Optimal Production Plan and Resource Allocation among Sedentary Agropastoralists in Adamawa State, Nigeria

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ABSTRACT--- ***Livestock-crop farming is an important component of agriculture among the agro-pastoralist. The study determined the best production plan and resource allocation among sedentary agro-pastoralists in Adamawa State of Nigeria. Multi-stage sampling was employed in selecting two hundred respondents in the study area. Linear programming technique was used to analyse the data collected. The optimal farm plan generated for maximizing total gross margin (TGM) recommended the two identified animal husbandry enterprises, namely; cattle/sheep/goat and cattle/sheep/goat/poultry enterprises although the former has the potential of generating much higher profit than the later. Consequently, the program recommended only two of the ten crop production enterprises, namely; maize/sorghum and maize/sorghum/rice/cowpea. The maximized Total Gross Margin (TGM) for livestock production enterprise was ₦655,095.14 per season, while that of the crop production enterprise was ₦220,194.92 per hectare. On the resource allocation and use pattern, farm size, hired labour and other costs were fully utilized in arriving at the optimal solution in livestock production enterprise; while farm size and seed were fully utilized in arriving at the optimal solution in crop production enterprise. It is recommended among others that the agro-pastoralist be educated on modern methods of agricultural production to raise their level of production. Also, production inputs especially improved seeds be made readily available and affordable to the farmers.***

Keywords--- Agro-pastoralism; Optimal production plan; Resource allocation; Adamawa State.

1. INTRODUCTION

Agro-pastoralism is the rearing of animals and the cultivation of crops by the same farmer on the same land or different lands [1]. Similarly, [2] defined agro-pastoralist as a group of people known for rearing animals and are now settled to cultivate land for subsistence. These group of people live and carry out their production and consumption activities together as a unit within their environment. This co-existence creates opportunities for beneficial and negative interactions. On the positive side, it has led to greater crop-livestock integration and increasing productivity. Contrarily, it has resulted in competition between animals and crops for land, labour and capital, and has also caused different social conflicts among actor-herders and farmers, owners and non-owners of livestock, mobile, sedentary and semi-sedentary populations. Each group uses cropland and livestock to varying degrees, having come from different starting points and with different goals and assets.

Livestock-crop farming play vital roles in agriculture in sub-Sahara Africa including Nigeria. In large parts of Africa, where agro-pastoralism is practiced, livestock have multiple productive functions, as they serve as buffers against biophysical and socio-economic risk for resource-poor farmers [3]. These farmers depend on them to plough their fields, manure their crops and supplement their starch-heavy diets with animal-sourced protein and micronutrients. Thus, the contributions of livestock to the sustainability of crop-livestock systems through improved crop productivity, natural resources management and household income are now given increasing priority in sub-Saharan Africa [4].

However, In many of the areas where mixed crop-livestock farming systems are practiced, land is usually being degraded as a result of over-exploitation through expansion of cropland and increasing mixture of livestock; hence, there is the need for development of more intensive and sustainable farming systems. Additionally, rural population has increased slowly over the years, while urban population has grown at the rate of about 3% per annum; It is projected that by 2020,

human population in West Africa will reach about 370 million, of which 42% will live in rural areas and about 35% will be engaged in Agriculture [5,6].

Also, climatic changes in the savannah vegetation belt have caused major changes in the pattern of livestock ownership and agricultural production. An increasing proportion of the stock is now owned by crop farmers, who invest their surplus revenue from crop sales in animal production when crop prices are higher. They also take advantage of low livestock prices during drought to acquire animals from poor farmers or pastoralists. Although the process has fostered crop-livestock integration into mixed farming, it has also created problems for pastoralists. The result has been an increase in demand for cereals such as sorghum and millet (which also produce residues for livestock), and a much increased urban demand for livestock products such as meat and milk. Consequently, grazing land has also continued to diminish due to urbanization. Where there is less grazing land, farmers need to make better use of crop residues on their farms, through livestock-crop farming systems.

The nomadic agro-pastoralists are now becoming sedentary agro-pastoralist; who produce crop and raise cattle principally by grazing natural pastures, with milk sales as the source of regular income. Their herd size tends to decline with period of settlement, and more involvement in crop farming. This situation calls for efficient and optimal use of meager productive resources available to them. Resource allocation according to [7] refers to technical concept of efficiency, which brings about great product to the society from given resources.

