The Moroccan Association of Agricultural Economics (AMAECO)

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International Association of Agricultural Economics (IAAE) **&** **United Nations University-World Institute for Development Economics Research (UNU WIDER)**

Climatic constraints play a predominant role in the performance of national agricultures and their capacity to support economic growth and assure food security for the population. With the climate changes and projected inter and intra annual fluctuations, management of the agricultural sector takes a particular dimension including management of risks inherent in the sector and searching for sustainable growth for the sector. Agricultural policies must permit a continual adaption of the processes of agricultural production and a reduction of negative effects of climate change in order to assure food security for the population.

In the face of climate change, the adaptation strategies can generate important development opportunities. Also, governments have need for pertinent evaluations of the impacts of climate change.

Considering the importance of this problem; to permit an exchange of ideas among professional staff, researchers, and specialists in the domain of development; to contribute to a richer understanding of methods and analytical tools ; and to contribute to better preparation of decision making in this domain – the Moroccan Association of Agricultural Economics (AMAEco) in collaboration with the International Association of Agricultural Economics (IAAE) and the World Institute For Development Economics Research of the United Nations University (UNU-WIDER) are organizing an international conference 6-7 December in Rabat, Morocco under the theme:

« Impacts of climate change on agriculture »

Rabat, Morocco December 6-7, 2011

The principal themes proposed are the following::

1. Analysis of the impacts of climate change on agriculture: simulations and projections
2. **Climate change and sustainability of agricultural production systems**
3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**
4. **Water management in the context of climate change**

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Modeling the Impact of Drought on Agriculture and Food Security in Sudan

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Abstract

Global climatic changes and water scarcity are attracting major concerns in the recent literature. These issues are particularly important in a country like Sudan, where agriculture contributes over 31% to GDP and the bulk of agricultural production depends on rainfall. Similar to several countries in the Sahel belt of Africa, Sudan has suffered a number of long and devastating droughts during the last decades. The most severe drought occurred in 1984, which was accompanied by widespread displacement and famine, while localized and less severe droughts were also recorded during the late sixties, late eighties and early nineties (UNEP, 2007). This paper is an attempt to use the history of drought in Sudan exemplified by the famous droughts of 1984 and 1990 to estimate the economic effects of future droughts on Sudan. The two drought periods are simulated in a Computable General Equilibrium (CGE) modeling framework that is defined and calibrated to produce parameters necessary for the analysis. The model uses the most recent Social Accounting Matrix (SAM) that represents the Sudanese economy in 2004 as underlying database. Results indicate and confirm the ability of the model to determine the magnitude of the loss in the domestic supply as well as the welfare and overall economic implications of droughts. This provides insights for all relevant institutions such as the Strategic Reserve Corporation and the food aid agencies working in Sudan to estimate the mitigation requirements for future drought incidents in Sudan.

Keywords: *drought, CGE, Agriculture, Food supply, Sudan.*

1 Introduction

Changes in climatic conditions have considerable impacts on societal stability because it can increase resource scarcity, which in turn can increase the likelihood of violent conflict in various ways (Link *et al.* 2010). The widely expected magnitude of climate change in the next decades can exceed the adaptive capacities of many societies in all regions of the world, which implies a substantial conflict potential.

Natural disasters in the contrasting forms of drought and flooding have historically occurred frequently in Sudan, and have contributed significantly to population displacement and the underdevelopment of the country. A silent and even greater disaster is the ongoing process of desertification, driven by climate change, drought, and the negative impact of some human activities (UNEP, 2007).

Annual variability and relative scarcity of rainfall in the northern Sudan have dominant effects on the country's agriculture and food security. That has also been strongly linked to the chronic conflicts. Together with other countries in the Sahel belt, Sudan has suffered a number of long and devastating droughts last decades. The worst impacts have been felt in the central and northern states, particularly in Northern Kordofan, Northern state, Northern and Western Darfur, Red Sea and White Nile states. The most severe drought occurred in 1980-1984, which was accompanied by widespread displacement and famine. Localized and less severe droughts (affecting between one and five states) were also recorded in 1967-1973, 1987, 1989, 1990, 1991, 1993 and 2000 (UNEP, 2007).

Droughts of the 1970s and 1980s caused losses in the resource base of households, especially in the west and northeast. That has led to serious economic deprivation and severe food shortages and famines during the 1970s and 1980s. For a country known for its vast agricultural resources, this is both unfortunate and ironic (Teklu *et al.* 1991).

