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Research Article

Economic Analysis of Smallholder Major Crop Production Under Condition of Risk: The Case of West Arsi and East Shewa Zones of Oromia

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Abstract

The present study was carried out with the objectives of understanding the existing resource allocation practice, the possibility of increasing farm income through optimal allocation of resources under risk situation, and to develop risk efficient sets of farm plans for representative households based on cross-sectional data drawn from 240 households who were selected using stratified multi-stage random sampling technique during the 2022/23 production year. Linear programming and MOTAD model were used to analyse the data. The results of descriptive analysis show that most of the socioeconomic variables were found to be significantly different among the three agro-ecologies. Based on the existing farm situation and prevailing price levels, households in highland, midland, and lowland areas were obtaining the total annual income of Birr 19,480.00, 22,356.00, and 14,717.00, respectively. From the results of the MOTAD risk programming model, Sustainable plans within which households can minimize risks and remain efficient are suggested for the three identified agro-ecologies. The model results also show that, in all agro-ecologies under risk neutral plan, there is substantial difference between households' existing plan and gross income maximization plan implying that if farm households reallocate their resources among different activities, there is a much room to increase their income under risk neutral plan. Overall, from general discussion there is need for policies that spur investment in public infrastructure, rural financial markets, private investment, and support institutions to address the problems of high transaction costs to investors, and reduce risks faced by farmers.

Keywords

Cropping pattern, Optimization, MOTAD Model, Resource Allocation, Linear Programming Analysis

1. Introduction

1.1. Background and Justification

Agriculture is the backbone of Ethiopia's economy. It contributes 36.2 percent of the country's gross domestic product (GDP) and 72.7 percent of employment and 70 percent of export earnings [1]. 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 [2] and low resource use efficiency [3]. are the two major contributing primary factors of low performance of agriculture in Ethiopia.

Recognizing the low productivity of agriculture and the

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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 [4]. These efforts are currently pronounced in national macroeconomic plans such as Ethiopian Growth and Transformation plan (GTP) [5]. 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 [5]. However, strategies are mainly focusing on increasing productivity and the role of decision making to eradicate extreme poverty and achieve sustainable development goals is hardly considered.

However, strategies are mainly focusing on increasing productivity and the role of decision making to eradicate extreme poverty and achieve sustainable development goals is hardly considered. According to [6] farm planning that don’t include the risk factor has had limited and sometimes unacceptable results. Therefore, the condition of uncertainty and risk inevitable associated with crop production cannot be neglected. In traditional agriculture, crop planning decisions were mainly guided by the farmer's judgment and experience. However; with advancement in agriculture and increasing pressure on land and other resources, coupled with increased specialization and the adoption of capital intensives production systems, the development of more formal planning methods based on the construction and analysis of a mathematical model has been stimulated. This is why farm plan studies by [6] have incorporated the risk factors in the linear programming model for the farm planning to determine the combination of activities of lower risk and higher return.

Therefore, Knowledge of how these farmers make production decision under condition of risk and uncertainty are important in the; Development of appropriate strategies necessary to drive agricultural intensification and Development in the smallholder sector to match raising aggregate food demand. However, there is no empirical study undertaken in the study area seeking the efficient allocation of limited resources have not been formulated for the major crop farming production of West Arsi and East Shewa zones of Oromia Regional National State. Therefore, this study designed to fill the above-mentioned skill gap and attempt to review the various approaches and techniques used specifically for optimum crop planning.

1.2. Objective of the Study

The objective of this study was to conduct an updated economic optimization study of smallholder agricultural crop production in West Arsi and East Shewa zones of Oromia and characterize the risk levels inherent to the profit-maximizing solution and alternative farm plans.

Specific Objective of the study:

To identify the *cropping pattern* of crop produced in West Arsi and East Shewa zones of Oromia

To identify *optimal farm plans* feasible with the given set of farm resource endowments and constraints

To generate a feasible set of *risk efficiency farm plans* that can be used as a guide to minimize production risk at farm level

2. Research Methodology

2.1. Description of the Study Areas

This study was conducted in West Arsi and East Shewa Zones. West Arsi Zone found in the south part whereas East Shewa Zone is found in central part of the Oromia National Regional State. West Arsi Zone encompasses different agro-ecologies namely high land, midland and lowland. In the Zone the high land agro-ecology (47.92%) took more coverage followed by midland (42.50%) and lowland (9.82%) agro-ecologies [7]. East Shewa Zone has different agro-ecologies which categorized as highland, midland and lowland agro-ecologies. In the Zone, 18.70% of the agro-ecology is high land, 27.50% is midland and 53.80% is lowland [7].

2.2. Types and Method of Data Collection

Both primary and secondary data were used collected from different sources at different levels. Primary data was collected through focus group discussions, key informant interview and household’s interview using checklist and semi-structured questionnaire. Primary data was collected from 240 small farm households for 2022. production season by using semi-structured questionnaire. The household data on demographic profile, land holding, cropping pattern and input-output of crops will be collected through a household survey. Data were collected on demographic variables; crop and livestock activities that are considered in the production process; the amount of input required per unit of activity; the amount of annual crop yield; the selling and buying price of each output; resources (land, labor, and capital) available on the farm for production purposes; and type of activities performed by family labor and duration of the activities. Data on price and yield of crops for the last five years (2017/18-2021/22) was obtained from West Arsi and East Shewa zones of Market and trade office, CSA and other related office using checklists.

