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Role of Linear Programming Based Cropland Allocation to Enhance Performance of Smallholder Crop Production : A Pilot Study on Abaro Kebele, Shashemene Zuria District, West Arsi Zone, Oromiya Regional State, Ethiopia

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Abstract

Crop production is a major livelihood activity of smallholders in Ethiopia. However, it is often characterized by low performance. In an effort to improve crop production, a series of agricultural extension programs have been running in Ethiopia since the 1950s. Nevertheless, the performance of agriculture is still low. In this study, it is argued that the limited attention given to cropland allocation methodologies is one of the major causes of low performance of crop production and increased environmental degradation. This study used linear programming to examine the role and impacts of cropland allocation methods on performance of crop production. The data for this study was drawn from household survey of 75 randomly selected households combined with focus-grouped discussion, key informant interview, and secondary data. In the current conventional cropland allocation, households were not able to meet their household consumption. The average profitability of farms under current practice was found significantly below than estimated optimal level of profit that could be realized using linear programming. In addition, it uncovered that low performance of crop production (in terms of meeting household consumption demand and profitability) is the primary cause that limited the effort of households to participate in environmental and natural resource management. This study suggests the use of linear programming-based cropland allocation to enhance the profit performance of smallholder crop production, meeting household consumption requirement, and thereby promote sustainable utilization of natural and environmental resources.

Key words: Cropland allocation, linear programming, Crop production performance, Smallholder, resource management

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1 Background

In Ethiopia, smallholder agriculture has long history as a major economic activity. According to the Central Statistical Agency of Ethiopia (CSA, 2008), smallholder agriculture contributed 50.7% to the country's GDP in 1990, 42.2% in 2004, and 45% in 2011. 85% of the workforce is also engaged in agriculture (FDRE, 2012). However, commercialization and development of agriculture in Ethiopia has not yet realized its full potential and the country is one of the least developed countries in the world. Low input supply (Berhanu, 2012) and low resource use efficiency(Mussaa et al., 2011) are the two major contributing primary factors of low performance of agriculture in Ethiopia**.** Reports indicate that resource use inefficiency and low-productivity of agriculture are also the major causes of deforestation, environmental pollution, and land degradation worldwide, including developed countries (Bengtsson, 2007; Joneydi, 2012; Virto et al., 2014).

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Now a days , in Ethiopia, declining land productivity coupled with population growth has also driven households to further cultivate marginal lands (such as steep slopes and forest lands) and exploit natural forests as sources of fuel wood and cash income (Zewdie, 2002; Lemma, 2005; Dessie et al., 2007; Kahsay and Hansen, 2016). Such crop cultivation practices are among the key factors that worsen soil erosion and in turn cause pollution of surface water and ground water through siltation and nutrient leaching (Boatman et al., 1999; Asefa and Zegeye, 2003).

Recognizing the low productivity of agriculture and the potential contribution of smallholder agriculture to national economic growth and food security, the government of Ethiopia has made substantial efforts to improve smallholder performance through agricultural extension service programs mainly focused on input supply via credit systems and training for improved crop management since 1950s (Berhanu et al., 2006; Berhanu, 2009). These efforts are currently pronounced in national macroeconomic plans such as Ethiopian Growth and Transformation plan(GTP) (FDRE, 2012) and in the Climate Resilient Green Economy Strategy of Ethiopia launched in 2012 that targeted to increase productivity of smallholder agriculture with an ultimate objective of achieving middle income economy status by 2025 following a "green growth path"(FDRE, 2011). However,strategies are mainly focusing on increasing productivity and the role of decision making to eradicate extreme poverty and achive sustainable development goals is hardly considered.

