Sorghum and Sesame Markets Performance under Climate Change in Sudan

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ABSTRACT

Sorghum and sesame are produced under the rain fed sector in Sudan; they are competing each other for agricultural input and resources since they are grown in the same season. The purpose of this paper is to examine sorghum and sesame performance under climate change, including supply, demand, exports and imports and food security variables. The economic performance of the country particularly agriculture; depends on weather conditions especially rainfall. Summer rainfall pattern has been decreasing by 15 to 20 percent in the last forty years. The study has developed a stochastic multi-market model for sorghum and sesame, the model comprices important characteristics of agriculture in Sudan including the dependency of agricultural supply on rainfall. Sorghum and sesame markets have been simulated by calibrating supply and demand functions; the climate scenario simulates sorghum and sesame under climate change of rainfall with a decreasing trend of 20%. The model has introduced prices and rainfall as stochastic variables; it has also incorporated food security indicators, which are directly affected by the agriculture performance. The uncertain stochastic variables in the model are presented in their Cumulative Distribution Functions (CDFs) by the help of BestFit; a software within the @Risk program based on annual observations from 2000-2013. The final results are graphed in the form of Cumulative Distribution Function (CDF). The model scenario simulations revealed that, the impact of the decreasing trend of rainfall would overall lead to considerable losses in sorghum and sesame supplies and hence a deterioration in the country's external sector and food security situation.

Keywords: Sorghum, Sesame, climate change, Multi-market model, Sudan

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أداء أسواق الذرة والسمسم في ظل التغيرات المناخية في السودان

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ملخص الدراسة

ينتج محصولا الذرة والسمسم بصورة رئيسية في القطاع الزراعي المطري، حيث أنهما يتنافسان على الموارد الزراعية بحكم أنهما ينتجان في موسم زراعي واحد. تهدف هذه الورقة إلى استقصاء أداء أسواق هذين المحصولين في ظل التغيرات المناخية من ناحية العرض والطلب والصادرات و الواردات بالإضافة إلى مؤشرات الأمن الغذائي. يعتمد الأداء الاقتصادي للدولة وبصورة خاصة الزراعة على العوامل المناخية وخاصة معدلات الأمطار. حيث أنه تلاحظ انخفاض معدلات الأمطار في الأربعين سنة الأخيرة بنسبة تتراوح بين 15-20%. قامت هذه الدراسة بتطوير نموذج الأسواق المتعددة بمتغيرات عشوائية لمحصولي الذرة والسمسم. ويشمل هذا النموذج على أهم صفات الزراعة في السودان وهو اعتمادها على الأمطار. تمت محاكاة أسواق المحصولين بالنسبة للعرض والطلب في ظل الظروف العادية ومقارنتها بانخفاض في اتجاه الامطار بنسبة 20%. تم إدخال متغيرات العرض والطلب بالإضافة إلى الأمطار كمتغيرات عشوائية في النموذج. كما تم عرض النتائج في صورة الدوال الاحتمالية Cumulative Distribution Function (CDF) وذلك باستخدام برنامج@RISK. أظهرت نظم المحاكاة للتغيرات المناخية الى انخفاض عام في عرض الذرة والسمسم وبالتالي أدى إلى انخفاض في أداء مؤشرات التجارة الخارجية والأمن الغذائي.

الكلمات المفتاحية: الذرة، السمسم، التغيرات المناخية، نموذج الأسواق المتعددة العشوائي، السودان.

1. Background

Sorghum and sesame are interdependent crops especially in rain fed areas, where they are grown at the same season competing on same factor inputs. Farmers tend to expand production of one crop at the expense of the other following the prices trend of the previous season (Mustafa, 2006).

There is a declining trend of rainfall across the country in the last decades, rainfall decline in semi-arid Sudan since 1965 has continued and intensified in the 1980s, with 1984 the driest year on record and all annual rainfalls from 1980 to 1987 well below the long-term mean.(Walsh *etal*, 1988). Between the mid1970s and late 2000s, summer rainfall pattern decreased by 15 to 20 percent across many parts of the Sudan (USAID, website).

Since most of the agricultural production in Sudan under rain fed, agricultural production and markets is expected to be substantially affected. Deterioration in both rainfall quantity and quality has increased since the major drought of the 1980s, which caused famine, especially in Kordofan and Darfur (El-Dukheri, 2007).

More than 80% of sorghum is grown under rain fed sector, it is the major cereal crop throughout Sudan, and considered as main pillar of food security in the country providing about 60% of the quantity of the cereal consumed (Abdel Karim, 2002). Sorghum needs at least 300-380 mm water during the growing period. It is one of a few crops that can tolerate short periods of water logging; (Acland 1971 in Mustafa, 2006).

