Optimal Selection Of Crops: A Casestudy Of Small Scale Farms In Fanteakwa District, Ghana.

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Abstract: The main purpose of this study was to present a formulated Linear Programming(LP) Model for 16 selected small scale farmers from 32 operational areas of Fanteakwa District in the Eastern Region of Ghana. The study considered ten (10) crops namely garden eggs, water melon, cabbage, onion, tomato, cucumber, okra, pepper, cocoa (nursery) and plantain. The formulated LP Model for this study assumed profit maximizing behavior, a single-period planning and a certain environment. The formulated LP Model suggested no production of sole crop enterprises like cabbage, onion, cocoa (nursery), pepper (grown on raised bed), pepper and garden egg (grown on raised bed + irrigation). The model also prescribed no production for crop mixtures like garden egg/okra and cabbage/cucumber/pepper. The formulated LP Model prescribed production of 1 acre of garden egg, 3 acres of watermelon, 4 acres of tomato, 2 acres of cucumber, 1 acre of plantain, 2 acres of garden egg (irrigation), 1 acre of okra/garden egg/pepper and 1 acre of pepper/garden egg. Comparison of results obtained by using existing farming plan and the LP Model indicate that results obtained from the LP Model were significant improvements of the existing farming plan. The LP Model saved 0.2% and 0.6% of available capital and labor requirement respectively. A 16.25% significant increment of the net returns was obtained by the LP Model. This was as result of net returns increasing from GH¢77,848.00 to GH¢88,177.00. These results suggest the essence of application of formulated mathematical models like the LP Model to planning and management of limited resources.

Index Terms: Linear Programming; Cropping Patterns; Small Scale Farms; Net Returns; Optimal Solution.

1 INTRODUCTION

Farmers and for that matter small scale farmers are faced with complex decisions to make in every growing season. Decisions about which crops to grow, by what method and in what quantities to produce always confronts them. These decisions made by these farmers are subject to the prevailing farm physical and financial constraints. In developing countries and for that matter Ghana, small scale farmers rely on experience, intuition and comparisons with their neighbors to make their decisions. These decisions made by the small scale farmers lack budgeting techniques and comparative analyses which are key ingredients, useful for making decisions about which crops to grow, by what method and in what quantities, Hazel and Norton [4]. According to Hazell and Norton [4], whole-farm planning which is achieved by the application of linear programming could aid small scale farmers to efficiently adapt to a changing economic and technological environment. Linear Programming is a method of determining a profit maximizing combination of farm enterprises that is feasible with respect to a set of fixed farm constraints, Hazell and Norton [4]. In the agriculture sector extensive studies have been done in the application of linear programming models to allocation of limited resources. In the study done by Igwe et al. [7], the technique of Linear Programming was used to determine optimum enterprise combination using 2009/2010 farm data in Abia State, Nigeria. Majeke [9], developed a linear programming planning model for a farm to address the resource allocation problem in Zimbabwe.

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Crops included this study were tobacco, maize, soya beans and potatoes. Results showed that tobacco gained acreage by 128% and potatoes by 38%. Ofori et al. [11], formulated a Linear Programming Model that incorporated System of Rice Intensification (SRI) in Ghana. Results of this study indicate that the LP Modelsaved 50% of irrigation water in both the major and minor seasons and also obtained an increment of 101.50% of the net returns. Gadge et al. [2] formulated linear programming model to suggest the optimal cropping pattern for surface ir-rigation in a command area. The objective of this model was to achieve the maximum net benefits. Hassan et al. [3] utilized LP Model to calculate crop acreage, production and income. Kakhki et al. [8] applied and com-pared linear programming model and a fuzzy multi-objective fractional programming model in Taybad. Frizzone et al. [1] optimized water resource using LP Model. Majeke et al. [10], modeled a small farm livelihood using Linear Programming Model in Zimbabwe. Results obtained from the model were compared to traditional farming method and a difference of 44.65% was achieved with the model. Igwe and Onyenweaku [5] and Igwe et al. [6] applied Linear Programming Models to determine optimum food crops and livestock in Nigeria. This present study seeks to formulate a linear programming model for sixteen (16) small scale farmers in the Fanteakwa District to help obtain optimal selection of sole crop and mixed crops considering farmers' resources that would maximize the net profit. The model considers ten (10) crops namely garden eggs, water melon, cab-bage, onion, tomato, cucumber, okra, pepper, cocoa (nursery) and plantain. The Linear Programming Model for this study assumes profit maximizing behavior, a single-period planning and a certain environment in other words no uncertainty about yields, prices etc. - Hazell and Norton [4].