Agro-pastoralist households are assumed to meet their food need primarily from their own production and little if any from food purchase. Efficient allocation of resources through an optimal crop-livestock combination is usually among the multiple goals of the agro-pastoralists and this has not been fully achieved in small holder farm economy in sub-Saharan Africa [8]. [9] submitted that farmers may be seen as efficient under the family food survival strategy, they are however, inefficient under profit maximization objective as they produce sub-optimal mixtures of enterprise, allocate farm resources inefficiently, and over-utilize their land resources. Farmers' efficiency in resource allocation is reflected not only in the returns, but also in the sustainability of the production systems [10]. Presently, there is no empirical study on the optimal production plan and resource allocation among the agro-pastoralists in the study area to take advantage of the growing urban markets for crops and livestock products. Modelling of crop and livestock enterprises has remained at subsistence level and its applicability impaired by problems of calibration and lack of data. However, there is the need for a paradigm shift considering their importance in smallholder farming systems.

Conceptual Framework and Empirical Review

A linear programming (LP) is a widely used mathematical technique designed to assist managers in decision making and resource allocation. It is the simplest and the most common mathematical programming model and it involves the optimization of a linear function of one or more variables subject to one or more linear constraints. The model is useful in situations where the objective is to efficiently allocate scarce resources among competing activities [11].

The linear programming problem is an allocation problem which arises when the objective function to be optimized is known, alternative (but not equally efficient) courses of action or plans are available and resources for attaining the objective are limited. Allocation problems are generally concerned with the utilization of limited resources to best advantage [12]. If there were no resource constraints, the farmer perhaps could allocate resources without optimizing, or optimize without considering the allocation implication but not both [11]. Greater emphasis upon efficient utilization of the existing resources and combination of enterprises in an optimal manner is of paramount importance.

[13] used the linear programming and food security index to determine the optimal farm plan and food security situation among agro-pastoralist households in Giwa area of Kaduna State, Nigeria. The result revealed that the optimal farm plan that ensures food security among agro-pastoralist households recommended that an average household should devote 0.35 ha to the production of maize/sorghum and 2.60 ha to the production of maize/cowpea. Three resource constraints were used, namely; land, labour and capital. Of these only land was efficiently used in arriving at the optimal solution.

[14] determined the optimal farm plan in food crops and livestock enterprises in Aba Agricultural Zone of Abia State, Nigeria using the linear programming approach. The LP maximization model recommended that for optimum gross margin of ₦374,850.00 which is about 61.35% of the existing gross, an average farmer should devote 0.31 hectares to cassava/maize/yam/mucuna, while 0.14 of 500 birds of broiler 1 raised usually between January-May and 0.11 of 1,000 fish of 2 done between July-December and 0.07 of 15 pigs are produced.

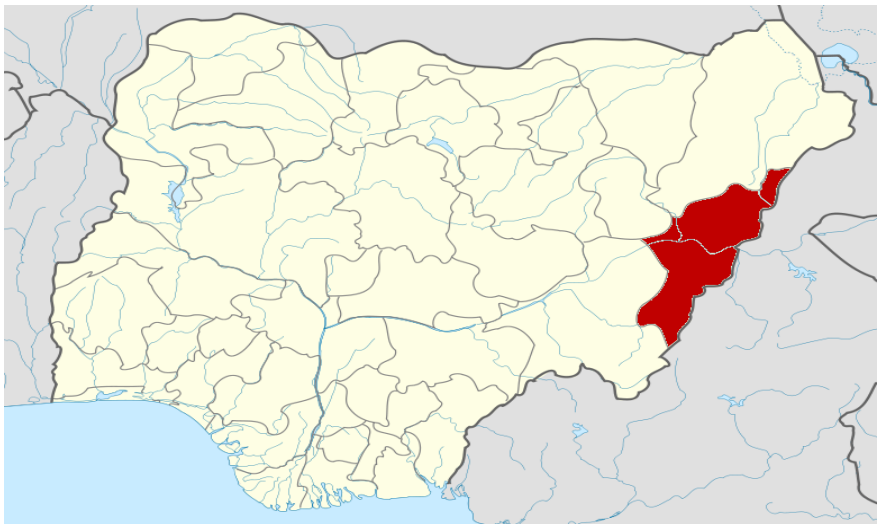
2. METHODOLOGY

Adamawa State is located in the North-eastern part of Nigeria between Latitudes 8^{o}N and 11^{o}N of the equator and Longitudes 11.5^{o}E and 13.5^{o}E of the Greenwich Meridian (Fig.1). The state is bordered to the east by the republic of Cameroun; while Taraba, Borno and Gombe states share border with the state to the south-west, north and north-west

respectively. The population of the State is 3.71million at a projected rate of 3.2% from the 2006 census [15]. The total land area of the State is approximately 38,741km^2, with about 22,604 km^2 being arable [16].

