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DETERMINANTS OF CROP CHOICE IN NORTH SHEWA, ETHIOPIA: A FRACTIONAL MULTINOMIAL APPROACH

Harun ME[1]* and B Legesse[2]

Mohammed Endris Harun

*Corresponding author email: mohzein1@yahoo.com

[1]Center for Rural Development, College of Development studies, Addis Ababa University, Addis Ababa, Ethiopia

[2]School of Agricultural Economics and Agribusiness, Haramaya University, P.O. Box 148, Haramaya, Ethiopia

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ABSTRACT

Rapid population growth and climate change remain challenges of addressing food security in sub-Saharan Africa. Improving productivity and commercialization of smallholder famers are recognized as effective strategies in addressing food security and sustainable agriculture. Crop choice is a tool for efficient utilization of land, stabilizing food prices and creating a balanced food system. Despite the presence of national agricultural output growth in Ethiopia in recent years, there is widespread concern that the contribution of agricultural output to gross domestic product is below its potential. To find ways to increase smallholders' crop production and productivity and achieve food security, this study investigated factors determining crop choice in North Shewa Ethiopia. A total of 392 farmers were selected using a Multi-stage random sampling technique. A schedule interview using questionnaire was used to collect cross-sectional data from smallholder farmers, while focus group discussions were organized to supplement the quantitative analysis. Results from descriptive statistics revealed that major sources of income were crop production activities. Findings also revealed that households had acquired land through redistribution and purchasing. The study also revealed that market-associated problems including transportation, weak land contractual enforcements, and inadecquacy of wage laborers during harvesting negatively affect farm income. The study found sorghum, teff, onion and mungbean as dominant crops covering 95 % of the total cultivated land. The finding also indicated that land allocation for each crop is interdependent between crop types and between households through their socio-economic facts. The Fractional multinomial model indicates that market distance and irrigation use were found to influence all four crop shares. The analysis also predicts the association of each variable with each crop share in the form of average marginal effects. The key policy implication is that optimal crop choice and sustainable crop production could easily be achieved through market related mechanisms like insurance and contractual farming.

Key words: Ethiopia, Fractional Multinomial Logit, Mung bean, Smallholder farmers

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INTRODUCTION

Across the developing world, most of the poor and hungry live in rural areas, where smallholder agriculture is dominant. Agriculture is the foundation of Ethiopia's economy, accounting for over 40% of Gross Domestic Product (GDP), engaging more than 80% of its labor force and is the source of most of the country's food crop production and 90% of the export value [1]. According to Salami *et al.* [2], from the total crop production, 95 % is generated by smallholder farms, producing mainly for home consumption and using traditional technologies. This shows the potential of agricultural development in rural Ethiopia to facilitate greater national food security and emulate overall economic growth. The Ethiopian government formulated a plan for accelerated and sustained development to end poverty (PASDEP) by promoting the commercialization of agriculture. The current national growth plan (GTP I) also recognizes the pivotal role of agriculture. It plans to encourage farmers to change from low value to high-value products in order to increase their cash incomes as one way for accelerated growth for the sector [3].

Some 50% of Ethiopia's land area is arid or semi-arid and largely represent the lowland areas of the country, either Kola or Bereha. In such areas, the coefficient of inter-annual rainfall variability around the mean is as high as 30% [4], leaving farmers living in this area more vulnerable and causing repeated droughts. Ethiopia's vulnerability to the adverse impacts of climate change due to heavy dependence on rain-fed agriculture and high population growth, an effective adaptation of agriculture to climate change is crucial to achieving food security [5]. Fafchamps demonstrated that farmers' crop choices are dependent on price and yield risk [6]. The degree of attention to the behavior of agricultural producers under risk has recently been increased by the progressive liberalization of the world agricultural markets [7].

Ethiopia's crop agriculture is complex, involving substantial variation in crops grown across the country's different regions and ecologies. The five major cereals (teff, wheat, maize, sorghum and barley) are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of total area cultivated. After cereals, the second most important crop group (in acreage) is pulses [8]. A farmer's crop choice decision-making process is believed to be implicit and internal, cyclical and recurrent, which leads to better understanding and evaluation of production terrains [9]. As the basic farm decision-making unit, the farm household makes critical decisions in agricultural production, particularly on land use and farm resource utilization. Such decisions are usually motivated by the goals, objectives, and values of the farming households [10]. They are also

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influenced by socioeconomic, institutional and climatic constraints including those beyond the farmers' control. Factors influencing crop choice decision-making processes, particularly in the face of climate change, have been studied using different econometric approaches and models [11, 12]. Studies on crop choice in the literature are diverse and focus on its impact on income or the overall production. This study intends to fill this gap by investigating crop choice determinants and proportion of land allocated to each. Therefore, the objective of the study is to identify factors affecting crop choices of smallholder farmers.