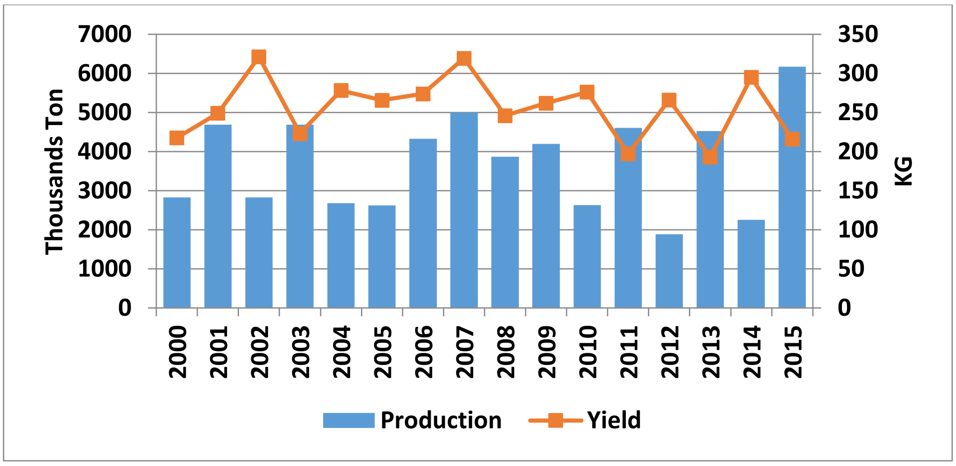

Figure 1: Sorghum Production and Yield 2000-2015, Sudan.
Source: Ministry of Agriculture and Forests

Sorghum production and yield are quite volatile as it follows rainfall patterns, the country produces surplus at good rainy seasons, and be in deficit when draught occurs in good seasons the production could reach more than 4 million tons as in years 2003, 2006, 2007, 2009, 2011, 2013 and 2015. While in bad seasons the production of sorghum falls to less than 3 million tons as in the years 2004, 2005, 2008, 2010 and 2012 (figure,1). Sudan exports relatively small amounts of sorghum in surplus seasons.

Sesame is moderately drought resistant crop. A level of 380-510 mm of water by rainfall is needed during the growing season. Moist conditions are necessary during the early stages of growth. Most varieties of sesame are photoperiod sensitive. Sesame is very intolerant to water-logging but diseases seldom do serious damage (Acland, 1971 in Mustafa, 2006). Sesame is an export crop and grown entirely under rain fed conditions in the traditional and the mechanized agricultural systems. The major sesame growing areas in Sudan are located in the

Kordofan, Sinnar, Gedarif, and Blue Nile provinces. The climate is semi-arid, precipitation occurs from April to October, with unpredictable variability, from 470 mm to 750 mm per year. The vast majority of sesame fields (about 80%) are about 2 hectares in area. In these fields, sesame is grown under the traditional farming system with little or no use of machinery or modern inputs.

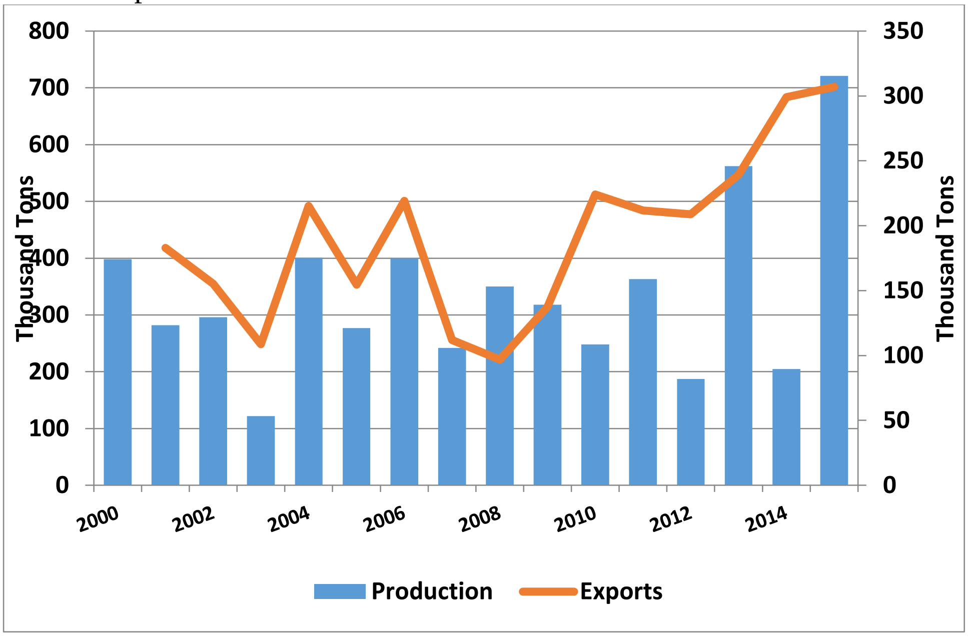

Figure 2: Sesame Production and Exports 2000-2015, Sudan.
Source: Ministry of Agriculture and Forests

During the period 2000-2015 sesame production fluctuated from 187 thousand tons in minimum to 721 thousand tons at the maximum level, the high level of production in 2015 was attributed to farmers' response to the increasing world market prices. The increasing trend of market prices also has attracted more exports to reach 307 thousand tons in 2015(figure, 2).

