Domestication of Terminalia brownii Among Smallholder Farmers in Eastern Kenya: A Double Hurdle Approach.

Albert, M. Luvanda[1]*   Christopher, N. Kamau[2]   Sylvia, M. Uchi[1]   Pauline Bala[3]
Michael M. Okeyo[1]
1.Kenya Forestry Research Institute (KEFRI), Dryland Eco-Region Research Programme (DERP) - Kitui. P.O BOX 892, Kitui, Kenya
2.Department of Agricultural Economics, Kenyatta University P.O BOX 43844, Nairobi
3.Kenya Forestry Research Institute (KEFRI), Rift Valley Eco Region Research Programme (LVRP), Turbo Sub Centre, P.O. Box 5 Turbo Kenya

Abstract
Evidence has shown that the population of *Terminalia brownii* continue to dwindle in its native range due to drought, agricultural expansion and settlement and over exploitation for charcoal, beehives, carvings and timber. High levels of exploitation accompanied by awareness creation on value addition remains an exit strategy towards poverty alleviation for improved rural livelihoods, hence, the need to support its domestication. Scientists and researchers have prioritized promotion of this species in Eastern Kenya. However, information on intensity of domestication of the species remained scanty. A sample of 346 *T. brownii* producers were selected using a multi-stage sampling procedure in Embu, Machakos, Kitui and Makueni Counties in Kenya. Primary data was collected using a pretested structured questionnaire while secondary data was acquired from the Kenya Forest Service offices in the study area. A double hurdle econometric model was used to analyse the determinants of decision and intensity of use of *T. brownii*. Results revealed that five variables that significantly influence the decision to domesticate *T. brownii* include; education level of household head, importance of farm to the household income, access to credit, dependency ratio and intercropping. On the other hand, education of the household head, size of the farm and total income from livestock sales influenced intensity of domestication of *T. brownii*. Therefore, there is need to develop programs to sensitize farmers on the importance of the species on their farms. Lastly, we need to promote structures for commercialization of the agroforestry products from this tree species to reduce unemployment.
Keywords: Terminalia brownii, Domestication, Agroforestry, Dryland, Double Hurdle
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Introduction
Smallholder farmers have often been blamed for being the main cause of deforestation since as they gain access to forests after logging companies have harvested timber or partially converted the natural forest to other uses. Furthermore, the role of smallholder farmers as agents of reforestation is usually not acknowledged. As local forest resources disappear, smallholder farmers protect and plant on farm trees for subsistence and income purposes. The scarcity of forests or tree products provides farmers with an opportunity to diversify farm production and income streams. The rapidly increasing population significantly contributes to deforestation as farmers strive to meet their requirements for fuelwood, building materials and clearing for agricultural land. As access to forest products dwindles, an increasingly higher proportion of households are finding it necessary to explore options to domesticate trees and shrubs in their small farms (James *et al.,* 2000).

Majority of smallholder farmers within the tropics rely on various indigenous tree species including *Terminalia brownii* (Fresen) as a secure source of livelihood (Neufeldt *et al.,* (2012). Studies have revealed that forest goods and services provide security for over 80% of the smallholder farmers thus contributing to poverty reduction and national development (Nasi *et al.,* 2008). Further, indigenous trees mitigates soil erosion menace in many of the developing countries in Africa (Mutegi *et al.,* 2008; Ma *et al.,* 2009) thus addressing the vulnerability to negative climate impacts (Garnity *et al.,* 2010). According to Sileshi *et al.,* (2011), conservation of trees helps improve on grain production thus addressing food insecurity. Trees have been found to generate good returns hence impacting on poverty alleviation among the rural households (CIE, 2011). Many indigenous tree species that provide fruits, medicine, oils, beverages, timber, firewood, charcoal and other industrial raw materials remain largely wild. This implies that there is a huge potential for rural communities to increase their income streams through domestication of indigenous specific tree species. Therefore, domestication remains an avenue of addressing the negative climatic hazards through food and income diversification (Thorlakson and Neufeldt, 2010; Altieri *et al.,* 2015). Furthermore, promoting trees growing positively improves on nutrition of the inhabitants especially in Sub-Saharan Africa (Von *et al.,* 2014: Covic and Hendriks, 2016 & FAO, 2017). Notably, prioritizing tree domestication has been identified as a new frontier towards science based agroforestry

development which will apparently translate to achievement of Millennium Development Goals (MDGs) (FAO, 2017).