However, increased productivity may be achieved at the expense of high input costs; hence this strategy may not always ensure profitability and may not bring the desired results of poverty alleviation, improved household food security, resilience to climate change ,and improved natural and environmental resource management (Trostle, 2008; Esther, 2011; Munthali and Murayama, 2013; FAO, 2014). But as Wilson et al. (2011) smallholder

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agriculture resource use efficiency has the potential to meet the twin objectives of large-scale poverty reduction and sustainable economic growth. Linear programming is a widely used optimization method for decision-making in various sectors such as transportation, assignment, and other types of resource allocation problems including agricultural land use(Dykstra, 1984; Hillier and Lieberman, 2001; Govindrao and Kabeer, 2011; Chamheidar et al., 2011; Walangitan et al., 2012a). Linear programming integrated with GIS is commonly used in land use optimization decision-making

Hence this study seeks to fill the information gap surrounding the potential of improved farm decision tools to increase the efficiency of smallholder crop production using linear programming land allocation methodology. Drawing on primary data from *Abaro Kebele* in southern Ethiopia this research applied linear programming-based cropland allocation technique to compare production self-sufficiency and profitability outcomes under alternative cropland allocation scenarios for six crops commonly grown in the study area. Specifically the study addressed the following objectives (1) investigating the farm- and village level profitability of current crop production, (2) estimating the annual production and profit possible from an optimal cropland use allocation based on linear programming and, (3) examining how the use of linear programming based cropland allocation influence sustainable use of environmental and natural resources.

2 Materials and Methods

2.1 Description of the Study Area

Abaro *Kebele* is found in Shashemene zuria woreda, Oromiya Regional State, Ethiopia at about 07º 06' N latitude and 38º 37' E longitude (Dessie et al., 2007). It is situated in an altitude ranging from 1900 to 2600 m.a.s.l (Eshetu and Hogberg, 2000). The mean annual rainfall of the study area is 1200 mm and has a steady annual temperatures around 19^0 C. It is characterized by two rainy seasons, the long rainy season (July to September), and a short rainy season (March to April). The average land holding in the study area is less than one hectare (Wolde-Amanuel, 2003). The area is bordered by the disturbed natural forests of Munessa Shashemene in the southeast (Figure 1). The livelihood practice of households in the particular kebele is sedentary farming complemented with limited livestock production as the majority of rural household in the highlands of Ethiopia. The study area is one of the most densly populeted kebeles in the region with an average population density of 370.4 persons per square kilometer(CSA, 2008).

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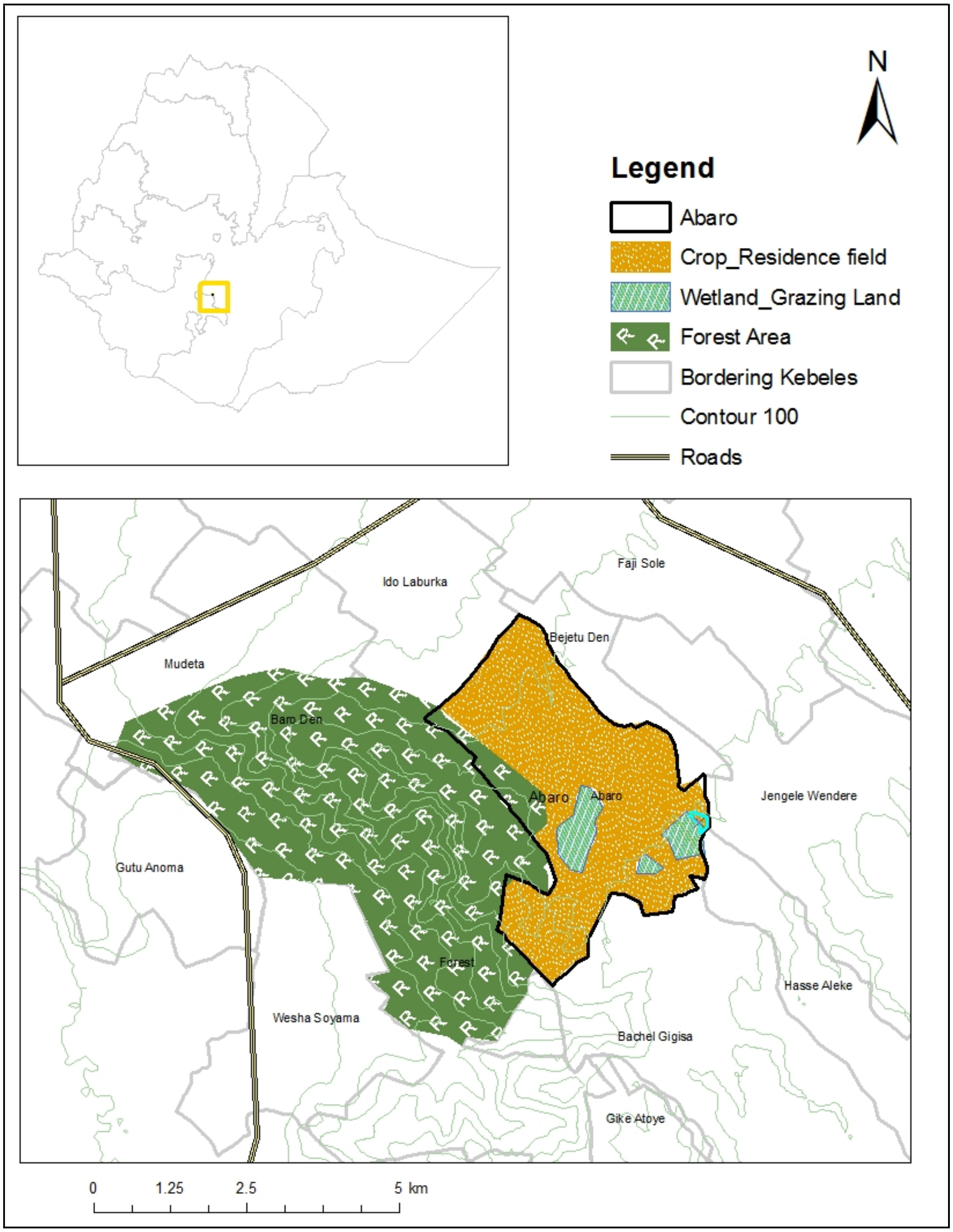

