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Determinants of land allocation decision to food crops - tree production in Mufindi

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Abstract

Understanding the determinants of land allocation decisions by farmers in food crops-tree production is vital for formulating land use plans and policies for the sustainability of the land resource. This study used 413 randomly selected households to investigate the factors that guide smallholder farmers' decisions in land allocation between food crops and trees. Results from the fractional multinomial logit model show that sex, household size, land size, awareness of land use policy, access to market information, and labor influenced land allocation decisions to tree farming more than food crops. All the results were statistically significant at P<0.05. The study recommends that the government sensitize women on the importance of tree farming; provide education about balancing between the production of food crops and trees, and create policy awareness and access to market information aimed at enhancing the production of food crops

Keywords: Food crops; fractional multinomial logit; land allocation; tree farming

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1. Introduction

The rising demand for food, wood products, and livestock feed to support a rapidly growing population is a policy issue requiring a clear understanding of the determinants of household land allocation decisions among the competing demand for a land resource that is scarce and fixed in nature (Wartenberg et al., 2021; Hinz et al., 2020; Wan et al., 2022). In Tanzania, the National Land Policy , states the importance of land in poverty reduction. The National Agricultural Policy (URT, 2013), also pinpoints that, the pace of land use planning and management is slow and that, there are growing environmental concerns and land use conflicts between various sectors, including farming, and forests inclusive. The same policy also states that agricultural land needs to be identified and set aside. In addition, the report on strategy for addressing land use planning challenges in Tanzania, prepared by the National Land Use Planning Commission indicates that sustainable use of land is vital for economic development, food security, and poverty reduction in Tanzania.

While both land and agricultural policies identify the importance of land allocation to different needs, little is known about the factors that guide farmers in allocating a piece of land at their disposal to agriculture and non-agricultural activities (Ullah & Dwivedi, 2022; Li et al., 2023). Land allocation studies by farmers have received special attention among researchers and policymakers worldwide (Mwaura and Adong, 2016; Adjimoti, 2018; Allen and James, (2014); Yigezu *et al.* 2018; Grise and Kuishreshtha, 2016; Nguyen *et al*. 2017). Moreover, the Village Land Act of 1999, and the Land-use Planning Act of 2007 mandate that land is allocated for a variety of uses, such as farmland and forestland, to enable effective and orderly regulation of land use and give users the power to make better and more productive use of their land (Ng'elenge *et al*., 2022). However, for making these land use acts work and ensuring the sustainability of the land resource, an understanding of the determinants of land allocation decisions by farmers is vital.

A study conducted by Ng'elenge *et al*, 2022 shows that in the Mufindi District smallholder farmers allocate land to tree plantations, maize, beans, finger millet, wheat, potatoes, and green peas. On average the same study report that smallholder farmers have allocated about 3.62 acres of land to food crop production, 4.28 acres to tree plantations, while 0.39 are left for fallow. The question arising from this analysis is about how farmers make such decisions. Un-informed land allocation decisions may result in welfare loss by smallholder farmers (Liu *et al.* (2016) and Hettig *et al.* (2016).

In examining the determinants of households land use, studies have used land share allocations to individual crops as dependent variables and found that sex, age, education, household size, land size, land use policy, access to market, labor, and income determine the allocation (Mwaura and Adong, (2016); Adjimoti, (2018); Allen, (2014); Gebresilassie and Bekele, (2015); Yigezu *et al.* (2018); Ndhlove, (2010); Alam *et al*. (2016); Amare *et al*. (2018); Jianhong *et al.* (2013); Nguyen *et al*. (2017) and Grise and Kuishreshtha, (2016). While the above studies are fundamental in explaining land allocation decisions, they have first focused on modeling land allocation to individual crops rather than a production system. Secondly, none of those studies have considered a scenario involving allocation between tree plantations and the production of food crops. Thirdly, none of the studies were conducted in Tanzania in general and Mufindi in particular where land-use change is at a great stance between food crops and tree plantations.