Considerable attention has been given to climate change and its impacts on agriculture and food security. Agriculture is considered to be one of the sectors most affected by climate change. It is clearly evident that in low-latitude regions, where most developing countries are located, reductions of about 5 to 10 per cent in the yields of major cereal crops are projected (UNEP and WTO, 2009). Many studies have recently addressed the potential impacts of climate change on food production, many of these studies have been global in scope, most of them have used empirical, linear models (e.g., Lobell and Field 2007) relating food production and climate variability.

Based on the above background, this paper aims at examining sorghum and sesame markets performance under climate change, including the economic variables of supply, demand, export and import, self-sufficiency and foreign exchange.

The paper is organized as follows. In the next section a stochastic multi-market model is laid out with two scenarios used in the model. Section three represents the model results for sorghum and sesame supply and demand and the related indictors under the proposed scenarios. In section four conclusions are drawn.

2. Methodology:

A stochastic multi-market model has been developed to simulate sorghum and sesame markets. In the model the interaction between supply and demand functions describes the behavior of producers and consumers in the market. The model starts by formulating supply and demand functions where prices and rainfall are assumed to play a major role in the model;

it works as determination variables of supply and demand equations for the two commodities. Domestic prices are assumed to be linked to world market prices which in turn are determined by the world demand and supply.

The model assumes the homogeneity of the products and the perfect competition on the market. The final result depends on the elasticities in the model which are taken as exogenous and constant. The supply and demand equations are represented by isoelastic (Cobb-Douglas) functions in which the price and income elasticities are constant (Kirschke and Jechlitschka, 2002). The supply of each commodity is assumed to be uncertain (stochastic) and represented by the quantity produced which is function of its own price and the prices of the competing commodities in addition to rainfall as climate element. Quantities, prices and rainfall are considered as stochastic variables and represented in the model by their distributional functional form.

On the other hand, the demand (consumption) quantity of a commodity is set to depend on its own price, the prices of close consumption substitutes or complementary commodities and the consumer per capita income. Demand quantities and prices are also calculated in their distributional fictional form.

2.1. The supply equation:

The commodities considered in the model are sorghum and sesame. The supply of each is assumed to be uncertain and represented by the quantity produced which is a function of its own price and the prices of the competing commodities. Quantities and prices are considered as uncertain variables. The product supply equations represented as follows:

$$q_i^s = c_i * (p_i^s)^{\varepsilon_{ii}} * \prod_{j \neq i} (p_j^s)^{\varepsilon_{ij}} * (R^r) \ , \qquad i, j = 1,2 \qquad (1)$$

Where

q_i^s denotes the amount of the i^th commodity supplied

c_i is the supply calibration coefficient of the i^th commodity

p_i^s is the supply price of the i^th commodity

p_j^s is the supply price of the j^th product

ε_{ii} is the supply price elasticity of the i^th product

ε_{ij} is the supply cross price elasticity of the products j^th that are competing the i^th product

j is the set of relevant competing substitutes of the i^th product.

r rainfall elasticity

2.2. The demand equation:

Demand (consumption) quantity of a commodity is set to depend on its own price, the prices of close consumption substitutes or complementary commodities and the consumer per capita income. Demand quantities and prices are considered as uncertain variables. So, the system of the demand function can be expressed as follows:

$$q_i^d = b_i * (p_i^c)^{\eta_{ii}} * \prod_{j \neq i} (p_i^c)^{\eta_{ij}} * I^{\mu_i} , \qquad i, j = 1,2 \qquad (2)$$

Where,

q_i^d denotes the amount of the i^th commodity demanded

b_i is the demand calibration coefficient of the i^th commodity

p_i^c is the demand price of the i^th commodity

I is per capita income

η_{ii} is the demand price elasticity

η_{ij} is the cross price elasticity of the ithcommodities that are complementary or substitutes for the jth commodities.

μ_i is the income elasticity of the ith commodity.

The term μ_i represents the per capita income of the consumer which is calculated in the model as the outcome of the Gross Domestic Product over the number of total population.

2.3. Export/Import:

The model assumes the surplus of each commodity would be exported, while deficit should be covered through imports. Export and import of sorghum and sesame are the outcomes of supply minus demand are explained by the following equation:

$$Export/Import = q_{i}^{s}{-}q_{i}^{d} \qquad i = 1,2 \qquad (3)$$

2.4. Self-sufficiency ratio (SSR):

Sorghum is the major staple food for the population used as the food security component in the model; whereas, sesame is a cash exportable crop. Self-sufficiency ratio (SSR) is used as food availability indicator.

$$SSR = \sum q_i^s / q_i^d \qquad i = 1,2 \qquad (4)$$

2.5. Foreign exchange:

Foreign exchange is calculated in the model as:

$$Fex = (q_{i}^{s}{-}q_{i}^{d})p_i^w \qquad i = 1,2 \qquad (5)$$

Where, *Fex* in the model is sorghum and sesame export and import values.

q_i^s and q_i^d supply and demand of the two commodities

p_i^w world market price

All indicators are presented in their stochastic distributions since prices and supply and demand quantities are stochastic.

