in 2020. An estimate on the nexus between rural infrastructure and trade margins for African countries by Schürenberg-Frosch (2014) finds an elasticity of 0.19 for the agricultural sector and 0.15 for the non-agricultural sector. Thus, an increase of 10%, on average, in the density of rural roads could reduce transport and trade margins for agricultural sector by 1.9% and non-agricultural sector by 1.5%.

Subsidies for agricultural inputs and equipment: Burkina Faso imports nearly 95% of agricultural fertilizers and produces only 5% (Wanzala-Mlobela et al., 2013). In addition, the rate of use of improved seeds is low at 12%, and fertilizer use is low at 11kg/ha against a target of 50kg/ha (Alliance for Green Revolution Africa - AGRA, 2017). The government of Burkina Faso, like other Sub-Saharan African countries, launched a subsidy programme in 2008 to encourage farmers to adopt chemical fertilizers and improved seeds to improve agricultural productivity. The intervention was general but targeted crops such as maize, rice, cotton and sesame. The cost of the programme is estimated at 30.9 billion CFA Francs in 2013, or about 15% of total agricultural expenditure (Yameogo et al., 2017). The level of subsidy is currently around 35% of the price of fertilizer to the producer (Maître d'Hotel and Porgo, 2019). This support for agricultural input markets allows farmers to purchase intermediate inputs at prices below the market price. The objective of the subsidy policy is to reduce the acquisition cost of chemical fertilizers. Since Burkina Faso imports chemical fertilizer, the price of chemical fertilizer on the local market is determined by the import price plus taxes or subsidies on imported fertilizers. This shows that in the absence of a tax or subsidy, the price of fertilizer is exogenous and producers' demand for fertilizer is determined by the equilibrium between the marginal productivity of fertilizer and the price of fertilizer. Based on criticism concerning the effectiveness of subsidies, the government intends to reduce the amount of fertilizer subsidy. Following the recommendations of Maître d'Hotel and Porgo (2019), we simulate a subsidy of 10% on the acquisition cost of chemical fertilizer. In addition, the government, as part of the modernization of the agricultural sector, has launched a programme to provide 100,000 ploughs to small farmers over a period of five years, which will increase the supply of agricultural capital. Based on the 2013 year regarding SAM, this will increase the supply of agricultural equipment by about 10%.

Development of irrigation: Water control is one of the driving forces behind the development of agriculture in Burkina Faso in a context of scarce rainfall. Burkina Faso has 233,500 ha of irrigable land and 500,000 ha of lowlands that can be developed, but irrigated agriculture remains poorly developed. The government's plan is to develop 13,146 ha of irrigated land to increase the total area of irrigated land from 12,854 ha to 26,000 ha in 2020. Based on the work of Inocencio and al. (2007), the unit cost of developing irrigation infrastructure in Sub-Saharan Africa is 5,726 dollars per hectare. Development of 13,146 ha of irrigated land would cost FCFA 42 billion. This will result in an increase in government capital investment expenditure of 6.75% over the 2013 SAM year. Based on information from the SAM, development of new irrigated areas would increase the share of arable land capital by about 7%. Table 2 summarizes scenarios implemented in this work.

Table 2: Summary of simulations

Simulation Scenario		
Degradation	Soil erosion	A decrease of 2% in land productivity
Infrastructure	Soil erosion + rural infrastructure investment	A reduction by 8.17% in trade and transport margins for agricultural products A reduction by 6.45% in trade and transport margins for agricultural products Financing with an increase in direct taxes of 15% and 11% support from partners
Subsidy	Soil erosion + subsidies on farm inputs and equipment	A 10% subsidy on purchase price of chemical fertilizers and a 10% increase in supply of agricultural equipment Financing with a 15% increase in direct taxes and a 10% increase in external aid
Irrigation	Soil erosion + expansion of irrigation capacity	A 7% increase in farmland capital base To be financed by a 4% increase in direct taxes and a need for external aid of an additional 3% over the baseline

5. Simulation results

We present results from four simulation scenarios. The first scenario concerns the effect of land productivity loss induced by soil degradation. The last three scenarios deal with different policies for mitigation and adaptation to the adverse effects of land degradation. Assessment of agricultural policy deals with the increase in public expenditure on rural infrastructure, subsidies for fertilizer and agricultural equipment purchase costs and, finally, public investment in irrigation. Results from the estimation of equation 2 show a crop yield loss of about 2% (Annex 9).

Macroeconomic impacts

The CGE model provides changes in socio-economic variables following simulations of soil productivity losses and public investment policies in agriculture. As expected, macroeconomic effects are small, given that loss of land productivity is relatively moderate (2%) and mainly concentrated in the agricultural sector. However, loss of land productivity negatively affects Gross Domestic Product (GDP). Simulation results show that the decline in agricultural land productivity has negative effects on household consumption, total investment, agricultural and non-agricultural employment and on the Gross Domestic Product (real GDP). This decline in GDP (-0.016%) follows a drop in private consumption (-0.011%), total investment (-0.008%) and total exports (-0.008%) (Table 3). Loss of land productivity led to a decrease in agricultural value-added commodities by 0.03%. This led to a fall in income from taxes on production by 0.002% and taxes on goods and services by 0.003% (Annex 10). In addition, decline in value-added commodities led to a loss of demand for agricultural and non-agricultural labour, and soil erosion led to a decline in agricultural and non-agricultural rate of returns and a decline in wage rate in the non-agricultural sectors. Given the negative relationship between the wage rate and the unemployment rate, there was an increase in unemployment rate of 0.02% in the non-agricultural sectors.

