Comparative Advantage Analysis of the Crops Production in the Agricultural Farming Systems in Sudan

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Abstract

Most rural people in developing countries are highly dependent on resource-based subsistence economies using products obtained from plants and animals. The purposes of this study are: 1. To asses the efficiency and sustainability in the use of domestic resources and tradable inputs of crops production of the farmers in the dominating farming systems. 2. To analyze the comparative advantage and protection of the major agricultural crops. The study was conducted in the irrigated, traditional and mechanized rainfed farming systems. The study applied the liner programming associated with Policy Analysis Matrix to determine competitiveness and policy effects of crops production in the farming systems in Sudan.

The results explain that the production costs of domestic food commodities of the farmers are considerably high. Beside the prices of fertilizers are considerably high. The misuse of the resources and lack of appropriate technologies were among the important factors that led to the low returns from farms. Food crops are disappeared from the optimal plan of the models set for the farmers.

On applying the sensitivity analysis to indicate the stability of results, it was illustrated that on increasing the gross margins the optimal plan and/or resource use remained constant, however, the returns of tenant's households increased. Moreover when the total land holdings increased in the three farming systems, the optimal returns of the farmers increased in the case of the traditional and the mechanized farms and remained unchanged in the irrigated farms.

The PAM results show that the farmers grow the food crop only to maintain self-sufficiency level as it will be cheaper in domestic market than to invest on import of food crop. And it has comparative advantage for the three representative farms, both under the current policies and in the absence of government intervention

Keywords: Crop Production, Policy Analysis Matrix, GAMS, Sudan.

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1. Introduction

As in many developing and other African countries, agriculture is the foundation of Sudan's economy. It considers as the main sector in the Sudanese economy in terms of its contribution to the gross domestic product by about 38.6 percent in 2005 (Sudan Bank, 2005). After petroleum, which represented 75 percent of the country's total export value in 2000, agricultural products are Sudan's main export commodities. About 75% of the population relies on it on providing them with food and jobs. Beside that it provides the raw materials for the local industries and also significantly contributes in the export proceeds.

The agricultural farming systems include the mechanized rain-fed agriculture (with an area of 13.7 millions feddans), traditional rain-fed agriculture (with an area of 2.1 millions feddans) and the irrigated agriculture (with an area of 5 millions feddans). The main cash crops are cultivated in these farming are cotton and Gum Arabic (specifically in the traditional rainfed farms) whiles the main food crops are sorghum, millet and wheat. The oil crops are groundnuts; sesame; sunflower. Beside the watermelon seeds which is commercially cultivated in traditional rainfed farms.

2. Motivations and Purposes of the Study

A large portion of the Sudan's rural people today live in highly degraded lands and vulnerable environments which make them in contentious struggle to maintain their needs. The rural Sudan has facing food deficits in many of its regions. The rural farm households are faced by two main aspects. The natural aspect: the unexpected changes and fluctuations of the environments lead to low production of the food and cash crops and deterioration in pastures. The economical aspect: the formulation of the price policy has been disfavoring the main food and export commodities, which would ultimately result into poverty incidence. In addition, the unfair resources allocation leads to conflicts and civil wars in some regions of the country and obliged the rural population to migrate from their homes seeking for shelter, food and water in worthy and secured regions, the ultimate end would be falling into food insecurity and forced to live in the poverty sphere.

The overall purpose of this study is to address the major crops produced in the farms and environment within a context of policy analysis. The specific purposes of the study are two folds:

1. To asses the efficiency and sustainability in the use of domestic resources and tradable inputs of crops production of the farmers in the dominating farming systems.
2. To analyze the comparative advantage and protection of the major agricultural crops.