2.6. The model scenarios:

Two scenarios have been developed in order to simulate the impact of climate change. The first scenario (basic scenario) simulates the past period of supply, demand, and environment, and used as base to compare to other simulations. The second scenario (climate change scenario) simulates sorghum and sesame under climate change of rainfall with a decreasing trend of 20%. In each scenario, production, prices and rainfall were presented in their stochastic form. All scenarios were run simultaneously using 1000 random samples from each of the stochastic variable distributions. The BestFit distribution-fitting software program that is bundled with @RISK was used to estimate smooth (CDF) for each scenario based on annual observations from 2000-2013.

A time series data for the period 2000-2014 were collected from secondary sources mainly Bank of Sudan annual reports and the Arab Organization for Agricultural Development statistical year book. In the first step, the distribution of the stochastic variables of supply, demand, prices and rain fall has been determined with the help of @Risk program. Rain fall distribution is defined by the function RiskTriang (350,600,800), by taking a declining trend of 20% of rain fall the distribution of the climate change is determined by the function RiskTriang (250,350,400). In the second step of the analysis all stochastic variables are applied to the multi-market model and the determined scenarios.

3. Results And Discussion:

3.1. The supply effect:

In normal situations sorghum and sesame supply variations are attributed to rain fall and prices. Figure (3.a) outlays the CDF supply simulation results of sorghum under the two scenarios. Under the first scenario, in which normal rainfall distribution is simulated; the supply mean is estimated to 3.754 million ton at 0.5 cumulative probability. While the mean in second scenario of climate change, the supply will fall to 3 million ton at a lower cumulative probability level of 0.41, this is attributed to the decreasing trend of rain fall where the supply distribution curve shows a shift to the left towards lower levels of supply. However, self-sufficiency level of supply of 4 million ton will be attained at 0.58 cumulative probability in the normal conditions of the first scenario, while this level would be attained at higher cumulative probability of 0.85 under the climate change scenario.

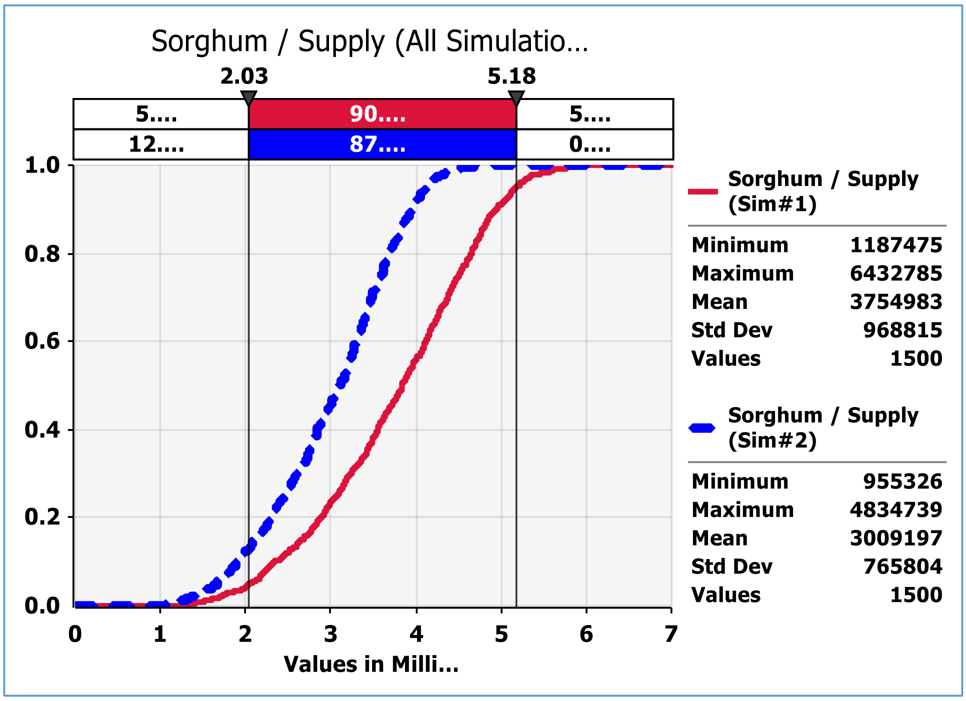

Figure (3.a): ***CDF*** **Distribution of Sorghum Supply, under the Two Scenarios**

Sesame supply is normally exceeding demand. Figure (3.b) depicts the two scenarios CDF graphs. About 74.7% of the simulated results of the first scenario lies between 180 to 510 thousands ton. While, in the climate change scenario 69.1% of the simulated results lies within the same levels. Under the first scenario; the simulated supply mean is estimated to 360,293 tons at 0.5 cumulative probability. While the mean in second scenario of climate change trend will fall to 273,194 tons at the same cumulative probability level. Although of the assumption of declining rain fall trend the country will maintain a surplus of sesame.