2.3. Sampling Procedure and Sample Size

Both zones have different agro-climatic characteristics. The sampling frame for this study encompasses rural households that are found in the three agro-ecological zones. The study employed a multi-stage stratified random sampling procedure to select representative sample households. Firstly, rural district was stratified into agro-ecological zones (highland, midland and lowland), which determines the production patterns and the level of income of the households due to the likely variations in amount and distribution of rainfall, soil type, pest and disease incidence and other factors influencing crop as well as livestock production. Secondly, from stratified three agro-ecological zones (highland, midland and lowland) one district from highland, two district from midland and one district from lowland were selected. Thirdly, three rural kebeles from each selected district were selected. Thirdly, 240 representative sample households were randomly selected from the selected sample kebeles, the sample households were proportionately selected with respect to the number of total households of each sample kebele by using Yamane formula, (1967).

$$n = \frac{N}{1+N(e)2}$$

Where, n = is the sample size of sampled producer households, N= total number of households farmers, e= level of precision considered 6.5% (0.065).

2.4. Method of Data Analysis

In this study, descriptive statistics and mathematical programming models were used to analyze the data collected from both primary and secondary sources. For data analysis the zones classified in to three agro-ecologies: High land, Midland and lowland. This study formulates optimum farm plans in the face of risk and uncertainties for arable crop farmers in West Arsi and East Shewa zones of Oromia national regional State. The study employed analytical tools such as descriptive statistics, Linear programming analysis and Target MOTAD (Minimization of Total Absolute Deviation). Linear programming analysis is used to identify optimal farm plans feasible with the given set of farm resources endowments and constraints. MOTAD analysis is done to generate a feasible set of risk-efficient farm plans that can be used as a guide to minimize production risks at farm level.

3. Result and Discussion

3.1. Socio-Economic Characteristics of Sample Households (for Continuous Variables)

As the study result indicate that, the average age of the household head was 51.82, 40.77 and 40.71 years in the highland, midland and the lowland, respectively. It was statistically significant between the three agro-ecologies. The average family size of the households in the highland, midland and lowland areas was 8, 6 and 6 persons, respectively having 5.45, 4.98 and 4.98 man equivalent respectively. According to descriptive statistical analysis results, the average livestock holding (TLU) of the sample households was 7.67, 6.35 and 6.35 in the highland, midland and lowland, respectively having 2.4 oxen per household head. The results also show that there was statistically significant mean difference between the sample households in the three agro-ecologies in terms of livestock holding. The results of descriptive statistics show that the overall average land holding size in the study area was 1.52 ha.

In the highland, the average land holding size of the sample households was about 1.72 ha and that of the midland and lowland of the sample households was about 1.88 and 0.94 ha, respectively. The results of statistical analysis show that there was statistically highly significant difference between sample households in the three agro- ecologies in terms of land holding size. To know the labour supply, the proportion of labour force available for farming has been determined taking into consideration the labour division of the family according to which each of them gives priority to specific duty in their daily life. The observed family labour, who participates on farming activities, is converted into man equivalent based on the working capacity weight given to each age and sex group of the household members.

Total man-days available per month are obtained by taking into account the amount of labor force, for farming, supplied per day times the average number of working days in a month times the number months in a respective labour period.

Table 1. *Socioeconomic characteristics of sample households (continuous variables).*

Variable	Highland		Midland		Lowland		Total		F-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age	51.82	12.32	40.77	13.94	40.71	10.86	44.43	12.37	3.46**
Family size	8	2.96	6	2.99	6	3.78	7	3.23	1.56
Experience	20.93	11.82	23.15	12.27	23.15	12.27	22.41	12.12	1.44
Man equivalent	5.45	2.61	4.98	2.69	4.98	2.69	5.14	2.84	1.86*

Variable	Highland		Midland		Lowland		Total		F-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
TLU	7.67	5.03	6.35	3.37	6.35	3.37	6.79	4.01	1.60*
Land holding	1.72	0.779	1.88	1.114	0.94	0.798	1.52	1.064	6.52***
Educational level	6.06	2.74	6.43	2.74	6.43	2.74	6.31	2.74	1.6
Oxen keeping	2.414	1.235	2.042	1.572	1.413	0.834	2.400	1.434	1.54
Working Capital	6,350.1	3330.2	7500.1	4980.81	3750.3	1996.14	6678.8	4491.57	4.68***
Gross income/existing	19,480	8400.1	22,356	21,680.2	14,717	11564.3	19761	18339.8	2.01*

Source: Own computation results based on survey data (2022); *Significant at 10% level of significance **Significant at 5% level of significance, ***Significant at 1% level of significance

Table 2. Area cultivated and major crops grown in the 2022 production year.

