Optimizing the Cropping Pattern in Gezira Scheme, Sudan

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Abstract- The objectives of the study were to determine the optimum cropping pattern and assess the impact of some scenarios on farm income and resources use. The results of LP models revealed that the real cropping was different from the basic cropping pattern, the net farm income in the optimal models was over the current situation by 59.3%, most of the land was allocated to onion crop which was 8.68 feddans, followed by cotton crop which was 6.88 feddans, while sorghum and groundnuts entered in the optimal plan with small areas 1.74, and 0.92 feddans, respectively, wheat and chickpea did not enter in the optimal plan. In the real situation cotton, sorghum, and onion occupied about the same area 4 feddan, followed by wheat and chickpea, 3 feddan, and then groundnuts 2 feddan. Many scenarios were tried by developing the parameters of the free LP model to reflect a range of production options.

Index Terms- Crop pattern, optimimization, linear programming model, Gezira scheme, Sudan.

I. INTRODUCTION

The Gezira scheme is the oldest and most important irrigated scheme in Sudan. The Gezira scheme is the area that extends from latitude 13º N to latitude 15º N between the Blue and White Niles. It covers a net cultivable area of little less than one million hectares (about 2.1 million feddans). Gezira scheme consists of two main parts: Gezira main and Managil extension. The main crops grown in Gezira Scheme are cotton, sorghum, groundnut, wheat, vegetables, fruits, and Fodder. It contributes to cash and food crops of the agricultural sector in Sudan [1]. Gezira scheme has adopted different types of crop rotations since its establishment and changes in crop rotation are dictated by scheme management during the period (1925-2005). After the Gezira Scheme Act for the year 2005, farmers are not restricted by a certain crop rotation, where the Act has insured that farmers are free to manage productive and economic determinants in the context of art and the use of technology to upgrade the productivity and maximize their profitability. This Act of 2005, to influence for rotation in scheme and deterioration area under crops cultivated and lead to low yield in recent years and decreasing of profitability . The objectives of the study were to determine the optimum cropping pattern and assess the impact of some scenarios on farm income and resources use.

II. METHODOLOGY

2.1 DATA COLLECTION

Primary and secondary data were used for the study purposes. Primary data were collected by using structural questionnaire using stratified random sampling techniques through direct personal interviewing, where a sample of 150 farmers was collected during season 2011/2012. Secondary data collected from different relevant sources which include Planning and Socio-economic Research Administration of the Gezira schemes, in addition to different documents.

2.2 METHOD OF DATA ANALYSIS

2.2.1 Linear Programming Model (LP)

Determine the optimum cropping pattern and assess the impact of some polices on farm income and resources use were studied through linear programming model.

Defined Linear programming as an efficient way of determining optimum plans only if there are numerous enterprises or processes and numerous restrictions in attaining a specific objective such as maximizing farm profits or minimizing production costs [2]. Linear programming as a method of determining a profit maximization combination of farm enterprises that are feasible with respect to a set of fixed farm constraints [3]. Linear programming was applied in the agricultural sector of Sudan by several individuals among them [4, 5, 6, and 7].

2.2.2 Empirical Specification of the Linear Programming Model

2.2.2.1 Structure of the LP technique:

The objective function of the representative farm model maximizes net farm income after satisfying family requirements from the main food crops. The mathematical form of the model used is as follows:

$$\text{Max } Z = \sum_{t=1}^{n} CjXj$$

$$\text{Subject to} = \sum_{t=1}^{n} aijXj \leq bi$$

And

Xj>=0, all j=1 to n

Where:

Z= objective function value.

Cj= gross margin per feddan of the jth farm activity i.e. input/outpu

Xj= the level of the jth farm activity.

aij= the quantity of the ith resource required to produce one unit of the jth activity i.e. input/output coefficients.

bi= vector of resource availability.

2.2.3 Linear Programming Model Building

The objective of farming practice in the Gezira scheme is profit maximization after household food security of sorghum.

2.2.3.1 Linear programming model's technical input-output coefficients and resource endowments formulated into a matrix.

(a) Activities set:

The activity set in the model includes the following:

1- **Crop production activities:** This includes the production of cotton, sorghum, groundnuts, wheat, onion and chickpea (table 1). The objective function coefficients for the production activities represent the total cost of production per feddan excluding the cost of hired labor. This cost is subtracted from the operating capital streams in the months they are incurred. These production activities are linked with production balance equations and their respective yields per feddan are shown as negative figures in these equations.