The nature and extent of crop choice decisions are usually motivated by the goals, objectives, and values of the farming households [13]. They are also guided by prevailing socioeconomic and environmental constraints including those outside the farmers' control like long-term change in soil fertility [14]. In addition to that, Mottet *et al.* [15] found technological change (introduction of tractors) playing a significant role in explaining crop choice decisions. The study, through identification of factors with strong relationships to crop choice, would help to move farmers from producing low value to high value crops based on specific comparative advantage in order to enhance their productivity and income from agriculture. It also help to facilitate and mange introduction of new crops into their crop mix and support efficient response to climate change.

MATERIALS AND METHODS

Data and the study area

The study site is located in the north shoa zone of Amhara regional state of Ethiopia. It has a predominantly Kola [1]agro-ecology. The economy is based on crop production supplemented by livestock production. Agriculture is the dominant economic activity engaging 92% of the labor force [16]. The land is degraded and the soils have low fertility and crop yields are, therefore low. Agriculture is rainfed, with two rainy seasons, kremt[2] and belg[3], although the big harvest is the meher from the kremt rains. The major crops grown in the area are sorghum, maize, teff, mung bean (masho), tobacco, fruits and vegetables. Most families also rear livestock. Oxen provide traction power for the cultivation of agricultural lands on the other hand, livestock are kept as a source of income through milk, butter, meat and egg production. This kola livelihood zone has fertile soils.

[1] Kola- an area with a higher temperature
[2] Kiremt/Meher- long rain season in Ethiopia - June, July, & August
[3] Belg (Autumn) – short season in Ethiopia - March, April, & May

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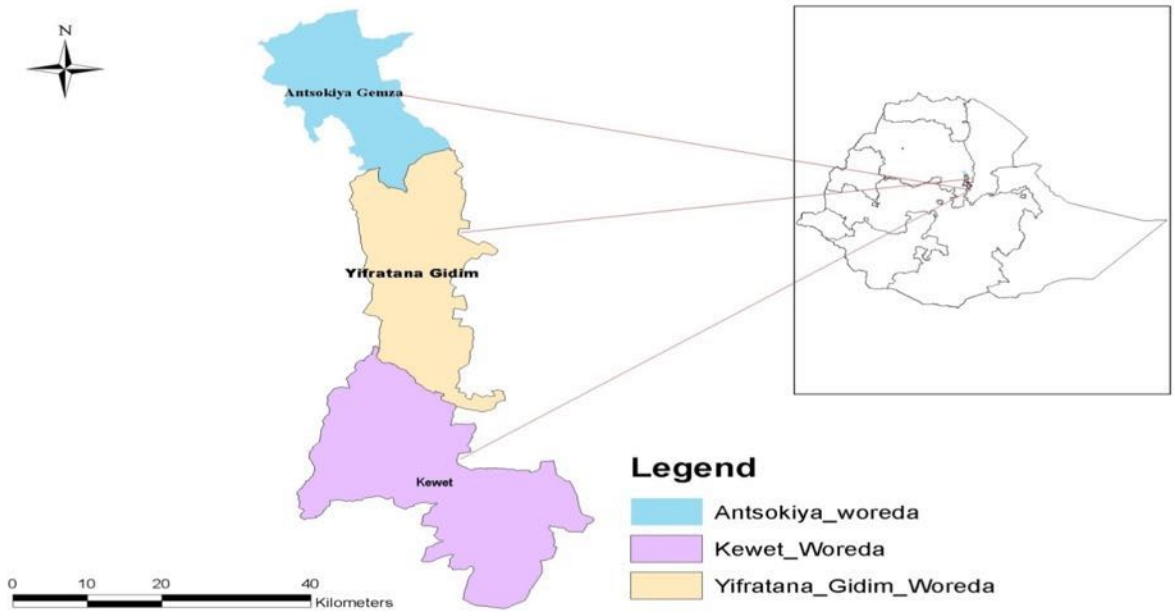