Crop type		Teff	Wheat	Barley	Maize	HB	Potato	Carrot	Total
Highland	Hectare	0.25	0.35	0.29	0.23	0.00	0.26	0.34	1.72
	Percent	14.5	20.35	16.86	13.37	0.00	15.15	19.77	100
Midland	Hectare	0.42	0.5	0.32	0.24	0.23	0.05	0.12	1.88
	Percent	22.3	26.6	17	12.8	12.25	2.66	6.38	100
Lowland	Hectare	0.18	0.12	0.02	0.3	0.28	0.04	0.00	0.94
	Percent	19.15	12.77	2.13	31.9	29.79	4.82	0.00	100

Source: Own computation results based on survey data (2022)

3.2. Actual Farming Practice of Typical Farm Households

As indicated in above table 2; In three agro-ecologies;
Highland: Wheat and Barley dominant crop produced
Midland: Wheat and teff dominant crop produced
Lowland: Maize and HB dominant crop produced

3.3. Existing Farm Income

The main sources of income for the households are from farm (crops and livestock) activities. Based on the existing farm situation and the prevailing price levels, households in highland, midland, and lowland areas obtain the total gross income of Birr 19,480.00, 22,356.00, and 14,717.00 birr, in that order. Comparing the three agro-ecological zones of the both zones in their sources of income, those residing in the highland and midland areas earn more of their incomes from crop than livestock production while those residing in the lowland areas get more of their income from livestock than crop production. This difference is because of the difference in topography and whether condition of the three agro-ecological zones. For instance, topography and whether condition in the lowland area is not more suitable for crop production rather it is suitable for livestock production.

Table 3. Existing farm income.

Income source	Agro-ecologies					
Crop	**Highland**	**% share**	**Midland**	**% share**	**Lowland**	**% share**
wheat	4012	32	5022	33	705	14
Teff	2445	19	4226	28	852	17
Barley	1626	13	1327	9	430	6
Maize	1129	9	1289	8	1093	25
HB	0.00	0	2067	13	1584	32
Potato	1010	8	352	2	253	5
Carrot	2328	19	1053	7	0.00	0.00
Sub-total	12,550	100	15,336	100	4,917	100
Livestock	Highland	% share	Midland	% share	Lowland	% share
Ox	3462	50	3162	45	3980	41
Cow	1250	18	1320	19	2260	23
Sheep	610	9	868	12	495	5
Goat	258	4	359	5	1129	12
Donkey	752	11	735	10	925	9
Poultry	176	3	152	2	74	1
Egg	102	1	124	2	235	2
Honey	130	2	150	2	400	4
Butter	190	3	150	2	302	3
Sub total	6,930	100	7,020	100	9,800	100
Total income	19,480		22,356		14,717	

Source: Own computation results based on survey data (2022)

3.4. Results of MOTAD Model

After identifying the exiting farming situation, the next question not the resource allocation is optimal, considering both risk neutral and risky situations. This helps to envisage how the farm resources in the study area should be reorganized in order to improve farm income with the existing level of technology. The model was run on the GAMS (General Algebraic Modelling System), software package for mathematical programming problems. The model was first run for highland area followed by midland and lowland, separately. Given preference to different objectives of the households; a set of feasible risk efficient farm plans were generated by parameterizing the risk-aversion parameter (RAP) from zero to point where the value does not display further changes in solution plans of the model. The solutions obtained for these plans are from different value of Namely, 0.00, 0.50, 1.00, 1.50, and 2.00 are the value of considered in the model. The decision maker is risk-neutral when the RAP value is zero and this value corresponds to profit maximization (risk neutral) plan I, and Risk minimized farm plans (Plan II to V), are developed from the MOTAD model by varying the risk-aversion parameter.

3.4.1. Existing and Optimal Farm Plan with Minimized Risk for Highland Typical Farm Households

The MOTAD model results generated for a typical household in the highland area is presented in Table 4 which summarizes the combinations of different activities and resource use patterns for the existing practice (which represents the average farm plan as is being practiced), the profit maximization plan (Plan I), and for risk minimizing alternative plans (II- V). The trade-off between risk and return (CV, measures of associated level of risk, in percent) indicates that as the CV reduces, the return also decreases this implies that risk per return to resources is reduced this will enable them to increase their profit level with minimum risk. The pronounced difference between the households' observed plan and income maximization plan is that, linear programming model aims at profit maximization alone whereas traditional or smallholder farmers have additional objectives such objectives are; the maintenance of a minimum level of family self-sufficiency in food supply and risk reduction besides maximizing income.

The total annual income earned at the existing level of resource endowments of a typical farm household is Birr 19,480 in this agro-ecologies. As the Model results, depicted in Table 4, Farm households operating under income maximizing plan, plan I, obtain Birr 26,479.58 which is higher than the income households derive under the existing plan. The cropping pattern, in risk neutral plan, is dominated with maize and wheat which allows household keep family self-sufficiency in food supply. However, this plan is associated with high risk and high return which is likely to be selected by risk-neutral or risk-taking households. Therefore, Plan IV is the best suggested sustainable plan of the existing farm plan in terms of enterprises mix. The result confirms the theory of comparative advantage which dictates that specialization can lead to maximum profit; however, the level of profit is associated with higher variability, that is, higher risk. The model also makes clear that except at the current production plan of households, carrot and haricot bean is completely out of the risk efficient production plans at various level of RAP showing it is non-optimal to produce in the area. Hence, with prevailing farm environment, inclusion of carrot and haricot bean is not a risk minimizing strategy with optimum income. Interestingly, among typical crops grown in the highland areas; The area allocated to teff and barely, have shown a slight increase with increase in risk aversion implying that risk associated with these crops is less as compared to other crops. Hence, producing these crops has a risk stabilizing effect. The area allocated to maize and wheat decreases with an increase in the value of risk aversion indicating the high level of income instability associated with these crops.

Table 4. Existing and optimal farm plan with minimized risk for highland typical households.

