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Research Article

Linear programming: optimization of the productivity and income of small scale farmers in Azum locality of Central Darfur State, Sudan

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Abstract: The study is attempts to know the optimum crop combination that maximize farmers' income during 2017/2018 cropping season. Questionnaires household survey was applied for primary data. 50 household was randomly selected. Clustered random sampling technique was applied. Linear programming model used for data analysis. Although descriptive statistical analysis was run for mean, frequencies and percentages. Results of socioeconomic characteristics indicated that the age group of the household was range between 30 – 50 years. Further Analysis explored that the average family size was 8 person. I t was also noted that 72% of the households have different education levels while only 18% has no schooling. Descriptive analysis also showed that 72% of households practicing agricultural farming. It was observed that 46% of household agreed with extension services and 54% said no extension activities. Results concerning extension methods founded that 28.6% of household having extension via demonstration farms and 34.7% by cross visit. Statistical results of the household also explored that 26% trained in technology transfer while 74% have no training. The optimal solution result of field crops recorded that cultivation of 0.8, 3.175, 0.5, 0.7, and 0.3 hectare of Millet, sorghum, groundnut, watermelon and cowpea earned a total of SDG of 74,254 gross margins. While for vegetables crops, cultivation of 0.76, 2.94 and 0.43 hectare of potato, onion and tomatoes obtained a total of SDG 138,657. Partial crop budget showed that most crops gave positive net returns, while some others gave negative returns. The highest net returns was obtained by potato (SDG 80407) followed with mango 66953 SDG, millet SDG 14521 and sorghum SDG 10857. The study recommended that enhancing food security situation through improved technology is necessary in the study area.
Keywords: Linear programming, productivity, optimization, Descriptive statistics.

1. INTRODUCTION

Darfur contributes largely to Sudan's food security, which dominates the Sudanese economy. In fact, food security through increased crop production is amongst the highest priorities of Darfur States that accords a high attention to the issue and provides support to the food production and productivity almost in all the food insecure (FAO & WFP, 2012) localities. In spite of the fact that agriculture in Sudan contributed by about 31% to the gross domestic product of the country in 2011, yet labour force engaged in it exceeds 75% of total population, with majority being in Darfur. Most crop production in Darfur is typically a traditional rain-fed farming of small-scale farms. However, limited areas devoted for semi-mechanized farming in South Darfur where farms are large and mechanization as well as manual labours employed. Some farmers practice winter farming, mostly vegetables production, using wadi and small-scale irrigation techniques. However, crop performance in both season results in low yields, reflecting unreliable rainfall, poor soils, low-input agriculture and low level of technology adoption. This is due to many reasons among which limited research efforts on improved cultivation practices for both rain-fed and *wadi* crops, weak coordination and linkages among stakeholders, unfavorable climatic conditions, weak implementation capacity of SMOA and SMOAR, and poor transfer of agricultural technologies are the most that has not been satisfying the interest of all the categories of the farmers.

Agriculture is the main economic activity of the population in Central Darfur state. The majority of the population depends heavily on cereal crops

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production as a main source of Livelihood and income; they make use of their local knowledge to achieve food security (Sabahalkheir *et al*, 2015). People cultivate many varieties of cereal crops in Central Darfur state; some were indigenous, while others were introduced.

Azum economy is predominantly based on agriculture which is not only a source of food for most households but also a source of revenue both in food, cash crops sales and in the creation of labour opportunities. The agricultural sector of Azum employs more than 70% of the workforce through small-scale, mainly subsistence-oriented family farming units. However, the performance of this sector is very poor and most of the population lives under the national poverty line. The high prevalence's of poverty and hunger are mainly attributed to the rapid population growth which leads to land scarcity and degradation. The increase in agricultural production remains generally lower compared to the rate of population growth.

2. Research Objectives

The overall goal of the study is to ensure food security: In addition the specific objectives were:-

- To estimate the situation in a mathematical way and reaching conclusion results reflecting the optimum combination of resources at farmer level.
- To draw picture of agricultural decision and plans of agricultural specialist in smallholder farming as an alternative way out of poverty.

3. MATERIALS AND METHODS

The area of the study is located between latitudes 12 – 13^0 N and longitudes 22 – 23^0 E. The micro study was conducted during 2017/2018 cropping season. The total population was 65,670 person and the rain fall is 450 – 500 mm. Questionnaires household survey was applied for primary data collection. 50 household was randomly selected to represent the whole area of the study. Clustered random sampling technique was applied. Descriptive Statistic analysis was run for mean, frequencies and percentages. Linear programming model used for data analysis. Partial crop budget used to run cost benefit analysis.