Terminalia brownii is an indigenous tree species that usually grown to a height of 4-15m high and its widely distributed in high rainfall woodlands, bushlands, and wooded savannah of the arid and semi-arid lands of Africa (Mosango, 2013, Orwa *et al*., 2009). It is a fast growing, drought tolerant and termite resistant species in Combritaceae family. It is a deciduous tree native to Eritrea, Ethiopia, Kenya, Somalia, Sudan, Tanzania, Republic of Congo and Uganda (Maundu and Tengnas, 2005; Orwa *et al*., 2009; Mbwambo *et al*, 2007, Machumi *et al*. 2013, Mbiri *et al*, 2016; Francis *et al*., 2013, Asmait *et al*, 2018). The distribution is influenced by temperature, rainfall and soil conditions (Schmidt, 2010; Enass, 2017). The species thrives well in deep, sandy and loam soils with mean annual rainfall of 500 to 1 300 mm. In Kenya, the tree grows in agro-ecological zones such as; zone III, and IV. It flowers from March to June under normal climatic conditions. In its natural range, it is known as *shagarat elsobag* in Sudan, *Leh heli* (Boni), *Biress* (Boran), *Muuku*, muvuku *or Kiuku* (Kamba), *Mbambaro/ mbarao* or *mwalambe* (Kiswahili), *koloswa* (northern region, Kenya), *weba* (Ethiopia), *lbukoi* (Samburu), orbukoi (Maasai, Tanzania) (Thoria *et al*., 2011; Mbwambo et al, 2007; Maundu, and Tengnas, 2005).

Terminalia brownii is a multipurpose species that is widely used in construction and joinery works. It is mainly used as a source of high quality fuelwood for domestic, tobacco curing and drying and brick making (Orwa *et al*., 2009; ICRAF, 1992). Alternatively, the wood is used for furniture making, fencing posts, canoes/boat building, carvings (utensils, bowls, spindles, moldings, etc.) tool handles, beehives, walking sticks, coffin boards, beams, rafters/ foundation piles, joists, flooring, handcarts, shuttles, veneer and plywood, (ICRAF, 1992; Maundu and Tengnas, 2005; Mosango, 2013). According to Neufeldt *et al.,* (2012), the study supported the use of the species for timber and medicinal purposes. The human, crop and livestock medicine derived from *T. brownii* for treatment of bacterial, fungal and viral infections exceeds that of conventional drugs by 2-3 times (Mbiri *et al,* 2016; Kigen *et al,* 2013; Pal and Shukla, 2003). Furthermore, it is used alone or in combination with other plants for medicinal purposes. It is used to treat cough, jaundice, malaria, diarrhea, cut wounds, hepatitis, liver cirrhosis, yellow fever, tuberculosis, epilepsy, urino-genital problems, syphilis, gonorrhoea, body swellings, heartburn, stomach complaints, colic, eye infections, tonsillitis, typhoid, endometriosis, cystitis, leucorrhoea, snake bites and ring worm (Mbiri *et al*, 2016, Kareru, *et al*., 2007; Enass *et al.,* 2017; Mbwambo *et al.,* 2007; Khalid *et al.,* (2007; Kidane *et al*,. 2014).

Terminalia brownii water extracts are sprayed on wooden houses and furniture to protect them against insect attack (Salih *et al*., 2017). Other uses include provision of tannin, dye, shelter perfume, fodder, bee forage, soil improvement, shade and ornamental (Mosango, 2013; Mbwambo, *et al.,* 2007; Machumi *et al*, 2013 and Zakaria *et al.,* 2017). Therefore, *T. brownii*, contribute immensely to improving livelihood through domestic and cottage industry. *Terminalia brownii* is well adapted to the ecological conditions due to their drought tolerance nature and increasing importance in mitigating climate change, improving land productivity and provide an opportunity for commercial/industrial growth of the inhabitants in dry lands (Awodoyin *et al.*, 2015). However, domestication of *T. brownii* under an agroforestry system is hindered by lack of information on domestication which this study seeks to address.

