Food Security and Resource Allocation among Small Farming Households in Rain-fed Sector of Arid Zones in North Kordofan State, Sudan

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ABSTRACT

The current study was conducted in North Kordofan State, during two consecutive cropping seasons (2010/11 and 2011/12). The area represents the middle parts of the state covering all Bara localities, part of En-Nuhud and parts of Um Ruwaba localities . It is characterized by mixed rain-fed crops and livestock, agro-pastoral and household economy. The main objectives were to determine the optimum field crop combination that maximizes small- holders' profitability, to access food security situation in terms of food intake and net income, to estimate contribution of different production factors to the variation of different crop yields and to calculate the international competitiveness and comparative advantage for economic efficiency of resource allocation of different farming system for cash, food and minor crops grown. in the study area. The primary data were collected via structured questionnaire using multi-stage random sampling technique to select 130 householders. Linear programming (L.P), partial crop budget (P.B.), robust regression, household economy approach (HEA) and policy analysis matrix (PAM) as empirical analytical tools were used. The L.P results showed that, the optimum crop combination that maximized the small farmer gross margin (SDG 743 or US $ 406) was to grow 0.552 feddan (0.42 ha.) of sorghum and 3.576 feddan of millet. Results of partial crop budget revealed that, sorghum and millet gave highest gross margin of SDG 206 and 176 respectively. The coefficient of estimates for land, labor and capital showed significant difference from zero at level of 10%, and the average farm produced 96% of the potential production. The daily energy received per person per day equals 1133 Kcal, which was below the recommended amount. This result gives indication to the unbalanced food intake by households in terms of energy need and in term of net income. Accordingly, the area can be described as food insecure. Results obtained by PAM revealed that millet, sorghum and groundnuts production in the area have extremely high comparative advantage and international competitiveness. The study findings concluded that food security in the area can be realized by following the optimum cropping combinations, mitigating factors affecting comparative advantages and competitiveness, allocating production resources efficiently and improving nutritional status of people using recommended energy intake.

Keywords: Resource allocation, arid zone, food insecurity, optimum crop combination