Figure 1.Map of the study area

2.2 Population and Sampling

First Key informant interviews with, two local development agents, two experts from the District Office of Agriculture, and four selected model and elderly farm household heads were undertaken to have understand the farming practice of the community. Following the key informant interview seventy five (75) households (about 5% of the households in the study

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area) were randomly selected and surveyed using structured questionnaire. Finally focus grouped discussion were held with two *Kebele* extension agents, three model farmers and one *Kebele* administrator. Participants of both focus grouped discussion and key informant interview was selected based on their expertise, experience, familiarity with current annual crop production practices, and involvement in natural and environmental resource management. Characteristics of respondents participated in the survey is given in Table 1.

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Table 1. Socioeconomic characteristics of survey respondents

Parameter	**n**	**Mean (±SE)**	**Minimum**	**Maximum**
Age (years)	75	40.1 (±11.204)	24	70
Education (Grades completed)	75	2.97 ((±3.507)	0	12+1
Land holding (ha)	75	0.77 (±0.40))	0.25	2.0
Rented land for crop production (ha)	75	0.074 (±0.18))	0	1

89% of households were male headed; 81.3% of the respondents were married, 13.3% were divorced, and the rest were either single, widowed or widowers.

2.3 Nature and Type of Data

Both quantitative and qualitative data regarding crop production practices such as land size, costs of crop production, current farming practices, and productivity of crops per hectare were collected using structured household survey questionnaire, focus group discussion, and key informant interviews. Secondary data including reports from the Ministry of Agriculture and other offices were used. Quantitative data collected from primary and secondary sources were used to estimate costs and revenues of crop production per hectare for each crop. Annual national average price for each crop per kilogram of 2012 were taken from FAOSTAT (FAOSTAT, 2015). Qualitative data regarding factors of cropland allocation, involvement, and awareness of environmental and natural resource constraints and involvement in natural and environmental resource management practices were collected using key informant interview, focus group discussions, and household surveys.

2.4 Model Description

Aggregated model with the objective of profit maximization from crop production was used. The was run with three scenarios, including the current conventional cropland allocation scenario (as a reference), and two hypothetical scenarios.

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Current conventional cropland allocation profit performance was taken as first or reference scenario. The Second hypothetical scenario was run with the assumption of realizing current mean productivity per hectare of each crop with the objective of maximizing profit using linear programming method of cropland allocation. And the third hypothetical scenario was run with assumption of realizing theoretical mean farm field productivity per hectare with the objective of maximizing profit using linear programming method of cropland allocation.