Study site, data and sampling procedure

This study was conducted in Embu (Mbeere North and South), Machakos (Mwala), Makueni (Wote) and Kitui (Kitui south) counties which were purposively selected due to high *T. brownii* abundance in semi-arid farming zone, semi-arid ranching areas, arid-agro-pastoral area and arid-pastoral zone. Low rainfall and temperatures in these counties hinder rain-fed crop production making commercial tree production r to remain a top priority. A total sample of 346 respondents were sampled and interviewed in the four study sites. The respondents were distributed across Makueni (n=98), Machakos (n=85), Embu (n=83) and Kitui (n=80) representing 28%, 25%, 24% and 23% of the total respondents, respectively. The respondents were sampled using a multi-stage random sampling procedure. Primary data was collected using structured questionnaire, photography and direct observation. Secondary data was acquired from reports, journals and Kenya Forest Service records. The collected data was coded and entered into computer using an Excel Microsoft Office. Data was then cleaned using conditional formatting to check for outliers and duplicates values. The cleaned data was exported to STATA Software Version 13 for analysis. The explanatory variables were checked for multi-collinearity using correlation and Variance Inflation Factor (VIF) analysis. As a rule of thumb, if the VIF of a given variable is more than 10 and the R2 exceeds 0.90, then the variable is said to be highly collinear.

Specification of the Model and Analytical Framework

A Double Hurdle approach was used to analyse the data. It is a parametric generalization of Tobit model developed by Cragg, (1971). The two tier model is also referred to us censored regression models. First the models define participation or decision stage by the use of a discrete dependent variable ($y^*=0$, $y=1$).The second model is conditional on the result of the first stage. Tobit model assumes that the factors which influence the decision to

participate are the same factors that influence the intensity of participation. The assumptions of the Tobit model are relaxed by a double hurdle model that assumes different factors affect the decision of participation/adoption and the level of participation/adoption. According to Cragg (1971), adoption is faced by 2 tiers. The first is whether to domesticate or not to domesticate *T. brownii* and second stage is related to intensity of domestication. The relationship between the two tiers is hypothesized to be linked (Berhanu and Swinton, 2003). Therefore, various recent studies have been used to analyse this hypothetical relationship (Asfaw *et al*., 2011, Kuti, 2015; Gebremichael and Gebremedhin, 2014; Katengeza *et al.,* 2012; Akpan *et al.,* 2011 & Mal *et al.,* 2012).

The 2-tiers model specifications by Cragg (1971) are represented as follows:

$$D^*_i = \alpha Z_i + V_i \dots\dots\dots\dots\dots\dots\dots\dots \ (1)$$
$$Y^*_I = \beta X_i + U_i \dots\dots\dots\dots\dots\dots\dots\dots \ (2)$$

Where $D_i = \{1$, if $D_i^* > 0$; 0 if $D_i^* \le 0\}$ and $Y_i = \{Y^*$, if $Y_i > 0$ and $D_i^* > 0$; 0, if otherwise$\}$

D_i^* - latent variable that makes the value 1, if the farmer domesticates *Terminalia brownii*; 0 otherwise.

Z_i– Vector of household characteristics explaining domestication decision

X_i- Vector explaining the level of domestication and U_i and V_i– Stochastic terms.

The number of *T. brownii* trees was used to determine the intensity of domestication in the second hurdle of Craggs model.

The log likelihood function for the double-hurdle model is represented by equation below.

$$LogL = \sum_{/0} ln\left[1 - \phi(\alpha Z_i')\left(\frac{\beta X_i'}{\sigma}\right)\right] + \sum_{/+} ln\left[\phi(\alpha Z_i')\frac{1}{\sigma}\varphi\left(\frac{Y_i - \beta X_i'}{\sigma}\right)\right] \dots \ (3)$$

Where $\Sigma/0$ = summation over the zero observations; $\Sigma/+$ stands for summation over positive observations; and ϕ and φ are the standard normal cumulative distribution functions and probability distribution functions respectively.