Most of the drought incidents that have occurred in Sudan have been followed by famine and outbreaks of disease. The 1984-85 famine was the outcome of a long process of drought and desertification, absent or misplaced public food and agricultural policy, and insufficient public response (Teklu *et al.* 1991)[1]. Lacking in the government's response were a permanent institution responsible for famine preparedness and the political will to intervene early to prevent large-scale hunger and mass movements. Emergency food aid, which largely followed official recognition of the existence of famine, was constrained by

[1] Comprehensive survey and analysis on the production and income implications of the 1980's drought are covered by (Teklu et al. 1991).

untimely availability and logistical and managerial limitations. In addition, the macroeconomic policy environment in the 1970s and 1980s was not conducive to preventing erosion of the country's capacity to deal with the drought crises. A large drop in agricultural production occurred in 1984/85. This decline translated into a large drop in farm employment. A strong link between agricultural production and income (from crop production, local off-farm wage employment, and livestock) increased the extent of income failure (Teklu *et al.* 1991).

Unlike most of its neighbors in the Sahel and Horn of Africa, Sudan did not have a well-developed formal early warning system (EWS) at least until mid nineties. At national level, the EWS was poorly resourced and consequently very centralized and geared to conditions in Central Sudan. Coverage of more remote regions like Darfur, which were often the most food insecure, was patchy (Kelly & Buchanan-Smith, 1994). The food monitoring system that had been set up in Darfur in the mid-1980s was in a state of disarray and collapse just at the moment when it was most needed - at the end of 1990, when the most serious food crisis since its inception was imminent.

Based on this background, this paper tries to contribute to the scarce literature that empowers the mitigation of drought consequences in Sudan. It tries to estimate the losses that could be caused by drought based on the information available about the severity of the expected drought. The basic idea of the study is to utilize the historical information about drought episodes in the country and compare them to the future droughts in terms of severity. Afterwards, these information should be introduced into a macroeconomic modeling framework and detailed economic database those describe the state of the Sudanese economy. The model then will be able to estimate the losses in the overall economic variables and the reallocation of resources among the economy agents.

A CGE model is selected as the tool of analysis for this study because it suits the economy wide impact analysis, which incorporates the different sectors of the economy and allow for the backward and forward linkages among them. CGE models could also trace the distributional effects of consumer income changes and the changes in the factor and commodity markets after certain shocks (Hertel, 1999). The impact of different shocks on the government, production sectors, and households could also be assessed using CGE models allowing the analysis and changes to cut across both agricultural and non-agricultural sectors.

Horridge *et el. (*2005) used a CGE model to assess the impact of different scenarios related to the 2002 - 2003 drought on Australia. Their model (TERM) is a highly disaggregated, bottom-up and multiregional CGE model that treats each region as a separate economy. Another CGE application to modeling drought is provided by Diao *et al.* (2008). They employed a CGE model to analyze ground water (GW) regulation focusing on the stabilization value of GW under natural (drought) and economic (rural-urban water transfer) shocks in Morocco. In addition, Arndt & Tarp (2001) have also constructed and used a CGE model to examine the effects of alternative food aid distribution schemes for drought-response food aid in Mozambique. Their model is standard CGE model from the type of Dervis *et al.* (1982), on which they simulated two types of simulations. The first simulates a drought in the absence of any food aid for drought relief, while the second combines drought with food aid.

The methodology section of this paper provides a comprehensive description of the CGE model of the study. Section three shows the way in which drought simulations are setup and the changes introduced to accommodate drought shocks in the general equilibrium framework of the study. Moreover, it elaborates on the effectiveness of the scenarios to represent the intended drought simulations before showing and discussing the results of the analysis in the fourth section.

2 Methodology and Data

A CGE model of Sudan is constructed and used for this study. It is an open-economy single-country model that treats the rest of the world as one region. The model allows for two-way trade, assuming that imports and domestic demand as well as exports and domestic supply, respectively, are imperfect substitutes. Producers maximize profits subject to Leontief production functions, and households maximize utility with respect to interlinked Linear Expenditure Systems (LES). The model is static in nature solving for a new equilibrium within a single period, given a specified policy change, which is in general, a reasonable approach to be used for the objectives of this paper, provided the lack of data that allow for using a dynamic model.

The paper focuses on the analysis of how the economy will adjust and the nature of the new equilibrium of the economy under the drought shocks according to macroeconomic constraints and assumptions. The macroeconomic closure rules of the model and the specification of its factor markets are crucial to describe this convergence process properly and to determine the short, medium, or long-term character of the model. Thus, within a certain period, under some given conditions and some applied policies, the shocked economy adjusts to achieve a new state of equilibrium. Generally, this study's approach to CGE modeling follows the type of Dervis *et al.* (1982), and particularly based on the model developed at IFPRI and documented in Lofgren *et al.* (2002).

