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Abstract Agroforestry systems in Sub-Saharan African drylands are complex and heterogeneous in nature even under similar biophysical conditions. This can be attributed to household needs and socioeconomic status which influence the species and utility of the adopted trees. This has an impact on the trees establishment and management system through planting or Farmer Managed Natural Regeneration (FMNR). This study evaluates how trees for different utilities are managed and which socioeconomic factors influence these decisions. The study used primary data collected in Mutomo District, Kenya through a household survey based on a structured questionnaire. A paired sample *t*-test was done to assess the preferred mode of adopting trees for different utilities while factor analysis was used to characterize the households as either planting trees or practicing FMNR. Multiple linear regression using household regression factor scores as independent variables and socioeconomic indicators as dependent variables was done to ascertain which socioeconomic factors affect tree adoption. The results show that trees planted were mostly exotic species valued for their nutrition and commercial value, while FMNR was used for subsistence products and environmental services. Household size, livestock levels and mobility had a positive correlation with tree planting, while income, access to markets and roads had an inverse correlation. Access to natural woodland, distance to the nearest motorable road and land size had a positive correlation with tree protection. It is hoped that this knowledge will act as a reference point when designing agroforestry projects in similar areas to ensure they are more aligned to specific site and household conditions.

Keywords Agroforestry · Farmer Managed Natural Regeneration (FMNR) · Tree adoption · Drylands · Socioeconomic characteristics

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Introduction

Adoption of trees on farm and other agricultural landscapes, generally known as agroforestry (Nair

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et al. 2008), is a common practice in many developing countries. However, practices, products, system intensity and structures differ considerably from region to region and site to site (Iiyama et al. 2016; FAO 2013; Nair et al. 2008). Both biophysical and socioeconomic factors influence species selection, locality of planting, as well as management intensity (Sebastian et al. 2014; Mukungei et al. 2013; Sood 2006). Adoption of trees in agroforestry systems is either through deliberate planting of seedlings or management of naturally regenerating seedlings or coppicing tree stumps, mostly from remnants of the forests cleared for agricultural purposes (Fifanou et al. 2011; Fentahun and Hager 2010). Management of naturally regenerating trees is known as Farmer Managed Natural Regeneration (FMNR) (Haglund et al. 2011). Tree planting is practiced in diverse agroecological systems, but is more successful in high potential zones characterized by intensive land use systems (German et al. 2012; Nair et al. 2008; Jama and Zeila 2005). FMNR on the other hand is particularly successful in drylands where harsh conditions lead to high seedlings mortality (Haglund et al. 2011; Chidumayo and Gumbo 2010; Barranche et al. 2006).

Trees on farms play an important role in supporting the livelihoods in drylands by providing essential ecosystem goods and services like food, fuel, fodder, medicine, building materials, soil erosion and flood control as well as watershed and biodiversity protection (De Leeuw et al. 2014; FAO 2013). The role of trees in building resilience of rural livelihoods in drylands should not be underestimated, especially during crop failure due to droughts (De Leeuw et al. 2014; Chidumayo and Gumbo 2010). In such instances, fodder trees are the main sources of browse for animals (Mortimore and Turner 2005; Mortimore and Adams 2001), while charcoal production is the prevailing coping mechanism (De Leeuw et al. 2014; Jama and Zeila 2005).

Still, large parts of the agricultural lands in the African drylands have less than 10 % tree cover, far less than optimal (Zomer et al. 2009). Furthermore, the high dependency on trees and natural resource bases coupled with population pressures–both natural growth and migration from densely populated zones–has led to unsustainable harvesting of trees for timber, woodfuel and other non-timber products at a rate exceeding the re-growth rates (Ndegwa et al. 2016a; Iiyama et al. 2014; Chidumayo and Gumbo 2010; Jama and Zeila; 2005).The degradation and depletion of tree resource bases has undermined the capacity to provide ecosystem goods and services making dryland inhabitants extremely vulnerable to climate shocks and natural hazards (Iiyama et al. 2016; De Leeuw et al. 2014; Barrow and Mogaka 2007).