Regarding agricultural policies in response to land degradation, financing methods, i.e. raising the level of tax rates on production and aid from development partners, have an impact on government revenue. The three implemented agricultural policies have positive effects on government income. For agricultural input, and equipment subsidy policies and irrigation extension policy, government revenue increases by 2.31% and 1.43%, respectively, while rural infrastructure development policy increases government revenue by 4.02% (Annex 10). These effects are due to increased revenues from direct taxes on production as the policies lead to increased production, especially in the agricultural sector.

Increase in agricultural production results in an increase in domestic supply of agricultural products. Simulation results show an increase in real household consumption of 2.25% for the rural infrastructure development policy, 1.62% for irrigation development and 4.22% for subsidies for agricultural inputs and equipment. The increase in household consumption is attributable to the rise in their factor income. Increase in factor income is dictated by the increase in wage rate in the non-agricultural sectors and returns on agricultural capital. In addition, results of the model show that reallocation of government budget to capital spending leads to an increase in government consumer spending. Thus, government consumption increases by 7.52% in the case of investment in rural infrastructure, 1.25% in subsidy policy and 3.17% in irrigation extension policy. Household and firm savings decrease as a result of increased investment in irrigation and rural infrastructure, and consequently a decrease in total investment. Under the policy on subsidizing agricultural inputs and equipment, savings increase as total investment increases.

Variations in the level of Gross Domestic Product (GDP) are the sum of variations in other macroeconomic variables as a result of agricultural policy simulations. As expected, agricultural soil erosion reduces value addition and real GDP. However, the set of implemented agricultural policies leads to an increase in the value of GDP. This is due to the direct effect of agricultural policies on agricultural production and the use of agricultural products as intermediate consumption in non-agricultural sectors. While all the agricultural policies studied tend to accelerate the GDP growth rate, the analysis shows that the effect is more significant for agricultural input and equipment subsidy policy (3.65%), followed by investment in rural infrastructure (2.09%) and finally agricultural input and equipment subsidy policy (1.66%).

Table 3: Macroeconomic effects

	Baseline	Degradation	Infrastructure	Subsidy	Irrigation
Absorption	10,640,566	-0.006	0.42	2.45	0.49
Agricultural production	2344005	-0.025	0.00	5.13	1.17
Private consumption	3,535,081	-0.011	2.25	4.22	1.62
Public consumption	1,265,778.8	0.003	7.52	1.25	3.17
Total Investments	1,932,547	-0.008	-0.82	0.92	-2.06
Total Exports	1,515,979	-0.008	-2.42	-2.47	-0.62
Total Imports	2,420,564	-0.001	1.47	1.3	0.3
Commodities imports	26471	0.095	4.11	6.80	-3.86
Real GDP	5,830,937	-0.016	2.09	3.65	1.66
Consumption Price Index	1	0.018	0.84	-1.87	-0.03
Agricultural employment	121,419	-0.001	4.35	-5.13	1.97
Non-agricultural employment	1,010,222	-0.003	-1.08	1.44	1.46

Source: Author's compilation based on simulation results

Impact on production

Soil degradation has a negative effect on cereal production, food industry and non-agricultural production. This is driven by reduced demand for intermediate inputs. Loss of output has, therefore, led to a decline in the wage rate and an increase in the unemployment rate in the non-agricultural sectors. The rise in price level on market for agricultural products triggered an increase in demand for agricultural labour. According to Table 3, irrigation development policy can fully mitigate the effects of land degradation on agricultural production. This indicates that increasing the area of irrigated land is a profitable investment. Implementation of the government's irrigation policy in Burkina Faso could increase the production of maize by 4.98%, rice by 5.43%, tubers by 4.60% and vegetables by 5.33% (Table 4). The results also show that the irrigation investment policy is improving the country's socio-economic indicators. Thus, the demand for agricultural and non-agricultural labour is increasing. Similarly, the income of poor rural, poor urban, non-poor rural and non-poor urban households increases by 1.60%, 2.89%, 1.32% and 1.94%, respectively (Annex 11). Given the physical and climatic conditions of the country, the potential of irrigated land is low. However, the irrigation development policy should not be neglected, as it mainly targets cash crops that constitute a large share of agricultural GDP, and this type of strategy is a potentially profitable way of mitigating land degradation.

However, the development of rural infrastructure is beneficial to cereal farming and the agri-food industry (Table 4). This confirms, for example, that improved progressive access to rural areas helps to combat the effects of land degradation. The construction of rural roads improves household income (3.18% for poor rural households, 4.18% for poor urban households, 3.40% for non-poor rural households and 2.64% for non-poor urban households (Annex 11). An increase in income is mainly explained by increase in demand for agricultural labour. Based on GDP, the results show that such a policy is beneficial.

It is surprising, however, that the policy on irrigation development and rural infrastructure development is resulting in an increase in production in some non-agricultural sectors (food processing, water, electricity and gas, and public administration). This increase in production in the non-agricultural sector is mainly attributable to the direct effect of policies on certain sub-sectors that generate agricultural services. For example, development of irrigation and rural infrastructure directly affects the intermediate demand for the agri-food industry, as well as the water, electricity and gas, and public administration sectors.