To implement the intended simulations, a modified closure of the model is used. For the government balance of the model, the closure assume that the government saving is flexible, while tax rates which represent a major component of the government revenue are fixed.

Total government revenue (YG) is defined as shown in the flowing equation as the sum of revenues from taxes, factors, and transfers from the rest of the world. Taxes include income tax ($TINS_i \,.\, YI_i$), taxes on factors of production ($tf_f \,.\, YF_f$), VAT ($tva_a \,.\, PVA_a \,.\, QVA_a$), taxes on production ($ta_a . PA_a . QA_a$), import tariffs ($tmc_c \,.\, pwm_c \,.\, QM_c$), export taxes ($te_c \,.\, pwe_c \,.\, QE_c$), sales taxes ($tq_c \,.\, PQ_c \,.\, QQ_c$), and transfers from the rest of the world ($trnsfr_{gov\ row}$).

$$YG = \sum_{i \in INSDNG} TINS_i \,.\, YI_i + \sum_{f \in F} tf_f \,.\, YF_f + \sum_{a \in A} tva_a \,.\, PVA_a \,.\, QVA_a + \sum_{a \in A} ta_a . PA_a . QA_a + \sum_{c \in CM} tmc_c \,.\, pwm_c \,.\, QM_c \,.\, EXR + \sum_{c \in CE} te_c \,.\, pwe_c \,.\, QE_c \,.\, EXR + \sum_{c \in C} tq_c \,.\, PQ_c \,.\, QQ_c + \sum_{c \in C} YIF_{gov\ f} + trnsfr_{gov\ row} \,.\, EXR$$

On the other hand, the following equation defines the government consumption demand for commodity (c) as (QG_c), which is the base-year quantity of government demand (qg_c) multiplied by an adjustment factor (*GADJ*) that is exogenous and, hence, the quantity of government consumption is fixed.

$$QG_c = \overline{GADJ} \,.\, \overline{qg}_c$$

For the external balance, which is expressed in foreign currency, the real exchange rate is flexible while foreign savings (the current account deficit) is fixed. Given that all other items are fixed in the external balance (transfers between the rest of the world and domestic institutions), the trade balance is also fixed. If, ceteris paribus, foreign savings are below the exogenous level, a depreciation of the real exchange rate would correct this situation by simultaneously (1) reducing spending on imports (a fall in import quantities at fixed world prices) and (2) increasing earnings from exports (an increase in export quantities at fixed world prices).

This could be described as: (*Import expenditure + transfers to the rest of the world = exports revenue + transfers from the rest of the world + <u>foreign savings</u>*), where foreign savings will adjust to assure the equilibrium. The balance of payments equation that is expressed in foreign currency requires total payments for imports and the transfers from production factors to the rest of the world to equal total receipts from exports plus foreign savings ($FSAV$) and transfers from the rest of the world, as shown in the following equation:

$$\sum_{c \in CM} pwm_c \,.\, QM_c + \sum_{f \in F} trnsfr_{row\ f} = \sum_{c \in CE} pwe_c \,.\, QE_c + \sum_{i \in INSD} trnsfr_{i\ row} + \overline{FSAV}$$

Where: pwm_c is the world imports price of the commodity (c), QM_c is the imported quantity of commodity (c), $trnsfr_{row\ f}$ are the transfers to the rest of the world, $pwe_c\ .\ QE_c$ are the world export price and quantity of commodity (c), $trnsfr_{i\ row}$ are the transfers from the rest of the world, and $FSAV$ is the foreign savings.

Finally for the saving-investment balance, the model assumes an investment-driven environment, in which the value of base savings adjusts with same percentage points as investment (Siddig, 2009). At the end, the model should close by that total savings and total investment are equal. As defined in the following equation, total savings is the sum of savings from domestic nongovernment institutions (*YI*), the government (*GSAV*), and the rest of the world (*FSAV*), with the last item converted into domestic currency using the exchange rate. Total investment is the sum of the values of fixed investment and stock changes ($qdst_c$).

$$\sum_{i \in INSDNG} MPS_i\ .\ (1 - TINS_i)\ .\ YI_i + GSAV + EXR\ .\ \overline{FSAV} = \sum_{c \in C} PQ_c\ .\ QINV_c + \sum_{c \in C} PQ_c\ .\ qdst_c$$

CGE models are known to be very demanding in terms of data, because they basically rely on the Social Accounting Matrix (SAM). The SAM is a consistent data framework that captures the information contained in the national income and product accounts and the Input-output Table (IOT), as well as the monetary flows between institutions within the economy under consideration (Pyatt & Round, 1985). Moreover, it is a self-controlled accounting framework, because total receipts must equal total payments for each account contained within its square matrix. It follows the principle of double entry bookkeeping, presenting expenditures in the column and receipts in the row accounts; that is, each entry represents a monetary flow from a column to a row (Pyatt & Round, *op cit.*).