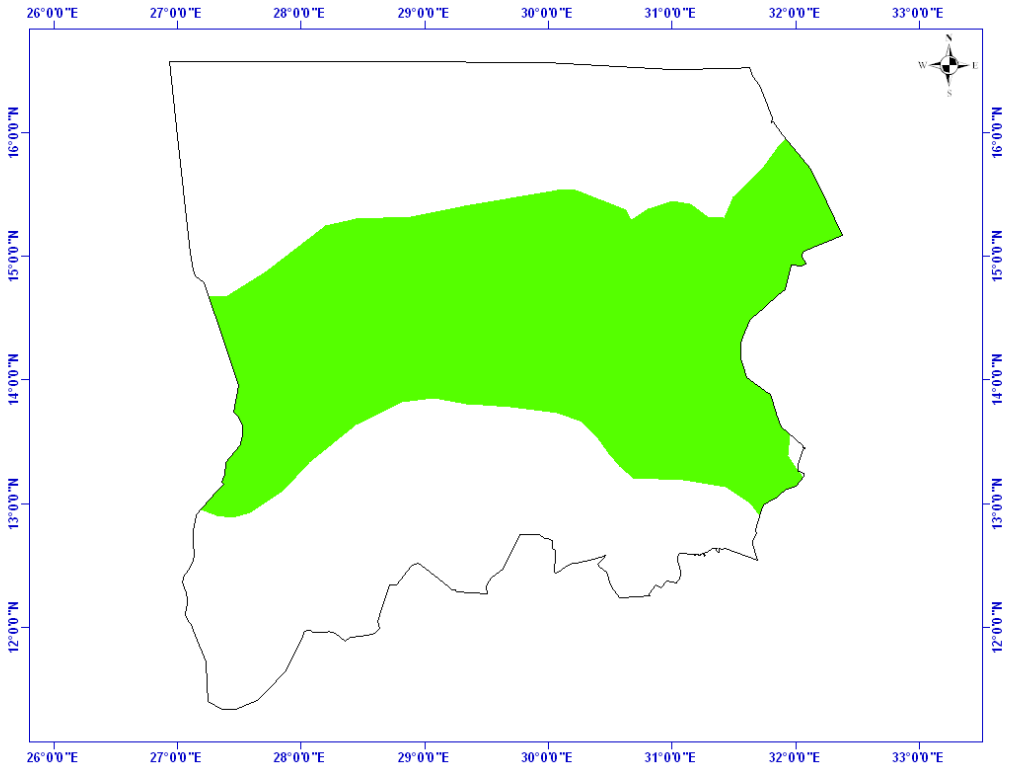

Fig 1: The study area across North Kordofan State,Sudan

INTRODUCTION

North Kordofan state is situated in central-western Sudan at the northern edge of the Savanna belt. The region is semi-arid and characterized by recurrent episodes of drought and increasing desertification. I t is located between longitudes 27.00 East and latitudes 12.20 and 16.40 North, (Daw El Bait, 1999). The State occupies an area about 242,000 square kilometers or about 59 million feddan. The study area represent the middle parts of the state covering all Bara localities, part of En-Nuhud and parts of Um Ruwaba locality for the traditional rain fed agriculture.Sorghm and millet are grown in the area as staple food crops, where as sesame and groundnuts as important cash crops, food and cash crop production in the area is constraint by several biotic(pest and diseases) and a biotic factors(such as erratic rainfall amount and distribution, drought episodes) that curtailed crop productivity and production to lower levels coupled with high production cost. Rural small farmers are frequently drudgeredby crop failure leading to inevitable food insecurity and poverty. FAO (2012) stated that Africa is still most seriously affected by food shortages, this situation is more critical in East Africa and famine conditions are emerging in several parts of the Horn of Africa. As a result of recurrent droughts and food shortages, many initiatives have emerged over the years ranging from addressing the problem to mitigation efforts. The food-security situation in North Kordofan reflected chronic poverty rather than a transitory situation. It is seemed to improve gradually from the north towards the south, with northern households having much-less-favorable consumption indicators. This appeared to be due to the generally drier conditions in the north, which limited the livelihood options of the people in the area (*ANLA - WFP Sudan - 2007*). Most farmers of North Kordofan State are of small holdings featured with low productivity, hence gaining low income, although the state is rich in natural resources providing livestock, gum Arabic, ground nut, Roselle, melon seed and food crops such as millet and sorghum. The productivity of the above mentioned crops is low compared with the national figure in the irrigated and mechanized sub-sectors. This is mainly due to the inefficient use of the resources, pest infestation, poor varieties, infertile soil and limited credit facilities. Although farmers in the study area cultivate both food and cash crops, but their present cropping patterns do not maximize their profit; so they need an appropriate crop combination that maximize

their profit and make efficient use of the available resources to achieve food security in the study area. According to Squire and Barnum, (1979) in the household production, profit maximization can be answered by comparing the estimated increase in output accompanying an increase in factor input with the factor price. It is well-known result of the theory of the firm that, if a firm is making optimum use of productive inputs (Land, Labor and Capital) output will be carried to the point at which the costs of additional inputs are equal to the value of additional output. Hazell and Norton (1986) reported that linear programming model is a method of determining a profit maximization combination of farm enterprises that is feasible with respect to a set of farm constraints. Partial budgeting is a method of organizing experimental data and information about the cost and benefits of the various alternative treatments (*Cimmyt, 1988).* Cafiero, 2003 stated that, PAM is best organized in terms of commodity systems, which are defined as the vertically integrated chains of production activities that go from the farm production to the retail market for consumption, including any processing and marketing activity that may exist in between. Robust regression provides an alternative to least squares regression that works with less restrictive assumptions. Specifically, it provides much better regression coefficient estimates when outliers are present in the data (*Hamilton, 1991*).

MATERIALS AND METHODS

To accomplish the objectives of the study, both secondary and primary data were collected using various tools .Due to the large size of the study area, along with the homogeneity exhibited in the socio-economic characteristics of rural population in the area under study random sample technique was used.

2.1 linear programming models.