1.1. Purpose of study

Understanding how households allocate land will highlight important insights about the sector's resource allocation influences. The information will also be useful for creating land policies and putting into practice the necessary plans to guarantee sustainable agricultural and land development. Therefore, this study aimed at investigating the determinants of land allocation decisions by smallholder farmers between food crops - tree production in selected villages in the Mufindi District in Tanzania. The study tests the hypotheses that, land share allocation decision to food crops, tree plantations, and fallow is determined by factors such as sex, age, education, household size, land size, awareness of land use policy, access to market information, availability of hired labor and income.

1.2. Theoretical Framework

The land-use allocation has been defined by Kai *et al*. (2011) as a process involving the allocation of land to different uses within a geospatial context, the aim being to maximize social, economic, and ecological benefits. Land allocation has a historical background from Von Thunem, (1826) who devised a theoretical model on agricultural land location and allocation. The fundamental assumption was that farmers will allocate land based on their access to the market. While the theory has good insights to explain land allocation decisions, it ignores other important attributes such as socio-economic factors that could also determine land allocation.

The agricultural household model was developed by Becker (1965). The model assumes that "agricultural households strive to maximize utility which is a function of both consumptions of agricultural goods, consumption of non-agricultural goods and leisure. Moreover, the model depicts that, the output (yield) from agricultural production is a function of several attributes such as household characteristics, land size, labor input, and perceived riskiness associated with the production of a crop.

Adjimoti (2018) presents the structural form of the agricultural household model as follows:

$Max\ U = F(C_a, C_m, C_I)$ (*Utility maximization) ….* (1)

S.t: $P_a(Q_a - C_a) - P_z Z - wL + Y = P_m C_m + wH$ $(Budget\ constraint$(2)

$Q_j = f(Z_j, a_j, L, A, X)$ *(Production constraint) …* (3)

$T = H + F + O$ $(Time\ constraint)$. (4)

$Ca, Cm, Q \geq 0$ *(Non-negativity) …* (5)

Where a farmer attempts to maximize his utility from the consumption of agricultural commodity (C_a), non-agricultural goods (C_m), and leisure (C_l) subject to budget constraints derived as profit from agricultural production and income from off-farm activities, and secondly; production constraints such as household characteristics (Z) such as sex, age, education, household size and perceived riskiness of the crop (a), labor input (L), land size (A), and income (X). The production constraints on the other hand determine agricultural output (Q) which is estimated as land share allocation to that particular crop.

Adjimoti (2018) reported that, in agricultural production, it is difficult to estimate output, hence due to this complexity supreme supply response models have been used to model land share allocated to a particular crop as a proxy for output. Therefore, in this study, the output in the production function conceived within the agricultural household model will reflect land share in various production systems practiced by farmers. Variables such as sex, age, education, household size, land size, land use policy, access to market information, hired labor, and household's annual income is included in the model to investigate their influence on land allocation to food crops, tree production, and fallow.

2. Materials and Methods

2.1. Description of Study Area

The study was conducted in Mufindi District, a pioneer in the country in timber plantations (PFP, 2017), as well as the production of food crops. Mufindi is one of the four District authorities of the Iringa Region located 80 km South of Iringa Municipal. It is bordered by Njombe Region to the south, Mbarali District (Mbeya Region) to the West, and Iringa Rural District to the North. To the North East lies Kilolo District. In terms of international identification, the district lies between latitudes 8°.0' and 9°.0' south of the Equator and between longitudes 30°.0' and 3°.0' east of Greenwich. Mufindi is divided into five divisions namely

Ifwagi, Kibengu, Kasanga, Malangali, and Sadani. Agriculture is the main economic activity employing about 95% of its population (URT, 2013). Major agricultural activities practiced by smallholder farmers in Mufindi District include the production of food crops such as maize, beans, round potatoes, wheat, finger millet, and green peas, and the growing of timber trees.

2.2. Research Design

This paper adopted a cross-sectional research design approach to collect data. This design was found to be more appropriate because is cost-effective and can generate useful information for descriptive purposes as well as the determination of relationships among variables. In this study, the major focus is on a farmer possessing agricultural land from which the decision to allocate land to food crops, tree plantations production system, or fallow can be made. A farmer is a rational agent who can decide to allocate all the land to food crops, trees, and fallow or allocate a share of the land to food crops, trees, or fallow. Therefore, the unit of analysis is a household possessing agricultural land used either for the production of food crops, trees, or fallow.