Results and Discussions
Socio-economic characteristics of the smallholder Terminalia brownii farmers in Eastern Kenya
The descriptive statistics describing the socio-economic characteristics of sampled households constitutes variables, mean, standard deviation and Chi square-test.

Table 1: Description of dependent and independent variables

Variable	County	Embu N=83	Kitui N=80	Mach N= 85	Maku N =98	Pooled N=346
Age of Household Head	*Mean*	52.88	54.30	57.79	56.48	55.43
	Std. Dev	15.003	17.30	14.19	15.21	15.48
	$\chi2$	3.514				
	P-Value	0.319				
Household Size	*Mean*	5.24	5.96	5.247	5.07	5.36
	Std. Dev	1.75	2.48	2.154	2.37	2.22
	$\chi2$	10.41				
	P-Value	0.015**				
Farm Size	*Mean*	4.298	5.902	4.779	8.420	5.955
	Std. Dev	4.141	5.077	3.378	8.479	5.975
	$\chi2$	89.12				
	P-Value	0.000***				
Tropical Livestock Unit (TLU)	*Mean*	3.217	5.081	4.356	5.487	4.571
	Std. Dev	3.716	4.885	2.970	3.986	4.014
	$\chi2$	20.16				
	P-Value	0.000***				
Total Income Livestock	*Mean*	7079	9607	12254	22073	13182
	Std. Dev	1715	1741	3399	5738	3716
	$\chi2$	170.7				
	P-Value	0.000***				
Dependency Ratio	*Mean*	90.995	115.56	66.73	136.47	103.60
	Std. Dev	101.96	174.65	99.36	132.85	132.42
	$\chi2$	35.39				
	Pr-Value	0.000***				

Source, Survey Data, (2018)

The mean age of the household head was 55.43 years. These findings suggest that the sampled household falls under the economically active members of the community. The findings revealed that there was a significant difference at 5% on household size. Approximately, there were five (5) members per household (Table 1).

However, posthoc tests (Tukey Test) depicts that households in Kitui comprised of more members as compared to Makueni. The farm sizes ranged between 4.298 to 8.42 acres. Embu and Makueni had the lowest and highest landholdings, respectively. Results from the pooled mean on land size revealed that landholding for the households in Embu and Machakos was lower. In contrast to Makueni County, there was a significant difference (Appendix 3). Tropical Livestock Unit (TLU) was computed using the various recommended bi-weights to quantify on the TLU Index. Households in Makueni reared more livestock as compared to Kitui, Machakos and Embu. This finding depicts that farmers in Makueni do practice livestock production as their major economic activity. Correlation analysis revealed a positive relationship between land size and the tropical livestock unit (Appendix 2). Previous reports indicates that majority of smallholder farmers in Makueni are dependent on livestock due to frequent crop failure witnessed in the area. The total dependency ration was high for Makueni as compared to other counties. However, Machakos County was reported to have had the lowest dependency ration of 66.73%. This inter county variation was statistically significant at 1% (Table 1). This implies that majority of the respondents in Makueni county were economically inactive.

Table 2 presents the totals, proportions and F-Test derived from Analysis of Variance (ANOVA) of the dummy variables of the sampled households. Participation in social group and access to credit for farm operations revealed significant differences between the counties. The Bartlett's test for equal variances for the two variables showed statistical significance at 1%.