Despite the overall pessimistic situation in SSA drylands, the Sahel has demonstrated a promising experience that this trend of degradation can be reversed through tree planting and FMNR (Mortimore and Turner, 2005; Mortimore and Adams 2001). It is therefore important to understand the enabling conditions for farmers to adopt tree planting and FMNR in SSA dryland contexts (FAO 2013; Mortimore and Turner 2005). However, there is still a general lack of knowledge on the agroforestry systems in drylands especially on the choice of species, mode of management, and intensity of adoption (De Leeuw et al. 2014; Chidumayo and Gumbo 2010). We assume that there are two critical features influencing the knowledge gaps.

The first feature is the structural complexity and the multiplicity of derived products and services (Abebe et al. 2013; Fentahun and Hager 2010; Sood and Mitchell 2009). The structure may vary from a simple two component system of tree + crops intercrop to a complex multi-strata system involving diverse tree species, crops and animals (Nair et al. 2008). Most of the systems are characterized by multipurpose tree species (both indigenous and exotic) as the farmers strive to maximize utility of the limited land, labor and financial resources (Iiyama et al. 2016; Wiehle et al. 2014; Bucagu et al. 2013). This diversity enhances the resilience of both the agricultural systems and households against environmental and socioeconomic risks (Sabastian et al. 2014; Wiehle et al. 2014).

The second feature is the heterogeneity of the systems where even under similar biophysical conditions, the socioeconomic conditions and needs of individual household make the mode of management and the intensity of adoption more dynamic (Dawson et al. 2014; Sebastian et al. 2014). Each household designs an agroforestry system that meets its needs within the prevailing socioeconomic conditions (Sabastian et al. 2014; Bucagu et al. 2013). This results in an agroecosystem with an agroforestry mosaic largely dictated by individual household's products demand (for personal use or markets) and resource endowment (FAO 2013; Kehlenbeck et al. 2011).

This study aims to address the above two knowledge gaps namely, characterizing complex, multi-dimensional agroforestry systems, and evaluating which socioeconomic factors influence tree adoption. The study used primary data collected through a household survey using a structured questionnaire in Mutomo District located in the drylands (arid and semi-arid lands) of Kenya. Unlike in the high potential zones of Kenya, the inhabitants of the Arid and Semi-Arid Lands (ASALs) are minimally engaged in tree planting activities to produce wood products, but mainly rely on natural tree stands on farms and open landscapes (Harding and Devisscher 2009; Jama and Zeila 2005). The study addresses the gaps by answering the following questions:

(1) Does the utility of the species adopted influence the mode of tree establishment and management chosen by a household?

(2) Do socioeconomic conditions of a household have an impact on agroforestry adoption and a particular management system?

We assume that a better understanding of the existing patterns will contribute to improvement in the design of agroforestry interventions and support formulation of policies that are not only ecologically suited to the area but also adapted to the local socioeconomic conditions. This approach is known to be the most effective in increasing adoption of agroforestry (Sood and Mitchell 2009).

Materials and methods

Hypotheses

In order to address the first research question, we assume that the mode of establishment and management depends on the utilities of the trees selected by the household. Even though there are structural, spatial and temporal differences in different agroforestry systems (Nair et al. 2008), tree establishment is either through planting or protection of naturally regenerating seedlings and coppices (Fifanou et al. 2011). Timber and fruit trees with high potential for commercialization and contribution to household nutrition are mostly established through deliberate planting (Iiyama et al. 2016; Bucagu et al. 2013; Fifanou et al. 2011). On the other hand, traditionally well understood trees with multiple benefits like provision of building materials, fruits, shade and fodder are protected by farmers so long as they do not affect the productivity of other crops (Iiyama et al. 2016; Abebe et al. 2013; Tambara et al. 2012; Fentahun and Hager 2010).