2- **Crop selling activities:** The selling activities include sales of crops. The objective function coefficients for the selling activities represent average price per unit of sale plus the value of crop residue (for sorghum and groundnuts). The objective function coefficients of selling activities also appear as supplying the operating capital stream in the month where selling takes place (Table 2).

3- **Sorghum consumption activities:** The tenants usually consume part of their production from sorghum. The objective function coefficient is zero for these activities (no cost). This activity is linked to sorghum consumption constraint and sorghum production balance equation (Table 1).

4- **Sorghum buying activities:** The buying activities are permitted to allow households to satisfy sorghum consumption constraint in case model production could not satisfy this constraint. The objective function value for this buying activity represents the average price household pays for purchased sorghum (Table 2).The purchase price is higher than the average selling price because purchase occurs at periods long after harvest.

5- **Hired labor activities:** The Gezira scheme farmers use both family labor (F.L.) and hired labor (H.L.) in conducting their field crop production activities. Table (3) shows the portions of the matrix representing H.L. activities. The labor hiring activities were introduced in the models to supplement the family labor on monthly basis. The unit of the activity is one manday (8 hours of work per day). A standard manday was taken as the effort exerted by a healthy adult in the age of 15-65 years in working day. A one day labor input was assumed to be 0.75 standard manday for women and 0.5 for children and old person [6]. The objective function coefficient of each of the hired labor activities represents average monthly wage rates estimated from the field survey. The coefficients carry negative sign since they draw from the value of the objective function.

6- **Capital borrowing activities:** In practice, Gezira scheme advances credit to tenants for cotton crop. Table (4) shows the portions of the matrix representing borrowing activities. Borrowing activities are used to supplement the amount of cash owned by the farmers, and include formal sources of finance mainly the Agricultural Bank of Sudan (ABS). The bank lending terms depend on Morabaha system, where the Morabaha margin for the year 2011 was 12%. This rate appeared as a negative coefficient in the objective function.

7- **Transfer capital activities:** Eleven transfer capital activities were included in the model to permit the transformation of capital from one month to another. The coefficients of capital transfer in the objective function carry zero values since it does not involve money transactions. Table (5) depicts the proportion of the matrix representing transfer of capital activities.

8- **Capital repayment activities:** This is composed of two types of repayment:-

1-Repayment of Gezira scheme advances which appeared as operating capital for the tenants in the model, it required that the total of the repayments should be paid back at the end of the season.

2- Repayment of the borrowed capital. These two have a zero objective function coefficient and they are linked to their respective constraints (Table 4).

Table (1): Crop production activities in the Gezira scheme Season, 2011/12

Activities	unit	cotton	Sorghum	groundnuts	wheat	onion	chickpea	Dir	RHS
Objective fun		-936.7	-683.5	-1020.5	-1045.9	-1982.5	-787.7		
Constraints									
Total land	Fed	1	1	1	1	1	1	<=	20
Cotton	" "	1						>=	0
Sorghum	" "		1					>=	0
Groundnuts	" "			1				>=	0
Wheat	" "				1			>=	0
Onion	" "					1		>=	0
chickpea	" "						1	>=	0
Jun labour	m.d/fed	1.39	7.25	15.07	0	0	0	<=	36
Jull labour	" "	10.57	3.29	6.18	0	0	0	<=	36
Aug labour	" "	8.97	7.3	6.18	0	0	0	<=	36
Sep labour	" "	5.4	6.63	3.4	0	0	0	<=	36