We also note that development of rural infrastructure has not been able to contain the negative effect of land degradation in maize production. This situation is mainly due to a 0.49% drop in demand for the intermediate consumption of maize. This is the effect of the decline in demand for agricultural labour and the increase in cost of agricultural capital. An increase in the market price of agricultural products explains the increase in demand for agricultural labour to benefit from the opportunities related to market for agricultural products.

Table 4: Effects on production (variation in % with respect to the baseline)

	Base	Degradation	Infrastructure	Subsidy	Irrigation
Maize	130,106	-0.07	-0.49	2.56	4.98
Rice	66,171	-0.03	0.94	2.63	5.43
Millet	116,463	-0.01	2.20	3.33	0.55
Sorghum	173,825	-0.01	2.04	5.73	0.51
Fonio	2,704	-0.07	8.80	1.44	4.45
Tubercle	154,558	-0.08	0.88	2.07	4.60
Vegetables	150,653	-0.08	0.04	0.52	5.33
Livestock	588,132	-0.00	0.12	10.51	0.00
Export farming	9,569	-0.03	-1.39	0.62	0.01
Forestry	725,844	-0.00	-0.04	7.44	0.02
Other farming	225,980	-0.13	-2.68	6.59	5.30
Extraction	897,891	-0.00	-2.32	-4.78	-0.94
Agri-food industry	900,611	-0.01	1.57	7.17	0.65
Manufacturing industry	352,296	0.00	-1.00	-0.04	-1.12
Water, electricity and gas	147,715	0.00	1.50	0.77	0.22
Private services	3,705,366	0.00	-2.95	1.05	-0.57
Public administration	1,282,217	0.00	7.15	1.13	2.82
Other services	105,880	0.00	-2.03	-3.11	-1.26

Source: Author's compilation based on simulation results

Regarding policy aimed at subsidizing agricultural inputs and equipment, the price of agricultural capital and inputs decreases by 13.70%, on average. As capital and fertilizer have become cheaper, producers are substituting labour for capital. As a result, demand for agricultural labour decreases by 5.13%. In addition, return on agricultural equipment capital decreases by 17.39%, non-agricultural capital increases by 3.73% and land returns by 6.51%. The increase in non-farm composite wage rate and composite return on capital explains the increase in price of value-added products in non-farm sectors, while the reduction in price of inputs and increase in supply of agricultural capital explain the decrease in demand for non-agricultural labour. The policy on subsidizing prices for chemical fertilizers and agricultural equipment has important socio-economic effects. Domestic absorption, which is the sum of consumption of local and external goods, describes the level of household welfare. Thus, domestic absorption increases with this policy of subsidizing agricultural inputs and equipment. In addition, the increase of real household consumption is dictated by the fall in prices for agricultural goods and increase in household income. The benefit of this policy is the increase in household income; that is 1.58% for poor rural households, 3.33% for poor urban households, 1.99% for non-poor rural households and 2.86% for non-poor urban households. The results show that this policy encourages domestic production and increases value addition in the agricultural sector. In addition, results suggest that the subsidy policy is profitable to the agricultural sector mainly through export-oriented agriculture, which is comprised of the main users of fertilizers.

Other important outcomes of these agricultural policies are the effects on prices. Indeed, effects on prices are mainly dictated by methods of financing public expenditure and especially the increase in taxes on production. Thus, an increase in the tax on production directly affects the price of production. The unit cost of production rises for all three agricultural policy scenarios, and increase in tax rate on production increases tax revenue and also government revenue. In the case of irrigation policy, an increase in domestic supply and decrease in imports of agricultural products leads to a decline in domestic agricultural prices.

Simulation results show that subsidy and irrigation development policies led to an increase in agricultural production, resulting in an average increase in exports of between 0.64% and 1.66% for agricultural products, a decrease in imports of agricultural products by 3.86% for the irrigation policy and an increase in imports of agricultural products by 6.80% for the subsidy policy. These results show that Burkina Faso's agricultural products have become more competitive on the international market. Finally, the rural infrastructure development policy was unable to mitigate the effects of soil erosion on agricultural production, resulting in a 4.11% increase in agricultural imports and a 2.33% decline in agricultural exports. The results show that the simulated policies reduce the effects of soil erosion, but the level of reduction varies according to policies. Thus, the irrigation development policy is more favourable to agricultural production, followed by the policy on subsidizing agricultural inputs and equipment, and finally the policy for developing rural infrastructure.

Impact on consumption

Table 5 shows the impact of degradation and policy interventions on household consumption. The results show that land degradation leads to a decrease in consumption by all groups of households. This decrease in consumption is linked to a decrease in household purchasing power due to an increase in consumer prices for agricultural products (Table 6). Monitoring variations in consumption gives a more precise indication of how these agricultural policies affect food security. The effect on consumption is more pronounced under productivity-enhancing interventions; subsidies on agricultural inputs and equipment (Table 5).

Food consumption at the national level as a result of the subsidy policy for agricultural inputs and equipment increased by 4.90%. Reduction of marketing and transport margins has led to an increase in national food consumption by 2.02%. Extension of irrigation capacity has increased national food consumption by 1.82%. In most cases, the policies analyzed has resulted in an increase of consumption of agricultural and non-agricultural products. The effects on consumption are very heterogeneous from one household to another. Rural and urban households (poor and non-poor) benefit from increased agricultural and non-agricultural consumption under different agricultural policies. Increase in household consumption is linked to increase in household disposable income. The magnitude of the results is also explained by the source of financing for the policy. Different policies lead to an increase in employment, especially in the agricultural sector. This will lead to an increase in disposable income and thus household consumption expenditure.