Variable	Existing Farm plan	Profit max. plan I-risk neutral (γ=0.00)	Risk minimized and efficient farm plans II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Crop/ha						
Maize	0.230	0.501	0.402	0.301	0.021	0.199
Wheat	0.350	0.706	0.516	0.425	0.235	0.101
Carrot	0.340	-	-	-	-	-
Teff	0.250	0.201	0.270	0.402	0.510	0.550
Barley	0.290	0.291	0.300	0.301	0.330	0.368
HB	0.00	-	-	-	-	-
Potato	0.260	0.021	0.031	0.081	0.404	0.502
Livestock/head						
Oxen pair	1.20	1.20	1.10	0.75	0.60	0.43
Cow	3.00	1.06	1.06	1.05	1.02	1.000
Goat	1.38	1.37	1.36	1.38	1.39	1.38
Sheep	2.63	2.63	2.63	2.63	2.63	2.63
Donkey	1.09	1.09	1.09	1.09	1.09	1.09
Expected Income	19,480	26,479.58	24,722.8	21,837.8	19,804.01	18,804.0
Minimized SD	-	3023.39	2646.24	2274.65	1842.17	1812.17
CV (%)	-	13.40	9.50	5.40	5.20	5.20

Source: Own computation from the 2022 survey data

As livestock production is an integral part of a mixed farming system, it has been incorporated into the model. The model solution shows that the number of livestock, in general, remains almost the same with existing farm plan indicating that they are optimally allocated at the existing level of production. This also shows that livestock are a risk stabilizing component of the farming system compared to other enterprises managed by the households and it is complimentary to the cropping system. The result is consistent with [8].

However, the level of oxen and cow decrease as the risk aversion parameter increases. This may be due to shortage of feed supply coupled with limited communal and private pasture land in the highland areas compared to the other two agro-ecologies. A decrease in the area of land allocated for maize (forage crops), and an increase in the proportion of potato could be another justification. The model results, in Table 5, also show the resource use patterns across the alternative farm plans. Land is fully utilized in all plans implying additional returns to the households (as given by the shadow prices) as more unit of this resource is utilized. The result is in-line with the finding of [9]. The shadow price of resources under different farm plans indicates the amount by which the expected income value would increase on average if the particular (binding) constraint is relaxed by one unit until the other resource becomes binding.

Table 5. *Existing and optimal farm plan with minimized risk for highland typical households.*

Resource/ Shadow price		Unit	Existing Farm plan	Profit max. plan I (γ=0.00)	Risk minimized and efficient farm plans II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Land	Used	ha	1.72	1.72	1.72	1.72	1.72	1.72
	Shadow price	Birr/ha	-	10,658.80	5387.68	4392.65	2000.45	1000.66
Labour1	Used	Man-day	187.7	285.77	192.10	214.05	235	248.68
	Shadow price	Birr/ha	-	-	-	-	-	-
Labour2	Used	Man-day	97.4	111.5	111.5	111.5	111.5	111.5
	Shadow price	Birr/ha	-	65.8	71.02	70.15	81.25	99.18
Oxen	Used	Oxen-day	90.4	65.91	48.40	31.02	23.48	20.53
	Shadow price	Birr/ha	-	-	-	-	-	-
Working Capital	Used	Birr(00's)	5872.5	6352	6352	6352	6352	6352
	Shadow price	Birr/ha	-	1563.2	9563.25	8562.77	656.29	492.56

Utilization of the non-binding resources across the plans increases as consideration for risk aversion increases. Hence, the alternative farm plans represent better use of farm resources reducing the slack value for the resources. This indicates that there is a need for reallocation of the existing resources so that they can be used efficiently and other objectives are met, as well. The results of the study also reveal that capital is another binding resource in all plans. This result is consistent with that of [10] who indicate that land and working capital are binding resources in all plans.

On the other hand, family labor and oxen-power, in general, are found to be the non-binding constraint for farming in this agro-ecology. However, in particular, labour period two is a binding constraint in all plans as they are fully utilized under the mentioned plans.

The model result showed that land is a scarce resource in the study area. To change the expected income value in the optimal solution the households therefore requires an extra amount of Birr, showed by shadow prices of land under different plans, to hire an extra hectare of land under respective plan. With increase in risk aversion coefficient, the shadow price of land falls indicating land is a risk-reducing input. The same is true for working capital which is a scarce resource.

Where a resource is completely exhausted and is constraining production, more of the resource can be added through hiring, borrowing or buying. For instance, working capital can be borrowed at the going interest rate and more land can be obtained through rent in land and share land where it is constraining. For instance, in the optimal solutions of this agro-ecology, more land can be rented in and share while more working capital can be attained through credit.

Information regarding the effects of risk on shadow prices of scarce resources is necessary for making decisions regarding resource development and management. The results of the analysis indicate that incorporating risk into the farm planning model would not only minimize the variability in returns from the farm activities but also signifies a direction towards the efficient use of the scarce resources. For some resources, there might be surplus that would be invested on off and/or non-farm activities. The marketing activities (buying and selling activities), consumption and transfer activities generated in the model at various risk aversion parameter values are presented in Table below. The result is in-line with the finding of [11].

Table 6. Consumption, sells, buying and replacement activity level in the highland areas.