2.3. Participants

The target population for this study was 4896 households in three divisions namely Ifwagi, Kibengu, and Kasanga. The major and common characteristic of all these households is that they own land and are engaged in the production of food crops as well as tree. The study adopted a multistage sampling technique involving the selection of three divisions from the district based on their potential in food and tree production, followed by a purposive selection of eight villages in each division that are potential in food crops and tree growing, and finally, a random sampling technique was used to select 413 households.

The sample size was estimated using Yamanes' sample size estimation formula for a finite population (Yamane, 1967);

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

$$n = \frac{4896}{1 + 4896(0.05^2)} = 370 \qquad 370 + (11.6/100*370) = 413$$

where 'N' is the population size and 'e' is the level of precision desired (0.05); while 'n' is the sample size to be estimated.

To cater to non-responses, sampling errors, and other survey problems, the sample was inflated by 11.6%. Thus, 413 households were sampled from the study villages based on the proportionality (percentage) as specified in Table 1. Random selection was then applied to select respondent households from each village.

Table 1

Sampling distribution

	Ifwagi Division				**Kibengu Division**		**Kasanga Division**		
Villages →	**Ifwagi**	**Ludilo**	**Igoda**	**Luhunga**	**Nundwe**	**Vikula**	**Mninga**	**Ikwega**	**Total**
Households	569	424	593	571	589	329	1145	676	4896
(%)	12	9	12	12	12	7	23	14	100
Sample	48	36	50	48	50	28	96	57	413

Source: NBS (2012)

2.4. Data Collection Instruments

Data used for this study are primary data collected using a structured questionnaire administered to heads of households from eight villages in the Mufindi District, Iringa region. The eligibility of the household to be involved in the sample size was the possession of land from which allocation to either food crops, trees, or fallow was made. The sampling frame of the study from which the sample size was estimated, was established through the assistance of the Village Agricultural Extension Agent.

2.5. Data Analysis

To analyze land share allocation, a household is assumed to allocate all available agricultural land to either food crops, tree plantations, or fallow or to all production activities simultaneously in such a way that for whatever allocation a farmer makes, the total allocation should add up to one (1).

Data were analyzed both descriptively and quantitatively. Descriptive analysis was conducted to summarize socioeconomic variables that are continuous where statistics such as mean, standard deviation, and range were generated. An independent sample *t*-test was done to determine if there were significant differences in land use allocation across the production systems. The fractional Multinomial Logit model (FMNL) was used to estimate the determinants of land share allocation across the production systems by farm households. In using the FMNL model, the present study assumed that a farmer having a piece of land allocates the land for food crops production, trees, and fallow where all fractions add up to a unit 1. Modeling such fractional dependent variables can be conveniently done within the framework of the fractional multinomial logit (FMNL). FMNL model is mostly preferred over the ordinary multinomial logit model as FMNL is capable of modeling fractions lying between 0 and 1. The fractional multinomial logit model assumes that $0 \leq y_{qi} \leq 1$ and $\sum_{i=1}^{l} y_{qi} = 1$, where *i* is an index that represents the activity type and q represents land share allocation to food crops, trees, and fallow. One (1) is the total of the fractions of land allocated to various uses and *yq* is the proportion of land allocated to a specified use out of the total land cultivated by a farmer. The explanatory variables are the factors that determine simultaneously land allocation decisions for the production systems. Papke and Woodridge, (1996) present the FMNL model which was also used by Ye and Pendyala (2005) as described in equation 1; *E(log[y/(1-y)]/x) = xβ ………………………………………………………………………………………………1*

This log-odds ratio only applies when y is strictly between 0 and 1 and is estimated using a quasi-maximum likelihood estimator as described in equation 19.