Among the interventions examined, in terms of income, poor urban households particularly benefit from spending on marketing systems, subsidies and irrigation, since part of the expenditure related to these investments accrues to urban households in the form of returns on investment from their engagement in rural road construction, agricultural amenities and marketing activities for agricultural inputs and equipment. Urban households benefit more from the irrigation development policy, followed by the inputs subsidy policy and finally the rural infrastructure development policy. These households are the main consumers of irrigated farm products and, therefore, the expansion of irrigation increases availability of irrigated agricultural products and reduces their prices. Poor rural households, in terms of consumption, benefit more from the infrastructure development policy and irrigation development policy monitoring. Finally, for the agricultural policy package, the three agricultural development policies increase the consumption of all households in a situation of land degradation.

Table 5: Effects on consumption

	Degradation	Infrastructure	Subsidy	Irrigation
Poor rural households				
Cereals farming	-0.02	1.86	1.32	1.95
Export farming	-0.01	1.27	1.39	1.26
Other farming	-0.02	0.90	7.45	2.18
Agri-food industry	-0.00	3.23	5.21	1.52
Non-agricultural activities	0.00	2.97	2.04	1.72
Poor urban households				
Cereal farming	-0.05	2.42	2.26	4.99
Export farming	-0.02	1.98	2.68	2.47
Other farming	-0.03	1.59	8.92	3.28
Agri-food industry	-0.02	4.33	7.21	3.44
Non-agricultural activities	-0.01	4.11	4.05	3.63
Non-poor rural households				
Cereal farming	-0.02	1.80	1.35	2.13
Export farming	0.00	3.21	5.13	1.00
Other farming	-0.02	1.00	6.72	1.84
Agri-food industry	0.00	3.21	5.13	1.00
Non-agricultural activities	0.00	3.00	2.27	1.21
Non-poor urban households				
Cereal farming	-0.03	1.25	1.98	2.60
Export farming	-0.02	0.78	2.16	1.34
Other farming	-0.03	0.45	7.43	2.30
Agri-food industry	-0.01	2.33	6.17	1.71
Non-agricultural activities	-0.01	2.16	3.23	1.89

Source: Author’s compilation based on simulation results

Effects on food security

To understand the results on food security, we begin our discussion by looking at indicators of food supply and demand. The implementation of the three agricultural policies leads to an increase in total production compared to baseline level. In addition, infrastructure development and subsidy policies lead to an increase in unit costs of agricultural production compared to the baseline level due to an increase in production tax. The irrigation development policy leads to a decrease in unit cost of agricultural production compared to reference level. Implementation of the rural infrastructure development policy financed by a tax on production therefore increases the unit costs of production in the cereals sector. This increases the prices of agricultural products for consumers compared to the reference level. The policy on subsidizing agricultural inputs and equipment leads to lower prices of agricultural export products for consumers. In the case of irrigation development and subsidy policies, cereal consumption increases due to lower prices and increased cereal production; in the case of rural infrastructure development and agricultural input, and equipment subsidy policy, an increase in household disposable income has compensated for the increase in the price level of cereal products. Generally, imports are increasing, leading to an increase in domestic absorption (Table 3).

Table 6 illustrates the effect of agricultural policy shocks and soil erosion on agricultural and non-agricultural commodity prices. Declining land productivity leads to higher consumer prices for agricultural products, and the policies implemented have differentiated effects on consumer prices depending on the policy. Compared to the situation of land degradation, rural infrastructure development policy leads to an increase in consumer prices due to an increase in production tax by 15% to finance a 10% increase in government expenditure. Since subsidy leads to a reduction in the price of inputs and agricultural capital, it reduces the output price of export agriculture and consequently there is a decrease in the consumer price of exporting agricultural products. Secondly, irrigation development policy leads to a decrease in price of agricultural products and an increase in price of non-agricultural products. The drop in prices of agricultural products as a result of increase in production leads to an increase in the real consumption of agricultural products by households.

The effect of all agricultural policies on production of staple foods differs between policies. Infrastructure development policies (rural roads and agricultural commodity markets) that are agriculture supportive do not improve maize production. The decline in maize production (-0.49%) increases maize imports by 2.66%. In addition, the irrigation development policy leads to an increase in production of maize (4.98%), rice (5.43%), tuber (4.60%) and vegetables (5.33%), reducing maize imports by 7.86%, rice by 13.96%, tubercle by 6.80% and vegetables by 8.80% (Table 4). However, policies aimed at subsidizing inputs and equipment are considered favourable to agriculture and increase the production of all agricultural crops by 5.13%, and also increase imports of all agricultural commodities by 6.80% compared to the situation on soil degradation (Table 3).