Figure 1: Map of the study area Source: Extracted from GIS

Population, sample size and sampling techniques

The study was carried out in Kewot woreda of North Shoa Zone with total population of 118,381 [16]. Using a Multi-stage random sampling technique, 400 households were selected from 5 kebeles (table 1). Initially, Kewot woreda was selected, considering the potential growing area of the taget crop (mung bean), Secondly, the 5 kebeles were randomly selected from the woreda. Finally, 400 farm households were selected using proportionate random sampling where 8 of them were dropped due to technical issues. The required sample size was computed using equation 1 which is developed by Yamane [17]. The data were collected in the 2017/2018 season through trained enumerators using a pre-tested questionnaire.

$$n = \frac{N}{1+Ne^2} \qquad (1)$$

Where: n = sample size
e = error limit
N = Total household number

The Fractional Multinomial Logit

To analyze the socio-economic factors affecting smallholder farmers' crop choice in the study area, the fractional multinomial model (fmlogit), which fits by quasi maximum likelihood, was used. The fractional multinomial model is the expansion

of the multinomial logit to fractional responses which considers the proportion of land allocated in addition to the crop type chosen [18]. This technique allows examination of shares of land allocation instead of yes or no responses. The proposed model by Papke *et al.* [19] has dependent variables that each range between 0 and 1 and must always, for each observation, add up to 1 with a multivariate generalization.

RESULTS AND DISCUSSION

Descriptive Statistics

Data characterizing the surveyed households is given in Table 2. The average age of the respondents was 41 years, with a minimum of 20 and a maximum of 68 years. The result depicts that the farm households were in active working age and were relatively younger, tending to adopt new crops, take a risk and have the ambition for higher income and commercialization [20, 21]. Family size ranged from 2 to 9 people with average family size of 4.14 members, which is slightly lower than regional average of 4.3 [16]. The increasing family size especially in rural areas causes the land holding of each household to decrease influencing crop choice [22].

The gender composition of the sample households indicated that about 90% of the households were male-headed and the remaining 10% were female-headed. UNESCO [23]; Luh [24] outlined that education has a profound effect on agricultural production and effectively copes with dynamic life changes. In this study, the educational outcome of the household heads is captured as “Illiterate,” “Read and write” and “High school completed.” The largest category of education was the “Read and write” group comprising 73% and the remaining 20% and 6% of the sampled household heads were under “Illiterate” and “High school completed” groups, respectively. Twenty percent of the respondents were found without any education despite Ethiopia’s attention and much effort to cut illiteracy to below 5% [3].

Credit and extension services are vital for farmers to use modern technologies and cope with seasonal problems such as food shortage. However, as the descriptive results in Table 2 show, 66.6% of the sample households, had no access to credit service or were not involved in credit service. On the other hand, about 95% of the respondents had access to extension service, from this, only 25% of the respondents used fertilizer which is against previous result where higher extension service contact found directly associated with higher utilization of modern inputs in cash crop areas [25]. Farmers use the local market and Shewa Robit city as a

major trading center. On average sample respondents had a distance of 7 and 12 Kms away from local and Shewa Robit city markets, respectively, with the average quintal transport cost of 38 birr to Shewa Robit. Respondents also mentioned Debrebrhan, Dessie and Addis Ababa markets as their direct market destinations.

Land use

This section presents land-use related issues as they in one way or another influence farm decisions and are an indispensable resource in agricultural production. Evidence shows that cropping systems practiced by farmers were significantly derived by farm size and land characteristics [26]. Overall, the average land-holding of the sample respondents was found to be 1.4 ha with a standard deviation of 0.17 ha. The maximum land size of sample households was 4.75 ha while the minimum was 0.6 ha. The sample average was higher than the national figure, 1.2 ha implying relatively better land-holding in the study area [16]. This larger land-holding invited huge labor from the north and south Wollo and this is evident from the large labor market observed in the study area, but due to the high temperature and less suitability of the area, laborers prefer working temporarily rather than permanently settling there. Participants of the group discussion also supported that the area is less preferable due to its high temperature, diseases and inter-ethnic conflicts.

Land attributes have a significant role in crop choice and other farm decisions. Sixty nine percent of the sampled respondents reported that their land was plain, while 29% and 2% reported moderate and sloppy, respectively. The less marginal land utilization (two percent) supports environmental sustainability. Further more, 80% of the respondents claimed that land available for rent has medium fertility and rated the availability of land for rent as high, that, inturn, contribute to sustainable production. More than 90% of land rent is legally documented and few land-related disputes appeared in the past years. Sixty seven percent of the respondents say there was no change in their farm size in the past ten years, while the remaining 33% reported reduction in farm size owned due to inheritance to siblings and taken away by government for rail way construction. The low land transfer through inheritance, which is 15% when compared to purchase and redistribution could indicate native youth reduced involvement in agriculture.