In order for the SAM to be constructed, an IOT is required. Unfortunately, it is always difficult to find recent IOTs as they are normally developed each several years due to the amount of data and effort required. This problem is particularly apparent in a developing country like Sudan, where the advanced tools and experts for data collection, monitoring and manipulation are always scarce. In the case of Sudan, the only IOT that was developed by the statistical authorities was produced in 1961 (Siddig, 2009). Nonetheless, the CGE model and SAM of this study is benefiting from the most recent IOT and SAM of Sudan for the year 2004, which is developed and documented in Siddig (2009a).

The 2004's SAM and IOT are based on data collected from official sources in Sudan. Namely the Central Bureau of Statistics, the Central Bank of Sudan, Ministry of Finance and National Economy, and the Ministry of Agriculture and Forestry in addition to several relevant administrations such as custom administration and tax administration.

The Sudanese IOT and SAM provide data on 33 sectors, including 10 agricultural sectors, 10 industrial sectors, and 13 service sectors. Each activity in the SAM is assumed to produce only one single commodity, i.e. there are 33 commodities as well. Production factors are disaggregated to Labour, land, and capital, while households are grouped based on income to three groups; namely high, middle, and low. The government account is divided into four subaccounts including current government accounts, tariffs, direct taxes, and indirect taxes (excluding tariffs). In addition, the SAM also includes accounts for saving-and-investment, enterprises and separates one account for the rest of the world.

3 The Setup of Simulations

In order to better implement drought simulations in the CGE modeling framework of this study, a comprehensive effort was allocated to collect detailed information on the impact of previous droughts on the Sudanese economy. Collecting detailed information about previous droughts is of particular importance for the study because it provides the base for the analysis and the medium of comparison between previous and future droughts in Sudan.

In particular, the effects of 1984 and 1990 droughts on the economy were the focus point at the stage of setting up the simulation scenarios. Comprehensive information is obtained from the 1986 and 1987 annual reports of Central Bank of Sudan (CBOS), the 1986/87 economic survey of the Ministry of Finance and National Economy (MFNE), and agricultural sector statistics. Additionally, experts' assessments and opinions were also collected from Khartoum University, Gazira University, and the Center of Economic Policy Research in Khartoum. Because the data is obtained from different sources and prepared by different institution for different objectives; some efforts were allocated to carefully conciliate it before considering it for the analysis. Moreover, additional mapping and concordance between the sectors for which data is available and the SAM sectors was made, hence, comparisons could be performed between the original and simulated values for each sector.

In simulating drought in Sudan, it is worthwhile to note that agriculture in Sudan is composed of three main farming systems, namely traditional rain-fed sector, mechanized rain-fed sector, and irrigated sector. The traditional rain-fed sector has occupied an average of 60% of the total cultivated land and employed about 65% of the agricultural population during the last ten years. The rain-fed sectors including the traditional and mechanized agriculture covers about 90% of the total cultivated land in Sudan (Siddig, 2009). Moreover, agricultural production in the traditional sectors is essentially the process of converting labor into agricultural goods. The vast majority of production is smallholder based using rudimentary technology. Input use is essentially confined to seed, capital involves rudimentary tools only, and land is generally abundant.

In this environment, drought can be adequately simulated by shocking technology parameters of the value added function of the CGE model. Since labor and capital are fixed by agricultural activity, the technology declines will directly translate into production declines. Accordingly, the declines in technology parameters in this case were repeatedly changed until conformity between the historical and simulated losses in the domestic output for each affected sector is obtained. This approach in simulating the impact of drought is similar to the approach used in Arndt & Tarp (2001) for evaluating the impact of drought in Mozambique.