Table 2: Descriptive statistics for binary variables of the sampled households

Variable	County	Embu (N=83)	Kitui (N=80)	Machakos (N=85)	Makueni (N=98)	Total (N=346)	Prob>F
Gender Household head	Female	22 (6.4%)	30 (8.7%)	24 (6.9%)	25 (7.2%)	101 (29.2%)	
	Male	61 (17.6%)	50 (14.5%)	61 (17.6%)	73 (21.1%)	245 (70.8%)	0.768
On-farm Participation	Yes	72 (20.8%)	66 (19.1%)	78 (22.5%)	88 (25.4%)	304 (87.9%)	
	No	11 (3.2%)	13 (3.8%)	7 (2%)	10 (2.9%)	41 (11.8%)	0.3836
Group Membership	Yes	41 (11.8%)	59 (17.1%)	43 (12.4%)	71 (20.5%)	214 (61.8%)	
	No	42 (12.1%)	21 (6.1%)	42 (12.1%)	27 (7.8%)	132 (38.2%)	**0.0002**
Access to Credit	Yes	14 (4%)	3 (0.9%)	3 (0.9%)	1 (0.3%)	21 (6.1%)	
	No	69 (19.9%)	77 (22.3%)	82 (23.7%)	97 (28%)	325 (93.9%)	**0.000**
Off-farm participation	Yes	33 (9.5%)	27 (7.8%)	39 (11.3%)	38 (11%)	137 (39.6%)	
	No	50 (14.5%)	53 (15.3%)	46 (13.3%)	60 (17.3%)	209 (60.4%)	0.462

Source (Survey data, 2018)

Majority (70.8%) of the households were male headed. On the other hand, female headed households comprised 29.2%. This indicates that most of the decisions in the households were made by men. On-farm participation was a major practice with 87.9% reporting to actively working on their farms for crop production. A small proportion of the respondents (11.8%) did not work on their farms. Most (61.8%) of the sampled households participated in social group. However, 38.2% of the respondents did not have group membership. As shown in Table 2, the ANOVA results between the counties revealed significant differences at 1% level of statistics level.

Based on the results, only a small proportion (6.1%) of respondents had no access to credit to support farming. Embu County registered the highest number of farmers who had accessed credit while Makueni had the lowest leading to significant differences between the two counties at 1% statistical level). Credit was acquired from the various microfinance institutions located within the study areas. The difference in access to credit may be attributed to the reduced proximity to credit facilities. A report by World Bank asserts that improving access to financial services remain essential. Moreover, the report affirmed that physical distance, inability to meet the requirements for an account and paperwork complexity remains bottlenecks to credit access (World Bank, 2014). Results also revealed that 39.6% of the respondents participated in off-farm activities to sustain their livelihoods. On the other hand, a majority of 60.4% relied more on the farm activities to derive their rural livelihoods.

Determinants of the decision to propagate Terminalia brownii
The results (Table 3) highlight the factors that influencing the decision of smallholder farmers to domesticate *T.*

brownii. Five variables that significantly influence the decision to domesticate include; education level of household head, importance of farm to the household income, access to credit, dependency ratio and intercropping. On the other hand, education of the household head, size of the farm and total income for sale of livestock influenced intensity of domestication of *T. brownii*.

Education of the household head had a positive significance at 5% statistical level influence on the decision to domesticate *T. brownii*. The marginal effect implied that an increase in education by one level increased the decision to domesticate by 8.2% while holding other variables constant (Ceteris paribus). The possible justification was that farmers who have read, heard or trained on *T. brownii* were more likely to propagate the tree. Therefore, farmers will tend to allocate more resources in order to acquire more seedlings. Consequently, education places a farmer in a better position with regard to access and synthesis of production information translating to more production options with better varieties of trees. The finding is in line with those of Danso-Abbeam *et al.*, 2017; Caswell *et al,* 2001; Akudugu *et al.,* 2012). The total dependency ratio was found to have significant negative effect at 10% statistical level on the decision to domesticate *T. brownii*. An increase in dependency level by unit decreased the decision by 0.3% (Table 3). This implied that dilemma on scarce resources due to inactive economic contribution reduced chances of allocating more resources to propagation of *T. brownii*. Therefore, the poverty levels in the areas might have escalated farmers dropping out of the domestication activities. Intercropping *T. brownii* with other crops such as green pea, cowpeas, beans, maize, and sorghum had a positive effect on decision to domesticate the tree. The marginal effect implied that intercropping management system increased propagation decision by 24.6% while holding other variable constant (Ceteris paribus). Previous studies have reported that intercropping management system increase total productivity per unit area through maximum land utilization, production factors such as water, light, nutrients and human labor (Lithourgidis *et al.,* 2006; Li *et al,* 2010). Access to credit for on farm use was found to have a positive significant effect on decision to domesticate *T. brownii*. The marginal effect value implied that access to credit boosted the decision to domesticate by 28.17 percent. This means that household heads with access to credit were more likely to domesticate *T. brownii*. Poor households faced challenges to domesticate *T. brownii*. Therefore, improved access to credit will put them in a better financial position to adopt *T. brownii* growing. This result coincide with findings by Lerman, (2004) who observed that credit plays a crucial role in enhancing and linking farmers to networks that facilitate access to information, modern technology and essential inputs in agricultural production. These findings revealed that the contribution of farm activities to the household income had a negative significant effect. An increase in the range of farm importance by one unit decreased the propagation decision of Terminalia by 5.7%, holding other variables constant. The justification for this is that farmers in the sampled households gave priorities to production of other cash crops with short-term production returns thus reducing domestication of *T. brownii*. The significant factors that influence the intensity of domestication of *T. brownii* include education of household head, farm size and total earnings from sale of livestock (Table 3).