As shown in Table 3, majority (74%) of the farmers acquired their farm plots through inheritance and redistribution, while 24.6% acquired through purchase and rent. Fifty seven percent of the farmers acquired land through redistribution, implying farmers are working on relatively better quality land, in which most of the land associated with redistribution and resettlements are less fragmented and less

exploited. On the other hand, acquisition through lease and gift were not common among respondents. From the total land cultivated by sample respondents, 77.5% of the farmers cultivated their own land while 14.3% cultivated using different share cropping arrangements and labor. Participants of the group discussion also confirmed a high level of interference by the land owner specifically on the type of crop to be cultivated.

Farm practices and problems

Farm practices are part of decisions and play a crucial role in influencing farm efficiency. In the study area, 91% of the farmers reported that they apply rotation despite only 55% of them believes as an effective strategy for land productivity than fertilizer and compost use. Eighty percent of the respondents reported that they changed the crop type they used to grow at least once in their farming years. This could be an indicator of flexibility in their farm decisions, where 18% of the respondents indicated marketing problem and 32% production decline as a reason for the change they made. Table 4 presents major crop production problems, which are ranked using Rank Aggregation (RA), a process of combining multiple ranked lists into a single ranking (weight). Based on this, marketing problems and irrigation take first and second problems faced by farmers of the study area. Lack of support takes the last and from the group discussion, they indicated that they wanted constant contact with development agents, in the form of discussion not order or instruction. For smallholder farmers, fertilizers are often unaffordable, resulting in adverse impact. The current application rate of inorganic fertilizer is around 27 kg/ ha, which is slightly lower than the national average of 32 kg [27]. Conflicts are common in the area affecting farmers' productivity. The author witnessed serious conflicts in that short stint during data collection which is exacerbated as the area is a border between the Afar and the Amhara regional states.

Crop choice

Cropping System

The study identified teff, sorghum, onion and mungbean as the major crops grown in the study area covering about 95 % of the total land allotted to crop production. The other crops cultivated included maize, tobacco, mango, banana and vegetables. The relative importance of crops to the farmers could be seen from the proportion of land they allocated to their cultivation. In this regard, the share of the cultivated area allotted to each crop is presented in diagram 2, where 35% of the total area is covered by sorghum, higher when compared with the national teff coverage of 25% [16]. The dominance of sorghum production in the study is clear but not unique as most dry land farmers prioritize sorghum for their own

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consumption (ref for dry-land sorghum dominance) but the surprising fact is that it is also the highly traded crop in the area. Next to sorghum, teff, onion and mung bean took 24.00%, 16.98%, and 13.49% of the total crop production, respectively.

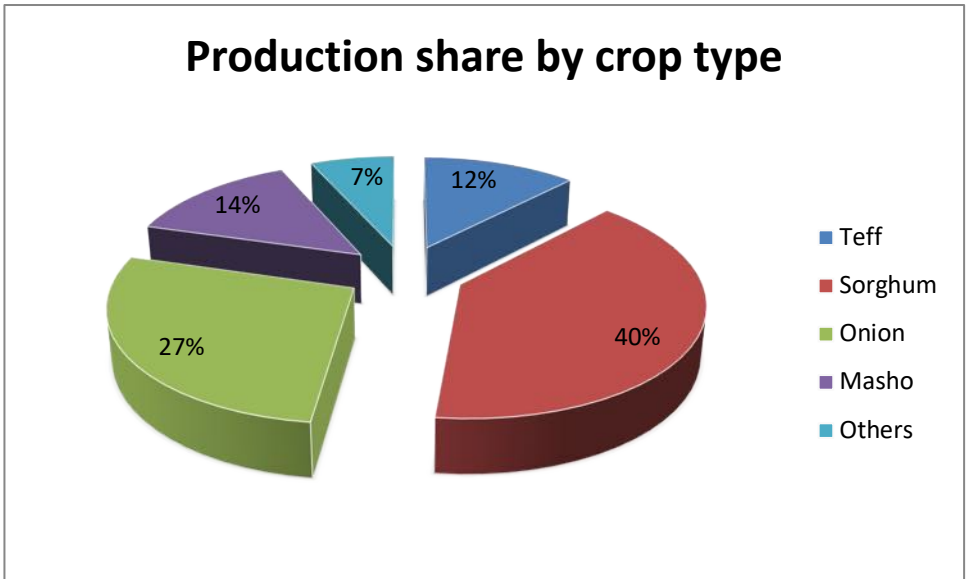

Figure 2: Share of each crop category from the total production (own survey, 2017/18)