3.1 Linear Programming

Linear means a proportionate relationship of two or more variables in the model. Linear Programming is a mathematical technique used for optimum allocation of limited or scarce resources by choosing the best alternative from a set of feasible solutions in a situation in which objective function as well as constraints can be expressed as linear mathematical relationships (Kaur, cited 2018). Accordingly the linear programming model is specified as:-

Maximize Z = ∑cjxj +∑cj*xj*   objective Function:
Subject to:
∑aijxj ≤ bi constrained equation
xj and xj* ≥ 0 non-negativity constraint activities
Where:
Z = Gross margin
cj = Price of production activities
xj = level of jth production activity
cj* = price of non production activity
xj* = level of jth non production activity
aij = the ith resource required for a unit of jth activity
bi = the resource available with the sample farmers
j = refers to number of activities from 1 to n
i = refers to number of resources from 1 to m

Constraints
(i) Land/hectare
∑aijxj≤ OL and ∑aijxj≤ RL,
Where: OL and RL are the size of owned land and rented land holding, respectively.

(ii) Family labour/man days
∑atj-htxj* ≤ Lt, htxj* ≤ At
Where:
Lt and At = available family labour and hired labour in the t th period.
ht = is the amount of hired labour required in the t th period for jth* activity.
Atj = is the amount of labour required in the t th period for jth activity.

(iii) Working capital/SDG
∑kijxj ≤ WK
Where:
WK = is the amount of available working capital
Kij = is the amount of working capital required for production and non production activities.
Working capital is the value of inputs (purchased or owned) allocated to an enterprise with the expectation of a return at a later point. The cost of working capital is the benefit given up by the farmer by trying up the working capital in the enterprise for a period of time, (Breima, annual report 2016).

3.2. Partial Crop Budget

Partial budgeting analysis was used to estimate the returns for crops grown based on the average price and productivity. The total variable costs were calculated by summing up the different variable costs. The average price multiplied by productivity equal to the gross margin and the net returns equal the difference between gross margin and average variable cost (Breima *et al*, 2015).

4. RESULTS AND DISCUSSIONS

4.1 Linear programming formulation

4.1.1 The objective function: maximize z.

Z = ax1+bx2+cx3+dx4+ex5 + Fx6 for field crops

Z = ax1+bx2+cx3+dx4+ ex5 for vegetable crops

Where a, b, c, d, e, F are coefficients of objective function.

The general formula of the inequalities:

Ax1+Bx2+Cx3+Dx4+Ex5 Fx6 ≤ H (for field crops)

Ax1+Bx2+Cx3+Dx4+Ex5 ≤ H (for vegetable crops)

Where A, B, C, D, E, F are the coefficient of the constraints inequalities and H is the right hand side.

The production activities and decision variables used in the study for Field crops are:

X1= sorghum, X2 = millet, X3 = G/nut, X4 = sesame x5 = watermelon, x6 = cowpea

The production activities and decision variables used in the study for vegetable crops are:

X1 = potato, X2 = onion, X3 = Tomato, X4 = rocket, X5 = eggplant, table 3.

4.1.2 Optimal Solution or Base Model Results, Field Crops

The maximum crop combination was obtained by Millet, sorghum, groundnut, watermelon and cowpea. It should be noted that by cultivating 0.8, 3.175, 0.5, 0.7, and 0.3 hectare of Millet, sorghum, groundnut, watermelon and cowpea, a total of SDG of 74254 gross margins can be obtained, Table 4.

4.1.3 Optimal Solution or Base Model Results, Vegetable Crops

It was observed that the optimal solution of the base model reached by potato, onion and tomatoes with SDG gross margin of 60780, 75231 and 2646 with cultivating area hectare of 0.76, 2.94 and 0.43, respectively. A total of SDG 138,657 was earned by vegetable crops, Table 5.

4.1.4 Partial crop budget analysis

Result of partial crop budget in table 6 indicated that most crops gave positive net returns except okra, radish and Guava. The highest net returns obtained by potato (SDG 80407) followed by mango (SDG 66953), cowpea (SDG 26078), watermelon (SDG 16630), millet (SDG 14521) and sorghum (SDG 10857).