Table 3.3: Double hurdle on domestication of Terminalia brownii in Eastern Kenya.

Variable	Probit Model				Truncated Model			
	Marginal Effect ($\partial y/\partial x$)	Robust Std. Err.	Z	P>z	Coeff	Rob. Std Err	Z	P>z
Age of Household head	-0.0453	0.0545	-0.83	0.406	-0.1916	0.1828	-1.05	0.294
Gender of House. Head	0.0015	0.0017	0.88	0.378	0.0029	0.0059	0.49	0.621
On-farm Participation	-0.1213	0.0754	-1.61	0.108	0.2854	0.2346	1.22	0.224
Education level of Hhead	0.0822	0.0268	3.07	0.002**	0.1682	0.0919	1.83	0.067*
Household Size	-0.0134	0.0105	-1.28	0.200	0.0351	0.0343	1.02	0.306
Farm Size	0.0072	0.0049	1.45	0.146	0.0219	0.0117	1.87	0.061*
Importance of Farm	-0.0576	0.0171	-3.37	0.001***	-0.0095	0.0743	-0.13	0.898
Group Membership	0.0265	0.0471	0.56	0.573	-0.1359	0.1664	-0.82	0.414
Access to Credit	0.2817	0.0955	-2.95	0.003**	-0.1171	0.5680	-0.21	0.837
Off-farm Participation	0.0082	0.0535	0.15	0.878	-0.1245	0.1851	-0.67	0.501
Total income (Livestock)	0.0022	0.0010	0.88	0.381	0.0001	0.0001	1.83	0.067*
Dependency Ratio	-0.0003	0.0002	-1.8	0.072*	0.0000	0.0006	0	0.998
Tropical Livestock Unit	0.0066	0.0066	1	0.317	0.0069	0.0207	0.33	0.741
Intercropping	0.2460	0.0440	5.59	0.000**	0.2301	0.1960	1.17	0.240

Source (Survey, 2018) *** *Significant at 1%, ** significant at 5%, * significant at 10%; N=346*

Based on the results of this study, the value of VIF was less than 10, clarifying no problem of multi-collinearity (Appendix 1). Breusch Pagans test / Cook Weisberg test for heteroskedasticity in this study was

insignificant (Prob> chi2=0.132). Further, the Ramsey RESET test confirmed that there were no omitted variables in the process of analysis (Prob> F=0.348).

Determinants of the intensity of domestication of Terminalia brownii

Results revealed that level of education of the household head was significant at 10% confidence level to influence the intensity of farmers to domesticate *T. brownii*. This implied that more years of formal education translated to opportunities for utilization of production information and further to realize more market opportunities for *T. brownii* products. The findings are consistent with those of Mal *et al.,* (2012). Size of the farm significantly influenced the intensity of domestication at 10% confidence level. This implies that as farm size increases, the probability of increased intensity of propagation increased. The direction of this relationship affirms with those of Martey *et al.,* (2014) who observed increased levels of commercialization with increased land size. Farmers with large farm size have the capacity to diversify their farm enterprises reducing dependence on livestock. Total income from sale of livestock was found to have a significant influence on the intensity of domestication of *T. brownii* effect at 10% confidence interval. This indicates that farmers in the study area allocated more resources on domestication of *T. brownii*. This might be through purchase of farm inputs and utilization during intercropping. The findings are in line with those of Omotesho *et al.,* 2016. The correlation analysis revealed a positive relationship between intercropping and total income derived from sale of livestock.