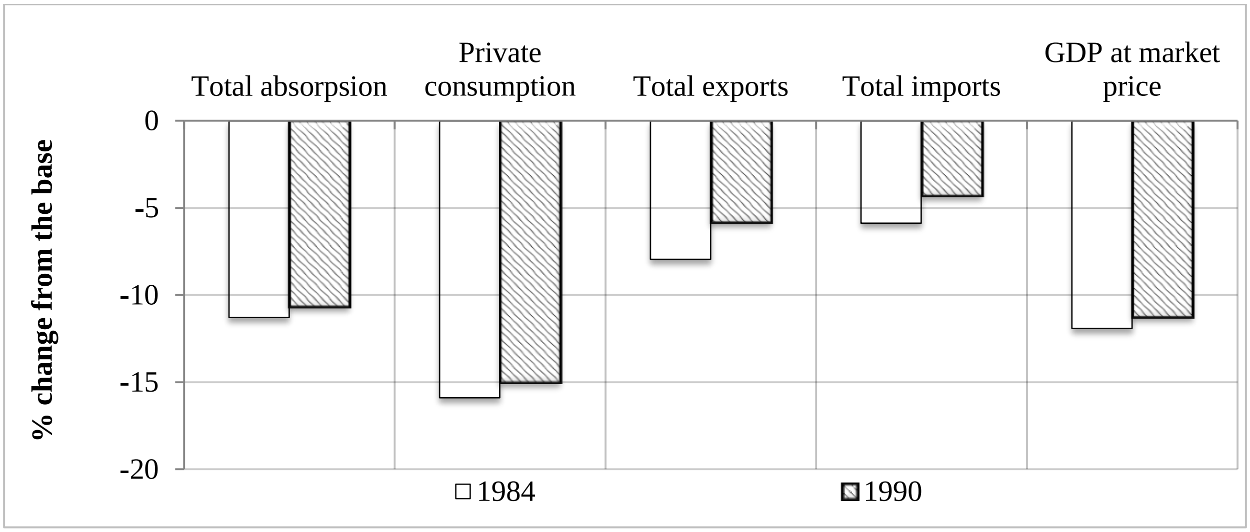
According to the described approach, two simulation scenarios are declared for the 1984 and 1990 droughts in Sudan. The severity of future drought incidents in Sudan might not be typically similar to any of the simulated experiments; however, the differences between the two scenarios in terms of severity allow approximating the effects of future droughts relative to each of them. Hence, the findings of the study could be a base for approximately estimating the consequences of all future drought incidences in Sudan. The technology parameters of the rain-fed based sectors (only) are changed, while the related changes in the output of other sectors would be captured by the model.

4 Results Discussion

This section discusses the simulation results on the Sudanese economy represented by selected macro-indicators, domestic output, exports and imports, and household welfare.

Figure (1) illustrates the macroeconomic effects of the two drought shocks. As expected, the drought results in a decline in GDP at market price due to the two experiments. The steep decline in private consumption and total absorption contribute to the decline in the GDP. The 1984 scenario leads to 18% reduction in the private income, 19% in government income, 6% in total imports, and 8% in the total exports. Deteriorations in these selected indicators contribute to the decline in the GDP by 12%. They are driven by huge declines in the domestic agricultural output. Output decline is not only noticed in the rain-fed agriculture, where the study's simulation scenarios reduced the technology parameters, but also in the output of the irrigated agriculture. Furthermore, output declines were also seen in some of the agro-industries and service sectors (Table 1). This reflects the tied linkages between the different farming systems in Sudan, and conforms to the corresponding reports of the Central Bank of Sudan. It also confirms the effectiveness of the study's model as a tool that shows the linkages between the overall sectors of the economy in response to the simulated shocks.

Figure 1. The impact of drought on selected macroeconomic indicators



The impact of the 1990 scenario is shown to be always less the 1984 scenario with all the variables to show relative proportions of changes compared to1984. The changes in the variables due to the two experiments to take similar direction is important because other droughts with less or more severity could be also quantified based on them. Because the model employed in the study is static in nature; the results provide a snapshot of the economy in the short run. For instance, government income also deteriorates due to the declining tariff revenue driven by the lower imports. However, imports might tend to increase to compensate the deterioration in the domestic supply created by the shocked domestic output in a longer run.

Agricultural output as shown in Table (1) declines by averages of 23% and 18% due to the two scenarios, respectively. The industrial and service sectors will also deteriorate. Mohamed (1998), conducted a study to assess the impact of drought and civil strife on food security in Sudan taking the production of sorghum as an example. His results showed that that the effect of 1984 drought was not only on the rain-fed sector, but also irrigated sector. Particularly, he found that the production of wheat grown in the Gezira scheme, which is, completely an irrigated scheme also declined due to the delay in the onset of the rains that had led to a late planting of crops and increased the stress on the irrigation canal network.