3. Research Methods

The study is based on both primary and supportive secondary data sources. The primary data are collected from the field survey using questionnaire. The study is covered three production domains named as traditional rainfed farms (rural Kordofan State), mechanized rainfed farms (rural Blue Nile State) and irrigated farms (rural Gezira State). The information of the crops productions are collected included: socioeconomic information, ownership patterns, land use, labour use, crops production issues (cost, price, quantities and etc…), water use and etc…

3.1 Linear Programming Analysis

The study used the Linear Programming model (LP) to determine the optimal resources allocation of the farmers by specifying farm activities for improving the income level at household level. Bierman *et al*. (1961) and Boehlje and Eidman (1984) stated that, LP is essentially a mathematical technique for solving a problem that has certain characteristics. The conventional and mathematically statement of the LP model takes the following form:

A. Objective equation subject to:

$$\text{Max } Z = \sum_{j=1}^{n} C_j X_j \quad \text{-------- (1)}$$

Where:

Xj = is the level of the **j**[th] farm activity such as the area grown with field crops and vegetables.

n: denotes the number of possible activities; the ***j*** = 1 to *n*.

C*j* = the objective value, in this case the forecasted gross margin of a unit of the j[th] activity (US$ per feddan[7]).

B. constraints equation subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i, \text{ all } i = 1 \text{ to } m \quad \text{-------- (2)}$$

and the non- negativity constraint activities is subject to:

$$X_j \geq 0 \text{ all } j = 1 \text{ to } n \quad \text{-------- (3)}$$

Where:

$\mathbf{a}_{ij}$ = quantity of the **i**[th] resource (land, labour, fertilizers, etc…) required to produce one unit of the **j**[th] activity (sorghum, millet, groundnut, watermelon seeds, etc…).

m: denote the number of resources; then i = I to m.

$\mathbf{b}_i$ = amount of the **i**[th] resource available (e.g. feddan of land or days of labour, etc..). The objective is to find the cropping system (defined by a set of activities levels $\mathbf{X}_j$, **j** = 1 to n) that has the highest possible total gross margin, **Z**, but dose not violate any of the fixed resource constraints or involve any negative activity levels.

The main household recourses constraints included land, measured as total cultivated land for each household and labour measured in total man-days devoted to crop production including hired labour. We also included the total amount of fertilizer and seeds acquired by the household in the given season. The information obtained from the LP analysis included the objective function value (returns), the optimal crops combination and resources used and their respective marginal productivities. The analysis focused on the optimal cropping pattern and optimal resources use in each farm as illustrated later. The LP model was analyzed by using GAMS soft ware program.

The aims of the LP model are two folds:

1. To establish the optimal cropping pattern (plan) of the rural farm households.
2. To compare the optimal plan between the three selected farms.

3.2 Policy Analysis Matrix (PAM)

The LP associated with PAM were analyzing by using GAMS Soft program. Recently, several studies have used PAM that relates the above parameters of comparative advantage and policy effects (Masters and Winter-Nelson, 1995; Khan, 1997; Khan, 2001; Khan, 2002; Mohanty *et al*., 2002; Khan, 2004; Khan and Akhtar, 2005; Hussain *et al.*, 2006 and Atiya , 2007).

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[7] One feddan= 0.42 ha. = 1.038 acres

The PAM is developed by Monke and Pearson (1989) and augmented by Masters and Winter-Nelson (1995), for measuring input use efficiency in production, comparative advantage, and the degree of government interventions. The basis of the PAM is a set of profit and loss identities, i.e. is a matrix of two-way accounting identities (Nelson and Panggabean 1991). Furthermore Monke and Pearson (1989) established the basic format of the PAM, as shown in Table 1.

Table 1: Basic Format of PAM

Prices (Accounts)	Value of out put (Revenue)	Value of Input: Tradable input cost	Value of Input: Non-tradable input cost (Domestic factor)	Profit
Private prices	A	B	C	N
Social prices	D	E	F	O
Policy transfer (divergence)	G	H	I	P

Source: Monke and Pearson (1989) .
Note: Private profit: N=A-(B+C); Social profit: O=D-(E+F); Output transfer: G=A-D; Input transfer: H=B-E; Factor transfer: I=C-F; Net policy transfer: P=N-O.