Table: 1 demographic structure of the household

pentameter	**freq.**	**valid %**
Age structure		
less than 30 year	7 (14%)	14
31 – 40 year	19 (38%)	38
41 – 50 year	16 (32%)	32
51 – 60 year	4 (8%)	8
above 60 year	3 (6%)	6
not cited	1	2
Total	**50**	**100**
Education levels		
illiterate	9	18
khalwa	2	4
elementary	17	34
primary	11	22
secondary	9	18
university	1	2
post graduate	1	2
Total	**50**	**100**
Occupation structure		
farmer	36	72
herder	1	6
trader	3	2
farmer/trader	1	14
free works	7	2
not cited	1	
Total	**50**	**100**
Extension services structure		
yes	23	46
no	27	54
total	**50**	**100**
Extension methods		
demonstration farms	14	28.6
T & V system	1	2
cross visit	17	34.7
field training	2	4.1
not cited	6	
Total	**50**	**100**
Training on technology transfer		
yes	13	26
no	37	74
total	**50**	**100**

Source: Author, 2017

Table: 2 family size structures

parameter	**N**	**minimum**	**max.**	**sum.**	**mean**	**stdv.**
family number	50	2.00	17	415	8	3.2903
male number	50	1.00	9.00	153	3.060	1.9421
female number	50	1.00	8.00	157	3.14	1.6036
children number	47	1.00	7.00	133	2.8298	1.4792

Source: Author, 2017

Table: 3 linear programming tableaus

Row name	X1	X2	X3	X4	X5	X6	RHS
Field crops							
Max. Z	**10857**	**14521**	**5482**	**1764**	**16630**	**26078**	
Land/ha	1	1	1	1	1	1	6
Labor/Man days	54	48	48	24	40	48	262
WC/SDG	1050	1105	5694	845	315	315	9324
Average cultivated area/ha	0.8	0.5	0.5	0.3	0.7	0.3	156
Vegetable crops							
Max. Z	**80407**	**25616**	**6154**	**1592**	**956**		
Land/ha	1	1	1	1	1		5
Labor/Man days	120	130	50	90	104		494
WC/SDG	13750	1912	470	76	3.5		16211
Average cultivated area/ha	0.4	2	0.43	1.2	0.4		59

Source: HHs survey 2016, max = maximization, WC = working capital, SDG = Sudanese Genih

Table: 4 shows optimal solution, field crops

Crop	Coefficients	Area/feddan	Optimal solution	Final value SDG
sorghum	10857	0.8	8686	8686
millet	14521	3.175	46104	46104
groundnut	5482	0.5	2741	2741
sesame	1764	0	0	0
watermelon	16630	0.7	11641	11641
cowpea	26078	0.3	7823	7823
Total				**74,254**

Source: HHs survey 2017

Table: 5 shows optimal solution, vegetable crops

Crop	Coefficients	Area/ feddan	Optimal solution	Final value SDG
potato	80407	0.755899644	60780	60780
onion	25616	2.936861867	75231	75231
tomato	6154	0.43	2646	2646
rocket	1592	0	0	0
eggplant	956	0	0	0
Total				**138,657**

Source: HH survey 2017

Table: 6 partial crop budgets

crop	yield kg/ha	Gross field benefit SDG/ha	Cost variation SDG /ha	Net returns SDG/ha
Mango	4550	68250	1297	66953
Rocket	29	2900	1308	1592
Guava	222	2664	3111	(447)
Okra	1108	3324	4233	(909)
Sorghum	2037	15341	4484	10857
Sesame	1639	6556	4792	1764
G/nut	882	10702	5220	5482
millet	2111	19901	5380	14521
Radish	389	3890	6250	(2360)
eggplant	972	9720	8764	956
watermelon	6734	27778	11148	16630
tomato	8988	17976	11882	6154
onion	17361	38780	13164	25616
cowpea	5863	41041	14963	26078
potato	10071	100710	20303	80407

Source: HH survey 2017

CONCLUSIONS

The statistical analysis founded the household posses' large family size and sizable education level. The results of linear programming identified that sorghum; millet, groundnut and cowpea were the most common crops can be cultivated by small farmers, while potato, onion and tomato were the best among vegetable crops. Partial crop budget also indicated that the investment of potato, mango, cowpea, sorghum, millet production in the study area was highly profitable.

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