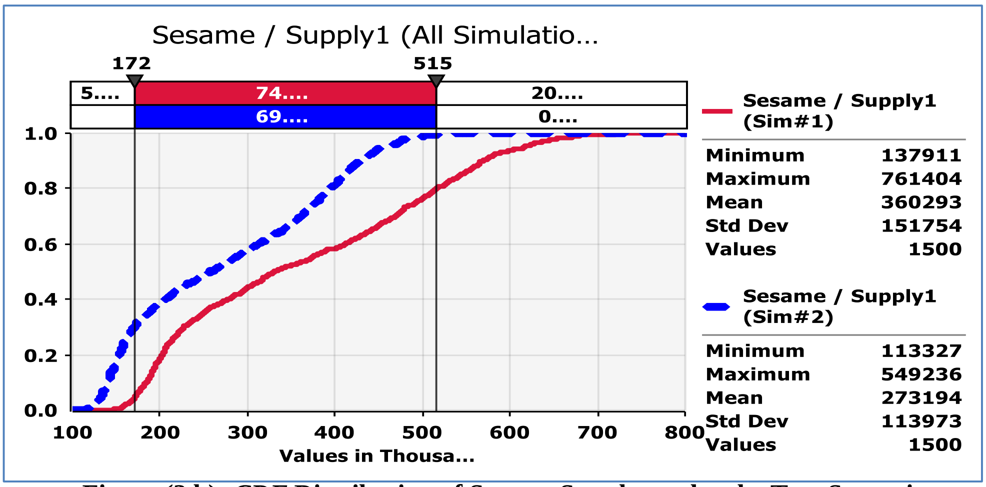

Figure (3.b): ***CDF*** **Distribution of Sesame Supply, under the Two Scenarios**

3.2. The demand effect:

Rain fall has an indirect effect on demand, where under the declining rain fall, production will decrease and bring prices up which will significantly reduce the demand. In the model, the demand is responding to changes in prices and per capita income, where the simulated results showed no significant change of the demand CDF under climate change. Figure (4) shows the simulated results of the possible responses of consumer demand for sorghum and sesame in the climate scenario if prices increased by 50%. Sorghum mean demand might go down to 3,193,113 tons at cumulative probability of 0.40. While, Sesame mean demand could reach 125,723 tons at 0. 9 level of probability.

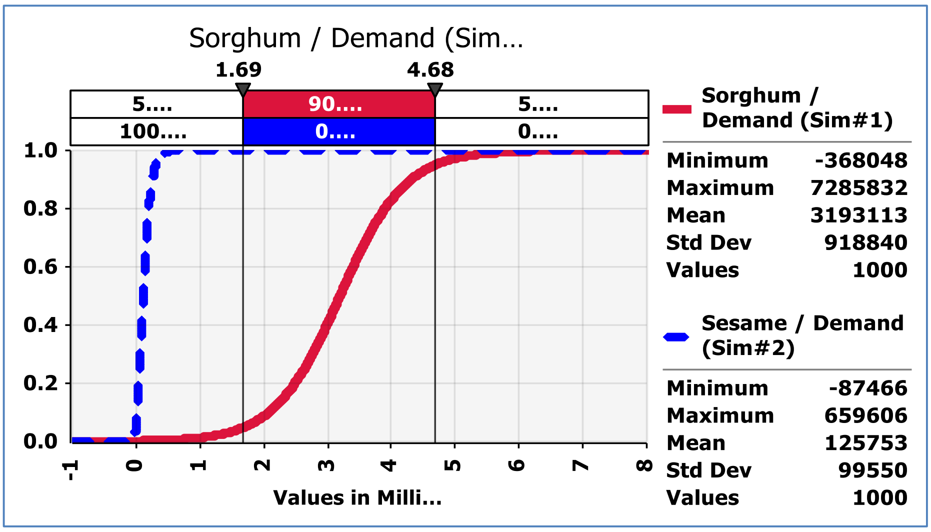

Figure (4): ***CDF*** **Distribution of Sorghum and Sesame Demand, under Climate Scenario**

3.3. Exports and imports:

The model assumes that the surplus of each commodity will go for exports and the deficit should be covered by imports. Sorghum surplus might be directed to exports or added to the national grain reserves; according to the binding policy set by the government. From the CDF graph of the first scenario, the country might attain very low surplus of sorghum with mean of 4464 tons or less at low cumulative probability less than 0.2, this is due to fact that in normal seasons the country consumed what has been produced of sorghum.

While under climate change scenario the supply demand balance revealed a possible deficit mean of 742,293 tons at 0.8 cumulative probability (figure 5.a). Under this scenario the country might turns to import sorghum to cover the deficit.