Thus, $E(\log[y/(1-y)]/x) = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots \beta_{10} X_{10}$ ………………………………………………………………………………2 $= \beta_1 + \beta_2$*sex*$+ \beta_3$*age*$+ \beta_4$education + β_5Household size+ β_6Land size + $\beta_7$land use Policy + β_8 access to market information + $\beta_9$labour + β_{10} Income

Table 2

Description of explanatory variables used in the Fractional Multinomial Logit Model

Independent Variable	Variable Definition	Measurement
Sex (X_1)	Sex of the household head (dummy)	1 if male and 0 otherwise
Age (X_2)	Age of household head in years	Continuous
Education (X_3)	Years of schooling by the household head	Continuous
Household size (X_4)	Total number of people living in the household	Continuous
Land size (X_5)	Total land owned by a household (acres)	Continuous
Policy (X_6)	Whether the household is aware of the land use policy (dummy)	1 if yes and 0 otherwise
Market access (X_7)	Whether the household has access to market information (dummy)	1 if yes and 0 otherwise

Labor availability (X_8)	Whether the household allocates land based on available farm labor	1 if yes and 0 otherwise
Income (X_9)	Total annual household income (Tshs)	Continuous

Table 2 displays the description of explanatory variables used in the fractional multinomial logit model.

2.6. Ethical Consideration

The Jordan University College Deputy Principal (Academics) approval was sought before data collection. The concerned Local government officials, including the District Executive Director, Ward Executive Officer, and Village authorities, were then presented with it. The following ethical principles were closely respected during data collection: informed consent, which is when a person offers his assent voluntarily, knowingly, and intelligently; respect for anonymity and secrecy; respect for privacy; and consideration of vulnerable groups of individuals.

3. Results

3.1 Socio-Economic Characteristics of Respondents

An assessment of the socio-economic characteristics of the respondents is of paramount importance as it gives a prediction of the response to different stimuli subjected to them. The socioeconomic variable included in this study were household head sex, age, education, household size, land size, awareness of land use policy, access to market information, farm labor, and income.

Results in Table 3 show that respondents mainly consisted of males (77%), farmers who were not aware of land use policy (73.4%), farmers with access to market information (75.3%), and those who had easily available farm labor 71.2%). Moreover, the respondents had a mean age of 44.6 years (23 - 72 years), education level ranged between 0 – 18 years of schooling with a mean of 7.1 years (primary school levers), and household size was found to range between 1 - 10 people (mean 4.5 people). This means household size is just above that reported in the national statistics (URT, 2013) which was 4.3 in Mufindi District. The land size was moreover found to range between 0.5 – 47 acres, with a mean of 8.25 acres, and the mean household's annual income was Tshs 1 648 680 (ranging between 10 000 - 32 000 000), which was below the national average of 2,275,601. Household income is fundamental in agricultural investment; hence low income is likely to reduce land allocation to food crops/trees.

Table 3

Socio-economic and demographic variables

Variable	Variable category	Frequency	Percent
Sex	Male	318	77
	Female	95	23
Whether aware of land use policy	Aware	110	26.6
	Not aware	303	73.4
Whether have access to market information	Yes	311	75.3
	No	102	24.7
Labor availability	Yes	294	71.2
	No	119	28.8

	Obs	Mean	Std. Dev	Min	Max
Age	413	44.64	12.64	23	72
Education	413	7.11	2.95	0	18

Household size (Hhsiz)	413	4.5	1.78	1	10
Land size (Landsize)	413	8.25	7.53	0.5	47
Income	413	1 648 680	3 124 228	10 000	32 000 000

3.2. Land Allocation

Table 4 shows that the mean land allocated to food crops by households was 3.57 acres, ranging from 0.5 to 18 acres with a standard deviation of 2.8, while the mean for trees was 4.28, ranging from 0 to 42 acres with a standard deviation of 5.9, and that of fallow was 0.39, ranging between 0 to 15 acres, and having a standard deviation of 1.44. These results imply that households in Mufindi District have generally allocated more land to tree plantations, followed by the production of food crops and fallow. The reason could be attributed to the utility in terms of profit tree growers get from tree production.