Revenues, costs (tradable and non- tradable inputs) and profits are calculated using two sets of prices: **A**. private prices: these are the prices which private agents actually face in the market. **B**. social prices: these prices are designed to measure the opportunity cost to the economy of using a resource or domestic factor. Yao (1997) stated that the most difficult tasks for constructing a PAM are estimating social prices for outputs and inputs. For computing social prices for various commodities, including both outputs and inputs, world prices are used as the reference prices in the study. The difference between private and social prices reflects the size of transfers which are either fed in or taken out of the system by all kinds of government intervention and market distortions. All values are expressed per unit of output.
Tradable inputs include those inputs, which can be traded in the world market, e.g. imported fertilizers and pesticides. Non-tradable inputs are mainly domestic factors that are not traded internationally, e.g. land, labour and local capital. In empirical PAM analysis, the revenue and cost categories in private prices (entries A, B, and C) are based on data from farm and processing budgets. The data in the first row provide a measure of private profitability (N), defined as the difference between observed revenue (A) and costs (B+C). The second row of the matrix calculates the social profit that reflects social opportunity costs. Social profits measure efficiency and comparative advantage. In addition, comparison of private and social (efficiency) profits provides a measure of efficiency. The third row of the matrix estimates the difference between the private and social values of revenues, costs and profits, which can be explained by policy interventions.
The social (efficiency) prices for domestic factors of production (land, labor, and capital) are estimated also by application of the social opportunity cost principle.
Because domestic factors are not tradable internationally and thus do not have world prices, their social opportunity costs are estimated through observations of rural factor markets (Pearson *et al*., 2003).
The PAM framework also used to calculate important indicators for policy analysis, e.g. the nominal protection coefficient (NPC). The NPC is a simple indicator of the incentives or disincentives in place is defined as the ratio of domestic price to a comparable world (social)

price. NPC can be calculated for both output (NPCO) and input (NPCI). NPCO is the ratio between private and social revenue of the output (i.e. the ratio of domestic market price of the product to its parity price at the farm-gate). If NPCO >1, it indicates that the private price of output is greater than its parity price and hence producers are positively protected for the product. If NPCO < 1, it indicates that producers are implicitly taxed on the product. If NPCO = 1, it indicates a neutral situation. NPCI is the ratio of private to social cost of tradable inputs (i.e. the ratio of the private to the social values of all the tradable inputs). If NPCI >1, it indicates that producers are taxed when they buy tradable inputs. If NPCI < 1, it indicates that they are subsidized. NPCI = 1 represents a neutral situation. The other indicator used is the effective protection coefficient (EPC). EPC measures the total effects of intervention in both input and output markets. EPC is the ratio of value added measured at private prices (A-B) to that of social prices (E-F). An EPC value of greater than one suggests that government policies provide positive incentives to producers i.e. it implies that the overall impact of the existing policy results in a net positive incentive to produce the commodity while values less than one indicate that producers are not protected through policy interventions (represents a net disincentive). EPC = 1 implies either no intervention or the net impact of various distortions in both the input and product markets results in a neutral effect on value added.

The various indicators are used to compare the relative efficiency or comparative advantage between agricultural commodities. In this study the Domestic Resource Cost (DRC) and private profit coefficient (PPC) indicators are used. The DRC it has been widely used in developing countries to measure efficiency or comparative advantage and guide policy reforms (World Bank 1991; Appleyard 1987; Morris 1990; Gonzales *et al*. 1993; Alpine and Pickett 1993, Mohanty *et al.*, 2002). DRC, is defined as the shadow value of non-tradable factor inputs used in an activity per unit of tradable value added (F/(D-E)). The DRC indicates whether the use of domestic factors is socially profitable (DRC<1) or not (DRC>1). The DRC values are calculated for each crop in each farm. The crops can be ranked according to the DRC values, and this ranking is taken as an indication of comparative advantage or disadvantage within that state. A farm will have a comparative advantage in a given crop if the value of the DRC for that crop is lower than the DRC for other crops grown in that farm. The data requirements for constructing PAM in this study include yields, input requirements, and the market prices for inputs and outputs. Import/export tariffs, and exchange rates are also required to calculate social prices.

4. Results and Discussions

Agriculture remains as the main source of livelihood of the rural people in the surveyed farms as more than half of the population derive their livelihoods from land. Majority of the rural households in the traditional farms (78.4%) were fully occupied with their tenancies (had no off-farm occupation).

The results indicate that the farmers owned agricultural land but lack appropriate technology and removal of subsides from the production inputs (e.g. from fertilizers) which make them as the main factors for being poor yield in these farms. The most of land is not occupied efficiently to satisfy the rural household’s needs.

