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Determinants of distribution and utilization of *Terminalia brownii* (Fresen) in Eastern Kenya

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***Terminalia brownii* (Fresen) is one of the drought-resistant treespecies that support livelihoods in the rural households of Eastern Kenya. The tree is preferred for its versatile functions such as; medicinal use, carvings, energy, construction, and cultural reasons. In this regard, there has been an increased demand for Fresen products which include; charcoal, poles, posts, bee-hives, nativities among others. Forestry stakeholders, researchers among other tree promoters have been at the pole position to support the propagation of this species through various programs. It is therefore vital to comprehend the determinants of the distribution of the species among farmers in Eastern Kenya. The study documents various uses of the species in the study area. A semi-structured questionnaire and direct observations were used to interview a total of 346 farmers selected through a multistage sampling procedure. Descriptive statistics and a logarithmic logistical econometric model were adopted for data analysis. Results revealed that most of the farmers preferred the species for; firewood, quality charcoals, prevention of soil erosions, poles and posts, medicinal use, and carvings. The size of the farm, income from the sale of livestock, and the land tenure system were the key determinants of the distribution of the species. Policies should focus more on the issuance of legal documents particularly title deeds which will motivate farmers to domesticate the species. Further, programs should be designed to strengthen livestock production and marketing which serves as a diversification strategy given the erratic nature of rainfall patterns.**

Key words: Domestication, livelihoods, socio-economics, diversification.

INTRODUCTION

The environment of the dry-land site is characterized by wide fluctuations in moisture conditions (Bargali and Bargali, 2016; Baboo et al., 2017). In such a situation, the seeds of species that can germinate under fluctuating moisture conditions can germinate and survive (Quinlivan, 1968; Bargali and Bargali, 1999; Vibhuti et al.,

2015). Soil water supply is an important environmental factor controlling seed germination and seedling establishment (Kramer and Kozlowski, 1960; Bargali et al., 2018). If the water potential is reduced, seed germination will be delayed or prevented depending on the extent of its reduction (Hegarty, 1977). As a result,

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primary and secondary bare areas are created frequently and need immediate restoration to arrest environmental degradation (Bargali et al., 2019; Manral et al., 2020). A large number of studies have been carried out on the effects of water stress on the germination of the forest as well as crops (Shahi et al., 2015; Baskin and Baskin, 1998; Zobel et al., 1995).

Domestication of trees plays important roles in most of the rural households through; poverty reduction and addressing nutritional requirements in the local communities (FAO, 2015; Jamnadass et al., 2011; Ofor et al., 2014; Dawson et al., 2013). Globally, it is estimated that 1.3 billion people rely on trees and forests for their household income and livelihoods (World Bank, 2016). Precisely, tree products serve the purpose of promoting the livelihood status of millions of people in the tropics (Dawson et al., 2014). Further to this, rehabilitation of trees in the ecosystem avails an opportunity of combatting climate change through; adaptation and mitigation agendas and also the provision of resilient landscapes (World Bank, 2016; FAO, 2015). Tree production supports the modification of micro-climate more so in lands that are prone to harsh weather conditions (Maliki et al., 2012). In Africa, efforts have been made by stakeholders to promote systems such as; process-based models for land use strategies regarding tree-based agricultural systems to discourse climate change (Sendzimir et al., 2011; Dixit et al., 2011). In particular, tree plantation provides interplanetary for carbon sequestration thus reducing the effects of global climate change which has been a major concern (Ingram et al., 2016; Nair, 2012). The climate change menace in Arid and semi-arid lands in Africa has been attributed to land degradation (Wessels et al., 2007).

It is estimated that a third of agricultural land in sub-Saharan Africa comprises more than 10% of tree cover (Zomer et al., 2014). Earlier studies have reported a positive impact of on-farm trees on household welfare (Kalaba et al., 2010; Mbow et al., 2014). This is accredited to improved household income and food security to tree domestication (Schreckenberget al., 2006; Masters and Addaquay, 2011). According to Angelsen et al. (2014), natural areas simultaneously contribute significantly (28%) to the income of rural livelihoods in developing countries. Venturing into tree production in the rural areas of developing countries acts as a diversification strategy towards agricultural shocks thus giving solutions to economic torment (Noack et al., 2015; Poverty and Environment Network, 2015; Angelsen and Dokken, 2015). It is worth noting that tree production provides employment and wealth generation opportunities with more than 13.2 million people specializing in valuable wood-based products (FAO, 2014). Therefore, articulation on the domestication of trees in the rural households should be prioritized to improve agroforestry functions, thus addressing the climate variability and poverty levels among subsistence

farmers (Jamnadass et al., 2019; Thorlakson and Neufeldt, 2012; Parihaar et al., 2015; Padalia et al., 2018; Karki et al., 2021a and b).