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2.4.1 The Objective Function

As the main aim of this study is to investigate the profit performance of current household crop production practice (emphasizing on cropland allocation methodology) profit is the objective function. Given n crop choices practiced in the study area with productivity per unit of land $q_i, i = 1,2,3,...n$ and total land size L, the LP problem is what size of land $L_i\ i = 1,2,3,...n$ should be allocated for each crop to maximize profit subject to a set of constraints (social constraint, financial constraint and Ecological Constraint).

Given market price P_i, $i = 1,2,3,...n$ per kilogram of each crop and cost of production per unit hectare of land of each crop $C_i\ i = 1,2,3,...n$,, the model of objective function $\prod$ is modeled as

$$\Pi = \sum_{i=1}^{n}(P_i L_i q_i - C_i L_i).......$$ 1: Profit Equation

2.4.2 Constraints

Studies indicate that resource degradation and poverty has a two way relationship where one exacerbates the other, particularly in developing countries like in Ethiopia (Zhou, 2010; Birachi et al., 2011; Mpandeli and Maponya, 2014). Thus this study used linear programming cropland allocation methodology to investigate the role of improved decision making in addressing resource use efficiency in general and enhancing profitability in particular. To this end aggregate (community)-level linear programming model was employed with ecological constraints (Walangitan et al., 2012b; Wankhade and Lunge, 2012) and financial constraints (Jaleta et al., 2009; Wankhade and Lunge, 2012; Mugabe et al., 2014). In addition production self-sufficiency (minimum requirement for consumption) was included as social constraint .

2.4.2.1 Ecological Constraints

The land holding (L) of households in the study area is less than one hectare on average (Dessie et al., 2007). The opportunity for households to expand their farm land is almost nonexistent(and in cases where expansion does occur it is often at the expense of neighboring forest, as landowners expand their farm by clearing natural protected forests illegally)(Igwe et al., 2011; Majeke et al., 2013). Based on the results of household surveys the total land size allocated for all crops (L) should allocated for different crops in the same cropping season based on suitability analysis for each crop (i.e., land where cropping is possible without incurring land degradation such as soil erosion),however in the study area, crops that are suitable to practice were selected with supplement of chemical fertilizer. The sum of land allocated among selected crops, L_i, $i = 1,2,3,...n$, must not exceed the total land size L .

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$$\sum_{i=1}^{n} L_i \leq L.............$$ 2: Ecological Constraint Equation

2.4.2.2 Financial Constraints

Studies indicate that financial access is one of the constraining factors that limit performance of smallholder agriculture in developing countries(Maliwichi et al., 2014). Based on results of household survey, key informant interview and focus group discussions, cost per hectare of each crop was estimated and thus, the financial constraint is modeled by equation 3 where Y is the total crop budget.

$$\sum_{i=1}^{n} c_i L_i \leq Y......$$ 3: Financial Constraint Equation

2.4.2.3 Social Constraint (family goal)

Key informant interviews, focus group discussions, and household survey results provided detailed information on goals of crop production in addition farming systems and farming practices. According to the assessment minimum household food production requirement is the primary goal of crop production in the study area. Therefore, the minimum requirement for consumption of each crop $Q_i, i = 1, 2, 3, ...n$ was included explicitly in the model.

$$q_i L_i \geq Q_i......$$ 4: Social Constraint Equation

Finally, linear programming based cropland allocation or crop mix-selection model with the objective of profit maximization subject to financial, social, and ecological constraints, AScenario Model, outlined below was used for the study to estimate the profit that can be realized using linear programming cropland allocation methodology.

$$\left.\begin{array}{l} \text{Maximize}\Pi = \sum_{i=1}^{n} (P_i L_i q_i - C_i L_i) \\ \text{Subject to:} \\ \quad \sum_{i=1}^{n} c_i L_i \leq Y \ \text{(Budget Constriant)} \\ \quad \sum_{i=1}^{n} L_i q_i \geq Q_i \ \text{(Minimum Requirement for Consumption)} \\ \quad \sum_{i=1}^{n} L_i \leq L \ \text{(Land Constriant)} \\ \quad Li \geq 0, \ i = 1,2,3,...,n \end{array}\right\} .... 5 \text{ AScenario Model}$$

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2.5 Method of Data Analysis

Descriptive statistics were used to estimate model parameters from household survey data and the linear programming model was solved using Microsoft excel solver 2010.