4.1 Interpretation of LP Results

Sorghum crop did not appear in the optimal farm plan in all farms despite the fact that it is the main food staple in the farms, particularly in the irrigated farms. The groundnut crop also disappeared from the irrigated and traditional farms models, while in the mechanized farms it was the only crop that appeared at optimal solution and its area was increased in the optimal solution (Table 2). The optimal crop plan in the irrigated farms is vegetables crop and its area was dropped in the optimal solution (Table 2). This result agreed with Elzaki (2005), who confirmed that the vegetables crops were more profitable than other crops in the irrigated farms. No millet and sesame crops appeared in the optimal solution in the mechanized or traditional farms (Table 2). The optimal plan in the traditional farms was the watermelon seeds and its area was dropped in the optimal solution (Table 2). The optimal model showed a significant change in the farmer's returns. The optimal returns of the crops production are US$ 1242.19 in the irrigated farms, US$ 5808.73 in the traditional farms and US$ 5828.09 in the mechanized farms, which was greater than the actual returns by 12 percent in the irrigated farms, 41 percent in the traditional farms and 71.2 percent in the mechanized farms. This result reveals that the mechanized farms had more wealth than the other two farms deem to differences in soil fertility in these farms.

Table 2: Optimal Crop Production Plan per Tenancy in Diverse Feddans Areas in the Agricultural Farms

Farm	**Irrigated farms (Rural Gezira State)**			**Traditional farms (Rural Kordofan State)**			**Mechanized farms (Rural Blue Nile State)**		
Item	**Actual**	**Optimal**	**Units**	**Actual**	**Optimal**	**Units**	**Actual**	**Optimal**	**Units**
A. Cropping pattern:									
1. Cotton	4	-	Fed.	0	0	-	0	0	-
2. Sorghum	3.8	-	Fed.	7	-	Fed.	38		Fed.
3. Groundnut	3.6	-	Fed.	3	-	Fed.	4.9	15.9	Fed.
4. vegetables	3.6	2.2	Fed.	0	0	-	0	0	-
5. Millet	0	0	-	6.4	-	Fed.	3.5	-	Fed.
6. Sesame	0	0	-	10.7	-	Fed.	24	-	Fed.
7. Watermelon	0	0	-	6.3	5.7	Fed.	0	0	-
B. Resource use									
1. Land	20	8	Fed.	36	36	Fed.	78	78	Fed.
2. Family labour	214	48.9	MD	366	27	MD	164	36.6	MD
3. Hired labour	241	46.75	MD	99	-	MD	200	127.3	MD
4. Fertilizer	614	614	Kg	137	137	Kg	N. a	N.a	Kg
5. Seeds	107	22	Kg	103	8.9	Kg	903	85.4	Kg
C. Returns:									
Objective function value	979.06	1242.19	US$	2435.56	5808.73	US$	979.06	5828.09	US$

Source: Models Results, 2005/2006. *Note: Fed. = feddan, 0 = No cultivated crop, - = No value, N.a = Not available and MD = Man days

No changes regarding the total land use in the traditional and mechanized farms in optimal plan solution, while the total land in the irrigated farms reduced to 8 feddans, representing 42.8 percent of the total available land use in the actual solution. As well, the models results showed that the labour use and seeds use dropped in the optimal solution in all farms. The amount of seeds reduction was high in traditional farms (by 84 percent) and mechanized farms (by 82 percent) while it represented 66 percent in the irrigated farms. As well the fertilizers remain with unaffected in the traditional and irrigated farms. These results also indicate that the deficiencies of technical methods of cultivation were the main factors constraining the optimal utilization of the resources use.

4.1.1 Marginal Productivities of Crops and Constraints of the Rural Households

The shadow price is the Marginal Value Product (MVP) of a resource. For farm situation MVPs indicates the increase in the objective function value that would be obtained if a particular resource is expanded by one unit. The negative values of marginal productivity reduction in the objective function if an additional unit of resource is introduced. From Table 3, it is comprehensible that the total land has the highest marginal value productivity, reaching US$ 161.49 in traditional farms and US$ 74.78 in mechanized farms per season that is why farmers always charitable it more care to cultivated large areas, even if the land was fertile or not. The MVP of the total fertilizer in the irrigated farms was estimated at US$ 2.02, which confirmed that the land resource in traditional and mechanized farms are most fruitful contrasting with others resources, whilst using of supplementary fertilizers in the irrigated farms is the only constructive resources that constraint the farmers. All the cultivated crops displayed a negative MVP, which implies that if one unit of these crops increase would lead to reduction in the optimal objective function (gross margin) of the farmers.