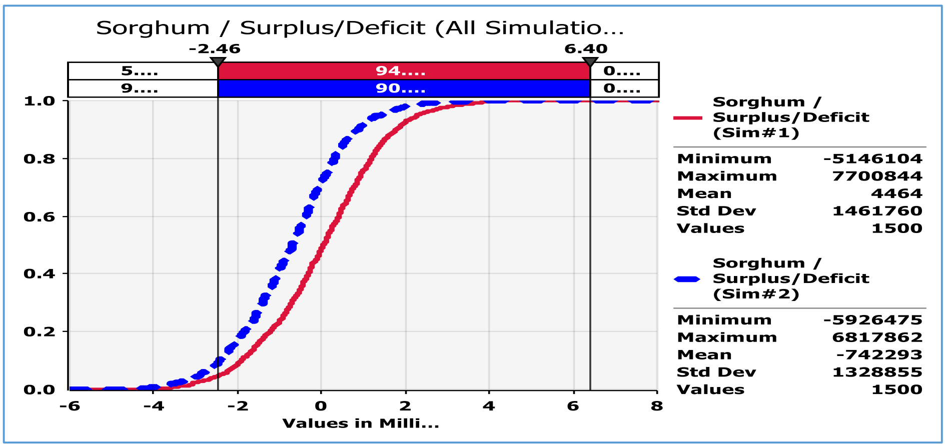

Figure (5.a): ***CDF*** **Distribution of Sorghum Surplus and Deficit, under the Two Scenarios**

Sesame performance reflects a surplus in both scenarios (Figure 5.b). In the first scenario under the normal conditions the supply and demand balance of sesame shows a surplus of 206,269 tons or less at the cumulative probability of (0.5). Whereas, in the second scenario still there is surplus with mean of 118,950 tons or less at 0.4 cumulative probability levels. This indicates that, although of the declining rain fall trend the country could continue exporting sesame but at lower amounts.

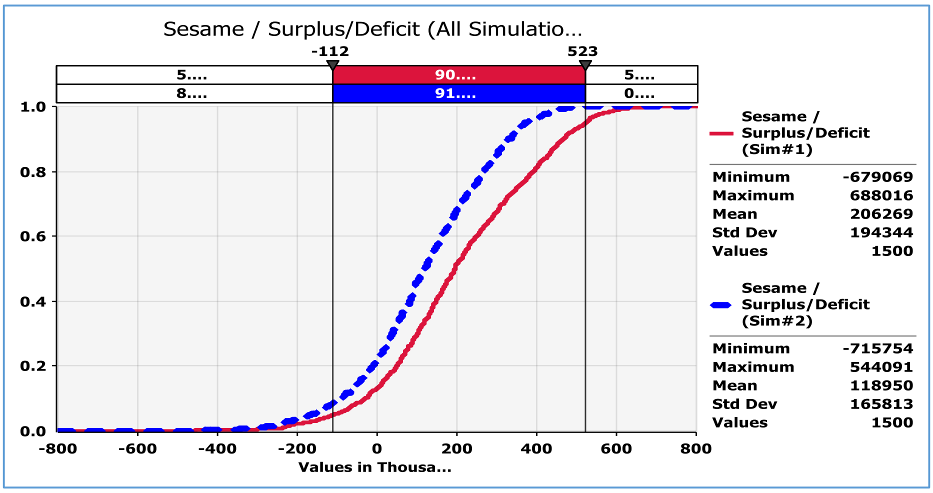

Figure (5.b): ***CDF*** **Distribution of Sesame Surplus and Deficit, under the Two Scenarios**

3.4. Self-sufficiency ratio (SSR):

The annual average amount of sorghum consumption in Sudan is around 4 million ton. Figure (6.a) provides an indication of the possible changes in
SSR of sorghum resulting from climate change. The simulation of the first scenario explains that the SSR mean or less is 1.02 at cumulative probability of 0.5 which reflects a surplus in sorghum supplies, while under climate change scenario the SSR mean will fall to reach 0.8 or less at higher level of cumulative probability (0.7), in this situation the country has to import sorghum to achieve self-sufficiency level.

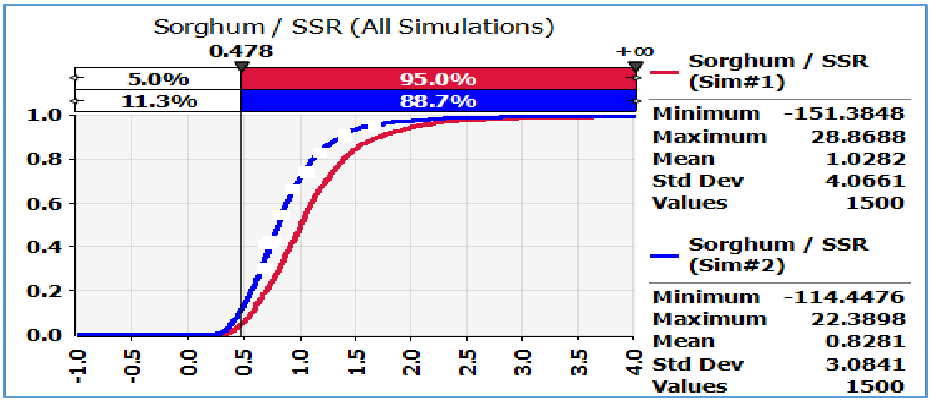

Figure (6.a): The *CDF* Distribution of Sorghum SSR, under the Two Scenarios

Regarding sesame, exported sesame is normally more than consumed locally. Figure (6.b) reveals the possible changes in SSR of sesame resulting from climate change in the two scenarios. The simulation of the first scenario explains that the SSR mean or less attained is 4.3 at 0.7 cumulative probability which reflects a surplus in sesame supplies, while under climate change scenario the SSR mean would decrease to reach 2.9 or less at the same level of cumulative probability (0.7), in this situation the country continue exporting sesame at lower amounts.