The climate of the state is characterized by distinct dry to rainy season which is typical of tropical climate. The dry season starts in November and ends in April, while the rainy season is between April and October. August and September are usually the wettest months with rainfall ranging from 700mm to 1600mm. The maximum temperature in the state can reach 46^{o}C particularly in April, while minimum temperature can be as low as 18^{o}C between December and January. Relative humidity is as low as 25% in March to as high as 80% in August [16].

The soils of the State are classified as ferruginous tropical, and generally have marked differentiation of horizons and abundance of free iron oxides usually deposited as red and yellow mottles of concretion. These soils include luvisols, legosols, combisols, verbisols, lithosols among others [17]. The major vegetation formations in the state are Southern Guinea Savannah, Northern Guinea Savannah and the Sudan Savannah. Within each formation is an interspersion of thickest tree savannah, open grass savannah and fringing forests in the river-valley. Majority of the inhabitants are farmers, cultivating different variety of crops and rearing of animals. The major crops of economic importance in the state include maize, millet, sorghum, rice, yam, cowpea and groundnut. Animals such as cattle, sheep and goats are the predominant livestock produced. The farming system in the area extends from mono-cropping to mixed farming.



Coordinates 9^{o}20'N 12^{o}30'E

Fig 1. Location of Adamawa State in Nigeria

Sampling Technique

Multi-stage sampling technique was employed in the selection of respondents for the study. The State is divided into 21 Local Government Areas and four administrative zones under the Agricultural Development Programme (ADP) namely; Mubi, Gombi, Mayo-Belwa and Guyuk zones. First stage sampling involved the random selection of one Local Government Area (LGA) from each of the four ADP administrative zones, making a total of four LGA. In the second stage, five (5) villages were also randomly selected from each of the four selected LGAs, making a total of 20 villages. Finally, purposive sampling was used in selecting 200 agro-pastoralists from the sampled villages in proportion to the size of the villages due to their relative high concentration.

Data Analysis

Linear programming was used to determine the optimum production level of resource allocation of the sedentary agro-pastoralists. It involves determining the enterprise combination that maximizes the Total Gross Margin (TGM) subject to production constraints associated with the available resources. The model equation as used by [18] is presented as:

$$Max\ Z = \sum a_i X_i \qquad \text{---------- (1)}$$

Subject to: $\sum b_j X_i \leq G_j$ ---------- (2)

and $X_i \geq 0$ ---------- (3)

Where Z = Total Gross Margin to be maximized as the objective function

a_i = Gross Margin of the i^{th} enterprise

b_{ij} = Input-output coefficients or the quantity of a resource i required to produce a unit of an activity

G_j = Available resources for the j^{th} activity

X_i = Decision variables to be maximized which are the different activities or enterprises

The iteration was done using the linear programming module TOS (TORA Optimization System) Version 2.00 [19].

Gross margin: This was obtained as the difference between the enterprise' total revenue and the total variable cost. It is a short term measure of profitability under the assumption that fixed cost component in production is negligible.

Input coefficients: The input coefficients for the livestock and crop enterprises were calculated on the basis of the actual quantities of different resources used for the particular livestock and crop enterprise.

Resource constraints/restrictions in the model: Six constraints were incorporated in the model. These were land(in hectares), inorganic fertilizer (in 50kg bags), seed (in kg), hired labour (in mandays), family labour (in mandays), crop residue (in naira) animal traction(bullock/day), other cost (replacement,bags,tranpost,vet service) in naira.