In addition, socioeconomic characteristics of a household such as income and wealth, access to markets, mobility, education level, gender, household size, access to information, farm size and land tenure among others also affect the decision and modes to adopt agroforestry (FAO 2013; Assé and Lassoie, 2011; Fentahun and Hager 2010; Nair et al. 2008; Kiptot et al. 2007). For example, households with high income and livestock levels (proxy for wealth) are more likely to invest in capital intensive agroforestry activities (Sebastian et al. 2014; Gibreel, 2013; Gijsbers et al. 1993). Likewise, households with access to markets, roads and means of transport can easily procure farm inputs and transport their produce to the markets (Abebe et al. 2013; Gibreel 2013; Sood and Mitchell 2009). Farmers with high education levels are likely to adopt trees as they can easily understand their benefits through mass media, reading or advice from extension providers (Fentahun and Hager 2010; Barranche et al. 2006). The impact of gender on adoption of agroforestry is best demonstrated by the fact that some communities restrict land ownership and tree-based investment and exploitation to men (Kiptot and Franzel, 2011; Assé and Lassoie, 2011). For household size, it has been observed that large households have sufficient household labour which can be allocated to intensive tree planting and management while small households with less labour are more likely to adopt less intensive practices (Sebastian et al. 2014; Mukungei et al. 2013; Sood, 2006). Since the households in the study area had similar biophysical conditions, we assume that socioeconomic factors play a fundamental role in household choice of agroforestry adoption and a particular management system.

Study area

The study was carried out in Mutomo District of Kitui County (see Fig. 1) which is located in the Eastern Province of Kenya, one of the districts categorized as ASALs. ASALs make up about 84 % of Kenya's land surface area (WRI 2007). The Kenyan drylands play an important role for the national economy, as they