Table 6: Effects on the consumption price index

	Baseline	Degradation	Infrastructure	Subsidy	Irrigation
Maize	1.05	0.12	1.26	2.29	-6.15
Rice	1.02	0.07	1.97	2.82	-9.48
Millet	1.04	0.02	0.61	0.67	1.71
Sorghum	1.12	0.02	0.38	0.69	1.91
Fonio	3.81	0.04	-4.36	2.87	-0.99
Tubercle	1.07	0.15	2.10	0.56	-5.44
Vegetables	1.04	0.12	1.89	2.88	-6.27
Livestock	1.03	-0.01	2.67	-13.51	1.22
Forestry	1.06	-0.01	3.09	-14.9	2.08
Other crops	1.16	0.03	1.06	0.31	-1.31
Export farming	1.12	0.03	1.78	1.07	0.33
Agri-food industry	2.21	0.00	0.36	-2.31	0.85
Extraction	1.23	0.00	-2.90	2.48	0.66
Chemical products	1.36	0.00	-1.00	0.53	0.20
Manufacturing industry	1.46	0.00	-0.94	0.68	0.25
Water, electricity and gas	1.09	0.00	-0.30	1.31	0.97
Private services	1.06	0.00	1.96	1.52	0.53
Public administration	1.00	0.00	2.35	2.78	3.57
Other services	1.04	0.00	0.86	0.80	0.57

Source: Author's compilation based on simulation results

We now discuss the impacts of implementation of the three strategic interventions on food security indicators. First, the Food Self-Sufficiency Index (FSSI), defined as the quantity of national cereal production divided by domestic cereal consumption (imported or domestic), is an indicator showing the gap between cereal production and consumption. We have seen in Table 4 that cereal production (other than maize) increases under rural infrastructure development policies compared to land degradation scenario. According to Table 7, cereal production is higher than cereal consumption for all scenarios. However, compared to the land degradation situation, the cereal food self-sufficiency indicator has not improved in the context of rural road development. In the case of subsidy on agricultural inputs and equipment and expansion of irrigation, cereal production is clearly higher than cereal consumption, but compared to the situation of declining soil productivity, we can see that the FSSI indicator has not fully increased.

Table 7: Effects on food security indicators

	Baseline	Degradation	Infrastructure	Subsidy	Irrigation
Food Self-Sufficiency Index (FSSI)	1.28	1.28	1.27	1.3	1.27
Maize Self-Sufficiency Index	1.1	1.1	1.08	1.12	1.1
Rice Self-Sufficiency Index	1.38	1.38	1.38	1.4	1.36
Millet/Sorghum Self-Sufficiency Index	1.11	1.11	1.12	1.15	1.12
Fonio Self-Sufficiency Index	0.55	0.55	0.58	0.56	0.57
Food Trade Balance Index (FTBI)	5.38	5.38	5.03	5.23	5.23
Household Food Coverage Index (HFCI)	1.83	1.84	1.85	1.78	1.83

Source: Author's compilation based on simulation results

The FTBI index measures the ratio of total export income to the value of food imports. It is an indicator of a country's ability to meet its domestic food needs through international trade. As Table 7 clearly shows, subsidy on agricultural inputs and equipment, development of irrigation and rural infrastructure leads to a decrease in FTBI index compared to the baseline situation and the index value in the land degradation scenario. This is explained by the increase in food imports compared to the baseline level. However, the index level shows that the value of exports is sufficient to cover food import expenditures, and that the country is able to meet its domestic food needs on international markets.

Finally, the HFCI is defined as the ratio of total household expenditure to the value of household expenditure on all food and beverages. This indicator measures the ability of households to cover their food bill from their current income. In the case of land degradation, the index has an initial value of 1.84. The simulated rural infrastructure and irrigation development policies result in a positive deviation on the index from the baseline level and land degradation scenario. This means that the ability of households to purchase given food items improves relatively to what it would have been in the baseline situation. This result is mainly because of increased household income. In particular, the increase in the price of food for the buyer leads to an increase in household food expenditure, which is thus mitigated by the increase in household disposable income in both agricultural policies.

6. Conclusion and policy implications

This study uses a Computable General Equilibrium model to explore the potential impacts of soil degradation on agricultural production and food security by implementing three intervention options regarding the agro-forestry-pastoral sector policy of the Government of Burkina Faso. Thus, four simulation scenarios were tested. The first scenario deals with the effects of reduction of land productivity. The last three scenarios deal with policy options to control soil erosion. The policy options relate to: (i) rural infrastructure development policy (roads); (ii) agricultural input and equipment subsidy policy; and (iii) irrigation extension development policy. The following conclusions can be drawn from the results:

In general, the policies analyzed have shown significant impacts on food production, consumption and security. The benefits are significantly greater for urban households, demonstrating the positive role that these policies can play on agricultural production and food security.

A comparison of agricultural policies shows that development of irrigation effectively resolves the problem of soil erosion through increased household production and consumption, followed by policy regarding subsidies for agricultural inputs and equipment, and finally development of rural infrastructure (roads, markets, storage and extension stores). This suggests that for Burkina Faso, where supply is limited, it is more effective in the short term to focus on agricultural production and on interventions aimed at subsidizing agricultural inputs and equipment to improve productivity and food security. In the medium term, focus on irrigation development and long-term focus on rural infrastructure development are essential aspects.

With regard to the sources of financing for required interventions, mobilization of internal and external resources for financing of agricultural policies gives better results, especially for rural infrastructure development policies and irrigation development, and we also note that the financing of these projects through mobilization of new funds via taxation could have favourable effects on production and food security. In summary, while input subsidies are a rapid and short-term instrument to achieve rapid agricultural growth and improved food security, the medium- to long-term solution to increase food security lies in further development of irrigation, as access to irrigation can also help reduce the risk of crop failure in times of climate change.