Table 3: Shadow Prices for Limiting Resources and Crops Land

Irrigated Farms (Rural Gezira State)		Traditional Farms (Rural Kordofan State)		Mechanized Farms (Rural Blue Nile State)	
Resources/ crop land	**Shadow price in US$**	**Resources/ crop land**	**Shadow price in US$**	**Resources/ crop land**	**Shadow price in US$**
Total fertilizer	2.02	Total Land	161.49	Total Land	74.78
Sorghum land	-0.02	Sorghum land	-0.014	Sorghum land	-0.03
Cotton land	-48.67	Millet land	-0.01	Millet land	-0.01
Groundnut land	-16.38	Groundnut land	-0.03	Sesame land	-0.01
-	-	Sesame land	-0.01	-	-

Source: Models Results, 2005/2006.

4.1.2 Sensitivity Analysis

Techniques such as sensitivity analysis have been used in the model to determine those variables which affect the model outcome most significantly, hence reduced the poverty of the rural in the farms. As mentioned previously, no food crops appeared in all farms' models. However the farmers need to increase their returns to fill a gap of their food crops spending. Consequently the importance of increasing output of all cultivated crops and hence often gross margin were affected the returns of the tenants and their income, which consequently reduce their poverty incidence. The basic solution is used as a reference for the sensitivity analysis.

It is noted that from the sensitivity analysis (Table 4) when the gross margins in all farm's models were increased by 25 percent no change occurred in the optimal plan and/or resource use. But the returns were increased by 11 percent in all farms.

Table 4: Impact of Increasing Gross Margin of Cultivated Crops by 25 Percent in the Agricultural Farms

Farm	Irrigated Farms (Rural Gezira State)			Traditional Farms (Rural Kordofan State)			Mechanized Farms (Rural Blue Nile State)		
Item	**Basic**	**Optimal**	**Units**	**Basic**	**Optimal**	**Units**	**Basic**	**Optimal**	**Units**
A. Cropping pattern:									
1. Cotton	-	-	Fed.	0	0	-	0	0	-
2. Sorghum	-	-	Fed.	-	-	Fed.			Fed.
3. Groundnut	-	-	Fed.	-	-	Fed.	15.9	15.9	Fed.
4. vegetables	2.2	2.2	Fed.	0	0	-	0	0	-
5. Millet	0	0	-	-	-	Fed.	-	-	Fed.
6. Sesame	0	0	-	-	-	Fed.	-	-	Fed.
7. Watermelon	0	0	-	5.7	5.7	Fed.	0	0	-
B. Resource use									
1. Land	8	8	Fed.	36	36	Fed.	78	78	Fed.
2. Family labour	48.9	48.9	MD	27	27	MD	36.6	36.6	MD
3. Hired labour	46.75	46.75	MD	-	-	MD	127.3	127.3	MD
4. Fertilizer	614	614	Kg	13.7	13.7	Kg	N.a	N.a	Kg
5. Seeds	22	22	Kg	8.9	8.9	Kg	85.4	85.4	Kg
C. Returns:									
Objective function value	1242.81	1553.52	US$	5811.63	7264.54	US$	5831.00	7288.76	US$

Source: Models Results, 2005/2006

If it is assuming that there are improvements in the total land constraint e.g. superior land preparation and preservation, this will lead to an increase in the total land use. Table 5 illustrates the changes that occurred when the total land of the rural farmers had increased by 25 percent in the selected farms. The results obtained from the Table explained that: there are no changes occurring in the limited resources use or returns regarding the irrigated farms; and this perhaps was due to the small size holding of the land in these farms (since in these farms the land right is in the government authorities and the farmers are compelled to adopt the crop rotation recommended by the Gezira scheme).

Noticeable changed was occurred in the traditional and mechanized farms models when the total land increased as follow:

Cropping pattern: The watermelon seed area was increased by 11 percent from the basic solution in the traditional farms. Additionally, the groundnut area in the mechanized farms was increased by 11 percent.