Other benefits from the domestication of the trees include; energy provision; food production; medicinal use etc, and cultural reasons (Dawson et al., 2013; Bromhead et al., 2012; Vodouhe and Dansi, 2012; Muriuki et al., 2012; Parihaar et al., 2015; Padalia et al., 2018; Karki et al., 2021a, b). Firstly, it is speculated that demand for fuel will aggravate twofold by 2030, given that majority of the rural households in Africa rely on wood or charcoal (Bromhead et al., 2012; Carsan et al., 2014). Secondly, the few explored case studies report the medicinal contribution of stem-woods, stem-barks, and other extracts towards the improved livelihoods among the rural households (Leakey et al., 2012; Jamnadass et al., 2019). Tree domestication supports effective competition with other food crops by supporting food production, further improve on the precarious agro biodiversity that affects food security (Barrios et al., 2015; Keating and Carberry, 2010; FAO, 2019). Traditional agroforestry could be a better option to improve the soil conditions and overall production (Bargali et al., 2004, 2009a, b; Vibhuti et al., 2020).

The creation of value attached to these products in these areas, therefore, serves as an avenue towards a positive impact on rural livelihoods (Hunsberger et al., 2017). More attention to the domestication of native tree species remains imperative and more focuses should be embedded on the entire tree value chain (Nichols and Vanclay, 2012; Catacutan et al., 2013). Resilience in rural households can be improved by focusing more on tree economic products which serve a dual purpose (products can be sold or get processed for home consumption (Thangataa and Hildebrand, 2012). This fascinates for better engagements with markets and market developers through entrepreneurship which has been identified as a pertinent value addition strategy for scaling up tree domestication thereby reducing the poverty gaps (Amrouk et al., 2013; Leakey et al., 2012; Wiggins and Keats, 2013). It is projected that the distribution of trees will double by 2050 (Indufor, 2012).

Terminalia brownii (Fresen) is one of the key woodland species domesticated by smallholder farmers in Eastern Kenya. This part of Kenya is composed of countries where most parts are classified as dry lands (semi-arid and dry sub-humid) thus vulnerable to climate change (RoK, 2018; FAO, 2019). Urgent actions to restore these dry lands such as domesticating Fresen would provide an alternative solution towards addressing the increased aridity index which is speculated to increase (10 to 23) by the close of the 21st century (FAO, 2014). Smallholder farmers prefer the species for its ability to tolerate drought and most of the infinitive uses are attached to it (Sebukyu and Mosango, 2012). Demand for products of *T. brownii* (Fresen) has dominated both the domestic and international markets and available quantities not



Figure 1. *Terminalia brownii* Fresen tree.



Figure 2. Seeds of *Terminalia brownii* Fresen.



Figure 3. Pestle and Mortar from *terminalia* fresen.

adequate (Seeds of Gold, 2020). Figures 1 to 5 show some of the products derived from *Terminalia brownie* Fresen among the smallholder farmers in Eastern Kenya. The species have been recognized for the treatment of infectious diseases such as hepatitis, wounds, diabetes, liver cirrhosis, yellow fever among others (Keter and Mutiso, 2012; Kigen et al., 2014; Mbiri et al., 2016).

Stemwood, barks, and woods of Fresen are a major source of antimicrobial compounds thus preferred for the treatment of infections (Salih et al., 2017). As well, the species has been highly ranked for quality poles and timber which are susceptible to pests (Muddathir and Mitsunaga, 2013).

More efforts are therefore recommended to provide



Figure 4. A nativity from *terminalia brownii* Fresen.