2 MATERIALS AND METHODS

2.1 Study Area

Fanteakwa District lies within longitudes $0°32.5°$West and $0°10°$ East and latitudes $6°15°$ North and $6°40°$ North. The district is located exactly in the middle of the Eastern Region. It is bordered to the North by the Volta Lake, North - West by

Kwahu South District, South - West by East Akim District, East by ManyaKrobo and South East by YiloKrobo Districts. The district has a total land area of 1,150 sqkm and cultivable area of 76,133 ha. Fig. 1 captures Fanteakwa District and it sub - districts.

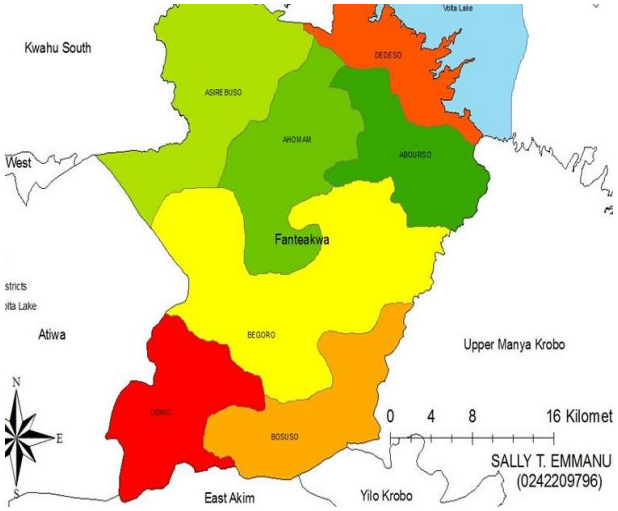

Fig. 1. *Map Showing all Sub-Districts of Fanteakwa District*

The district is generally hilly and has an undulating land form. Average height of the land is about 8,762 meters above sea level. The principal soil type is the forest ochrosol and the major rock types are the Birimian and Voltarian formations. The vegetation of this district consists basically of the wet-semi deciduous rain forest and the savanna scrub which is found to the North of the district on the hills close to the Volta Lake. Rainfall in this district is bimodal with major rains staring from March to early August with maximum in June and minor rains starting from late August to November with maximum in October. The mean annual rainfall forthe district is between 1,500 mm and 2000 mm. Bush fallow alongside slash and burn are the farming systems in the district. The crop farming patterns in the district are mixed, mono and inter cropping. In the area of animal farming, livestock and poultry are the main animals kept. These include cattle, sheep, goats and poultry. The cattle is found in the northern fringes of the district along the lake where the grassland vegetation is mostly predominant. Average farm size in the district is 1 hectare.

2.2 Data and Method of Solution

Data for this study were both primary and secondary. The secondary data was obtained from the Ministry of Food and Agriculture and the primary data were collected from the 16 farmers in the 32 operational areas of the district via face - to - face interview. These farmers were selected based on the reason that the major crops grown in the study area are cropped by these farmers. Also these selected farmers are evenly located in the 32 operational areas of the Fanteakwa District. The main crop farming patterns in the study area are practiced by these 16 selected farmers. Table 1 captures the data for the study.