Table 1. The impact of drought on the domestic output

Produced commodities	Base value (SG millions)	Percentage changes from the base	
		1984	1990
Agriculture (average)	***302.2***	***-22.6***	***-18.2***
Wheat	42.0	-4.2	-4.5
Cereals	183.6	-23.4	-22.3
Cotton	106.7	-37.4	0.4

Produced commodities	Base value (SG millions)	Percentage changes from the base	
		1984	1990
Oilseeds	93.1	-45.5	-45.0
Other crops	765.6	-11.4	-10.5
Livestock	1547.5	-31.5	-30.6
Milk	11.8	-31.9	-31.0
Forestry	19.6	-27.1	-25.7
Sugar	197.5	-6.4	-5.9
Fishery	54.4	-7.2	-6.6
Industries (average)	***241.2***	***-1.5***	***-1.8***
Food industries	801.1	-7.2	-6.6
Other mining	65.1	-6.0	-5.2
Petrol	924.1	7.0	5.2
Textile	82.6	-4.4	-4.6
Wood	14.6	-4.6	-5.0
Chemical	286.4	-4.7	-3.7
Metal	90.7	3.6	2.6
Service (average)	***307.0***	***-4.9***	***-4.1***
Electricity	271.0	-5.0	-4.5
Water	63.7	-9.0	-8.0
Other transports	676.2	-4.9	-4.5
Water transports	39.8	-4.9	-3.9
Air transports	41.1	-5.5	-4.2
Communication	75.6	-4.9	-4.1
Finance	84.9	-5.2	-4.3
Insurance	18.1	-8.2	-5.7
Business services	252.3	-4.4	-3.8
Other services	474.8	-6.4	-5.9

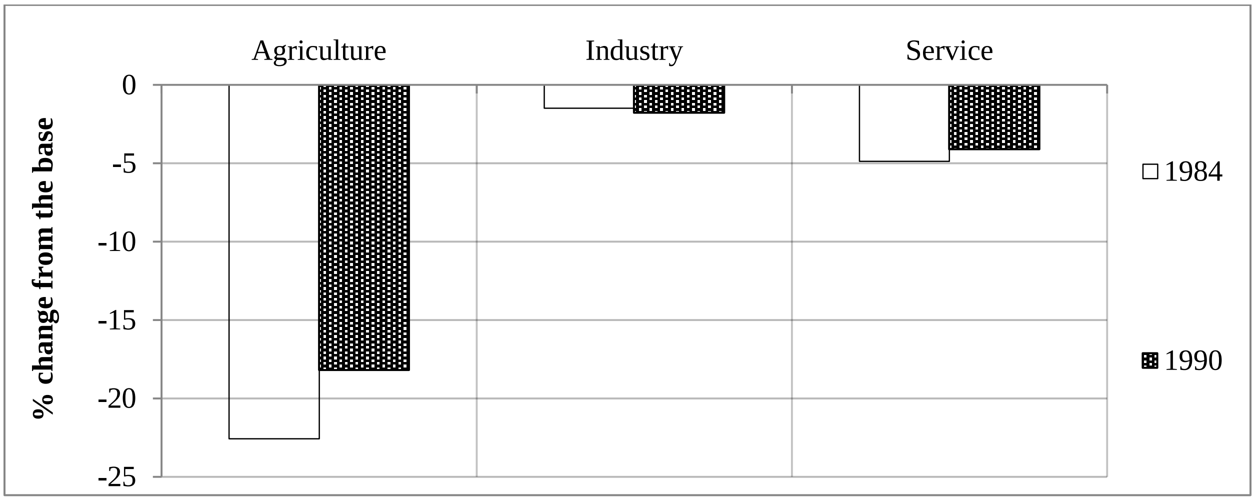
Among the agricultural sectors, oilseeds[2], livestock, and forestry show greater declines in their output because they are mainly grown in the rain-fed sector, while food industry are the most affected among the industrial sectors. The latter is due to the reliance of the majority of the Sudanese agro-industries on agricultural raw materials.

Demand for value-added follow similar trend to output. It shows huge declines in the agricultural sector, followed by services and then industrial sector (Figure 2). However, these aggregated results could be misleading given the fact that, full employment is assumed in the model and only reallocation of these factors is possible. Labour demand in the agricultural sector shows an average increase of 8% due to the 1984 scenario. Within

[2] This sector (oilseeds) includes sesame, groundnuts and sunflowers. The first two are mostly grown in the rain-fed areas.

the agricultural sector, livestock leads by 79% increase in labour demand, followed by cereals with 43%, milk with 37%, and forestry with 27%, respectively. These could be explained by the high labour demand during the drought seasons especially with livestock needing to be moved for long distances in search of water. Besides, labor reallocates to the industrial sector such as petroleum, where it shows 24% increase in labour use. This is justified by that the agricultural sector can no longer absorb labour and hence labour must reallocate out.