Hazell and Norton (1986) reported that linear programming model is a method of determining a profit maximization combination of farm enterprises that is feasible with respect to a set of farm constraints. Linear programming model has been developed to determine the area to be used for different crops for maximum contribution and for improving farmers' income. The model expressed as follows:

*** Objective equation**

Maximize Z = $\sum_{j=1} c_j x_j$

Subject to:

$\sum a_{ij} x_j \leq b_{i = 1 \text{ to } n}$

$Xj \geq 0$ all j = 1 to *m* non-negativity constraint activities

Where:

Z = Gross margin

c_j = Price of production activities

x_j = level of jth production activity

a_{ij} = the ith resource required for a unit of jth activity

b_i = 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

$\sum a_{ij} x_j \leq$ OL and $\sum a_{ij} x_j \leq$ RL,

Where: OL and RL are the size of owned land and rented land holding, respectively.

(ii) Family labour

$\sum at_j - htx_j \leq Lt$, $htx_j \leq At$

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.

At_j = is the amount of labour required in the t th period for jth activity.

(iii) Working capital

$\sum k_{ij} x_j \leq WK$

Where:

WK = is the amount of available working capital

K_{ij} = is the amount of working capital required for production and non production activities.

***The objective function: maximize z.**

Z = $ax_1+bx_2+cx_3+dx_4$

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

The general formula of the inequalities:

$Ax1+Bx_2+Cx_3+Dx_4 \leq H$

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

2.1.1 Model specifications

Four crops were grown in this area, x_1 = sorghum, x_2 = millet, x_3 = groundnut and x_4 = sesame. Production of one feddan required 10, 13, 13, 16, and 234, 184, 235 and 134 man hours of labor and SDG of working capital for Sorghum, millet, groundnut and sesame, respectively. Thus 52 man hours of labor is available for producing all crops during the year. Table (1).

Table (1) linear programming tableau, in rain-fed sector in arid areas of North Kordofan State

Row name	**X1**	**X2**	**X3**	**X4**	**RHS**
Objective function	206	176	164	69	**Max.**
Resource constraint					
Land/ha	1	1	1	1	323
Labor/MH	10	13	13	16	52
Working capital/SD	234	184	235	134	787
Av. cultivated area/ha	**4.48**	**1.6**	**2.5**	**0.77**	

Source: Study Field survey 2012. Where, RHS = right hand side, and AV. = average.

2.2 Partial crop budgeting

Partial budgeting is a method of organizing experimental data and information about the cost and benefits of the various alternative treatments *(Cimmyt, 1988).*

2.3 Food security situation for the households

2.3.1 Households income

The main sources of income for household were agricultural production (crop production and animal production), and off –farm activities.

2.3.2 Households expenditure

The food needed by households classified into three categories which are the food consumed in summer, autumn and winter as it is expected that people consumed different quantities of food among the different seasons. When the quantities of food consumed by households in the different seasons summed together and the average is calculated.

2.4 Robust regression

Robust regression techniques are iterative procedures that seek to identify the outliers and minimize their impact on the coefficient estimates. The amount of weighting assigned to each observation in robust regression is controlled by a special curve called an influence function. There are three influence functions available.

2.5 Policy analysis matrix (PAM)

The aim of PAM is to ascertain whether these products are efficient in terms of international competitiveness and comparative advantage, and whether these products deserve continuing government support. The coefficients of the PAM models that measure the economic efficiency and policy distortions are:

1. Nominal Protection Coefficient on Output (NPCo).
2. Effective Protection Coefficient on Input (NPCi).
3. Profitability Coefficient (PC).
4. Subsidy ratio to producer (SRP).

5. Domestic Resource Costs (DRC).

According to Mahmoud (2004) there are two main activities in a constructing a PAM database:

1. Establishing the production system budget at private prices.
2. 2.Social valuation of inputs and outputs.

RESULTS AND DISCUSSION

3.1 The optimal solution

The crop combination of the small holders in this area was to grow 0.552 feddan of sorghum and 3.576 feddan of millet to get maximum gross margin equal SDG 811.95, table (2).This agrees with Sheikh Eldien (2013) who reported that, the optimality in this area comes with the cultivation of millet and sorghum.