TABLE 1
FARMERS AND THEIR RESPECTIVE CROPPING PATTERNS AND CAPITAL

Farmer	Cropping Patterns	Capital (GH¢)
1.	Garden egg	3,700.00
2.	Watermelon	5,045.00
3.	Cabbage	4,485.00
4.	Onion	6,660.00
5.	Tomato	3,184.00
6.	Cucumber	3,050.00
7.	Cocoa(Nursery)	350.00
8.	Pepper(Bed)	2,000.00
9.	Plantain	1,000.00
10.	Garden Egg(Irrigation)	2,000.00
11.	Pepper	1,500.00
12.	Garden Egg(Bed + Irrigation)	3,500.00
13.	Garden Egg/Okra	3,300.00
14.	Okra/Garden Egg/Pepper	700.00
15.	Pepper/Garden Egg	2,500.00
16.	Cabbage/Cucumber/Pepper	3,000.00
	Total	**45,974.00**

Source: *Field Survey, 2014.*

TABLE 2
RESPECTIVE LAND AREA, LABOR AND NET PROFITS.

Land Area (Acres)	Labor (GH¢)	Net Profit (GH¢)
5	870.00	5,300.00
3	1,300.00	8,951.00
3	1,340.00	6,071.00
2	2,000.00	8,470.00
4	1,284.00	5,656.00
2	950.00	8,200.00
0.5	150.00	700.00
2	800.00	3,000.00
1	400.00	2,500.00
2	600.00	3,500.00
1.5	600.00	2,000.00
3	1,200.00	4,500.00
6	1,000.00	5,500.00
2	200.00	1,500.00
1	800.00	6,000.00
4	1,000.00	4,000.00
42	**14,494.00**	**75,848.00**

Source: *Field Survey, 2014*

The solution to the Linear Programming Problem was obtained using the Simplex method with an available computer program.

2.3 Linear Programming Model (LP)

LP is one of the approaches of mathematical optimization techniques which uses several related concepts of mathematics to allocate limited resources among competing demands in an optimal way. It uses models in mathematics to describe problems of concern. The application of linear programming as an optimization tool is dependent on five(5) conditions and these are:

1. There are limited resources.

2. There is an explicit objective function (knowing what each variable is worth and what the goal is in solving the problem).
3. The equations are linear (no exponents or cross products).
4. The resources are homogeneous (everything is in one unit of measure).
5. The decision variables are divisible and nonnegative.

The LP Model formulated in this paper was based on data obtained from the farmers that were interviewed. The farming resources of interest in this study were captured by the formulated model as crop production which iseither sole crop or crops mixture, capital for farming enterprise, cost of labor, area of land for cultivation of crops and the net profit for the crops of interest. In the area of crop production, critical features like raised beds used for cropping and the use of irrigation water in growing crops were incorporated into the formulated LP model. Profit maximizing behavior, a single-period planning and a certain environment are the assumptions underlying the formulated LP Model for this study. Linear Programming Problem was formulated as:

Maximize:

$$\boldsymbol{Z = \sum_{i=1}^{n} N_i X_i, i = 1, 2, 3, \ldots\ldots\ldots, n.}$$

Variable description:

$Z = The\ total\ net\ returns\ from\ all\ the\ crops\ (GH¢)$
$n = The\ number\ of\ crops$
$N_i = The\ net\ return\ from\ ith\ crop\ (GH¢)$
$X_i = The\ area\ under\ ith\ crop\ (acres)$

Constraints
Subject to:

Land usage:

$$\boldsymbol{\sum_{i=1}^{n} X_i \leq TA}$$

Where:
$TA = Total\ Land\ area\ under\ cultivation\ of\ crops\ in\ acres.$

Capital:

$$\boldsymbol{Z = \sum_{i=1}^{n} C_i X_i \leq TC}$$

Where:
$C_i = The\ capital\ requirement\ for\ ith\ crop\ (GH¢)$
$TC = The\ total\ capital\ requirement\ for\ all\ the\ crops$