Oct labour	" "	3.4	1.82	3.4	1.42	1.54	0	<=	36
Nov labour	" "	3.4	8.53	7.38	2.52	12.64	8.75	<=	36
Dec labour	" "	8.8	0	0	3.07	9.48	6.9	<=	36
Jan labour	" "	0	0	0	4.1	8.24	8.2	<=	36
Feb labour	" "	0	0	0	3.6	8.24	3.2	<=	36
Mar labour	" "	2	0	0	1.8	12.92	1.6	<=	36
Apr labour	" "	0	0	0	0	0	7.62	<=	36
May labour	" "	0	0	1.27	0	0	0	<=	36
Jun water	CM/fed	0	0	373	0	0	0	<=	8200
Jull water	" "	292	0	731	0	0	0	<=	8200
Aug water	" "	547	145	846	0	0	0	<=	8200
Sep water	" "	877	575	646	0	0	0	<=	8200
Oct water	" "	990	877	0	0	0	0	<=	8200
Nov water	" "	788	666	0	320	511	292	<=	8200
Dec water	" "	183	0	0	800	701	768	<=	8200
Jan water	" "	0	0	0	864	593	718	<=	8200
Feb water	" "	0	0	0	570	323	282	<=	8200
Mar water	" "	0	0	0	0	244	163	<=	8200
Apr water	" "	0	0	0	0	0	0	<=	8200
May water	" "	0	0	0	0	0	0	<=	8200
OC Jun	SDG/fed	225	221.5	160.5	0	0	0	<=	17400
OC Jull	" "	123.3	93.6	277.5	0	0	0	<=	0
OC Aug	" "	224.8	122	36.4	0	0	0	<=	0
OC Sep	" "	44.7	36	0	0	454	0	<=	0
OC Oct	" "	0	0	337.2	242.1	94.7	200	<=	0
OC Nov	" "	0	210.1	0	279	314.8	133.3	<=	0
OC Dec	" "	120.6	0	0	229.1	56	120.3	<=	0
OC Jan	" "	75	0	0	39.3	56	56	<=	0
OC Feb	" "	0	0	0	0	1007	0	<=	0
OC Mar	" "	121.5	0	0	54.1	0	31	<=	0
OC Apr	" "	0	0	0	202.3	0	247.2	<=	0
OC May	" "	0	0	208.9	0	0	0	<=	0
Cotton prod	Kantar/fed	-5.2						<=	0
Sorghum prod	Sack/fed		-7.8					<=	0
Ground prod	Sack/fed			-14.7				<=	0
Wheat prod	Sack/fed				-8			<=	0
Onion prod	Sack/fed					-80.5		<=	0
Chickpea prod	Sack/fed						-6	<=	0
Sorghum cons	Sack							=	12.5

Source: Constructed from survey data

Table (2): Crops selling, consumption and buying activities in the Gezira scheme, season 2011/12

activities	unit	Cotton selling	Sorghum selling	G.N selling	Wheat selling	Onion selling	Chickpea selling	Sorghum cons	Sorghum buying	Dir	RHS
Obj.function		475	164	102.2	155	48.5	235	0	-170		
constraints											
OC Jun	SDG/fed									<=	17400
OC Oct	" "		-164							<=	0
OC Nov	" "			-102.4						<=	0
OC Mar	" "					-48.5				<=	0
OC Apr	" "	-475			-155		-235			<=	0
Cotton prod	Kantar/fed	1								<=	0

Sorghum prod-	Sack/fed		1					1	-1	<=	0
Groundnut prod	Sack/fed			1						<=	0
Wheat prod	Sack/fed				1					<=	0
Onion prod	Sack/fed					1				<=	0
chickpea prod-	Sack/fed						1			<=	0
Sorgh- cons	Sack							1		=	12.5

Source: Constructed from survey data
***OC =** Operating capital *pro = production *G.N = Groundnut *cons = consumption *fed = feddan

Table (3): Labour hiring activities in the Gezira scheme, season 2011/12

Activities constraints	Objective function			HL 1 -15	HL 2 -15	HL 3 -15	HL 4 -15	HL 5 -15	HL 6 -15	HL 7 -15	HL 8 -15	HL 9 -15	HL 10 -15	HL 11 -15	HL 12 -15
	sign	unit	RHS												
Jun labour	<=	M.D	36	-1											
Jull labour	<=	" "	36		-1										
Aug labour	<=	" "	36			-1									
Sep labour	<=	" "	36				-1								
Oct labour	<=	" "	36					-1							
Nov labour	<=	" "	36						-1						
Dec labour	<=	" "	36							-1					
Jan labour	<=	" "	36								-1				
Feb labour	<=	" "	36									-1			
Mar labour	<=	" "	36										-1		
Apr labour	<=	" "	36											-1	
May labour	<=	" "	36												-1
OC Jun	<=	SDG	17400	15											
OC Jull	<=	" "	0		15										
OC Aug	<=	" "	0			15									
OC Sep	<=	" "	0				15								
OC Oct	<=	" "	0					15							
OC Nov	<=	" "	0						15						
OC Dec	<=	" "	0							15					
OC Jan	<=	" "	0								15				
OC Feb	<=	" "	0									15			
OC Mar	<=	" "	0										15		
OC Apr	<=	" "	0											15	
OC May		" "	0												15