Table (2): Optimal solution of crop cultivation in rain-fed sector in arid areas in North Kordofan State in SD/feddan

Crop	**Value/ SDG**
Sorghum	114
Millet	629
Groundnuts	0
Sesame	0

Source: Study Field survey (2012)

Results of partial crop budget revealed that, sorghum and millet gave best gross margin of SDG 206 and 176 respectively, Table (3).Results of food security situation when taking into account the newly adjusted optimal solution for food items requirement, the gross margin for the area, was found to be SDG of 10894.5, this makes an increment in gross margin by 77.88%, Table (4). Results of household's income and expenditure revealed that, the net household income found to be negative in this. The daily energy received per person per day was equal to 1138 Kcal, while the recommended Stephen (2006) Kcal was 2100 so accordingly, the daily energy received per person per day was below that amount. This result gives indication to the unbalanced food intake by households in terms of energy need and in term of net income and accordingly, the area is food insecure. Results of the adjusted household's income and expenditure revealed that, the net household income found to be positive in this area, table (5).Results of robust regression for millet production, found that, the coefficients of estimates for land, labor and capital were significantly different from zero at ten percent level and land labor and capital inputs reached higher goodness of fit of 91%. While for sesame was highly significant different from zero at one percent level and resources of production gave 88% goodness of fit. Groundnut estimates has also showed highly significant different from zero at one percent level and 92% goodness of fit and thus sorghum revealed highly significant different from zero at one percent level and 86% goodness of fit. This result indicated that all coefficients were statistically significant and important inputs Table (6).Results of PAM for rain-fed crop production in the area showed extremely higher financial (SDG 244) and economic (SDG 546.64) profitability. The NPC (equivalent to 0.53) and EPC (equivalent to 0.47) showed high burden of direct and implicit taxes imposed on the vegetables production within the marketed product (47%) and farming system (53%). The DRC and CIC results obtained in such respect revealed that millet production in the cluster has extremely high comparative advantage and international competitiveness, since the DRC ratio is far less than one (0.138) and the CIC expresses that only SDG 0.29 is invested to gain US$ that can be acquired by the SDG 1.8 (OER)/ 2.11 (SER) . For sorghum production the NPC (equivalent to 0.78) and EPC (equivalent to 0.71) showed the burden of direct and implicit taxes imposed on sorghum production within the marketed product (22%) and farming system (29%). The DRC and CIC results obtained in such respect revealed that sorghum production in the area has a very high comparative advantage and international competitiveness, since the DRC ratio is far less than one (0.07), the CIC expresses that only SDG 0.15 is invested to gain one US$. For groundnuts the NPC (0.43) and EPC (0.35) showed the high burden of direct and implicit taxes imposed on groundnuts production within the marketed product (57%) and farming system (65%). The DRC and CIC results obtained in such respect revealed that groundnuts production in the cluster has extremely high comparative advantage and international competitiveness, since the DRC ratio is far less than one (0.04) and the CIC expresses that only SDG 0.09 is invested to gain one US$, Table, (8), (9), (10) .

Table (3): Partial Crop Budget in Rain-fed sector in Arid Zones of North Kordofan State by kg and SDG./Feddan

Cultural practices	**Crops**			
	Sorghum	Millet	Ground nut	Sesame
Bush cleaning	23.3	20	33.3	20
Sowing	27	25	43.3	25
Ist weeding	45.8	40	33.3	30
2nd weeding	31.7	25	36.7	-
Harvesting	45	45	45	40
Threshing	48.0	17.5	26.4	-
Packing	4	4	3	4
Transportation	8.20	7.7	14	15
Total variable costs	234.0	184	235	134
Farm gate price	1.354	1.42	1.02	1.25
Yield	325	253.52	391.18	162.40
Gross out put	440	360	399	203
Gross Margin(GM)	**206.0**	**176**	**164**	**69**

Source: Study Field survey (2012)

Table (4): The optimal solution adjusted final value and the Effect on gross margin in rain-fed sector in arid areas of North Kordofan State

	crops	area	Final value	Average Cultivated area	Adjusted final value	Existing gross margin	%increment in gross margin
	X1	0.552	811.95	9.35	1839.1	1667.61	10.3
	X2	3.58					
Total		4.128					

Source: Study Field survey 2012

Table (5): Effects of adjusted gross margin on food items cost, in rain-fed sector in arid areas of North Kordofan State