Determinants of Crop Choice

Results of fractional multinomial logit

Table 5 summarizes some basic descriptive statistics about the dependent variables. The dependent variables are the crop shares for the portfolio of crops chosen by a household. The portfolio of crops for the study area consists primarily of sorghum, teff, mungbean and onion. The shares of a household's total cultivated hectares devoted to each of these crops are represented by sorghum share, teff share, mungbean share, and onion share, respectively. This makes four dependent variables. The standard deviations show heterogeneity of crop shares between households. The minimum value of crop shares which is zero for all crops indicates the presence of households not allocating any land for that specific crop, and a maximum value of 1 for sorghum and teff revealed the presence of households which allocate all of their land to one crop only. Minimum and maximum values of 68% and 72% for mung bean and onion respectively suggest that farmers are not growing mung bean and onion alone despite the existence of either teff or sorghum alone.

Drawing from 392 observations, eight were dropped due to technical issues, the fractional multinomial model converged on a log pseudolikelihood of -461.37 with a Wald chi-square value of 15106.73. The result in Table 6 shows the fractional logit

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function fits into the multinomial logit quasi-likelihood function. The dependent variables from the literature were considered at the start then selection of the variables was done based on best fittness after multiple regressions. Table 6 presents the average marginal effects of the independent variables on crop shares. Average marginal effects that are statistically different from zero at 5% and 1% levels are indicated with two and three asterisks, respectively; coefficients that are not statistically different from zero at the 5% level or below receive no asterisk. Of the model's 33 coefficients for average marginal effects, 24 are significant at 5% and 1% level. Furthermore, because crop shares must always sum to one as they are defined by the sum of total land allotted, the sum of the average marginal effects for any independent variable is zero; since one has to reduce the other to increase the one. Table 2 provides details on the variables used for the estimation.

Effect by Crop Type

For teff, market distance, animal ownership, irrigation and land type were found to have positive and significant effects on increased land allocation, while household size and extension contact were significantly associated with reduced land allocation for teff.

For mung bean, the share of land allocated was positively and significantly influenced by market irrigation extension and marital status. Education was the only significant variable that negatively affected mung beans' share of land.

Irrigation, extension, land size and marital status were significant variables positively affecting land allocation to onion while market and gender affected onion area share negatively.

Allocation of land for sorghum is significantly affected by market distance, animal ownership, irrigation, gender land ownership, all had negative effect except education which has a positive and significant effect.

Discussion by Variables

Market distance

A kilo-meter increase in market distance resulted in an increment in area share of teff and mung bean by six and four percent, respectively, while it created a reduction in area share of onion and sorghum by three and seven percent, respectively. The decrease in mung bean and onion land share when it is distant from the market is due to their short life-span than teff and sorghum. Recent moves by Ethiopian Commodity Exchange (ECX) to sort marketing problems for selected crops had a positive effect but was not sufficient.

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Animal ownership

Farmers owning more animals tended to allocate 0.5% and 0.3 % more land for teff and mung bean, respectively by reducing 0.8% of land from sorghum which had a significant and negative coefficient. This could be related with wealth where households with high number of animals prefered teff for their own consumption due to their relative wealth. This is in line with the results found by Mottaleb and Rahut [28], which established that poor household heads seem to have less resources and capability to invest into intensive crops.

Extension contact

Access to extension services was also significant and negatively related to the share of land allocated to teff and positively related to the land allocated to mung bean and onion. As shown in Table 5, the coefficients suggest that farmers having one week more additional extension contact have allocated a 19% less land share for teff while allocating 9% and 19% more land for mung bean and onion, respectively. Since the study area is a potential production site for mung beans because of its climatic suitability and source of foreign exchange, development agents could convince farmers to allot more land to mung beans.

Irrigation

Irrigation users allocated 10%, 12% and 11% more land area for teff share, mung bean share and onion share, respectively, to allocate the reduced 33% for sorgum share which has a negative coefficient than those with no access to irrigation. This could be related to the high revenue those trio crops, mung bean, teff and onion could generate, unlike sorghum. The result matches the finding of Dagninet and Adugnaw [29], where high welfare gains found from the production crops motivate irrigation use.

Gender

The result indicates coefficients of 0.15, 0.062 and -0.138 for teff share, mung bean share and onion share, respectively. This shows male-headed households allocated 15% and 6.3% more land to teff and mung bean shares, respectively and 13.8% less land to onion than their female counter parts.