Source: Constructed from survey data

Table (4) Borrowing capital activities in the Gezira scheme, season 2011/12

Source: Constructed from survey data

Activities constraints	Objective function			Bc1 -.12	Bc2 -.12	Bc3 -.12	Bc4 -.12	Bc5 -.12	Bc6 -.12	Bc7 -.12	Bc8 -.12	Bc9 -.12	Bc10 -.12	B11 -.12	B12 -.12	Cap rep	End cap
	sign	unit	RHS														
OC Jun	<=	SD G	17400	-1													
OC Jull	<=	" "	0		-1												
OC Aug	<=	" "	0			-1											
OC Sep	<=	" "	0				-1										
OC Oct	<=	" "	0					-1									
OC Nov	<=	" "	0						-1								
OC Dec	<=	" "	0							-1							
OC Jan	<=	" "	0								-1						
OC Feb	<=	" "	0									-1					
OC Mar	<=	" "	0										-1				
OC Apr	<=	" "	0											-1			
OC May	<=	" "	0												-1		
Cap rep	<=	" "	0	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1	
End cap	=	" "	17400														1

*Bc = Borrowing capital

Table (5) Transfer capital activities in the Gezira scheme, season 2011/12

Source: Constructed from survey data

constraint	Activities			Tc 1/2	Tc 2/3	Tc 3/4	Tc 4/5	Tc 5/6	Tc 6/7	Tc 7/8	Tc 8/9	Tc 9/10	Tc 10/11	Tc 11/12
	Objective function			0	0	0	0	0	0	0	0	0	0	0
	sign	unit	RHS											
OC Jun	<=	SD G	17400	1										
OC Jull	<=	" "	0	-1	1									
OC Aug	<=	" "	0		-1	1								
OC Sep	<=	" "	0			-1	1							
OC Oct	<=	" "	0				-1	1						
OC Nov	<=	" "	0					-1	1					
OC Dec	<=	" "	0						-1	1				
OC Jan	<=	" "	0							-1	1			
OC Feb	<=	" "	0								-1	1		
OC Mar	<=	" "	0									-1	1	
OC Apr	<=	" "	0										-1	1
OC May	<=	" "	0											-1

*Tc = Transfer capital

(b) Constraints set:

The constraints set of the model includes the following:

1- **Land:** The average tenancy is 20 feddan in main Gezira scheme. The total land in the model is restricted as equal to or less than 20 feddans. After Act 2005, the farmers are free to choice crops to grow that means no fixed rotation, the field survey found that the average area cultivated was 4, 4, 2, 3, 4 and 3 feddan for cotton, sorghum, groundnut, wheat, onion and chickpea, respectively.

2- **Labour:** In this study, the minimum available monthly labour (in mandays) to the household was estimated by the survey to be 36 mandays.

3- **Irrigation:** Irrigation was expressed in amount of irrigation water available to the tenant on a monthly basis. The available irrigation water in the Gezira scheme during the growing season was 8200 CM. This amount of irrigation water available represents the right hand side of irrigation constraint, table (1).

4- **Operating capital and credit constraint:** In this study, the Gezira scheme advances for cotton are used as operating capital. Additional operating capital was obtained from borrowing, off farm income and crops sales.
5- **Sorghum consumption:** Sorghum consumption was estimated from field survey by 12.5 sacks per household per year.
6- **Production balance equation:** This refers to the fact that the crop produced is used through sales and/ or consumption.
7- **Capital repayment:** Borrowing capital in the model was restricted to be paid back at the end of the season with a 12 percent Morabaha margin.

III. Results and Discussion

This part gives the results of the linear programming model discussing the basic solution and presents the different scenarios by changing the parameters of the basic model in the sensitivity analysis. The results of the basic model were compared to the actual situation.