Resources use: In the traditional farms, the family labour, fertilizers and seeds resources were increased by 11.5 percent, 10.7 percent and 5.8 percent; respectively. In the mechanized farms, the family labour, hired labour and seeds resources were increased by 10.35 percent, 10.8 percent and 9.8 percent; respectively.

Returns: The farmer's returns in the traditional and mechanized farms were slightly increased by 11 percent and 10.8 percent; respectively.

Table 5: Impact of Increasing the Total Land by 25 Percent in the Agricultural Farms

Farm	Irrigated Farms (Rural Gezira State)			Traditional Farms (Rural Kordofan State)			Mechanized Farms (Rural Blue Nile State)		
Item	**Basic**	**Optimal**	**Units**	**Basic**	**Optimal**	**Units**	**Basic**	**Optimal**	**Units**
A. Cropping pattern:									
1. Cotton	-	-	Fed.	0	0	-	0	0	-
2. Sorghum	-	-	Fed.	-	-	Fed.			Fed.
3. Groundnut	-	-	Fed.	-	-	Fed.	15.9	19.80	Fed.
4. vegetables	2.2	2.2	Fed.	0	0	-	0	0	-
5. Millet	0	0	-	-	-	Fed.	-	-	Fed.
6. Sesame	0	0	-	-	-	Fed.	-	-	Fed.
7. Watermelon	0	0	-	5.7	7.1	Fed.	0	0	-
B. Resource use									
1. Land	8	8	Fed.	36	45	Fed.	78	97	Fed.
2. Family labour	48.9	48.9	MD	27	34	MD	36.6	45	MD
3. Hired labour	46.75	46.75	MD	-	-	MD	127.3	158	MD
4. Fertilizer	614	614	Kg	13.7	17	Kg	N.a	N.a	Kg
5. Seeds	22	22	Kg	8.9	10	Kg	85.4	104	Kg
C. Returns:									
Objective function value	1242.81	1242.81	US$	5811.63	7264.54	US$	5831.00	7251.38	US$

Source: Models Results, 2005/2006

4.2 Interpretation of PMA Results

The rural and urban poverty reduction can be accelerated by the growth of the rural sector, especially agriculture (Ravallion and Datt 1996). The higher productivity growth benefits both the urban and the rural poor (Hayami and Herdt, 1977 and Alauddin and Tisdell, 1991). Growth in agriculture and its productivity are considered essential in achieving sustainable growth and significant reduction in poverty in developing countries (Prasada Rao *et al.,* 2004 and Mellor, 2001) Schubert (1994) noted a relationship between poverty and productivity.

LP results explained that the miss-use of the resources and lack of appropriate technologies were among the important factors that led to the low returns from farming and persistent poverty among the rural farmers. The results on protection coefficients for crops of the rural farmers in various farms are reported in Table 6.

Table 6: Summarized Results of the Protection Coefficients for Agricultural Farming Systems in Sudan (2005-2006)

Farm	Protection coefficients		
	NPCO	NPCI	EPC
1. Mechanized:			
Sorghum	2.87	0.05	0.05
Millet	1.38	1.21	0.86
Groundnut	7.00	1.41	-1.39
Sesame	10.67	1.28	1.01
2. Irrigated:			
Sorghum	1.26	0.19	0.18
Cotton	1.50	0.58	0.41
Groundnut	1.50	0.87	0.70
Vegetables	1.33	0.48	0.20
3. Traditional:			
Sorghum	0.99	0.87	0.42
Millet	0.99	0.87	-2.24
Groundnut	0.91	0.89	0.89
Sesame	0.94	0.88	1.07
Watermelon	0.94	0.89	1.06

Source: Calculated from authors' model, 2005-2006. NPCO: Nominal out put protection coefficient, NPCI: Nominal input protection coefficient, EPC: Effective protection coefficient

NPC in traditional farm is very close to one, suggesting that the domestic price is slightly below the international price, whereas in the mechanized and irrigated farms NPCs are much more than one. Similarly, NPCI values of more than one in irrigated farm suggest that the government policies are increasing input costs for the major crops in farms. NPC values of less than one for all input and most output markets clearly show government efforts to support the farms.