Size of cultivated land

Land size is positively associated with onion share with a coefficient of 0.16 while a coefficient of -0.43 showing a negative link with teff share. The results indicated that a 1 hectare increase in area of cultivated land induces a 16% increase in area share allotted for onion and a 43% reduction of share allocated to teff. This is

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consistent with the findings of Nigussie *et al.* [30] where they found a strong association between onion and land size.

CONCLUSION

The study identifies teff, mung bean, onion and sorghum as dominant crops cultivated in the area. The land owned found to be larger than national average and fertile and mostly acquired through redistribution. It shows the area is less degraded and has potential for higher production and productivity. The study finds that land allocation for each crop is interdependent where increasing share of one crop results in reduction of land allotted to the other crops chosen. Access to market and irrigation are found significantly affecting crop shares of all the four major crops. The remaining variables are found selectively affecting crop shares, where allocation to one crop type is made by reducind share of another crop with different combinations. The significance of the marketing variable needs further investigation as to how to intervene to sort out marketing problems.

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Table 1: Sampling distribution

Kebelles	Abay atir	Yelin	Tere	Kure Biret	Shoarobit	Total
Population	8,112	6,855	9,415	5455	5873	35710
Sample households	91	77	105	61	66	400

Table 2: Summary Statistics of the Respondents

Variable Mean	Category	frequency	percentage
Educational Status	Illiterate	80	20.41
	Read and write	288	73.47
	High school completed	24	6.12
Marital Status	Single	24	6.12
	Married	360	91.84
	Divorced or widow	3	2.04
Gender of the household head	Male	351	89.54
	Female	41	10.4
Travel to a nearby city	Frequently	32	8.16
	Weekly	144	36.73
	Monthly	216	55.10
Irrigation use	Yes	304	77.55
	No	88	22.45

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Table 3: Land charatersitics

Land description	Plain	271	69 %
	Moderate	113	29 %
	Sloppy	8	2%
Marginal land	Yes	56	15%
	No	320	85%
Location of farm sites	One site	32	8.2%
	Different sites	360	91.8%
Land acquisition	Inherited	56	15.9%
	purchased	64	34%
	redistribution	224	57.4%
Land arrangement	Only own land	304	77.5%
	rent	56	14.3%
	Share cropping	32	8.2%

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Table 4: Major crop production constraints

Constraint	Total score	weighted score	Rank
Marketing problems	1740		1st
Irrigation	1302		2nd
Financial problems	1293		3rd
Shortage of land	910		4th
Lack of support	406		5th

Table 5: Summary Statistics for Dependent Variables

Variable	Mean	Std.Dev.	min	maximum
Sorghum Share	44 %	0.21	0	1
Teff Share	17 %	0.18	0	1
Mung bean Share	18 %	0.16	0	0.72
Onion Share	21 %	0.19	0	0.68

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Table 6: Average marginal effects derived from the fractional multinomial logit

variable	Teff share		Mung bean share		Onion share		Sorghum share	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Household size	-.0004571	.0087	.0118465	.00696	-.0046397	.00438	-.0067452	.00763
Market distance	.0000619***	.00001	.0000468***	.00001	-.0000327***	.00001	-.0000759***	.00001
Animal ownership	.0054858**	.00116	.0033739**	.00132	-.0001621	.00065	-.0086975***	.00155
Irrigation	.1009955***	.02359	.120868***	.0209	.1103266***	.01343	-.3323049***	.02835
Extension contact	-.1891024***	.04433	.0932263***	.02069	.1974501***	.0143	-.1015741	.05204
HH Gender	.1505237***	.02267	.0618968**	.02609	-.1383243***	.02668	-.0739776	.06663
T cultivated land	-.0429517**	.01849	.0054544	.01318	.0162822***	.00506	.0211988	.01142
Education	.023984	.02689	-.1597338***	.03724	.0318356	.01726	.1038815***	.03757
Marital Status	-.2588266	.1904	.1593623	.12281	.0591349	.011073	.0402666	.09008
Land type	.1295786***	.01918	-.0348439	.02005	-.0138408	.01018	-.08088 ***	.01964
Farm location	-.0593509	.05374	-.0199534	.05962	-.013917	.05648	.0932354	.05309

ML fit of fractional multinomial logit
Number of obs = 392
Wald chi2(33) = 15106.73
Log pseudolikelihood = -461.37602
Prob > chi2 = 0.0000

Note: **significant at 5% and *** significant at 1 %

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