3.1 Optimal production plan

3.1.1 Cropping pattern

From table (6), it is clear that most of the land is allocated to onion crop which was 8.68 feddans, followed by cotton crop which is 6.88 feddans, while sorghum and groundnuts entered in the optimal plan with small areas 1.74, and 0.92 feddans respectively, wheat and chickpea did not enter in the optimal plan. In the real situation cotton, sorghum, and onion occupied about the same area (4 feddan), followed by wheat and chickpea, (3 feddan), and then groundnuts (2 feddan). From table (6), it is clear that cotton crop increased from 4 to 6.88 feddans by 72% compared to actual land allocated while onion crop increased from 4 to 8.68 feddans by 117%.

Comparison of the optimal and actual net farm income shows a difference. The actual net return was about SDG 11735.86 while the optimal plan's returns was SDG18697.24 which was more than actual one by 59.3%.

3.1.2 Resources use

The levels of resource use are shown in Table (6). It is clear that there is difference between the actual total land allocated and optimal total land, which was 20 and 18.22 feddans, respectively. It also noticed that the total labor mandays required for the basic solutions were 360 mandays and the actual mandays utilized in the Gezira scheme were 382mandays. In the basic solution, about 83.33% of available family labour was utilized in the Gezira scheme compared to 91.65% in the actual situation. 83.32% of the available hired labour was utilized in the Gezira scheme compared to 86.76% in the actual situation. Percentage of the hired labor out of the total labour in the basic solution was 61.74% as compared to 61.74% in the actual situation. About 83.33% of the total labour available was utilized in the basic solution compared to 88.42% in the actual situation. The total quantity of water required for the basic solutions were 59125.6 C.M and the actual cubic meter utilized in the Gezira scheme are 57982 C.M. In the basic solution, about 60.09% of available water was utilized in the Gezira scheme compared to 58.9% in the actual situation. The result of the basic model there was no cash problem cash except in March and April months. In March and April months there was a shortage in cash to meet harvesting operations.

Table (6): Optimum solutions of the basic model of the Gezira scheme in comparison with the actual situation.

Item	Model	Actual
Total land	18.22	20
Cotton land	6.88	4
Sorghum land	1.74	4
Groundnuts land	0.92	2
Wheat land	0	3
Onion land	8.68	4
chickpea land	0	3
Total labour	360	382
Family labour	137.74	146.15
Hire labour	222.26	235.85
% of F.L/ Total F.L	83.33%	91.65%
% of H.L/ Total H.L	83.32%	86.76%
% of utilized H.L/T.L.	61.74%	61.74%
% of utilized T.L/T.L.	83.33%	88.42%
Total quantity of water requirement C.M	59125.6	57982
%of utilized of water/ water available C.M	60.09%	58.9%
Net farm income SDG	18697.24	11735.86

Source: Program computed

3.2 Sensitivity analysis

Sensitivity analysis is the investigation that deals with changes in the optimal solution due to changes in the data [8]. The basic solutions of the LP models were developed by changing their parameters to present different policy analysis scenarios. These scenarios examined the impact of productivities, cost of production and prices on the crop mix and net farm income of the basic solutions. Table (7) depicts different scenarios of crops combination in the Gezira scheme.

3.2.1 Impact of crops productivities:

Sc1- Increase of productivity of cotton and sorghum crops by 25%

Cotton crop gains foreign currency and sorghum crop considered the crop which meets food security in the Gezira scheme area, Gezira scheme administration and Gezira Research Situation seek to increase the yield of these crops. Increase of productivity of cotton and sorghum crops by 25% in the basic model change net farm income and crops mix. Net farm income increased from 18697.24 SDG to 23411.96 SDG (by 25.2%). Sorghum area increased from 1.7 feddan to 2.08 feddan, while cotton, and onion did not change in areas, groundnuts, wheat, and chickpea did not enter the plan.

Sc2- Restricting sorghum area to the level required to meet consumption:

By restricting sorghum area in the Gezira scheme model to 2 feddans in order to produce 12.5 sacks, which is equal to the amount consumed by family during the year. The net farm income decreased from 18697.24 SDG to 18677.84 SDG (by 0.1%). Sorghum increased from 1.74 to 2 feddan, while groundnuts decreased from 0.92 to 0.22 feddan, and other crops did not change in areas.

3.2.2 The impact of prices:

Sc3- Increased of cotton price by 25%

Cotton price depends on world marketing price, increase demand for cotton in world market lead to increasing cotton prices. Increase price of cotton crop by 25% in the basic model did not change crops mix. It only increased the net farm income from 18697.24 SDG to 22947.5 SDG (by 22.7%).