NPCO for crops in mechanized and irrigated farms are greater than one, it indicates that the private price of output is greater than its parity price and hence producers in theses farms are positively protected for the product. While in the traditional farm the NPCO < 1, it indicates that producers in this farm are implicitly taxed on the product.

The producers in the mechanized farm are taxed when they buy tradable inputs (NPCI >1,). While the rural producers in irrigated and traditional farms they are subsidized (NPCI < 1).

From the literature the EPC is a more reliable indicator of the effective incentives than the NPC, as the former recognizes that the full impact of a set of policies includes both output price enhancing effects (import tariffs) and cost reducing effects (input subsidies). The EPC nets out the impact of protection on inputs and outputs and reveals the degree of protection accorded to the value-added process in the production activity of the relevant commodity.

The EPC values in Table 6 show that there are significant differences in the degree of policy transfer for crops across the three farms.

The overall impact of the existing policy results in a net positive incentive to produce the sesame and groundnut crops (in the mechanized farm) and millet, sesame and watermelon (in the traditional farm). For the irrigated farm all crops represents a net disincentive (EPC <1). There is either no intervention or the net impact of various distortions in both the input and product markets results in a neutral effect on value added of the crops in the three farms.

The other PAM indicators, such as DRC and PPC, for crops in each farm are reported in Table 7 and their rankings in each farm are reported in Table 8.
There is a positive correlation between protection and lack of comparative advantage for watermelon in the traditional farm. The DRC values for cotton and vegetables (in irrigated farms), sorghum (in irrigated and mechanized farms), groundnut (in all farms) and sesame in mechanized and traditional farms are greater than one and clearly smaller than those for sorghum in the traditional farm.

Table 7: Indicators of the Sudanese Agricultural Farming System Comparative Advantage (2005/2006)

Crop	Indicator	Farm		
		Mechanized	Irrigated	Traditional
Cotton	DRC		1.25	
	PPC		0.69	
Sorghum	DRC	1.00	1.00	4.63
	PPC	0.05	0.19	4.02
Groundnut	DRC	1.49	1.26	1.09
	PPC	2.11	1.093	0.97
Sesame	DRC	1.03		1.98
	PPC	1.32		1.74
Millet	DRC	3.20		10.06
	PPC	3.90		8.79
Vegetables	DRC		1.32	
	PPC		0.63	
Watermelon	DRC			0.51
	PPC			0.45

Source: Calculated from authors' model, 2005-2006

The DRC and PPC values for millet are much larger than their respective competing crops in mechanized and traditional farms. Suggesting those farms have a comparative advantage in producing others crops rather than millet.
Most sorghum and sesame crops are produced inefficiently in Sudan, with the DRC and PPC value greater than one. The results show the intervention of government policies on main crops self-sufficiency lead to significant allocative inefficiency.
Generally the coefficient for commodities not in the optimal solution is greater than one indicating that the cost of resources (land, labour and capital), when valued at their private or social shadow prices, exceed value added when measured at its opportunity cost.

Table 8: Comparative Advantage Ranking by Crop

Farm	Crop	DRC	PPC
Mechanized	Sorghum	1	1
	Groundnut	3	3
	Sesame	2	2
	Millet	4	4
Irrigated	Cotton	2	3
	Sorghum	1	1
	Groundnut	3	4
	vegetables	4	2
Traditional	Sorghum	4	4
	Groundnut	2	2
	Sesame	3	3
	Millet	5	5
	Watermelon	1	1

Source: Calculated from authors' model, 2005-2006

5. Conclusions

The outcome of the study findings is concluded that:

- Sorghum crop did not appear in the optimal farm plan in all farms despite the fact that it is the main food staple in all farms. The optimal crop plan in the mechanized, irrigated and traditional farms are groundnut, vegetables and watermelon crops; respectively.
- There are significant differences in the degree of policy transfer for crops across the three farms.
- The government policies on main crops self-sufficiency lead to significant allocative inefficiency.
- Complying with the competitive prices by reducing raw material costs and increasing the yield per area unit of the rural farmers.
- Self-sufficiency could be achieved with smaller deadweight losses by reducing input market distortions.

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