Conclusion and Policy Implication

This study analyzed the socioeconomic characteristics of *T. brownii* smallholder farmers in Kitui, Embu, Machakos and Makueni counties. Furthermore, the study aimed at documenting determinants in domestication of T. brownii. The decision and intensity to domesticate *T. brownii* was significantly influenced by socioeconomic characteristics and infrastructure. The results showed that household head level of education, importance of farm to the household income, access to credit, dependency ratio and intercropping influenced decision to domesticate *T. brownii*. On the other hand, the domestication intensity was significantly influenced by education of the household head, farm size and total earnings from of livestock sales. The results of this study show consistency with other studies on determinants of adoption and intensity of agricultural technology use among the smallholder farmers. The theoretical and empirical approaches that were adopted by this study produced satisfactory results. These results can be used in understanding the factors that underlie the propagation and regeneration of *T. brownii* in the context of smallholder farmers. Furthermore, this study shows that the domestication and intensity stages are made successively which concurred with previous studies. Future policy directives should target strengthening all the arrays of factors that have a positive influence on domestication of *T. brownii*.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

Appendix 1: Multi-collinearity test on some of the inter-items used in the Survey

Variable	VIF	1/VIF- Tolerance Factor
Off-Farm Participation	1.43	0.698445
Education of the Household head	1.43	0.700702
Age of the Household head	1.25	0.800012
Gender of the Household Head	1.23	0.81139
Farm Size	1.22	0.818177
Import of Farm to household income	1.22	0.821349
Dependency Ration	1.2	0.8358
Household Size	1.15	0.872977
Title Ownership	1.12	0.891299
Intercropping	1.1	0.90626
Total income (Livestock)	1.09	0.915129
On farm Participation	1.07	0.931218
Group Membership	1.06	0.945672
Access to Credit	1.02	0.980742
Mean VIF	**1.19**	

Appendix 2: Correlation Analysis Matrix of the variables used for Analysis

```
. correlate Trans1 GendHHead TitleOwnshp AgeHhead OnfarmPart EducHhead HholdSize FarmSize ImportOfFarm GrpMembership CreditAccess OffarmP
> art TotLivestockY DependencyRatio TropLivestUnit Intercropping
(obs=225)

            |   Trans1 GendHH~d TitleO~p AgeHhead Onfarm~t EducHh~d HholdS~e FarmSize Import~m GrpMem~p Credit~s Offarm~t TotLiv~Y
------------+--------------------------------------------------------------------------------------------------------------------
     Trans1 |   1.0000
  GendHHead |  -0.0207   1.0000
 TitleOwnshp|   0.1844   0.1406   1.0000
    AgeHhead |   0.0321  -0.1213   0.0516   1.0000
  OnfarmPart |   0.0536   0.0645   0.0349  -0.1731   1.0000
   EducHhead |   0.0314   0.2574   0.0480  -0.2840  -0.0187   1.0000
   HholdSize |   0.0419   0.1496   0.0370   0.0570  -0.0320  -0.2013   1.0000
    FarmSize |   0.2214   0.1095   0.2497   0.1943  -0.0403   0.0491   0.0766   1.0000
ImportOfFarm |  -0.1221   0.1111  -0.0944  -0.1214  -0.0643   0.1697  -0.0042  -0.1184   1.0000
 GrpMembers~p|   0.0095  -0.0403  -0.0396   0.0070  -0.0218   0.0450   0.0251  -0.0462  -0.1403   1.0000
 CreditAccess|  -0.0948   0.0489   0.0775   0.0331   0.0412  -0.0179   0.0143   0.0143  -0.0028   0.0016   1.0000
  OffarmPart |  -0.0596   0.1761  -0.1077  -0.2828  -0.0870   0.3860   0.0289  -0.1124   0.3535  -0.0372   0.0354   1.0000
 TotLivesto~Y|   0.1815   0.1335  -0.0237   0.0155   0.0718   0.0334   0.1351   0.1608  -0.1289   0.0360  -0.0030  -0.0386   1.0000
 Dependency~o|   0.1396   0.2147   0.0914  -0.0767   0.0921  -0.0058   0.1386   0.2140  -0.0193  -0.0547  -0.0730  -0.0773   0.1134
 TropLivest~t|   0.0652   0.1268   0.1150   0.1534  -0.0648   0.2130   0.0497   0.2418  -0.0352   0.0013  -0.0252  -0.0027   0.1987
 Intercropp~g|   0.1074  -0.0623   0.0524   0.0393   0.0182  -0.1126   0.0637   0.1010  -0.1440   0.1212  -0.0401  -0.0740   0.0455

            |  Depend~o TropLi~t Interc~g
------------+-------------------------------
 Dependency~o|   1.0000
 TropLivest~t|   0.1160   1.0000
 Intercropp~g|   0.1995   0.0259   1.0000
```