Adjusted gross margin	**Cost of food items SDG.**	**Net income**
10894.5	7770	2698.5

Source: Study Field survey, 2012

Table (6): Resource use of estimates of robust regression, in rain-fed sector in arid areas of North Kordofan State

Coefficients	**crops**			
	millet	**sorghum**	**sesame**	**groundnut**
Intercept	74.6*(19.9)	26.5(13.1)	-93.7(20.1)	-124.7(30.9)
Land (x1)	9.6*(3.8)	9.8(3.12)	-20.9(4.7)	-23.9(6.5)
Family labor(x2)	10.0*(1.3)	0.23(0.36)	-0.18(1.7)	-4.8(1.23)
Hired labor(x3)	-8.3*(0.56)	-6.7(3.0)	0.93(0.42)	-5.5(1.6)
Capital (x4)	-18.6*(4.0)	-2.9(0.95)	20.7(3.6)	35.4(7.5)
Adj. R squire	95.8	88.5	87.9	92
F value	47.6*	22.19***	22.99***	40.8***

Source: Study Field survey 2012. * Significant at 10%, ** significant at 5%, *** significant at 1%, na=not available

Table (7): Household Weekly Food Need and the equivalent K.cal in Rain-fed Sector in Arid areas of North Kordofan State

Food item	Kcal/kg	Summer		Autumn		Winter	
		qt.kg	Total Kcal	qt.kg	total kcal	Qt.kg	total Kcal
Sorghum	3350	0.89	2981.5	0.89	2981.5	0.89	2981.5
Millet	3350	5.78	1936.3	5.78	1936.3	5.78	1936.3
Wheat	3320	0	0	0	0	0	0
Meat	2020	0.73	1474.6	0.73	1474.6	0.73	1474.6
Milk	660	0	0	0	0	0	0
Sugar	4000	2.00	8000	2.00	8000	2.00	8000
Tea	685	0.18	194	0.16	173	0.19	205
Coffee	1080	0.14	96	0.89	610	0.89	610
Dry okra	350	0.22	77	0.22	77	0.22	77
Onion	410	1.78	801	1.78	801	1.78	801
Sauce	210	4.80	1008	0.47	98.7	0.63	132.3
Salt	710	0.30	213	0.40	284	0.40	284
Oil	8840	1.60	14144	1.50	13260	1.60	14144
Total			48352		47014		48063
Per person/day(6)							1138

Source: Study Field survey, 2012

Table (8): PAM indicators for Rain-fed sector in arid areas for Millet by kg and SDG/feddan in Rain-fed Sector in Arid areas of North Kordofan State

Contents of PAM Variables	Revenue (SDG)	Tradable inputs (SDG)	Cost of domestic resources (SDG)	Profitability (SDG)
Financial prices	359.97	60.72	123.28	244
Economic prices	677.69	43.25	87.81	546.64
Transfers	-317.72	17.47	35.47	-302.64

PAM Indicators/**feddan):**	
FP in SDG/feddan =	244
EP rin SDG/feddan =	546.64
PC=	0.446
NPC=	0.531
EPC	0.472
DRC=	0.138
CIC=	0.291

Source: Study Field survey 2012

Table (9):): PAM indicators for Rain-fed sector in arid areas for Sorghum by kg and SDG/feddan

Contents of PAM Variables	Revenue (SDG)	Tradable inputs (SDG)	Cost of domestic resources (SDG)	Profitability (SDG)
Financial prices	438.75	77.22	156.78	259
Economic prices	564.75	55	36.75	356.01
Transfers	-126	22.22	120.03	-97.01

PAM Indicators/feddan):

FP in SDG/feddan =	259
EP in SDG/feddan =	356.01
PC=	0.73
NPC=	0.78
EPC	0.71
DRC=	0.07
CIC=	0.15

Source: Study Field survey 2012

Table (10): PAM indicators for Rain-fed sector in arid areas for Groundnuts by kg and SDG/feddan

Contents of PAM Variables	Revenue (SDG)	Tradable inputs (SDG)	Cost of domestic resources (SDG)	Profitability (SDG)
Financial prices	399.64	77.55	157.45	164.64
Economic prices	938.14	18.33	37.22	882.59
Transfers	-538.50	59.22	120.23	-717.95