Sc4- Decrease of cotton and onion price by 25%

Decrease of prices of cotton and onion crops by 25% in the basic model changed net farm income and crops mix. Net farm income decreased from 18697.24 SDG to 6572.3 SDG (by 64.8%). Cotton, groundnuts, and onion areas decreased from 6.88, 0.92, and 8.68 to 6.3, 0.41, and 5.26 feddans, respectively, while sorghum and chickpea increased from 1.74 and zero to 2.8 and 4.72 feddan, respectively, wheat crop did not change in area.

3.2.3 The impact of production cost:

If there is a body (scheme management, farmer union …etc) supply or provide the inputs (seeds, fertilizers, pesticides and sack) at lower marginal cost price, this will reduce production cost of all crops change scenarios used.

Sc5- Lowering cost of all crops by 25%

Scheme management supply or provide the inputs (seeds, fertilizers, pesticides and sack) at lower marginal cost price, this will reduce production cost of all crops change, lowering costs of all crops by 25% in the basic model changed net farm income and crops mix. Net farm income increased from 18697.24 SDG to 25156.8 SDG (by 34.5%). The groundnuts increased from 0.92 to 1.53 feddan, sorghum decreased from 1.74 to 1.52 feddan, while other crops did not change in areas.

Sc6- Lowering cost of cotton and wheat by 25%

Lowering costs of cotton and wheat by 25% in the basic model did not change crops mix. It only increased the net farm income from 18697.24 SDG to 20288.6 SDG (by 8.5%).

Sc7- Lowering cost of cotton and wheat by 50%

Lowering costs of cotton and wheat by 50% in the basic model did not change crops mix. It only increased the net farm income from 18697.24 SDG to 21920.6 SDG (by 15.6%).

Table (7): Different scenarios of crops combination (in feddan).

Scenarios	Cotton	Sorghum	Groundnuts	Wheat	Onion	Chickpea	Net farm income/SDG
Sc0	6.88	1.74	0.92	0	8.68	0	18697.24
Sc1	6.88	2.08	0	0	8.68	0	23594.12
Sc2	6.88	2	0.22	0	8.68	0	18677.84
Sc3	6.88	1.74	0.92	0	8.68	0	22947.5
Sc4	6.3	2.8	0.41	0	5.26	4.72	6572.3
Sc5	6.88	1.52	1.53	0	8.68	0	25156.8
Sc6	6.88	1.74	0.92	0	6.68	0	20288.6
Sc7	6.88	1.74	0.92	0	6.68	0	21920.6

Source: Compiled by the author

IV. Conclusions

The results of LP models revealed that the net farm income in the optimal models was over the current situation by 59.3%, and for the basic model has cash problem to meet harvesting operations only for March and April months. The study revealed that there optimal model and all scenarios wheat crop unprofitable did not enter the plan.

References

[1] Ahmed, A.E. (2004). Economic Analysis of Irrigated Cotton Production Constraints in Sudan: Case study Gezira scheme. Ph.D. Thesis, University of Giessen, Germany.

[2] Heady, E.O and W.Canler (1973). Linear Programming Methods. The Iowa University Press, Ames, Iowa, U.S.A.

[3] Hazel, P.B.R. and R.D. Norton (1986). Mathematical programming for Economic Analysis in Agriculture. Macmillan Publishing Company New York, U.S.A.

[4] Khalid, Y. E. Ibrahim (2010). Economic Efficiency Analysis. A Case Study of Crops Production in the Rahad Agricultural Corporation. Ph.D. Thesis, Sudan University of Science & Technology, College of Graduate Studies.

[5] Ahmed, B.T., 2005. The determination of agricultural production and optimum cropping pattern in Northern State, Sudan. Ph.D. (agric) Thesis. University of Khartoum, Sudan.

[6] Abdelaziz, H.H., 1999. Analysis of small private farm production system: A case study of the River Nile State Ph.D. (agric) Thesis. University of Khartoum, Sudan.

[7] Ahmed, A.T., 1988. An Agricultural sector model for the Northern region of Sudan to evaluate new faba beans technologies. Ph.D. (agric) Thesis. Purdue University.

[8] Gass, S.I., (1985).linear programming: method and applications. Mc Graw-Hill: New York, U.S.A.

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