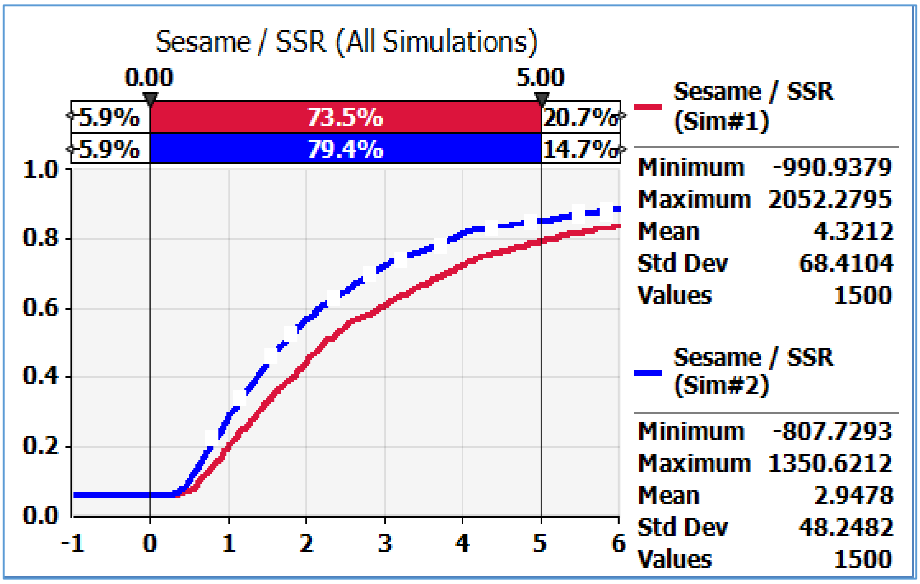

Figure (6.b): *CDF* Distribution of Sesame SSR, under the Two Scenarios

3.5 Foreign Exchange:

Figure (7.a) outlays the simulation results of foreign exchange transactions of sorghum. Foreign exchange in the model explains the value of sorghum external sector. The base line scenario explains that the country might have earnings of foreign exchange at cumulative probability of 0.45 or more in the case that the country permits exporting all surpluses. Under the second scenario of climatic change and less rain fall trend, the CDF graph reveals that the country might need to import sorghum of value US$ 209,888,777 or less at cumulative probability of 0.43. This is considered as additional burden to the government treasury.

Sesame earnings from exports could still be positive in the second scenario. Where, the foreign exchange earnings could reach a mean of US$140,432,284 at cumulative probability of 0.6. This is less than the earnings of the base scenario with a mean of US$242,771,405 at the same level of probability (Figure7.b). This is show a decline in the exports of sesame and hence low earnings of foreign currency from sesame exports.

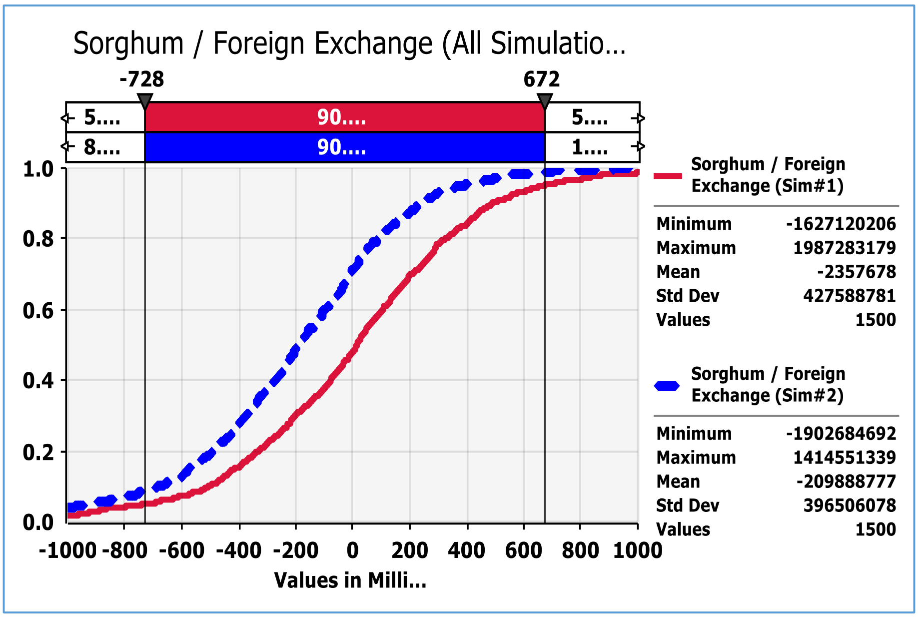

Figure (7.a): The *CDF* Distribution of Sorghum Foreign Exchange, under the Two Scenarios