Table 4

Land use share allocation

Variable	n	Min	Max	Mean	Std. Dev
Food crops (Acres)	413	0.5	18	3.57	2.81
Tree plantations (Acres)	413	0	42	4.28	5.99
Follow (Acres)	413	0	15	0.39	1.45

3.3. Determinants of Land Share Allocation Decision

The fractional multinomial logit model results converged on a log pseudo-likelihood of -282.43098 with a Wald chi-squared of 222.79. Moreover, the chi-square result has a probability of 0.0000 meaning that it is globally highly significant. Data analysis started first with finding a maximum likelihood (ML) fit of fractional multinomial logit FMNL, upon which, the average marginal effects of the independent variables on land shares were calculated from the FMNL fit (Table 5). Food crops' land share was used as a reference category as it was found to be produced by all households. Results were statistically significant at 5% and were used to explain the relationship between dependent and independent variables. The income variable was not included in the model due to the presence of outliers, hence inconsistent results.

Results in Table 5 show the variable sex to have a significant effect on land share allocation to trees. Female-headed households are associated with a 16.9% decrease in the relative log odds of land share allocation to tree plantations Vs food crops, while it is not significant in fallow. Results are found to be significant at $p<0.01$. The results were expected as females are mostly responsible for the production of food crops for family consumption than males, and therefore are likely to invest more in food production than in trees. While these results are in line with Alexander and Scott (2016) who reported that trees cannot overturn food crops as food is needed daily, there is a need for women sensitization to the production of trees, as they are vital in income generation, poverty reduction, and ecological balance. Villamor *et al*. (2014) also reported that males while motivated to grow trees also incorporate food crops, while females' interest is in food production and consumption.

Table 5, shows that the age variable was not significant ($p<0.1$) for both tree plantations and fallow. These results are in line with Kinuthia *et al.* (2018) and Obayelu *et al*. (2014), who found that older farmers were less likely to take up crop diversification or plant agroforestry trees and also adapt to new production practices.

Table 5

Average marginal effects derived from the Fractional Multinomial Logit (FMNL) Model

	Tree plantations' land share				Fallow land share			
Variable	dy/dx	Std. Err.	z	P>z	dy/dx	Std. Err.	z	P>z
SexX_1	-0.1690	0.0385	-4.39	0.000***	0.0014	0.0122	0.11	0.912
AgeX_2	-0.0021	0.0011	-1.9	0.057	0.0006	0.0003	1.88	0.060
EducatX_3	0.0042	0.0046	0.91	0.365	-0.0025	0.0014	-1.76	0.079
HhsizeX_4	-0.0121	0.0076	-1.58	0.114	0.0051	0.0024	2.19	0.029***
LandsiX_5	0.0262	0.0023	11.35	0.000***	0.0019	0.0005	3.58	0.000***
PolicyX_6	0.0617	0.0294	2.1	0.036***	-0.0071	0.0084	-0.84	0.402
MarketX_7	0.0954	0.0307	3.11	0.002***	-0.0121	0.0111	-1.1	0.273
LabourX_8	0.1164	0.0294	3.95	0.000***	0.0035	0.0075	0.47	0.636

Number of Obs =413
Log pseudo-likelihood = -282.43098
Wald chi^2 (16) =222.79 Prob > chi^2 = 0.0000

4. Discussion

Results presented in Table 5 show that years of schooling were not statistically significant (p>0.1) in influencing land allocation to both tree plantations and fallow. The study results are in line with Tefera and Lerra, (2016) who found that education level had no significant effect on allocating land to trees. However, it was found to contradict that of Aguilera, et al. (2013) who found that education level was significantly explaining land allocation decision to fallow, and gave an argument that, while following is seen as a strategy to enhance soil fertility, an educated farmer may instead of fallowing; nourish the soil through the application of organic manure and inorganic fertilizers while continuing to utilize the land for crop production.

An increase in household size was found to be associated with a significant increase in land share allocated to the fallow (P<0.05) relative to food crops. This finding brings a new insight that requires more investigation, as it was expected that, fallow land would decrease with an increase in household size. While counter-intuitive, this could be caused by the engagement of some family members in petty and other off-farm activities created by fast-growing and commercialized tree farming, hence farmers engage in those activities to meet the daily households' requirements, leaving land fallow.