3 Results and Discussion

3.1 Crops Selected for the Purpose of this Study

Six crops, wheat (*Triticum aestivum*), maize *(Zea mays*), potato (*Solanum tuberosum*), beetroot (*Beta vulgaris*), carrot (*Daucus carota*), and barley (*Hordeum vulgare*), were selected for the purpose of this study based on the number of households cultivating these crops and availability of data (Table 2) However ,there were also other crops cultivated in the area.

Table 2: Crops grown in the study area (July to September 2012)

No	Crop name	Scientific Name	% of households
1	Wheat	*Triticum aestivum*	93.7%
2	Maize	*Zea mays*	70.7%
3	Potato	*Solanum tuberosum*	49.3%
4	Beetroot	*Beta vulgaris*	49.3%
5	Carrot	*Daucus carota*	29.3%
6	Barley	*Hordeum vulgare*	26.7%
7	Cabbage	*Brassica oleracea*	14.7%
8	Sorghum	*Sorghum vulgare*	5.3%
9	Haricot bean	*Phaseolus vulgaris*	4.0%
10	Garlic	Allium sativum	4.0%
11	Finger millet	*Eleusine coracana*	1.3%
12	Teff	*Eragrostis tef*	1.3%

In addition, to annual crops households in the study area were found cultivating perennial crops such as Ensete (*Ensete ventricosum), coffee, eucalyptus, and apple (Malusdomestica).* . More than 93% of the households were found cultivating *Ensete* (*Ensete ventricosum)* as major staple food while 2.67% cultivate coffee, 2.6% cultivate eucalyptus and 4% cultivate apple. *Ensete* was cultivated on an average of $0.15(\pm 0.09)$ hectares of land.

As shown in Table 3 about 68% of maize producers and 17% of wheat producers were not able to produce the minimum required production levels needed the household using the current conventional cropland allocation practice.

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Table 3. Percentage of household realizing minimum requirement for consumption in the current convention land allocation scenario

	Crop Name	Total number of producers	Percentage of household who do not realize subsistence yield requirement
1	Wheat	73	17.8%
2	Maize	50	68.0%
3	Potato	36	25.0%
4	Beetro	23	4.3%
5	Carrot	19	36.8%
6	Barley	31	0.0%

3.2 Model Parameter Estimates

Based on the household survey and review of secondary data on national average producer prices from FAO(2015) and Minot and Sawyer (2013), annual crop production profits for the selected six crops were estimated for the three scenarios for 2012 July-September cropping season. Mean current practice yield per hectare, mean theoretical farm field productivity per hectare, mean cost paid in cash per hectare, mean total cost of production per hectare, mean profit per hectare, and minimum aggregated requirement for consumption were the main parameters estimated (Table 4).

Table 4.Parameter estimates of the six crops

Crop Name	Mean Total Estimated costs per hectare (C_i) (ETB)	Mean estimated cost paid in Cash (c_i) (ETB)	Land allocated for each crop in hectares	Mean estimated current Productivity per hectare in Kilograms	Mean theoretical farm field productivity per hectare in Kilograms	Minimum requirement for consumption in kilograms (MRFC)	Mean Profit per hectare (ETB)
Wheat	17201.37	10461.3	L_1	4560.64	4500	51250	15635.2
Maize	14640.47	8160.47	L_2	5764.71	7000	36710	9571.32
Potato	18512.22	12392.2	L^3	9908.33	29130	30316	13392.6
Beetroot	12502.01	5702.01	L_4	16614.81	28000	4850	39834.6
Carrot	14945.88	8265.88	L_5	20323.81	30000	4450	49074.1
Barley	15254.31	8514.31	L_5	4400	3550	7100	11365.6
Resource endowment	850636		43.76875				

Source: 2012 Household survey, (MoARD, 2009; Minot and Sawyer, 2013)

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3.2.1 Model Output

Having estimated model parameter estimates from survey data, the model was solved for three scenarios, reference scenario (AScenario#1), AScenario#2, and AScenario#3

3.2.1.1 AScenario#1: Aggregated Current Profit

Summing up the individual household possible profits estimated in HHScenario #1, the aggregated profit was estimated as ETB 591,324.6 from a total land of 43.77 hectares (Table 6).