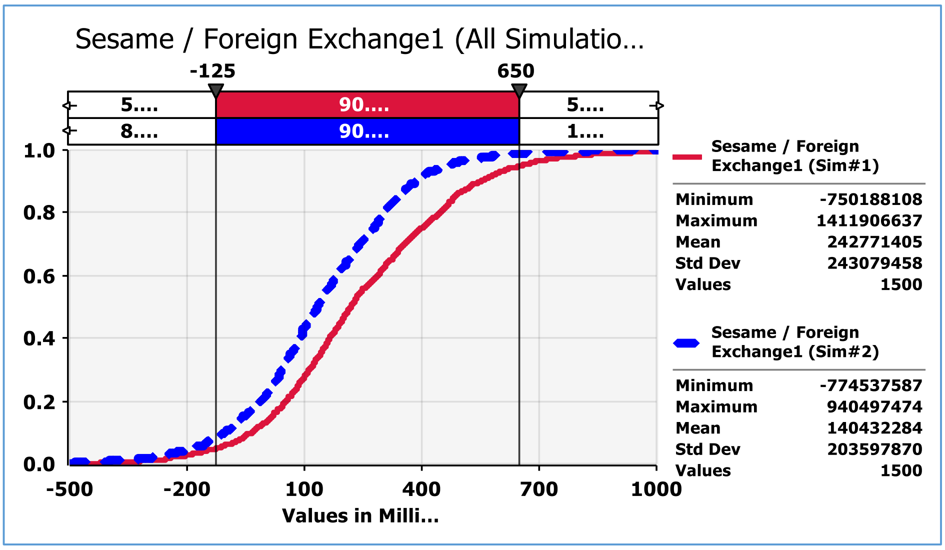

Figure (7.b): The *CDF* Distribution of Sesame Foreign Exchange, under the Two Scenarios

4. CONCLUSIONS

This paper aims to analyze the impact of climate change on sorghum and sesame markets in Sudan. Sorghum is the main staple food in Sudan, especially in rural areas. The two crops are produced under rainfall farming system.

The study has applied a stochastic Multi-market model for sorghum and sesame, the model stochastic variables are production, consumption and prices in addition to rainfall as a climate element, the data of these variables are taken for the period 2000-2013.

Two scenarios has been included in the model, the first scenario simulates the past period of environment and prices and used as base to compare to other scenarios simulations. The second scenario simulates sorghum and sesame markets under climate change of rainfall with a decreasing trend of 20%.

The simulation results of climate change of reducing rainfall trend shows a significant decrease in sorghum supply which has reflected in a deficit of sorghum balance to reduce the mean of SSR from 1.02 to 0.8. The country has to import around 742,293 tons at the cost of US $ 209 million on average to cover the deficit. Sesame supply will decline, however the country could maintain its self-sufficiency and continue exports at low levels.

To avoid climate change consequences of supply decrease and fluctuation, the country could expand sorghum and sesame production in the permanent irrigation sector.

References

Abdel Karim E. E., (2002), The Impact of Uruguay Round Agreement on Agriculture on Sudan’s Agricultural Trade. PhD Thesis, HU Berlin, Shaker Verlag.

AOAD, Arab Organization for Agricultural Development, Statistical Year Book, Various Issues.

CBOS, Central Bank of Sudan, Statistical Year Book, Various Issues.

El-Dukheri, I., Cirino Oketayot Oyiki, Ahmed S. El Wakeel and Silvestero Kaka Mesak, (2011), Review of the Food Security and Natural Resource Situation in Sudan DCG Report No. 63.

Jechlitschka, K. und Lotze, H. (1997), Theorie und Anwendung eines Mehr-Markt-Modelles zur Sektoralen Analyse von Agrarpolitiken. Zeitschrift für Agrarinformatik

Kirschke, D., Jechlitschka, K. (2002), Angewandte Mikroökonomie und Wirtschaftspolitik mit Excel. Lehr und Anleitungsbuch für computergestützte Analysen. München, Verlag Vahlen.

Lobell D, Field C., (2007), Global scale climate-crop yield relationships and the impacts of recent warming. Environ Res Lett 2:014002.

Rajaa H. Mustafa, (2006), Risk Management in the Rain-fed Sector of Sudan: Case Study, Gedaref Area Eastern Sudan, 2006, Farming and Rural Systems Economics, Edited by Werner Doppler and Siegfried Bauer, Volume 82, Magragf Publishers, Weikersheim, Germany.

SIFSIA, (2010), The Sudan Institutional Capacity Program: Food Security Information for Action (SIFSIA). RESULTS OF THE CEREAL AVAILABILITY IN THE NORTHERN STATES OF SUDAN, Khartoum

United Nations Environment Program and the World Trade Organization Trade and Climate Change, (2009), report, Printed by WTO Secretariat, Switzerland

USAID, https://pubs.usgs.gov/fs/2011/3072/pdf/FS2011-3072.pdf

Walsh, R., Hulme, M., and Campbell, M., (1988), Recent rainfall changes and their impact on hydrology and water supply in the semi-arid zone of the Sudan, Geographical journal, JSTOR.