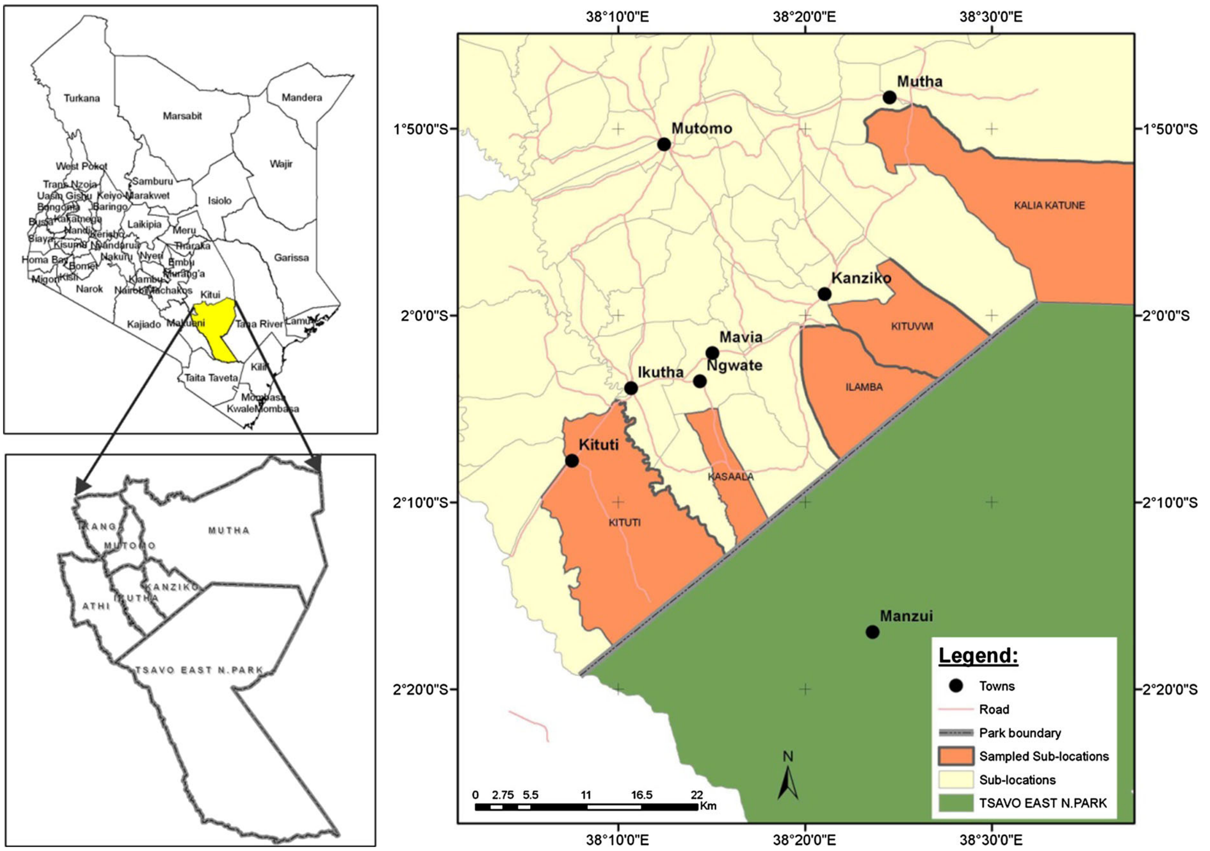

Fig. 1 Map of the study area *Source*: Authors

account for about 80 % of the country's ecotourism interests, and are home to about 75 % of the country's wildlife and 46 % of the livestock population (Barrow and Mogaka 2007). Furthermore, they are a major supplier of domestic energy in the form of woodfuels, especially charcoal for which 91 % of the wood is harvested from the natural dry woodlands (KFS and KNBS 2009).

Mutomo District has an altitude that ranges from 400 m a.s.l. in the floodplains in the south to 900 m a.s.l. on the Yatta plateau in the west (GOK 2009). It experiences high temperatures that range between 20 and 34° C and a bi-modal rainfall pattern ranging between 500 and 1050 mm per annum with 30 % reliability (GOK 2009; Kitonga 2009). Soils are shallow and low in fertility thus poor for agricultural activities (Ndegwa et al. 2016a; Kitonga 2009). Because of the poor soils and low and unreliable rainfall, the district is categorized as an agro-ecological zone for ranching and draught resistant crops (Jaetzold et al. 2012). The district has a population of about 180,000 people distributed into about 33,000 households (KNBS 2010).

The average land holding is 5 hectares even though most of the land is categorized as government trust land with only 3 % of the households having title deeds (GOK 2009). Almost all inhabitants are subsistence farmers, with the majority growing maize, while others grow drought resistant crops such as pigeon peas, cow peas, green grams, sorghum and millet. Other economic activities include charcoal production, bee keeping, livestock rearing, poultry farming and sand and ballast quarry mining (GOK 2009).

Sampling

Mutomo District is subdivided in six divisions, 15 locations and 60 sub-locations, of which the latter are the smallest administrative unit (GOK 2009). Sampling was done in five sub-locations selected randomly from a list of ten that border the Tsavo East National Park (Fig. 1), where a study on forest degradation was being conducted by the authors (Ndegwa et al. 2016a). The selected sub-locations capture the local diversity in terms of access to road (earth) infrastructure and population density which ranges from three to 78 persons km^2.

Subsequently, a list of all households in the target sub-locations was compiled and systematic random sampling employed to select respondent households, where the first was selected randomly from the first 20, and then each 20th household was picked thereafter. The interviews were conducted in June 2013 in 189 households out of the total number of 3782 households (5 % sample size) in the five sub-locations by administering a structured questionnaire.

Data collection, processing and analysis

Data collection

In the data collection phase using the structured questionnaire the households were asked how many trees they had planted and/or protected during the last three years, and their primary utility—among fruits, timber, shade, charcoal, firewood, soil improvement, soil erosion control, medicine, fodder, live fence and wind break. Any utility that was not reported was omitted in the subsequent analysis. Data on socioeconomic characteristics of the households which included income, livestock levels, access to market, access to roads, mobility (using bicycles or donkeys), household head education level, information access, household size, land size, and involvement in community organizations was also collected. The tree species utility and household socioeconomic data was entered and analyzed using *SPSS for Windows version 17.0*. All species planted or protected through FMNR were classified by the main use for which they were adopted.