Figure 2. The effects of drought on value-added



In Mohamed (1998), the famine of 1984-1985 led the domestic terms of trade (ToT) between cereals and livestock to be completely altered as they increased from (1:1) in 1980 to about (1:10) in 1984-85. Therefore, to acquire the same amount of cereals, 10 times more livestock had to be offered in 1884-85 than that of 1980. In this context, lessons could be learnt from the influence of drought in altering the domestic ToT, when discussing the changes in the country's international trade caused by drought. Table (2) illustrates the percentage changes in exports due to the two scenarios. Exports of all agricultural crops except sugar decline dramatically reaching (-85%) for livestock and (-67%) for cereals due to 1984 scenario. That is mainly driven by the declining domestic output that causes a huge gap in the domestic supply. Particularly, the huge decline in the exports of livestock is explained by that, during droughty season, livestock products do not meet the international standard in order to be exported.

Table 2. The effects of drought on exports

Exported commodities	Base value (SG millions)	Percentage change from the base	
		1984	1990
Cotton	92.5	-40.9	1.2

Exported commodities	Base value (SG millions)	Percentage change from the base	
		1984	1990
Oilseeds	67.9	-57.9	-58.0
Other crops	24.6	-6.5	-7.9
Livestock	80.3	-84.6	-84.0
Forest products	7.8	-59.4	-59.6
Sugar	2.5	25.4	19.3
Food products	1.2	18.8	13.5
Other mining	1.0	12.2	8.0
Petroleum	659.5	10.5	8.0
Metal products	14.8	18.3	13.3
Machinery	0.4	11.7	8.5
Manufactured goods	5.1	12.8	8.5
Trade services	0.4	22.7	17.1

Percentage changes in the exports sugar, food products, other mining, machinery, other manufactured goods and trade services could be disregarded here because their values in the base is very tiny, hence small value changes appears to cause huge percentage changes.

On the import side, imports of all commodities will decline due to drought except animal products that exhibits an increase of 178% from the baseline value due to 1984 scenario and 176% due the 1990 drought. The deterioration in imports is mainly driven by the declining household income. The income of the agricultural households is mainly generated by products sales and factors income, where both are declining due to drought. The increase in the imported animal products is to fill-in the huge gab in the domestic market created by drought, provided that the domestic demand of live animals is completely met from the domestic production in the baseline. However, other manufactured animal products are still to be imported.

Table 3. The effects of drought on imports

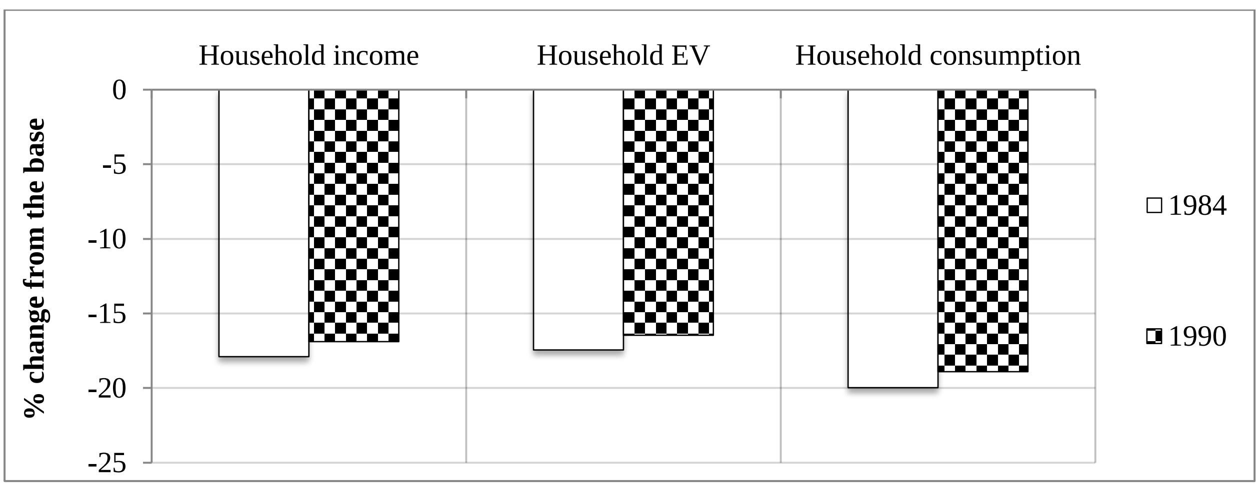
Imported commodities	Base value (SG millions)	Percentage change from the base	
		1984	1990
Wheat	134.1	-14.8	-12.9
Other crops	103.5	-15.8	-12.9
Animal products	32.5	178.1	175.8
Food industries	46.4	-25.8	-21.8
Petroleum	15.6	-11.7	-10.0
Textiles	169.1	-14.2	-12.0
Wood products	36.4	-10.7	-8.6
Chemicals	27.4	-22.4	-17.6
Metal products	30.8	-8.8	-6.6

Imported commodities	Base value (SG millions)	Percentage change from the base	
		1984	1990
Machinery	350.9	-1.5	-1.2
Manufactured goods	393.7	-10.0	-8.5
Construction	15.1	-9.5	-7.2
Transports	44.1	-20.7	-17.7

Wheat imports decreases according to Table (3), which is attributed to the fact that, wheat is not the staple food in most of the drought-affected areas, where sorghum and millet are the most important consumption staples. Domestic output prices also follow suit increasing by 70% for livestock, 23% for cereals, and 13% for milk, however, wheat price declines by 24%.