Finally, although these results provide insights into the adverse effects of land degradation on agriculture and the effects of agricultural policies, there are limitations to the study. First, the methodology used does not fully address the uncertainty associated with land degradation. Second, alternative strategies for adaptation to land degradation exist, and the paper did not consider them despite the possibility that they could have beneficial effects on agriculture. Finally, it is not possible to determine the optimal way to finance agricultural policies.

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Annex

Annex 1: Share of harvested area production and value of main agricultural crops in Burkina Faso in (%)

Crops	Production	Area	Production value
Sorghum	21.30	25.74	15.86
Maize	17.96	13.02	13.87
Millet	12.22	18.92	9.03
Rice, paddy	3.46	1.98	4.69
Fonio	0.23	0.35	0.37
Cotton	16.72	8.97	24.76
Cowpeas	0.10	0.01	0.13
Sesames	1.56	2.90	2.89
Groundnuts	3.96	6.40	3.10
Soya	0.25	0.23	0.17
Onions	0.20	0.02	0.25
Earth weight	7.43	17.8	8.58
Potatoes	0.02	0.01	0.03
Tubercles	2.99	0.43	1.51
Tomatoes	0.13	0.02	0.11
Others vegetables	3.05	0.70	3.98
Tobacco	0.01	0.01	0.02
Shea nuts	0.51	0.43	0.21
Mangoes	0.16	0.02	0.07
Other fruits	0.98	0.22	0.56
Cashew nuts	1.30	1.71	8.56
Other related wood products	0.02	0.04	0.10
Sugar cane	5.44	0.07	1.15

Source: Authors calculations based on FAO (2019) report

Annex 2: Crop yield in tones per hectare

	2010	2011	2012	2013	2014	2015	2016	2017
Sorghum	1.00	0.90	1.08	1.04	1.10	0.99	0.96	0.82
Maize	1.43	1.54	1.84	1.74	1.91	1.79	1.76	1.60
Millet	0.84	0.72	0.85	0.81	0.82	0.82	0.76	0.68
Rice paddy	2.02	1.77	2.33	2.20	2.41	2.28	2.26	1.97
Fonio	0.81	0.67	0.77	0.81	0.75	0.83	0.77	0.64
Cotton	1.14	1.12	1.14	1.22	1.37	1.38	1.20	1.00
Cowpea	12.61	13.12	15.00	13.96	13.01	13.10	13.27	13.44
Sesame	0.72	0.70	0.61	0.68	0.64	0.59	0.58	0.56
Ground nuts	0.83	0.68	0.78	0.78	0.89	0.85	0.88	0.60
Soya	1.26	0.89	1.09	1.35	1.14	1.11	1.12	0.93
Onions	16.75	16.69	16.67	16.36	16.45	16.59	16.63	16.63
Earth weight	1.76	1.59	1.60	1.66	1.64	1.60	1.59	1.58
Potatoes	1.84	1.86	1.88	1.91	1.93	1.95	1.97	1.99
Tubercles	18.49	27.87	18.75	21.90	13.78	12.53	17.82	19.93
Tomatoes	11.28	11.42	12.50	10.45	9.75	10.12	10.20	10.07
Other vegetables	24.50	24.44	24.59	24.68	24.37	25.89	26.07	26.31
Tobacco	0.65	0.69	0.78	0.81	0.79	0.77	0.80	0.81
Shea nuts	1.74	1.66	1.57	1.50	1.43	1.41	1.35	1.30
Mangoes	7.76	8.35	9.10	9.13	9.45	9.23	9.19	9.22
Other fruits	45.83	45.79	46.06	45.12	45.33	45.57	45.54	45.52
Cashew nuts	0.69	0.95	0.86	0.96	0.93	0.95	0.98	1.00
Other timber products	0.55	0.54	0.54	0.55	0.55	0.56	0.56	0.57
Sugar, cane	100.00	100.00	101.04	102.13	101.13	100.70	100.53	100.54

Source: FAOSTAT (2019)

Annex 3: Breakdown of value addition between production factors (%)

	TA	TNA	KDEQA	KDNA	KDT
Maize	11.46	0.00	19.22	0.00	69.32
Rice	2.70	0.00	18.67	0.00	78.63
Millet	22.18	0.00	26.10	0.00	51.72
Sorghum	19.19	0.00	28.56	0.00	52.25
Fonio	16.46	0.00	18.85	0.00	64.69
Tubercles	0.65	0.00	20.70	0.00	68.64
Vegetables	9.70	0.00	18.48	0.00	71.82
Export farming	14.79	0.00	30.01	0.00	55.21
Other crops	1.32	0.00	23.12	0.00	75.56
Livestock	0.01	0.00	99.99	0.00	0.00
Forestry	0.56	0.00	99.44	0.00	0.00
Extraction	0.00	21.53	0.00	78.47	0.00
Agri-food industry	0.00	32.39	0.00	67.61	0.00
Manufacturing industry	0.00	19.13	0.00	80.87	0.00
Water, electricity and gas	0.00	43.11	0.00	56.89	0.00
Other private services	0.00	16.98	0.00	83.02	0.00
Public administration	0.00	55.47	0.00	44.53	0.00
Other services	0.00	51.36	0.00	48.64	0.00

Source: Social Accounting Matrix - SAM (2013)
Note: TA: agricultural work; TNA: non-agricultural work; KDT: land capital; KDEQA: agricultural equipment capital; KDNA: non-agricultural capital

Annex 4: Structure of household and government expenditure (%)