		Profit max. plan Risk minimized and efficient farm plans				
Variable	Unit	I	II	III	IV	V
		(γ=0.00)	(γ=0.50)	(γ=1.00)	(γ=1.50)	(γ=2.00)
Teff buying	kg	80	80	80	80	80
Barley buying	kg	-	80	80	80	80
Maize buying	kg	140	83.5	83.5	123.5	176.66
HB buying	kg	60	60	60	60	60
Potato selling	kg	63	84	115	140	180
Teff selling	kg	70	70	70	70	70
Barley selling	kg	125	125	106	105	100
Wheat selling	kg	180	159	165	165	165
Potato consumption	kg	43	43	43	43	43
Barley consumption	kg	170	170	170	170	170
Wheat consumption	kg	120	120	120	120	120
HB consumption	kg	70	70	70	70	70

Source: Own computation based on survey data (2022)
Note: Activity levels that are not included in the table are zero in all plans.

3.4.2. Existing and Optimal Farm Plan with Minimized Risk for Midland Typical Farm Households

In the midland area, an examination of the existing cropping pattern indicated that cereals account for about 85 % of the total cropland (1.76 ha) while the remaining 15% is allocated to pulses. More than 49 % of the total crop land and about 58% of the cereals are dominated by wheat and teff. The total income earned at the existing level of resource endowments and enterprise mix of a typical household is Birr 22,356.00. Examination of the model results (Table 7) indicate that; risk neutral (total income maximizing) earn average income of Birr 29,830.25 which is higher than the income the households can get from the existing practice (22,356). However, this plan is associated with greatest variability of (9%) a likely scenario that may be preferred by the risk-taking households, if any. Therefore, Plan IV is the best suggested sustainable plan of the existing farm plan in terms of enterprises mix. Interestingly, among typical crops grown in the midland areas; The area allocated to potato and carrot, have shown a slight increase with increase in risk aversion implying that risk associated with these crops is less as compared to other crops. Hence, producing these crops has a risk stabilizing effect. However, the area allocated to wheat decreases indicating the high level of income instability associated with these crops. The result is in-line with the finding of [12].

Table 7. Existing and optimal farm plan with minimized risk for midland typical households.

Variable	Existing Farm plan	Profit max. plan I (γ=0.00)	Risk minimized and efficient farm plans II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Crop/ha						
Maize	0.240	0.061	0.120	0.121	0.121	0.230
Wheat	0.500	0.701	0.613	0.510	0.360	0.132
Carrot	0.120	0.301	0.331	0.473	0.620	0.701
Teff	0.420	0.241	0.251	0.252	0.251	0.299
Barley	0.320	0.118	0.055	0.021	0.021	0.060
HB	0.230	-	-	-	-	-
Potato	0.050	0.458	0.457	0.457	0.458	0.458
Livestock/head						
Oxen pair	1.00	1.00	1.00	0.852	0.998	1.009
Cow	3.01	0.516	0.128	1.051	1.023	1.000
Goat	0.75	0.750	0.750	0.750	0.750	0.750
Sheep	1.57	1.570	1.570	1.570	1.570	1.570
Donkey	0.95	0.950	0.950	0.950	0.950	0.950
Expected Income	22,356	29,830.25	25,725.94	18,039.18	18,039.18	18,039.18
Minimized SD	-	2200.62	1397.18	823.52	843.69	835.86
CV (%)	-	9.00	6.00	4.00	4.00	4.00

Source: Source: Own computation based on survey data (2022)

When the risk-aversion coefficient further increases, Plan III and IV (for a moderately risk- averse households), there is no much change in the areas allocated to teff and maize while the area allotted to carrot appears to increase when compared to the previous plan (Plan II) indicating that carrot to be a less riskier crop than teff and maize in these plans. For higher values of risk-aversion parameter (Plan V, i.e. relatively highly risk-averse households), there is an expansion in the areas under carrot, teff and maize while the reduction in area under wheat and barley. This indicates that the production of these crops are less risky compared to wheat and barley. The possible expectation is that these crops are not highly affected by pests and diseases (plant diseases such as rust which is a common disease that widely affect crops especially wheat in the study area) and hence, have lower variability in yield. The model results also show that area under bean did not show a clear pattern as it devoted to satisfy rotational constraint.

The results of the risk programming model, for this agroecology, shows that from the risk efficient or risk minimized farm plans, plan III is the best approximation of the existing farm plan in terms of the mix of enterprises as it is associated with the smallest CV value which measures the level of risk.

Like the highland area, the number of livestock kept remains almost constant as the value of risk aversion coefficient increases and the same with the existing plan implying that in the midland area the number of livestock kept is at an optimum level. However, here also the number of cow is found to slightly decrease as the value of risk aversion coefficient increases, which may be due to households in this area want to decrease the total number of cattle they hold as the land scarcity increases in the area. The result is in-line with the finding of [13].

The resource use level and the corresponding shadow price across the plans are presented in Table 8. Here too, it appears that land and working capital are fully utilized in all optimal plans implying additional returns to the households (as given by the shadow prices) as more units of these resources are utilized until other factors become binding constraint. The marginal contribution of a unit area of land is higher for a risk neutral plan. It is implied that risk taking households are willing to pay a rental price as high as the respective shadow price of land. The higher Shadow price of working capital is presumably due to the need of working capital to purchase material inputs (fertilizers, agrochemicals, improved variety etc.) which are expensive relative to product price, and for additional purchase of feed and mineral for livestock production. The result is in-line with the finding of [14].