Table 6.AScenario#1 Model Output Summary

	Crop Name	AScenario #1 Land allocation (ha)	AScenario #1 Profit(ETB)	Minimum requirement for consumption(MRFC) (kg)	Yield harvested (kg)	Surplus production (kg)
1	Wheat	23.6875	282082.5	51250	87600	36350
2	Maize	6.1875	31843.80	36710	22925	-13785
3	Potato	6.5625	86270.02	30316	69000	38684
4	Beetroot	3.2188	86651.86	4850	42200	37350
5	Carrot	1.9875	78096.35	4450	32700	28250
6	Barley	2.1250	26380.05	7100	8200	1100
Total Land		43.76875	591,324.6			

The survey result uncovers that under the conventional cropland allocation practice, the community was not even able to meet the minimum aggregated production requirement of maize, the most preferred food crop in the study area. As shown in the last column of Table 6., there is aggregate production shortfall of 1.3785metric tons of maize.

3.2.1.2 AScenario#2: Aggregate Estimated Profit Using LP with the assumption of realizing Mean Current Productivity in the Study Site

The AScenario #2 aggregated linear programming models was solved with the objective of maximizing of aggregated profit subject to the aggregated crop budget, aggregated land size allocated for selected crops in the particular cropping season and minimum aggregated production requirement for consumption constraint. The other assumption in this scenario was that the productivity per hectare of each crop is the mean current study site productivity Microsoft Excel Solver 2010 solution output of this scenario is given in Table 7. A total aggregated profit of ETB 1,347,871.218 or 17,971.61624 ETB per household was theoretically

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possible if linear programming were used to allocate cropland among selected crops from same size of land cultivated in the particular cropping season. This mean profit per household level is more than twofold of mean profit of crop production in the particular cropping season under conventional cropland allocation practice. Moreover, in this scenario the minimum aggregate production requirements for consumption of each crop are met as shown in surplus production column of Table 7.

Table 7.AScenario#2 Model Linear Programming Output Summary

	Crop Name	AScenario #2 Land allocation (ha)	AScenario #2 Profit (ETB)	Minimum requirement for consumption in kilograms	Yield harvested (Kg)	Surplus Production (Kg)
1	Wheat	11.2375	175700.33	51250	51250	0
2	Maize	6.3681	60950.69	36710	36710	0
3	Potato	3.0596	40976.66	30316	30316	0
4	Beetroot	0.2919	11628.06	4850	4850	0
5	Carrot	21.1980	1040275.40	4450	430825.00	426375.00
6	Barley	1.6136	18340.09	7100	7100	0
Total Land		43.76875	1,347,871.22			

3.2.1.3 AScenario #3: Aggregate Estimated Profit Using LP with the Assumption of Realizing Mean Theoretical Experimental Farm Field Productivity

In AScenario #3, aggregated linear programming model with the objective of maximizing aggregated profit subject to aggregated crop budget, aggregated land size and minimum aggregated consumption requirement constraints were solved using Microsoft Excel Solver 2010. The solver output is as shown in Table 8. In this scenario, a total profit of ETB 1,576,009.027 could be achieved from same land currently cultivated. The profit is more than twofold of the profit of the conventional current cropland allocation practice as in AScenario#2. Moreover, in this scenario the aggregated minimum requirement for consumption is also met as in AScenario #2. The variation of possible profit of AScenario#3 from Ascenario#2 (ETB 228,137.8119) is by far small compared to the variation of each AScenario#2 from Ascenario#1 (ETB 756,546.62) and Ascenario#3 from AScenario#1(ETB 984,684.4).