Figure 5. Samples of bee-hives from *Terminalia brownii* (Fresen).

measures of handling the expanded dry lands which have been on the rise for the last 60 years (Cherlet et al., 2018). Pertinent strategies by stakeholders such as Kenya Forestry Research Institute (KEFRI) among other agricultural stakeholders have been at the forefront of the promotion of *T. brownii* (Fresen) intending to reduce poverty gaps and further contribute to the shared prosperity by 2030 (KEFRI Draft Report, 2019).

Efforts have been made towards promoting the tree in support of reforestation through the development of appropriate dormancy breaking and germination methods to advance species domestication. However, information on the distribution and utilization of *T. brownii* (Fresen) among the smallholder farmers in Eastern Kenya is not adequately documented.

This calls for an assessment of the arrays of socioeconomic factors that determine the distribution of the tree further, identify some of the usages of this specific species in Eastern Kenya.

MATERIALS AND METHODS

This study was conducted in four counties: Embu (Mbeere North and South), Machakos (Mwala), Makueni (Wote), and Kitui (Kitui

South), which were selected purposively due to the high occurrence of *T. brownii* population in agro-eco-logical zone III and IV (RoK, 2010). The agro-ecological zones are generally classified as semi-arid farming zone, semi-arid ranching areas, arid-agro-pastoral areas, and arid-pastoral zone. Low rainfall and temperatures in these counties hinder crop production making commercial exploitation of woodlands major options as alternative livelihood strategies.

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 were collected using a structured questionnaire; direct observation and key informant interviews. Secondary information was accessed from reports, published journals, and from Kenya Forest Service files. The collected data were coded and entered into a computer using an excel microsoft office. Data were then cleaned using conditional formatting to check for outliers and duplicates values. Diagnostic tests for: distribution (Shapiro-Wilk Test and K-Density confirmed normal distribution); heteroskedasticity (Breusch-Pagan/Cook-Weisberg- $\text{Chi}^2(1)=1.79$; $\text{Prob}>\text{chi}^2=0.1814$ – absence of heteroskedasticity); multicollinearity (Variance Inflation Factor = 1.28, less than 10 which is the threshold); Specification errors (Link test - $_hatsq = 0.380$, insignificant and therefore correctly specified); and RAMSEY Test for omitted variables ($F(3, 213) = 0.52$; $\text{Prob} > F = 0.6720$ –

insignificant therefore no omitted variables) were carried out for data legitimacy. The cleaned data were exported to STATA Software Version 13 for analysis.

Specification of the model and analytical framework

Descriptive statistics were used to describe the farmer's demographic characteristics and institutional factors. A logarithmic logistical regression analysis was used to determine the socio-economic factors that influenced the distribution of *T. brownii* (Fresen) trees among the smallholder farmers in the study area. The model has been used in previous studies (Ayieko et al., 2014; Siyaya and Masuku, 2013). Therefore, the logarithmic functional model was specified as;

$$\ln Y = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \mu_i \tag{1}$$

Specified as;

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \mu_i \tag{2}$$

Where Ln Y = Natural logarithm of the number of trees; β_0 = intercept term ;($X_1 - X_n$) represented the independent variables while ($\beta_1 - \beta_n$) represented the coefficients of ($X_1 - X_n$) respectively. The coefficients were computed by the percentage change in Y as a result of the percentage change in X. Subsequently, μ_i represented the disturbance term which catered for the unobserved random effects. The model errors in this study were assumed to be independent, normally distributed {N (0, σ^2)} and conditional on X_i .

RESULTS AND DISCUSSION

Table 1 provides a summary of descriptive statistics of the socio-economic characteristics of smallholder *T. brownii* (Fresen) farmers in Eastern Kenya.

The majority (70.81) of the households domesticating *T. brownii* (Fresen) were male-headed and only 29.19% were female-headed. The mean age of the household head was 55 years. Results revealed that most of the sampled household heads had attained primary school. Thus, an affirmation that the heads was in a prospect to read and write.

Most of the households reported having relying on a major part (50 - 90%) of the farm produce for its cash income. The smallholders invested more in cereals such as; cowpea, pigeon pea, green grams, beans, etc. The average land size for the sampled households was 6 acres (Table 1). Results revealed that the majority (87.86) worked on the farm for cereals production while on the other hand, only 39.6% of the household heads engaged in off-farm activities. Intercropping was a major agricultural practice with 66.19% revealing to implement the technology. Notably, the majority (58.38%) of the sampled households owned land titles.