On the other hand, it would also be observed that oxen power and labour resources are generally not fully utilized in all plans. This implies an under-utilization of these resources which can be shown by the slack variables. However, oxen power in oxen period one (Ox1, February-July), which covers plowing and sowing duration, is fully utilized in all plans except the existing plan.

Table 8 depicts that, similar to highland areas, resource utilization increases as a consideration for risk increases. For instance, labor utilization increase from its level in the plan II as one move towards the least risk plan (plan V). Hence, alternative farm plans represent better use of the farm resources reducing the slack value for the resources. This indicates that there is a need for reallocation of the existing resources so that they can be used efficiently and other objectives will also be met. The use of oxen power in oxen period two (Ox2, August to January) did not show a clear pattern as there is a high use under the risk neutral plan and reduction afterward.

Table 8. Existing and optimal farm plan with minimized risk for midland typical households.

Resource/ Shadow price		**Unit**	**Existing Farm plan**	**Profit max. plan** I (γ=0.00)	**Risk minimized and efficient farm plans** II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Land	Used	ha	1.88	1.88	1.88	1.88	1.88	1.88
	Shadow price	Birr/ha	-	11,658.80	6387.68	5392.65	3000.45	1500.66
Labour1	Used	Man-day	212.87	289.56	221.93	235	249.59	274.19
	Shadow price	Birr/ha	-	-	-	-	-	-
Labour2	Used	Man-day	86.4	103.5	71.5	88.5	92.5	94.5
	Shadow price	Birr/ha	-	-	-	-	-	-
Oxen	Used	Oxen-day	125.4	155	155	154	154	155
	Shadow price	Birr/ha	-	39	55	69	70	71
Working Capital	Used	Birr(00's)	5872.5	8352	8352	8352	8352	8352
	Shadow price	Birr/ha	-	2147.746	1364.571	1639.314	2018.053	1909.574

Table 9. Consumption, sells, buying and replacement activity level in the midland areas.

Variable	**Unit**	**Profit max. plan** I (γ=0.00)	**Risk minimized and efficient farm plans** II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Teff buying	kg	158	158	85.29	49.09	49.09
Barley buying	kg	83.02	83.02	83.02	83.02	83.02
Maize buying	kg	260	108	108	108	108
HB buying	kg	60	60	60	60	60
Barley selling	kg	95.30	95.30	95.30	95.30	95.30
Wheat selling	kg	216.35	216.35	216.35	192.51	192.51

Variable	Unit	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Barley consumption	kg	118.25	118.25	118.25	118.25	118.25
Wheat consumption	kg	98.78	109.89	125.21	140.56	140
HB consumption	kg	55.02	55.02	55.02	55.02	55.02

Source: Own computation based on survey data (2022)
Note: Activity levels that are not included in the table are zero in all plan

3.4.3. Existing and Optimal Farm Plan with Minimized Risk for Lowland Household Typical Farm

Households in the lowland areas grow mainly maize, haricot bean, wheat and teff with livestock husbandry and hence, these crops were considered in the model. An examination of the existing cropping patterns showed that out of the total average cultivated land (0.94 ha), maize and haricot bean dominate the existing crop production plan of typical farm households operating in the lowland areas. That means, on average 0.58 ha (56%) of the total cultivated land is allocated to maize and haricot bean while, on average 0.30 ha (about 34%) is allocated to wheat and teff. Under this plan the level of total income that the household obtains is about Birr 14717.00. The model results for lowland area are depicted in Table 10.

The model results show that except at the current production plan of households; All crops are completely out of optimal plans at various level of risk aversion parameter showing that the all crops are not optimal to be grown under both risk neutral plan and risk aversion plans. Hence, with the prevailing farm environment, they are not a risk minimizing strategies with optimum income. Contrarily, maize and haricot bean are found in all plans showing that growing these crops in this area is optimal. As the model result indicate that, land devoted to Haricot bean has markedly increased at the expense of land devoted to maize production as consideration for risk increase showing that Haricot bean reduces income instability and is less risky crop compared to maize. Hence, producing haricot bean is slightly optimal compared to maize in this agro- ecology. Plan V is the best suggested farm plan in terms of enterprises mix as it is associated with the smallest CV value which measures the level of risk.

Table 10. *Existing and optimal farm plan with minimized risk for lowland typical households.*

Variable	Existing Farm plan	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Crop/ha						
Maize	0.300	0.569	0.457	0.407	0.310	0.290
HB	0.280	0.371	0.483	0.532	0.630	0.650
Wheat	0.120	-	-	-	-	-
Barley	0.02	-	-	-	-	-
Teff	0.180	-	-	-	-	-
Potato	0.04	-	-	-	-	-
Livestock/head						
Oxen pair	0.70	0.73	0.73	0.73	0.73	0.72
Cow	3.10	3.10	3.10	2.81	0.15	0.26

Variable	Existing Farm plan	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Goat	5.70	5.70	5.70	5.70	3.95	-
Sheep	0.34	-	-	-	0.34	-
Donkey	2.15	1.13	1.13	1.43	1.50	1.56
Expected Income	14,717	18,398	11,474	9,333	9101	8967
Minimized SD	-	1393	1384	1400	1067	889
CV (%)	-	7.60	7.5	7.4	7.2	7.1

Source: Source: Own computation based on survey data (2022)

The number of livestock kept remains almost the same with the existing farm plan, except cow and donkey, as the value of risk aversion parameter increases implying that, in the lowland area, they are optimal to keep. The number of cows decreases as the value of risk aversion increases, which may be due to feed supply variability coupled with erratic rainfall pattern in this area. On the other hand, the numbers of donkey increases as the value of risk aversion increases, which may be due to the increase in the demand for donkey to solve the transportation problem they face in the area. The number of sheep is found only in the plan IV of model result. Hence, keeping sheep out of this plan is not optimal in the lowland areas. The result is in-line with the finding of [15].