Labor:

$$\boldsymbol{\sum_{i=1}^{n} L_i X_i \leq TL}$$

Where:
$L_i = The\ labor\ requirement\ for\ the\ ith\ crop(GH¢)$
$TL = The\ total\ labor\ requirement\ for\ all\ the\ crops.$

Non-negativity:
$Xi \geq 0\ for\ i = 1, 2, 3, \ldots n.$

3 RESULTS AND DISCUSSION

Table 3 presents the comparison of existing cropping patterns with optimal cropping patterns. Table II depicts the number of crops that entered the optimal solution and their respective percentages over the existing plan in terms of acreage to be used in the cultivation of the optimal crops. Results from Table 3 indicate no production of sole crop enterprises like cabbage, onion, cocoa (nursery), pepper (grown on raised bed), pepper and garden egg (grown on raised bed + irrigation). Also the LP Model prescribed no production for crop mixtures like garden egg/okra and cabbage/cucumber/pepper. The optimal solution prescribed the production of 1 acre of garden egg, 3 acres of watermelon, 4 acres of tomato, 2 acres of cucumber, 1 acre of plantain, 2 acres of garden egg (irrigation), 1 acre of okra/garden egg/pepper and 1 acre of pepper/garden egg. Table 4 captures the comparison of results on resource utilization of existing plan with optimal solution. Resultsfrom Table III indicate 100% usage of land by both the existing plan and the optimal solution. In the field of capital utilization, the existing plan used up all the capital available (100%) whilst the optimal solution made a savings of GH¢103.00 (0.2%). This implies that the optimal solution used 99.8% of the available capital. In the area of labor requirements, the existing plan used up the entire available requirement for labor (100%) whilst the optimal solution made a savings of GH¢88.00 (0.6%). This implies that the optimal solution used 99.4% of the available resource for labor requirement.

TABLE 3
COMPARISON OF EXISTING CROPPING PATTERNS WITH OPTIMAL CROPPING PATTERNSFOR FANTEAKWA DISTRICT

Cropping Patterns	Existing Cropping Plan Size of Farm (Acres)	Optimal Cropping Plan Size of Farm (Acres)	% of Existing Plan
Garden egg	5	1	20%
Watermelon	3	3	100%
Cabbage	3	0	0%
Onion	2	0	0%
Tomato	4	4	100%
Cucumber	2	2	100%
Cocoa(Nursery)	0.5	0	0%
Pepper(Bed)	2	0	0%
Plantain	1	1	100%
Garden Egg(Irrigation)	2	2	100%
Pepper	1.5	0	0%
Garden Egg(Bed + Irrigation)	3	0	0%
Garden Egg/Okra	6	0	0%
Okra/Garden Egg/Pepper	2	1	50%
Pepper/Garden Egg	1	1	100%
Cabbage/Cucumber/Pepper	4	0	0%
Total	**42**	**42**	

TABLE 4
COMPARISON OF RESOURCE UTILIZATION UNDER OPTIMAL SOLUTION WITH EXISTING FARMING PLAN

	EXISTING PLAN		
Resources	**Land**	**Capital (GH¢)**	**Labor (GH¢)**
Available	42	45,974.00	14,494.00
Usage	42	45,974.00	14,494.00
% Usage	100%	100%	100%
Left Over	0	0	0
% Left Over	0%	0%	0%
	OPTIMAL SOLUTION		
Resources	**Land**	**Capital (GH¢)**	**Labor (GH¢)**
Available	42	45,974.00	14,494.00
Usage	42	45,871.00	14,406.00
% Usage	100%	99.8%	99.4%
Left Over	0	103	88
% Left Over	0%	0.2%	0.6%

Table 5 captures the comparison of results on total net returns of optimal solution with the existing total net returns obtained by the 16 farmers in Fanteakwa District. Result from Table IV indicates that the total net returns increased by 16.25%, i.e. optimal solution as a percentage of existing net returns. The increment of net returns from GH¢75,848.00 to GH¢88,177.00 shows a significant improvement in the net returns.