PAM Indicators/feddan):

FP in SDG/feddan =	164.64
EP rin SDG/feddan =	882.59
PC=	0.19
NPC=	0.43
EPC	0.35
DRC=	0.04
CIC=	0.09

Source: Study Field survey 2012

CONCLUSION

Within the crops grown in the area, the optimality came with cultivation of 0.552 feddan of sorghum and 3.576 feddan of millet to get maximum gross margin equal SDG 811.95 Partial crop budget indicated that, Sorghum and millet gave highest gross margin of SDG 206 and 176 respectively,. The entire abovementioned partial budget results were validated with linear programming results. According to the annual income and expenditures, the net household income found to be negative. This result reflects the bad food condition in the area. The daily energy received per person per day was below than that amount of Stephen (2006) throughout in this area (1138 k.ca.). This explained why net house hold income was negative. This result explicitly conferred evidence to the unbalanced food intake by households in terms of energy need and net income. When taking into account the newly adjusted optimal solution and compared it with the previous annual average cost for food items requirement, the gross margin for the area, found to be SDG 2432.7. This makes an increment in gross margin by 132%. This high increment in gross margin will be having positive effect in increasing the amounts of food items and hence reduce the food insecurity situation in this area. Also the increment in the gross margin makes the net income to be SDG 3358.3.This will in turn reduce the food insecurity in the area. When taking resource use under consideration; robust regression was used for crops grown in the area. In the case of millet, sesame, groundnuts and Sorghum production, the highest measure of fit (R^2) was estimated to be 93%, 80%, 83% and 88% respectively. These results implied that the greater part of the variations in the yield was explained by the resource factors.

REFRENCES

ANLA-WFP Sudan, (2007): *Rapid Food Security Assessment of IDP.*

Cimmyt, (1988). *From agronomic data to farmer recommendation: An economic training manual PP 8-37.*

Davies, S.M. Buchanan and Lambert, R. (1991): *Early Warning in the Sahel and Horn of Africa, the State of the Art. A Review of the Literature, Institute of Development Studies, Volume 1, Research Reports, University of Sussex, Brighton, U.K.*

Daw El Beit En Nur. (1999)*. Consequences of Coping with Drought in North Kordofan; M.Sc Thesis; University of Coventry; London; England*

Eldukheri, I. A. A. (1997). *Past Changes and Future Prospects of Traditional Rain fed Farming in North Kordofan, Sudan, PhD. Thesis, University of Munchen, Germany.*

Food and Agricultural Organization *(FAO, 1994): The State of Food and Agriculture, Food and Agriculture Organization. Agricultural series No 27, ISBN 92 – 5 – 103550-4, Rome.*

Food and Agricultural Organization *(FAO, 2012): Policy Statement and Plan of Action of the World Food Summit, Draft Working Paper at Inter-sectional Working Group of the Committee of World Food Security,Rome.*

.***Hamilton, L. (1991).*** *Regression with Graphics: A Second Course in Applied Statistics. Brooks/Cole Publishing Company. Pacific Grove, California Nations.*

Hazell, P. B. R. and Norton, R. D. *(1986). Mathematical programming for economic analysis in agriculture. Macmillan publishing company, University of New Mexico press, New York, USA. PP 1-77*

Mahmoud,T.E.(2004): *The Adequacy of price incentive on Production, Processing and Marketing of Gum Arabic In Sudan. Case of North and West Kordofan.Ph.D. Dissertation, Technical University of Dresden, Germany.*

Maxwell, S. (1992): *Food Insecurity in North Sudan, Discussion Paper no 262, IDS, University of Sussex, Brighton.*

Sheikh Eldin,M.T.(2013*):Optimality and Food Security in Arid Rain-fed areas of North Kordofan State.*

Stephen, Devereux. (2006): *Methods used to Assess Household Food Insecurity.*

Squire, L. and Barnum, H. N. (1979). *Household production. A model of an Agricultural Household, Theory and Evidence. World Bank Occasional Papers No. 27. The johns Hopkins University Press, Baltimore and London. PP 7-8.*