There is also discrepancy of income between the existing and the optimal plans, as in the two other agro-ecologies. The discrepancy in the model results from observed reality/existing situation suggests the importance of income risk minimization as a goal of households, for instance, fulfilling constraint of subsistence requirement. In other words, it may suggest that small farm operators are consistent with lower level of income and operate at low level of absolute risk (standard deviation).

The results of the risk programming model, for the lowland agro-ecology, show that from the risk efficient or risk minimized farm plans, plan V is the best suggested farm plan in terms of enterprises mix as it is associated with the smallest CV value which measures the level of risk.

The model result also reveals that it is possible to increase income and to reduce risk of smallholder farm households through optimal allocation of resources at their disposal. Such possibilities can be observed from the model output of shadow price of resources. The shadow prices in the model solution gives an indication of the importance of different limiting resources and hence priorities for their reallocation.

The results of the model for the various constraints indicate that, in this agro-ecology, only land is a binding constraint. The opportunity or marginal cost of renting in one more hectare of land under different plans is indicated in the Table 11. In order to be able to satisfy the optimum condition, as the results indicate, human labor, oxen power and working capital are non-binding constraints encountered by smallholder households operating in lowland areas. Hence, the shadow prices of these constraints are zero as neither of these resources is fully used for production under the existing technologies in the optimal risk efficient farm plans. The result is in-line with the finding of [16].

Table 11. *Existing and optimal farm plan with minimized risk for lowland typical households.*

Resource/ Shadow price		Unit	Existing Farm plan	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Land	Used	ha	0.94	0.94	0.94	0.94	0.94	0.94
	Shadow price	Birr/ha	-	2467.44	1091.69	1958.75	2674.67	2349.39

Resource/ Shadow price		Unit	Existing Farm plan	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Labour1	Used	Man-day	197.7	231.56	200.26	206.28	223.92	223.79
	Shadow price	Birr/ha	-	-	-	-	-	-
Labour2	Used	Man-day	47	86	72.50	49.72	75.08	80.64
	Shadow price	Birr/ha	-	-	-	-	-	-
Oxen	Used	Oxen-day	31.4	38.25	26.4	29.20	32.97	34.56
	Shadow price	Birr/ha	-	-	-	-	-	-
Working Capital	Used	Birr(00's)	3452.95	3704.7	3412.04	3482.3	3529.927	3679.76
	Shadow price	Birr/ha	-	2147.746	1364.57	1639.31	2018.053	1909.574

Table 12. Consumption, sells, buying and replacement activity level in the lowland areas.

Variable	Unit	Profit max. plan Risk minimized and efficient farm plans I (γ=0.00)	II (γ=0.50)	III (γ=1.00)	IV (γ=1.50)	V (γ=2.00)
Teff buying	kg	86	86	86	86	86
Wheat buying	kg	202	202	202	202	202
Maize selling	kg	83.5	83.5	83.5	276.26	83.5
Maize consumption	kg	121.31	121.31	121.31	121.31	121.31
wheat consumption	kg	106.25	106.25	106.25	106.25	106.25

Source: Own computation based on survey data (2022)
Note: Activity levels that are not included in the table are zero in all plans

On the other hand, here also the resource utilization increase across the plans as consideration for risk increases implying that there is a need for reallocation of the existing resources so that they can be used efficiently and other objectives will also be met. The slack or excess resources, for instance, labour and oxen (that are not utilized in the optimal plans) can be hired by other households or used in other non-farm income generating activities to earn more income, which can be used to improve the standards of living of his/her family.

In general, the model results presented in above Tables 4-12, show that at the existing level of production techniques and given resource endowments, the expected income of a typical household in the midland area of the woreda is higher than the expected income of households in the highland and lowland areas. The estimated plans for each agro-ecology (by increasing values of risk aversion parameter) show that households operating in the midland area of the both zones are relatively less risk averse compared to that of highland and lowland area. The less risk aversion behavior of the households in the midland areas may be related to the possible production choices in the areas. On the other hand, the limited number of crops to be grown and the very erratic nature of rainfall in the lowland areas may have resulted in higher risk aversion behavior of households in the area compared to that of midland and highland areas.

4. Conclusion, and Recommendation

This chapter presents the summary of the research work undertaken, the conclusions drawn and the recommendations made as an outgrowth of this study.

4.1. Conclusion

This study was conducted in West Arsi and East Shewa zones (in the three ago-ecologies) with the aim of understanding the existing resource allocation practices of smallholder households, examining the possibility of increasing smallholder farm income through optimal allocation of resources under risk neutral and risky situation, and developing risk efficient sets of farm plans for typical farm households in the study area. The descriptive statistical results of socioeconomic analysis show that most of the socioeconomic variables were found to be significantly different between the three agro-ecologies.