This study also investigates the implications of drought on the welfare level of the households. Results show that, household income generated from factors would decline by 21% due to 1984 scenario (Figure 3). This is mainly due to dramatic declines in the agricultural output and exports, and hence the lower factor demand, rents, and wages. The result is a deteriorating household income, household consumption, and equivalent variation[3] due to the two drought scenarios.

Figure 3. The impact drought on people's welfare



[3] The equivalent variation (EV) is the percentage change from the base consumption values of households due to the two scenarios.

It is noted that the declines in the consumption of households is greater than the fall in their income. These results are of particular relevance to the rain-fed agricultural community, where most of the consumption demand is satisfied from the farmers' own production. Although not included in the analysis, droughts episodes in Sudan are always followed by famines and malnutrition that needs a big chunk of the household income to be allocated to medications and health care, which could be also relevant justification of that, consumption is lower than income.

Household consumption demand for both food and healthcare is important to be considered in the mitigation process. The international food aid agencies and the strategic reserve corporation in Sudan as well as all the related institutions could count on the approximated declines in these variables together with the related information from the early warning systems about the severity of the future droughts in Sudan.

5 Conclusions

An attempt has been made in this paper to estimate the economic effects of future drought episodes that might hit Sudan. Detailed information on the historical consequences on drought episodes in Sudan were collected from different sources and introduced to the studies model to allow moving the state of the economy from the baseline assumptions to drought-affected economy. Two drought episodes were chosen to replicate their impact on the model and use the results as indicators for the assessment of future droughts, namely the 1984 and 1990 droughts.

The two droughts are introduced in the context of a CGE modeling approach to allow investigating the possible changes in the overall economy including production sectors particularly in agriculture, household income and consumption, trade and other macroeconomic indicators. The CGE modeling approach has the ability to trace the distributional effects of consumer income changes and the changes in the factor and commodity markets in response to shocks such as drought. It can also show the impact of drought on the government and households allowing the analysis and changes to cut across both agricultural and non-agricultural sectors. Accordingly, the technology parameters of the rain-fed based sectors in the Sudanese agriculture are reduced repeatedly for each scenario until conformity between the historical and simulated output values of the shocked sectors is achieved. Therefore, the two scenarios could be a good representation of the simulated droughts in the model, and hence their results are reliable and relevant to the related implementations.

Simulation results show that similar drought shocks to the 1984 and 1990 would be very costly to the Sudanese economy in large with all the macroeconomic indicators showing huge declines from their baseline values. It also shows huge declines in the domestic output particularly in the agricultural sector. The model has shown ability to capture the linkages between the different economic sectors. Beside the changes in the agricultural output, reductions are also depicted in the domestic output of industrial and services sectors due to the two scenarios. Moreover, the changes in the agricultural output, depicted by the model results do not only confine to the rain-fed crops, where the shock is introduced, however similar changes in the output of the irrigated crops are also reported. This conforms to the reality and the previous investigations conducted by researchers such as Mohamed (1998), as well as the data reported by the CBOS and the Ministry of Agriculture in Sudan.

In addition, the model has also shown ability to depict changes in the households' income and consumption. This can be account for during the mitigation processes considering both consumption expenditure as well as healthcare requirements during the famines that usually follows drought incidences in Sudan. The linkages between the domestic and foreign sectors are also captured by the model including changes in the sectoral domestic production, exports and imports. At the time that drought reduces the domestic production; it automatically reduces the share of the domestic production that is normally allocated to exports. However, the gab created in the domestic market cannot always filled-in by imports because domestic income is also declining leading the purchasing power in general to deteriorate.

The findings of this study are expected to provide scientific platform that could be relied on to estimate future drought losses and accelerates the mitigations processes. However, the model is a complement to advanced early warning systems (EWS) that need to be implemented to forecast future drought incidents and estimate their severity. Then the outcome of the EWS could be very useful inputs for the model to rely on and provide complete approximation of losses in both percentage and value terms.

Future developments could include a variable in the database and the model accounting for the food aid. This will allow for measuring the effectiveness of food aid in filling-in the domestic supply gab from one hand, and its effects in the domestic commodity market and domestic production and exports.

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