Further, results in Table 5 show that household land size has a statistically significant influence on land allocation decisions (p<0.01). A one-acre increase in household land size is associated with a 2.62% increase in the relative log odds of land share allocation to the tree against food crops. It is also, associated with a 0.19% increase in relative log odds of land share allocation to fallow versus food crops. All results are statistically significant at p<0.01. This means that a household having additional land is likely to allocate it to trees while bearing some for fallow as a way of replenishing soil fertility. Adjimoti (2018) also found that the share of land allocated to major food crops was significantly decreasing compared to other crops while increasing that of industrial crops. On the other hand, it is expected that, if a farmer has a large piece of land, given the resources at his/her disposal, it is possible to fallow some land.

Households' awareness of land use policy was found to be associated with a 2.94% increase in the relative log odds of land share allocation to trees versus food crops, while it is not significant for fallow land. The result is statistically significant at p<0.05. Thus, awareness created by various tree stakeholders including both international Companies such as Green Resource and other local institutions like Southern Paper Mills, Twico, carbon credit, timber traders, and the government, are likely to contribute to increased land share to trees because of its perceived benefits. Hettig et al. (2016) also pointed out that global markets and focus on global cash crop markets have created incentives for agents to switch their land use towards cash crop cultivation and for raising households' incomes. Thus, policies such as carbon credit might have resulted in a switch to allocating more land for trees.

The variable access to market information by the household was found to be associated with a 9.54% increase in the relative log odds of land share allocation to trees against food crops, while it is not significant for fallow land. Results are statistically significant at $p<0.01$. These results signal that households who have access to agricultural market information allocate 9.54% more land to timber trees than households without market information. The same results were also found by Allen (2014) who reported that villages with better market access were correlated with a much higher share of secondary crops. Ahimbisibwe (2019) also reported that a household's decision to select perennial and annual crops depends on the market price of the crop. Hence households are likely to make more land allocation decisions to trees for which market is readily available than food crops.

Table 5 reveals the availability of farm labor to be associated with an 11.64% increase in the relative log odds of land share allocation to trees versus food crops, while it is not significant for fallow. Results are statistically significant at $p<0.01$. Based on the findings above, labor is an important variable in tree production as compared to food crop production. This could be attributed to the fact that; the tree industry has created off-farm activities that attract more labor. These results are found to be related to Mponela *et al*. (2011), Coxhead and Demeke, (2004), and Perz, (2002) who reported the availability of farm labor to be among the factors that influenced land allocation to various crops.

5. Conclusion

The purpose of this study was to investigate the determinants of land use allocation decisions in food crop/tree production in the Mufindi District. This study found that on average farmers have allocated 3.57 acres to food crops, 4.28 acres to trees, and 0.39 acres to fallow. Sex was found to be significantly influencing land allocation decisions to trees, whereas male-headed households were found to be more prevalent than female-headed households. An increase in household size was found to be associated with an increase in land share allocated to fallow as compared to food crops. This could be contributed to engagement in petty activities created by the growing tree plantations industries, hence looking for petty income to sustain the family.

Also, an increase in the land size (acreage) of the household was found to be significantly influencing land allocation decisions to tree plantations rather than food crops. Availability of market information to households was found significantly influenced land allocation decisions to trees more than food crops. Moreover, results showed that households' awareness of land use policy significantly influences land allocation decisions for tree plantations more than food crops, and the availability of farm labor significantly influenced land allocation decisions to trees rather than food crops. All results were found statistically significant at $p<0.05$.

6. Recommendations

Based on the study findings, the following are recommended for policy action;

- The government should provide education and sensitize women on tree farming as the business play a great role in income generation, poverty reduction, and ecological balance.
- There is a need for the government to provide education to smallholder farm households about balancing between the production of food crops and trees, as income from trees becomes available after ten years, while food crops are harvested every year, and are a source of household income and food security in the short run.

- As results show that, both land policy awareness, access to market information, and labor are in favor of tree farming by smallholder farmers, this study recommends that there is a need for a balance between food crops and trees as both are vital for livelihoods given the nature of smallholder farmers. Hence the government should create awareness among farmers.
- Further investigation is needed to ascertain the reason for increased fallow land when household size increases.

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