Enterprises/activities in the model: Agro-pastoralist production enterprises were grouped into livestock and crop production enterprises. For each of the crop production activity, the unit of activity was measured on per hectare basis, while that of the livestock productoin was measured on tropical livestock unit (TLU). Ten crop production enterprises were identified and used for the analysis. The linear programming input matrix used for the optimization iteration in crop production enterprise is presented thus;

Maximize Total Gross Margin: $55{,}297.55x_1 + 45{,}244.47x_2 + 42{,}200x_3 + 59{,}772.63x_4 + 31{,}150x_5 + 42{,}225x_6 + 62{,}533.33x_7 + 39{,}960x_8 + 46{,}980x_9 + 55{,}116.67x_{10}$

Subject to Constraints:

Land(ha): $2.49x_1 + 2.96x_2 + 1.0x_3 + 3.65x_4 + 2.00x_5 + 1.86x_6 + 2.15x_7 + 0.86x_8 + 1.19x_9 + 2.11x_{10} \leq 15.38$
Seed(ha): $3.04x_1 + 4.27x_2 + 7.8x_3 + 3.47x_4 + 3.9x_5 + 4.12x_6 + 3.82x_7 + 2.64x_8 + 5.30x_9 + 2.11x_{10} \leq 6.15$
Fert (kg): $1.79x_1 + 1.77x_2 + 2.5x_3 + 2.22x_4 + 2.5x_5 + 1.88x_6 + 2.34x_7 + 4.11x_8 + 2.56x_9 + 2.15x_{10} \leq 38.33$
Family Labour: $7.49x_1 + 7.93x_2 + 8.00x_3 + 7.91x_4 + 9.00x_5 + 8.32x_6 + 6.38x_7 + 11.24x_8 + 8.11x_9 + 7.02x_{10} \leq 25.37$
Agro-Chemicals: $0.46x_1 + 0.61x_2 + 0.38x_3 + 1.27x_4 + 1.11x_5 + 0.49x_6 + 0.32x_7 + 1.12x_8 + 0.96x_9 + 1.13x_{10} \leq 4.42$

Two livestock production enterprises were identified and used for the analysis. The linear programming input matrix used for the optimization iteration in the livestock production enterprise is presented thus;

Maximize Total Gross Margin: $238{,}240.73x_1 + 276{,}715.31x_2$

Subject to Constraints:

Farm land (TLU): $1.42x_1 + 0.81x_2 \leq 7.35$
Hired Labour: $4.37x_1 + 5.34x_2 \leq 12.27$
Family Labour: $3.49x_1 + 2.93x_2 \leq 22.83$
Animal traction: $0.14x_1 + 0.33x_2 \leq 2.42$
Crop Residue: $0.20x_1 + 0.29x_2 \leq 2.96$
Other cost: $0.74x_1 + 0.24x_2 \leq 1.44$

3. RESULTS AND DISCUSSION

Livestock Production Enterprise

The study identified two livestock production enterprises, namely; cattle/sheep/goat and cattle/sheep/goat/poultry enterprises as shown in Table 1. It is evident in the two enterprises that cattle was the principal animal produced, and this may not be unconnected with its usefulness in agricultural production. It is also a good source of income to the farmers. The existing farm plan allocated 1.42 TLU per season to cattle/sheep/goat enterprise, while the optimal plan recommends 1.63 TLU per season indicating 14.79% increase from the existing plan. However, for cattle/sheep/goat/poultry enterprise, the existing farm plan allocated 0.81 TLU per season, while the optimal plan recommends 0.96 TLU per season indicating 18.52% increase from the existing plan. The value of the marginal opportunity cost (MOC) of zero indicates that the enterprises have completetly entered the programme; hence, no penalty on their adoption.

Table 1: Distribution of Existing and Optimal Enterprise Production Plans of Agro-pastoralists in Livestock Production Enterprise in Adamawa State

Enterprise	Existing Plan (TLU)	Optimal Plan (TLU)	Increase/ Decrease	Marginal opportunity cost (MOC) (₦)	Objective Value Contribution (₦)
Cattle/sheep/goat	1.42	1.63	0.21 (14.79%)	0.00	389,418.70
Cattle/sheep/goat/poultry	0.81	0.96	0.15 (18.52%)	0.00	265,676.44

Source: Linear Programming Output

The gross margin per season in naira for cattle/sheep/goat enterprise in the existing plan was ₦238,240.73, while the maximized gross margin from the optimal plan was ₦389,418.70, indicating 63.46% increase from the existing plan. However, cattle/sheep/goat/poultry enterprise had a gross margin per season in the existing plan of ₦276,715.31, while that generated in the optimal plan was ₦265,676.44, indicating 4% reduction from the existing plan (Table 2). This indicates that cattle/sheep/goat/poultry enterprise is produced at the optimal level by the agro-pastoralists. It can therefore be inferred that cattle/sheep/goat enterprise has the potential for generating 63.46% increase in gross margin (profit level) per season given the current state of technology. The maximized TGM from livestock production enterprise obtained from the program was ₦655,095.14 per season.