TABLE 5
COMPARISON OF TOTAL NET RETURNSUNDER OPTIMAL SOLUTIONWITH EXISTING FARMING PLAN

Total Net Returns(GH¢)		
Existing Net Returns	**LP Solution**	**% Existing Net Return**
75,848.00	88,177.00	16.25%

4 CONCLUSION

This study presented a formulated LP Model which helped in obtaining optimal selection of crops for 16 selected farmers in the Fanteakwa District given a set of fixed constraints and the maximization of their net returns. Comparison of results obtained by using existing farming plan and the LP Model show that results obtained from the LP Model were significant improvements of the existing farming plan. The LP Model saved 0.2% and0.6% of available capital and labor requirement respectively.A 16.25% significant increment of the net returns was obtained by the LP Model. This was as result of net returns increasing from GH¢77,848.00 to GH¢88,177.00. These results suggest the essence of application of formulated mathematical models like the LP Model to planning and management of limited resources.

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References

[1] J.A. Frizzone, R.D. Coelho, and D. Douradoneto; R. Soliant. Linear Programming Model to Optimize the Water Resource Use in Irrigation Projects: An Application to the Senator Nilo Coelho Project. Science Agric Piracicaba, 54:136–148, 1997.

[2] S. B. Gadge, S. D. Gorantiwar, Virendrakumar, and Mahesh Kothari. Linear Programming Approach for Allocation of Land and Water Resources in Canal Command Area under Surface Method of Irrigation- A Case Study. International Journal of Innovative Research in Science, Engineering and Technology, 3(4):153–168, 2014.

[3] Ishtiaq Hassan, Izhar Ahmed Khan muhammadArifRaza, and RehmatIlahi. Use of Linear Programming Model to Determine the Optimum Cropping Pattern, Production and Income Level: A Case Study from Dera Ghazi Khan Division. Journal Of Agriculture & Social Sciences, 1:32–34, 2005.

[4] Peter B. R. Hazell and Roger D. Norton.Mathematical Programming for Economic Analysis in Agriculture. Macmillan Publishing Company, 1986.

[5] K. C. Igwe and C. E. Onyenweaku.A Linear Programming Approach to Food Crops and Livestock Enterprises Planning in Aba Agricultural Zone of Abia State, Nigeria. American Journal of Experimental Agriculture, 3(2):412–431, 2013.

[6] K. C. Igwe, C. E. Onyenweaku, and L. Tanko. A Linear Programming Approach to Combination of Crop, Monogastric Farm Animal and Fish Enterprises in Ohafia Agricultural Zone, Abia State, Nigeria. Global Journal of Science Frontier Research Agriculture and Veterinary Sciences, 13(3):22–31, 2013.

[7] K.C. Igwe, C.E. Onyenweaku, and J.C. Nwaru.Application of Linear Programming to Semi-Commercial Arable and Fishery Enterprises in Abia State, Nigeria. International Journal of Economics and Management Sciences, 1(1):75–81, 2011.

[8] Mahmoud DaneshvarKakhki, Nasser Sahnoushi, and F. Salehi Reza Abadi.The Determination of Optimal Crop Pattern with Aim of Reduction in Hazards of Environmental. American Journal of Agricultural and Biological Sciences, 4:305–310, 2009.

[9] Felix Majeke. Optimum Combination of Crop Farm Enterprises: A Case Study of A Small-scale Farm in Marondera, Zimbabwe. International Researcher, 2:60–65, 2013.

[10] Felix Majeke, Majeke Judith, Mufandaedza Jonathan, and Shoko Munashe.Modeling a Small Farm Liveli-hood System using Linear Programming in Bindura, Zimbabwe. Research Journal of Management Sciences, 2(5):20–23, 2013.

[11] Johnson K. Ofori, CephasBosrotsi, and Joseph Otoo. Optimal Allocation of Irrigation Water for Rice Production in Ghana, Case Study: Kpong Irrigation Project (KIP). International Journal of Interdisciplinary Research and Innovations, 3(1):25–30, 2015.