Results also showed that farmers commercialized their livestock with an average income of Ksh.13, 182 (US\$=132). The region experiences erratic rainfall patterns thus leading to crop failure. As a pertinent diversification strategy, smallholder farmers in the study area invest in animal production mainly; cattle, poultry

(indigenous chicken, guinea fowl, and turkey). As shown in Table 1, the tropical livestock unit (TLU¹) indicates a positive investment in cattle and ruminants. The consideration was made with certainty that livestock remains the region's predominant livestock as they greatly contribute to total livestock resources. Notably, the dependency ratio as shown was high in the region. It is also worth noting that the average total dependency ratio was 88% which is above Kenya and Sub-Saharan Africa's average dependency ratio of 75 and 85.19%, respectively in 2017's (World Bank², 2017). A depiction, that the majority of the household members were economically inactive. This restricted them from solely accumulate resources and therefore the working faced a greater burden in supporting the children, youth, and the aging population. The average number of *T. brownii* (Fresen) was 17 trees. A proportion of 61.85 participated in agricultural-based groups and this would boost information access, thus reducing bounded rationality on the available markets for their agricultural produce. Lastly, only 6.07% of the household had obtained credit for agricultural use which was mainly derived from the SACCO's and among farmers groups.

Table 2 presents the various uses of *T. brownii* (Fresen) species among the smallholder farmers in Eastern Kenya. Most (92.49%) of the sampled households mainly used the species on firewood. Branches were mainly harvested for firewood using a panga. The respondents appraised the species to last longer during the cooking process. A proportion of 63.01 preferred using charcoal that was derived from the species whereas 60.4% utilized the species to control soil erosion at their farms. A large proportion of respondents (55.78%) used the species for posts and poles to support the construction of houses and fencing of the compound due to its firmness, durability, and termite resistance. Results also showed that the species were of curative importance. The species were also used for medicinal purposes with 50.29% of the respondents reporting its use for the treatment of fresh wounds, coughs and cold using bark and leaf extracts. The carving was a major practice in the study area. A minority (36.42%) of the respondents reported that they drilled the stem to produce beehive due to its durability and long shelf life; mold the pestle and mortar from the trunk. It is worth noting that wood carving was one of the key economic activities for the residents of the study area. Table 3 presents findings on the determinants of the distribution of *T. brownii* (Fresen) among the smallscale households in Eastern Kenya.

Three explanatory variables had a significant influence on the distribution of *T. brownii* (Fresen) trees among the smallholder farmers in Eastern Kenya. They included farm size, ownership of the land title, and the income

¹ (Conversion factors derived used were as follows; cattle = 0.70, sheep and goats = 0.10, pigs = 0.20 and poultry = 0.01- Source: Storck et al. (1991 as cited in Arega and Rashid, 2005, FAO, 2011).

² Accessed from -<https://data.worldbank.org/indicator/sp.pop.dpnd>.

Table 1. Descriptive statistics of socio-economic characteristics of *Terminalia brownii* (Fresen) farmers in eastern Kenya.

Continuous Variable	Mean	Std. Dev.	Min	Max
Age of Household head	55.43	5.480	18	97
Education of household head	1.46	0.999	0	4
Household size	5.36	2.217	1	14
Farm size	5.95	2.97	1	35
Importance of farm to HH income	2.42	1.3364	1	5
Total income from livestock	13181.5	716.17	0	50400
Tropical livestock unit (TLU)	4.571	4.0140	0	26.4
Dependency ratio	88.33	36.996	0	136
Number of trees	17.83	5.232	2	100
Binary variable				
Gender of household head	0.7081	0.4552	0	1
Title ownership	0.5838	0.4936	0	1
Off-farm participation	0.3960	0.4898	0	1
Intercropping	0.6619	0.4738	0	1
Group membership	0.6185	0.4865	0	1
Credit access	0.0607	0.2391	0	1
On-farm participation	0.8786	0.3270	0	1

Source: Data (2018).

Table 2. Utilization of *Terminalia brownii* (Fresen) among smallholder farmers in Eastern Kenya.