	DIT	CFH	CFGVT	VSTK
Maize	24.28	79.85	0.00	-4.12
Rice	36.53	65.23	0.00	-1.76
Millet	14.65	89.42	0.00	-4.08
Sorghum	55.44	54.43	0.00	-9.87
Fonio	7.16	162.76	0.00	-69.92
Tubercles	2.29	97.71	0.00	0.00
Vegetables	22.05	77.95	0.00	0.00
Export farming	76.87	20.06	0.00	3.07
Other crops	99.30	0.70	0.00	0.00
Livestock	41.23	52.31	0.00	6.46
Forestry	64.28	35.72	0.00	0.00
Extraction	94.50	3.51	0.00	1.99
Agri-food industry	16.59	82.44	0.00	0.97
Manufacturing industry	68.09	31.66	0.00	0.25
Water, electricity and gas	73.97	26.03	0.00	0.00
Other private services	80.00	20.00	0.00	0.00
Public administration	0.87	2.75	96.38	0.00
Other services	16.28	44.61	39.11	0.00

Source: Social Accounting Matrix - SAM (2013)
Note: CFH: Household Final Consumption; CFGVT: Government Final Consumption; DIT: Total Final Consumption Demand; VSTK: Stock Variation

Annex 5: Relations with the rest of the world

	IM/IMT	IM/Q	EX/EXT	EX/XS
Maize	0.00	0.07	0.47	5.51
Rice	0.04	1.48	0.04	0.87
Millet	0.03	0.68	0.02	0.21
Sorghum	0.00	0.00	0.05	0.44
Fonio	0.00	1.75	0.02	8.65
Tubercles	0.07	1.11	0.19	1.86
Vegetables	0.24	4.34	1.56	15.70
Export farming	0.06	0.53	20.03	51.62
Other services	0.62	62.07	0.03	4.39
Livestock	0.02	0.07	1.94	4.05
Forestry	0.01	0.06	0.04	0.26
Extraction	0.28	57.36	54.73	99.40
Agri-food industry	10.01	21.56	0.94	1.59
Manufacturing industry	73.01	85.39	3.26	14.07
Water, electricity and gas	1.22	16.80	0.00	0.00
Other private services	11.01	8.90	10.34	5.43
Public administration	0.40	0.76	1.26	1.49
Other services	2.98	70.68	5.10	72.12

Source: Social Accounting Matrix - SAM (2013)
Note: IM: Import; IMT: Total Import; EX: Export; EXT: Total Export; Q: Domestic Absorption; XS: Production by Sector

Annex 6: Intermediate consumption demand by product and activity sector

	Maize	Rice	Millet	Sorghum	Fonio	Tubercle	Vegetables	Export Farming	Other Crops
Maize	1,424								
Rice		1,457							
Millet			1,314						
Sorghum				2,302					
Fonio					686				
Tubercle						2,292			
Vegetables							4,284		
Export farming								175,554	
Others crops									8
Livestock									
Forestry									
Mining									
Food industry									
Manufacturing industry	25,458	4,731	33,466	37726	13	191	3857	49,091	23
Water, electricity and gas								9,848	
Private service								33,502	
Public administration									
Other services									
Source: Social Accounting Matrix - SAM (2013)									

Annex 7: Intermediate consumption demand by product and activity sector

	Livestock	Forestry	Mining	Food Industry	Manufacturing Industry	Water, Electricity and Gas	Private Services	Public Administration	Other Services
Maize				29,804					
Rice		11		18,918			4,399		
Millet	5,472			11,131					
Sorghum	24,707			80,160					
Fonio									
Tubercle							1,482		
Vegetables		5		9,368			16,813		
Export farming				33,959	16,744				
Others crops	6,151			19,171			2		
Livestock				262,042			22,511		
Forestry	24,786	14043		57,088	27,501		38,668		228
Mining	1,872		7	117	6,128		16,321		
Food industry	14,871	7		123,854	8,543		82,466		8
Manufacturing industry	127	1175	299621	44,125	108,302	76696	581,357	1E+05	11,258
Water, electricity and gas	101	2	13908	12,806	10,154	7755	48,190	35,272	3,592
Private services	77	227	119085	39,636	67,358	24872	1,372,327	1E+05	37,403
Public administration	4,397							6,691	
Other services				1310			1291	6,605	8,002

Source: Social Accounting Matrix - SAM (2013)

Annex 8: Households income sources

	TA	TNA	KDEQA	KDNA	KDT	MRP	MUP	MRNP	MUNP	FIRM	gvt	row
Poor rural household	3.66	25.16	13.02	13.72	24.51	0.00	0.31	1.36	0.06	0.00	14.46	3.75
Poor urban household	0.15	16.00	3.23	73.09	1.03	0.10	0.00	0.20	0.01	0.00	4.90	1.27
Non poor rural household	20.79	44.78	1.63	4.07	22.27	0.20	0.14	0.00	0.10	0.00	1.59	4.45
Non poor urban household	2.26	65.65	3.19	9.27	13.51	0.12	0.18	1.64	0.00	0.00	2.33	1.86

Source : Social Accounting Matrix – SAM(2013)

Note: TA: agricultural work; TNA: non-agricultural work; KDT: land capital; KDEQA: agricultural equipment capital; KDNA: non-agricultural capital; Gvt: government; ROW: Rest of the World; MRP; Poor rural household; MUP: Poor urban household; MRNP: Non poor rural household; MUNP: Non poor urban household

Annex 9: Productivity loss by crop for the year 2013

	Total area (TCi) (ha)	Production (PCi) (t/ha)	Production loss (PPCi)	Loss rate
Fonio	24,567	0.81	397.9854	0.02001234
Fresh beans	655	13.96	182.876	0.02000175
Maize	913,630	1.74	31,794.324	0.02005422
Millet	1,327,078	0.81	21,498.6636	0.01993256
Rice, paddy	138,852	2.2	6,109.488	0.02000605
Sesames	203,449	0.68	2,766.9064	0.02014537
Sorghum	1,806,529	1.04	37,575.8032	0.01998219

Source: Author's calculations
Note: The Land Productivity Loss Index (LPLI) is estimated at 2% and the Soil Erosion Coefficient (SEC) at 8%.