Table 2: Distribution of the Existing and Optimal Gross Margin Plans of the Agro-pastoralists in Livestock Production Enterprise in Adamawa State

Enterprise	Existing gross margin (₦)	Optimal gross margin (₦)	Increase/ Decrease	Percentage
Cattle/sheep/goat	238,240.73	389,418.70	151,177.97	63.46
Cattle/sheep/goat/poultry	276,715.31	265,676.44	-11,038.87	-3.99

Source: Linear Programming Output

On the resource utilization pattern in livestock production enterprise, the linear programming output shows that only two of the six resource constraints (inputs) used in the model were binding constraints, hence were fully utilized in arriving at the optimal solution (Table 3). These inputs were hired labour (X_2) and other costs (replacement, veterinary services, maintenance, depreciation, empty bags and tranportation) (X_6). Their shadow prices indicate the amount by which the objective function will increase if these constraints are increased by one unit. That is, TGM will increase by ₦50,844.55 and ₦21,689.26 for a 1-manday increase in hired labour and 1₦ increase in other costs respectively per season.

The non-fully utilized resources include farm land (X_1), family labour (X_3), animal traction (X_4) and crop residue (X_5), indicating that these resources were inefficiently utilized by agro-pastoralists in livestock production. Free or open grazing was mainly used by the agro-pastoralists as against the use of crop residue in feeding, and this is attributed to their low level of education as they rely mostly on traditional methods of production.

Table 3: Resource Allocation and use Pattern by Agro-Pastoralists in Livestock Production Enterprise in Adamawa state

Constraints	Use Status	Slack	Shadow Price (₦)
Farm land (ha) (X_1)	Not fully utilized	4.25-	0.00
Hired Labour(mandays)(X_2)	Fully utilized	0.00	50,844.55
Family Labour (mandays)(X_3)	Not fully utilized	14.31-	0.00
Animal Tracktion(day/bullock)(X_4)	Not fully utilized	1.87-	0.00
Crop residue(₦)(X_5)	Not fully utilized	2.35-	0.00
Other cost(₦)(X_6)	Fully utilized	0.00	21,689.26

Source: Linear Programming Output

Crop Production Enterprise

The study identified ten crop production enterprises as shown in Table 4. It is evident from the various crop combinations that maize is the principal crop. This is attributed to the fact that maize is the staple food of many households in the area. The optimal farm plan generated from the linear programming output revealed that only two of the ten crop enterprises entered the programme. They include; maize/sorghum (X_1) and maize/sorghum/rice/cowpea (X_7) enterprises. For maize/sorghum enterprise, the optimal farm plan recommended 1.57 hectares as against the existing farm plan of 2.49 hectares to maximize enterprise gross margin, indicating 36.95% decrease from the existing farm plan. Consequently, for maize/sorghum/rice/cowpea (X_7) enterprise, the the optimal plan recommended 2.13 hectares as against the existing farm plan of 2.15 hectares, indicating 0.93% decrease from the existing farm plan. This indicates that higher gross margin per hectare will be obtained by a reduction in area under current production.The maximized gross margin per hectare obtained from the program was ₦220,194.92

The non-basic activities are the other eight (8) cropping enterprsises which erstwhile did not enter the program. Their marginal opportunity cost (MOC) signifies how much the programme value (maximized total gross margin) will decrease if any of them is forced into the program. That is, when one hectare of the non-basic activities is forced into the plan, the optimal cost of production will increase by the value equal to the MOC. In this case, maize/sorghum/millet (X_3) and maize/millet/cowpea (X_5) enterprises have the greatest penalty for adoption with MOC values of ₦73,957.53 and ₦38,394.66 per hectare respectively. On the other hand, maize/sorghum/rice (X_4) and maize/sorghum/rice/millet/cowpea (X_{10}) enterprises had the least penalty for adoption with MOC values of ₦1,880.26 and ₦6,627.09 per hectare respectively.