This result uncovers that profit performance of crop production in the study area is very much compromised by lack of appropriate cropland allocation methodology than by realization of expected theoretical farm field productivity per hectare.

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Table 8. AScenario#3 Model Linear Programming Output Summary

	Crop Name	AScenario #3 LA (ha)	AScenario#3 Profit (ETB)	Minimum requirement for consumption in kilograms	TYIELD(Kg)	Production Surplus (Kg)
1	Wheat	11.3889	184600.22	51250	51250	0
2	Maize	5.2443	39456.20	36710	36710	0
3	Potato	1.0407	47772.54	30316	30316	0
4	Beetroot	0.1732	8465.91	4850	4850	0
5	Carrot	23.9217	1279351.93	4450	717649.41	713199.4
6	Barley	2.00000	16362.22	7100	7100	0
Total		43.77	1,576,009.03			

In both aggregate models; AScenario#2 and AScenario#3; land was allocated to crops other than carrot only for the purpose of satisfying minimum requirement for consumption. In both aggregated models, carrot was found as the most economically attractive crop from the six crops considered.

3.2.1.4 Sensitivity Analysis

Sensitivity analysis report of both AScenario #2 and AScenario #3 models (Table 9) shows that crop budget is not the limiting factor to maximize profit whereas land size is the common limiting factor of maximizing profit from crop production. A unit additional hectare of land has the potential to increase aggregate profit by ETB 49,074.1 and ETB 53,480.9 in AScenario #2 and AScenario #3 respectively. The aggregated minimum production requirement for consumption constraints except for carrot are binding in both scenarios. In the absence of expansion of agricultural land, the result of this study uncovers that the use of appropriate agricultural technology and decision support systems such as linear programming based

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cropland allocation significantly improves the performance crop production in terms of profit and ensuring food security. This result agrees with Gadge et al.(2014).

Table 9. Summary of Sensitivity Analysis

	Constraints	Shadow price	
		AScenario #2 LA	AScenario #3 LA
1	Aggregated Crop Production Budget	0	0
2	Aggregated Total Land Size	49074.1	53480.93
3	Minimum Production Requirement for consumption of Wheat	-7.33	-8.28
4	Minimum Production Requirement for consumption of Maize	-6.85	-6.57
5	Minimum Production Requirement for consumption of Potato	-3.60	-0.26
6	Minimum Production Requirement for consumption of Beetroot	-0.56	-0.16
7	Minimum Production Requirement for consumption of Carrot	0	0
6	Minimum Production Requirement for consumption of Barley	-8.57	-12.76

On the other hand, allocation of additional one hectare land for Barely results loss of ETBirr 8.57 in AScenario#2LA and ETBirr 12.76 in AScenario#3 LA.

3.2.1.5 Aggregated Land Allocation Comparison in the Three Scenarios

Land allocated for each of the selected crops is quite different in linear programming and conventional methods of cropland allocation. The size of land allocated for wheat using conventional method is at least halved in the linear programming cropland allocation whereas land allocated for carrot is more than tenfold of the land conventionally allocated to it. This indicates that provided that all factors such as market demand and climate variables was favorable for both crops, production of wheat is much less profitable when compared to carrot. Similar studies in Zimbabwe by (Felix et al., 2013), Nigeria by (Igwe and Onyenweaku, 2013) and Egypt by (Ahmed and Sayed Nawal, 2015) agrees with this finding.

3.2.2 Current Cropland Allocation & Crop Selection Factors

Based on key informant interview prior to household survey; four major factors of cropland allocation with at least two sub-factors underneath were included in the survey questionnaire

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to assess the major factors considered during cropland allocation. Accordingly, participants of household the survey ranked social factors (household consumption requirements) as the first criteria of cropland allocation and productivity per hectare, ecological factors (crop rotation, soil fertility management) as the second and third determining factors of cropland allocation in the particular cropping season. The ranking of main and sub factors considered during cropland allocation by households in the study area is summarized in Table 10 .This result uncovers that ecological factors such as soil fertility management, impact to other land uses due to other adjacency and avoidance of cultivation in steep slopes are least prioritized when compared to socio-economic and productivity related factors.