Annex 10: Impact of land degradation and agricultural policies on government incomes

	degradation	Infrastructure	Subsidy	Irrigation
Government income	0.000	4.02	2.31	1.43
Firm direct tax income	-0.003	2.80	-1.61	1.67
Household direct tax income	0.002	2.82	2.70	1.86
Indirect tax revenue on products	-0.003	0.95	1.65	0.07
Production tax income	-0.002	14.01	21.08	5.19

Source: Author's calculations on the basis of CGE model results

Annex 11: Impact of land degradation and agricultural policies on household incomes

	Basis	degradation	Infrastructure	Subsidy	Irrigation
Poor rural household	281141	0.01	3.18	1.58	1.60
Poor urban household	169328	0.00	4.18	3.33	2.89
Non poor rural household	1963757	0.01	3.40	1.99	1.32
Non poor urban household	1877076	0.00	2.64	2.86	1.94

Source: Author's calculations on the basis of CGE model results

Annex 12: Evolution of public spending on agriculture from 2008 to 2016

Title	2008	2009	2010	2011	2012	2013	2014	2015	2016
Specific expenditure on agriculture	54,022	69,961	91,835	76,710	116,767	136,295	70,704	47,413	94,057
Payments to employees of the agricultural sector	32,916	40,367	43,506	32,765	66,889	88,333	39,701	29,136	44,348
Payments to farmers	28,230	26,257	38,740	24,707	46,562	75,152	35,994	17,896	32,600
Variable input subsidies	12,019	11,012	15,970	13,678	25,190	30,889	17,238	7,105	7,494
Agricultural capital subsidy	10,543	12,930	20,310	10,380	20,005	44,191	16,696	10,236	19,262
Subsidy for extension services and technical assistance	1,618	1,009	1,568	312	1,189	52	2,060	555	1,400
Income support	3,776	0	0	0	0	18	0	0	4,444
Other payments to farmers	275	1,307	892	337	178	2	0	0	
Payments to consumers	4,439	14,031	4,097	5,995	19,944	1,1293	1,913	9,933	19,777
Food aid	990	4,757	1,525	5,995	13,275	7,933	1,833	9,845	9,293
Cash transfers	0	0	0	0	3,475	1,228	80	88	8,3430
School feeding programmes	3,450	2,411	2,572	0	3,194	2,132	0	0	0
Other payments to consumers	0	6,863	0	0	0	0	0	0	0
Payments to input suppliers	78	12	98	14	55	100	1,448	1,048	2,533
Payments to processors	168	67	571	2,049	329	1,787	347	259	1,610
General support to the sector	21,107	29,594	48,329	43,945	49,878	47,962	31,003	18,277	37,537
Agricultural research	2,923	3,111	4,608	2,382	2,298	4,087	1,489	1,792	2,533
Technical assistance	540	532	738	2,597	5,904	3,523	2,990	1,326	4,615
Training	7,629	9,185	10,818	7,783	8,866	7,853	4,979	3,033	6,870
Outreach/technology transfer	642	1,081	4,598	3,060	5,310	4,700	5,205	1,846	3,717
Inspection (plant/animal)	503	816	1,029	1,500	3,128	5,981	1,175	469	723

continued next page

Annex 12 Continued

Title	2008	2009	2010	2011	2012	2013	2014	2015	2016
Agricultural infrastructure (rural roads' irrigation)	6,453	1,0538	21,694	23,119	20,395	18,340	12,752	8,548	13,474
Storage	78	86	1025	596	1,045	1,716	444	331	1,547
Marketing	1,966	2,838	2,841	2,562	2,747	1,750	1,963	919	2,707
Other general support to the sector	373	1,406	978	347	183	13	5	12	30
Expenditure on agriculture	51,972	75,092	63,073	25,696	51,098	66,417	24,184	11,992	37,053
Rural education	22,240	28,064	13,333	1,192	4,555	8,903	2,661	4,041	2,626
Rural health	3,846	5,545	7,557	113	805	116	1,456	990	1,979
Rural infrastructure (roads, water, energy)	16,790	31,157	28,635	20,392	43,903	56,464	14,453	6,628	22,502
Other support to the rural sector	9,095	10,326	13,548	3,999	1,834	934	5,614	333	9,946
Grand Total	105,994	145,053	154,908	102,406	167,865	202,712	94,887	59,405	131,109

Source: MAFAP (2017)

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Contact Us
African Economic Research Consortium
Consortium pour la Recherche Economique en Afrique
Middle East Bank Towers,
3rd Floor, Jakaya Kikwete Road
Nairobi 00200, Kenya
Tel: +254 (0) 20 273 4150
communications@aercafrica.org