Uses	Yes (%)	No (%)	Rank
Firewood	320 (92.49)	26 (7.51)	1
Charcoal	218 (63.01)	128 (36.99)	2
Soil erosion	209 (60.40)	137 (39.60)	3
Pole and posts	193 (55.78)	153 (44.22)	4
Medicine	174 (50.29)	172 (49.71)	5
Carvings	126 (36.42)	220 (63.58)	6

Source: Data (2018).

derived from the sale of livestock. The effect of all the stated variables were significant at 5% statistical levels. Land ownership increased the distribution of *Terminalia* species by 41.43% while holding other explanatory variables at ceteris paribus.

This is an implication that having land entitlements had a reflection on the total number of trees planted in the study area. Previous studies report that land tenure is among other key determinants of husbandry among the smallholder farmers in developing countries (Mwase et al., 2015; Kabwe et al., 2009; Glover, 2013). Land tenure motivates farmers at investing in agroforestry which guarantees returns in the long run (Chitakira and Torquebiau, 2010; Kabwe, 2010; Opio, 2001). Further to this, a safe and sound tenure system reduces land loss risks hence incorporating vulnerability (especially women)

towards equitable carbon benefits among the smallholder farmers (Jindal et al., 2003; Shames et al., 2012).

Results also revealed that land size (acres) had a positive influence on the distribution of *Terminalia* species. An increase in farm size by one unit (acre) heightened distribution by 3%. The finding concurs with those of Glover et al. (2013) where farm size and adoption of woodlots or enriched fallows showed a positive relationship. A synthesis by Ajayi et al. (2003) in their various studies revealed a positive and significant relationship between farm size and investment in trees through fallows.

Other studies that revealed concurrence to the aforementioned and support of the positive relationship between farm size and the number of trees included those of Petro et al. (2015) and Emtage and Suh (2004).

Table 3. Factors influencing the distribution of *Terminalia brownii* (Fresen) among smallholder farmers in Eastern Kenya.

Variable	Coef.	Std. err.	T	P>t
Gender of household head	-0.2871	0.1947	-1.47	0.142
Age of household head (years)	-0.0001	0.0061	-0.02	0.987
Education of household head	0.05427	0.0910	0.6	0.551
Household size (family members)	0.00959	0.0369	0.26	0.795
Farm size (Acres)	0.03021	0.0135	2.23	0.027**
Land tenure	0.41428	0.1764	2.35	0.020**
Income total livestock (KES)	4.89E-06	1.95E-06	2.5	0.013**
Dependency ratio (%)	0.0005	0.0007	0.76	0.451
Tropical livestock unit	-0.0079	0.0220	-0.36	0.721
_cons	2.2095	0.4626	4.78	0.000

Source; Survey, 2018; ** Significant at 5%

Lastly, income from the sale of livestock influenced the number of trees despite having a marginal effect. Farmers in the study area rely on livestock as a major economic activity to support their livelihoods due to erratic rainfall, thus experience crop failure (RoK, 2010).

The finding is in line with those of Kabwe et al. (2009) which revealed income from livestock sales had a significant influence on biomass transfer technologies among smallholder farmers in Zambia. Similarly, Liliane et al. (2020) result revealed a positive relationship between the adoption of income and agroforestry practices in Rwanda. In addition to this, Franzel et al. (2002) assert that wealthier farmers took the risk of investing more in tree planting.

CONCLUSION AND RECOMMENDATION

The study sought to describe the utilization of *T. brownii* (Fresen) among the smallholder farmers in Eastern Kenya. Furthermore, it aimed at documenting the factors affecting the distribution of the species in the area of study. Based on the results, it can be concluded that the *Terminalia* species is of great importance to the smallholder farmers located in Eastern Kenya. The majority of the households utilized the species on firewood, burning charcoal which was preferred for quality while some farmers used the tree in controlling soil erosion. Poles and posts were appraised for being susceptible to pests and termites hence, preferred for their durability. In some selected households, the species were used for medication to heal fresh wounds, coughs, common colds, etc. Carvings were also a major activity and among the products derived from the tree include; nativities, county logos among other decorations. Secondly, the socioeconomic characteristics that influenced the number of trees included land size, title ownership, and the income derived from the sale of livestock among the smallholder farmers in Eastern

Kenya. It is therefore recommended that policies focus on streamlining the issuance of the legal land documents to motivate and promote domestication and propagation of *Terminalia* species strategically. Programs should also be designed to promote livestock farming as a form of a diversification strategy to boost agricultural growth and development.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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