Appendixes 3: Post Hoc on Tukey Test for Contrast between Counties

Household Size	Contrast	Std. Err	t	P>t
Kitui vs Embu	0.7215	0.3448	2.0900	0.1580
Machakos vs Embu	0.0061	0.3396	0.0200	1.0000
Makueni vs Embu	-0.1695	0.3283	-0.5200	0.9550
Machakos vs Kitui	-0.7154	0.3428	-2.0900	0.1590
Makueni vs Kitui	-0.8911	0.3316	-2.6900	0.0380
Makueni vs Machakos	-0.1756	0.3262	-0.5400	0.9500
Farm Size	Contrast	Std. Err.	t	P>t
Kitui vs Embu	1.6046	0.9036	1.7800	0.2870
Machakos vs Embu	0.4818	0.8899	0.5400	0.9490
Makueni vs Embu	4.1223	0.8603	4.7900	0.0000
Machakos vs Kitui	-1.1227	0.8983	-1.2500	0.5960
Makueni vs Kitui	2.5178	0.8690	2.9000	0.0210
Makueni vs Machakos	3.6405	0.8548	4.2600	0.0000
Tropical Livestock Unit	Contrast	Std. Err.	t	P>t
Kitui vs Embu	1.8636	0.6168	3.0200	0.0140
Machakos vs Embu	1.1394	0.6075	1.8800	0.2400
Makueni vs Embu	2.2705	0.5872	3.8700	0.0010
Machakos vs Kitui	-0.7243	0.6132	-1.1800	0.6390
Makueni vs Kitui	0.4068	0.5931	0.6900	0.9020
Makueni vs Machakos	1.1311	0.5835	1.9400	0.2140
Total LivestockY	Contrast	Std. Err.	t	P>t
Kitui vs Embu	2528.0440	5774.9380	0.4400	0.9720
Machakos vs Embu	5175.2630	5687.7920	0.9100	0.8000
Makueni vs Embu	14993.710	5498.2530	2.7300	0.0340
Machakos vs Kitui	2647.2190	5741.4960	0.4600	0.9670
Makueni vs Kitui	12465.670	5553.7910	2.2400	0.1130
Makueni vs Machakos	9818.4470	5463.1180	1.8000	0.2760
Dependency Ratio	Contrast	Std. Err.	t	P>t
Kitui vs Embu	24.5641	20.4099	1.2000	0.6250
Machakos vs Embu	-24.2620	20.1019	-1.2100	0.6230
Makueni vs Embu	45.4769	19.4320	2.3400	0.0910
Machakos vs Kitui	-48.8261	20.2917	-2.4100	0.0780
Makueni vs Kitui	20.9128	19.6283	1.0700	0.7110
Makueni vs Machakos	69.7389	19.3078	3.6100	0.0020