Table 10. Summary of Factors of Cropland Allocation and Crop Choice

Main Factor	Rank	Sub Factor	Sub Factor Rank
Socio-Economic Factors	1(37.9%)	Household Consumption Requirement	1
		Custom Food Requirement	2
Productivity Factors	2(22.4%)	Productivity per Unit of Land	1
		Expected Price	2
Ecological factors	3(20.7%)	Crop Rotation	1
		Soil Fertility Management	2
		Rain Fall	3
		Adjacency to different land uses	4
		Land Slope	5
Input Price Factors	4(19%)	Price of Fertilizer	1
		Price of Improved Seed	2
		Price of Pesticide	3
		Wage of Labor	4

3.3 Implications of the Use of linear Programming to Cropland Allocation for Natural and Environmental Resource Management

To assess the current involvement and awareness of natural and environmental resource management; sampled household heads were interviewed regarding their current involvement in forest conservation, soil fertility management and constraints and opportunities of participation in natural and environmental resource management. Result of the household survey revealed that the role of natural resources such as forests, land, and water are well

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noted among most community members. Uniformly all households participated in this study indicated/perceived that leaving crop residues on farm field significantly improves soil fertility and land degradation, which is also a threat to declining productivity of agricultural practice. The view of farm households is in-line with results of the studies by Philor(2011),Tefera et al.(2004) ,Baudron et al.(2014) and Duncan et al.(2016). In addition, existence of natural forest in and around the locality is perceived as fundamental resource for ecosystem service particularly for accessing rain in the right time in adequate quantity. However, due to pressing problems of meeting household food demand and cooking energy requirement; encroachment to natural forest for fuel wood consumption and collection of crop residue are unavoidable current practice. 94.7% and 88% of respondents were found to collect crop residue and fuel wood from natural forest respectively. A study by Simon et al. (2013) in similar smallholder agriculture areas indicated that awareness is major factor to participate in conservational practice of natural and environmental resource management. However, in this study, performance of livelihood practice in general and return of crop production in particular is the forefront factor identified that limited participation in conservation of natural and environmental resources.

Results of the household Survey, key informant interview and focused grouped discussion indicate that households in the study area willing to drop current environmentally hostile practices such as crop residue collection and natural forest encroachment, and add efforts in natural and environmental resource management if performance of crop production in terms of meeting household food requirement and profit is meaningfully enhanced. This result is supported by Joneydi(2012)and Nwaiwu et al(2013). Particularly, with regard to increasing returns from crop production the motivation of households to practice profitable exotic crops is also very high (100%).

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4 Conclusion and Recommendations

4.1 Conclusion

This study was carried out to investigate the performance of conventional cropland allocation compared to linear programming based cropland allocation with regard to meeting household consumption requirement, profitability, and implication to natural and environmental resource management. The result shows that the overall performance of linear programming based cropland allocation practice is significantly better than current conventional cropland allocation. In the conventional cropland allocation, households were not even able to meet the minimum required production levels however, when linear programming was used the profit earned is more than double.

Practice of environmentally hostile activities like collection of crop residue and forest encroachment were common following the poor performance of current conventional cropland allocation practice. Environmental factors such as cultivation in steep slopes, soil fertility management, and crop rotation are least considered in the conventional cropland allocation where as these factors can be equally considered as constraints in the linear programming land allocation. Although smallholder farmers in the study recognize forest ecosystem services and the role of natural and environmental resources, the decline in return from other economic practices such as crop and livestock production have put them to act environmentally unfriendly practices. Crop residue collection as fuel wood and other services, fuel wood and timber collection from nearby forest illegally are some of the environmentally unfriendly practices in the study area.

Finally, provided that all necessary information with regard to input and output prices, land suitability, potential yield and climate are in place, result of this study favors the use of improved decision support tools such as linear programming for cropland allocation in particular and agriculture in general to address the twin objectives, reduction of poverty and sustainable utilization of natural and environmental resources in smallholder agricultural landscapes to enhance the performance of crop production in terms of maximizing profit and enhancing food security meeting social, financial and ecological (natural and environmental) factors into consideration.

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