Table 4: Distribution of Existing and Optimal Production Plans of the Agro-pastoralists in Crop Production Enterprise in Adamawa State

Crop production enterprise	**Existing plan (ha)**	**Optimal plan (ha)**	**MOC(₦)**	**Objective value contribution**
Maize/sorghum (X_1)	2.49	1.57	0.00	86,899.58
Maize/sorghum/cowpea (X_2)	-	0.00	26,486.29	0.00
Maize/sorghum/millet (X_3)	-	0.00	73,957.53	0.00
Maize/sorghum/rice (X_4)	-	0.00	1,880.26	0.00
Maize/millet/cowpea (X_5)	-	0.00	38,394.66	0.00
Maize/rice/cowpea (X_6)	-	0.00	28,519.10	0.00
Maize/sorghum/rice/cowpea (X_7)	2.15	2.13	0.00	133,295.34
Maize/sorghum/millet/cowpea (X_8)	-	0.00	18,920.97	0.00
Maize/sorghum/rice/millet (X_9)	-	0.00	38,079.75	0.00
Maize/sorghum/rice/millet/cowpea (X_{10})	-	0.00	6,627.09	0.00

Source: Linear Programming Output

The gross margin per hectare from the existing maize/sorghum (X_1) enterprise was ₦55,297.55, while that obtained from the optimal plan was ₦86,899.58, indicating 57.15% increase from the existing plan. Furthermore, for maize/sorghum/rice/cowpea enterprise, the gross margin per hectare from the existing farm plan was ₦62,533.33 while that from the optimal plan was ₦133,295.34 indicting 113.16% increase from the existing plan (Table 5). The maximized TGM from crop production enterprise obtained from the program was ₦220,194.92 per hectare. This is an indication that more profit can be realised from crop production enterprise through efficient utilization of inputs given the existing technology.

Table 5: Distribution of Existing and Optimal Gross Margin Plans of the Agro-pastoralists in Crop Production Enterprise in Adamawa State

Enterprise	Existing Plan	Optimal Plan	Increase/ decrease	Percentage
Maize/sorghum (X_1)	55,297.55	86,899.58	31,602.03	57.15
Maize/sorghum/rice/cowpea (X_7)	62,533.33	133,295.34	70,762.01	113.16

Source: Linear Programming Output

The result of the resource utilization pattern revealed that only two of the five resource constraints (inputs) used in the model were fully utilized in arriving at the optimal solution (Table 6). The inputs were seed (X_2) and family labour (X_4). Their shadow prices indicate the amount by which the objective function will increase if these constraints are increased by one unit. That is TGM will increase by ₦12,540.01 and ₦2,293.18 for a 1kg increase in the quantity of seeds used and 1-manday increase in amount of family labour respectively in production. On the other hand, the non-fully utilized resources include farm size (X_1), inorganic fertilizers (X_3) and agro-chemicals (X_5), indicating that these resources were either over-utilized or under-utilized by the agro-pastoralists in crop production in the state.

Table 6: Resource Allocation and use Pattern of the Agro-pastoralists in Crop Production Enterprise in Adamawa State

Constraints	Use Status	Slack	Shadow Price (₦)
Farm size (X_1)	Not fully utilized	19.96	0.00
Seed (X_2)	Fully utilized	0.000	12,540.01
Inorganic fertilizers (X_3)	Not fully utilized	30.53	0.00
Family labour (X_4)	Fully utilized	0.00	2,293.18
Agro-chemicals (X_5)	Not fully utilized	5.18	0.00

Source: Linear Programming Output

4. CONCLUSION

Agro-pastoralism, is the dominant agricultural system practiced by sedentary agro-pastoralists in Adamawa state. Two types of livestock production enterprises and ten types of crop production enterprises were identified in the study. Resource-poor farmers engaged in this type of agriculture as a source of livelihood and also to minimize shocks associated with biophysical and socio-economic risk inherent in agricultural production. In both the livestock and crop production enterprise, it was found that many resource inputs were not efficiently utilized; hence, farmers were operating below the optimum level as indicated by the wide differential between the existing and optimal farm plans. There is a scope for increasing farmers' profit margin in the short- run through efficient utilization of existing inputs given the current state of technology.

5. RECOMMENDATIONS

i). Agro-pastoralists should diversify their sources of livelihood by engaging in other income generating activities. This will improve their income level and also uplift their living standards.

ii). Agro-pastoralists education on modern methods of production should be encouraged by both government and non-governmental agencies. This will improve their farm management skills and increase their efficiency in agricultural production.

iii). The government at all levels should make agricultural inputs readily availabile and affordable especially improved seeds, as this will boost their level of production.

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