An examination of existing farming practice of the study area shows that the main sources of income for the household are from on-farm (crops and livestock) activities. Based on the existing farm situation and prevailing price levels, households in highland, midland, and lowland areas were obtaining the total annual income of Birr 19,480.00, 22,356.00, and 14,717.00, respectively. Comparing the three agro-ecologies in their sources of income, the households those residing in the highland and midland areas earn more of their incomes from crop production while those residing in the lowland areas get more of their income from livestock than crop production. The typical households in the highland, midland, and lowland areas possess average cultivated land of 1.72, 1.88, and 0.94ha with 7.98, 6.10, and 8.92 TLU respectively. With regard to crop production, HB and maize in the lowland, wheat and teff in the midland, and wheat, barley, and potato in the highland area dominate the existing crop production plan of the households in the woreda.

MOTAD risk programming model has been chosen as an appropriate optimizing tool for the present study. The expected income-variance (E, V) analysis of risk, generated by MOTAD model, was used to determine optimal and risk efficient sets of production plans under different risk aversion parameter values. The results show that as the value of risk aversion parameter increases, the model generates an optimal and different set of risk efficient farm plans for each agro-ecology. From those plans, farm plan that has minimum variability of expected income, measured in terms of standard deviations (SDs) or coefficients of variations (CVs), was suggested (for each agro-ecology) as sustainable farm plan that minimizes risk and ensures desirable gross return. Plan III, plan IV, and plan V for midland, highland, and lowland households, respectively, can be recommended for adoption under current level of resource availability since they have lowest associated CV value in their respective agro- ecology. It has been also showed that households from midland areas are less risk averse as compared to households from highland and lowland areas.

The model result also shows that, in all agro-ecologies, risk neutral (gross income maximizing) programming of the activities performed in the area resulted in an expected income that is higher than the income the households can get from the existing practice. Furthermore, as model results show, the expected income decreases as the RAP () value increases throughout the plans. Crops like carrot, teff and maize in the midland, teff, barely and potato in the highland, and HB in the lowland area have more stable land allocation throughout the (E, V) frontier as their land allocation increases with RAP increase implying that they are less risky crops and thus contribute income stability. Contrarily, wheat and barley in the midland, wheat and maize in the highland, and maize in the lowland area have less stable land allocation as their land allocation decrease with RAP increase. Hence, they are risky crops that contribute income instability to the household in the respective agro-ecology. On the other hand, carrot in the highland, teff and wheat in the lowland area do not exist in the area allocation of the model solutions showing that these crops are not optimal to be grown under both risk aversion and risk neutral plan.

4.2. Recommendation

An examination of existing farming practice of the study area shows that households residing in the highland and midland areas earn more of their incomes from crop than livestock production while those residing in the lowland areas get more of their income from livestock than crop production. This difference may have resulted from the differences in topography and weather condition of the three zones. Therefore, the households in the study area should be advised by DAs and select the enterprises that go well with their respective environment.

In all agro-ecologies there is a substantial difference between the households' observed plan and income maximization plan implying that if risk taking households reallocate their resources among the different activities, there is a possibility to increase their return under risk neutral situation. Furthermore, as the RAP () value increases the expected income decreases. Here, one can safely conclude that the current allocation pattern of the resources by the households lean towards pursuing a risk efficient plan and farther from the profit maximization objective. Farm households operating under such plans can minimize income instability and meet their multiple objectives even though they have no much room to increase their expected income. Based on these conclusions, risk-taker farm households who are in a position to get maximum returns need to intensify the production of enterprises combined in profit maximizing plan. However, risk-averse farm households can easily move between different combinations of less risky enterprises if they opting for other plans.

In the study area, households from midland areas are less risk averse as compared to households from highland and lowland areas. The reason for this difference may be due to their differences in the number of crops grown and livestock kept based on suitability of weather conditions in the areas.

This indicates that the risk-bearing capacity of households in different agro-ecologies is different. The implication is that area specific development programs are essential to improve and secure the level of income of rural farm households which in turn helps to support the food security improvement efforts in the study area.

Higher risk higher return to farm resources is one of the sects of production plans observed. In spite of these higher returns, however, reduction in risk was not consistent with the variability in returns. This was basically due to a decline in yield levels from plan to plan. Therefore, reducing the negative effect of risk on resource allocation and income of households should be targeted by the public and private sector and agencies. To this end, it seems that a set of appropriate policies such as crop insurance, agricultural input and output price policies should be investigated and applied in the studied area.

Utilization of the non-binding resources is found to increase across the plans, in all agro- ecologies. This means, increased consideration for risk implies that these resources can reduce households' income instability. Thus, research and extension should focus on improving efficient use of existing resources and identify suitable enterprise mixes that suit diverse needs of households with heterogeneous resource endowments and ability to bear risks. Lastly, inclusion of livestock enterprises minimizes risks in farming, as expected. In addition, it contributes to an efficient use of labor. Therefore, research and extension activities that would improve the productivity of livestock should be given emphasis to improve the welfare of the households.

Abbreviations

AGP	Agricultural Growth Project
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GTP	Gross and Transformation Plan
MoANR	Ministry of Agriculture and Natural Resources
MoARD	Ministry of Agriculture and Rural Development
MOTAD	Minimization of Total Absolute Deviations
SSA	Sub-Saharan Africa
NPC	National Plan Commission of Ethiopia
UNDP	United Nations Development Programme
WB	World Bank

Author Contributions

Beriso Bati is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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