Data processing and analyses

Data analysis was done in three steps. In the first step, a paired sample t-test was conducted to assess if there was a preferred mode of adopting trees for a utility by comparing the means of the planted and protected trees. A paired sample *t*-test was used due to its ability to compare the means of two treatments on the same population (Field 2009). The two conditions investigated in this case were tree planting and protection for the different utilities. In the second step, factor analysis was done using the number of trees per utility planted or protected by the households as exploratory variables. Factor analysis was chosen with the assumption that there was a high correlation between the number of trees planted or protected by a household and their corresponding utilities (Iiyama et al. 2016). This would enable extraction of latent variables explaining the underlying relationship with the mode of establishment and management adopted (Tabachnic and Fidell 2007). A scree plot was used to determine the number of factors to extract as it has been found to be more consistent compared to the Kaiser criterion where all the factors with eigenvalues greater than one are retained. This is because the Kaiser criterion tends to retain too many factors (Field 2009; Tabachnic and Fidell 2007). Variables with very little communality-usually less than 0.32-and relatively low factor loadings across all factors were removed to improve the overall factor solution (Tabachnic and Fidell, 2007; Tucker and MacCallum 1997). Corresponding standardized regression factor scores for the extracted variables were estimated (see Grice (2001) for more information) and saved to be used in multiple linear regression as dependent variables (proxy for the intensity of tree planting or protection) with socioeconomic characteristics of households as dependent variables.

The socioeconomic characteristics used as independent variables included household head education level, household income, household size, distance to the nearest market, distance to the nearest water source, distance to the nearest motorable road, and land size. Six binary variables were used in the regression analysis, which are household head gender, access to natural woodland, membership to a community-based organization, ownership of a donkey, ownership of a bicycle and whether a household produces charcoal. Charcoal production was included because it was identified as an important economic activity while donkeys and bicycles were identified as the most commonly used means of transport in the area. In addition, two indices were calculated and used as independent variables. These are the information access index and the livestock index. Calculation of the indices is presented in Appendix I.

Results and discussion

Tree adoption overview

Table 1 shows that out of the 189 households interviewed, 66.1 % had protected trees for different utilities while 63.0 % had planted. Of those who were involved in protection, 36.8 % had protected between 1 and 5 trees, 24.0 % between 6 and 10 trees and 13.6 % between 11 and 15 trees in the past three years. For those who had planted, 20.2 % had planted between 1 and 5 trees, 21.8 % between 6 and 10 trees and 19.3 % between 11 and 15 trees. 33.9 % of the households did not protect and 37.0 % did not plant any trees, respectively.

The study identified eight main utilities for which the households had either planted or protected trees which are: fruits, timber, shade, charcoal, medicine, fodder, live fence and wind break. These gave rise to 16 tree utility variables, eight each for planted and for protected species which were used for further analysis. The results of a paired sample *t*-test in Table 2 revealed that there was a significant difference between the means of the number of planted and protected charcoal trees with more being protected than planted ($t\ (188) = -2.821$, $p < 0.05$). There was also a significant difference between the means of planted and protected fruit trees with more being planted ($t\ (188) = 5.957$, $p < 0.05$). Likewise, there was a significant difference between the means of planted and protected medicine trees with more being planted ($t\ (188) = 3.113$, $p < 0.05$). There was also a significant difference between the means of planted and protected fodder trees with more being protected ($t\ (188) = -2.654$, $p < 0.05$). However, there was no significant difference between the means of planted and protected timber, live fence, shade, and windbreak trees.

Factor analysis

Factor analysis with orthogonal rotation (Varimax) resulted in extraction of three latent factors. Number of protected live fence trees was not used in the analysis, because no household had protected any trees for this purpose. Five other variables were removed from the final analysis, because they had communality less than 0.32. The variables removed were: protected fodder, medicine and timber trees and; planted live fence and charcoal trees. In the end, ten variables were used for the analysis which resulted in a factor solution that explained 56.8 % of the total variance. The Kaiser—Meyer Olkin measure (KMO) of sampling adequacy was 0.608 meaning the sample was factorable (Fidel 2009).

Table 3 shows the analysis that resulted in a factor solution with five variables on tree planting loading highly on factor 1 and explaining 26.6 % of the total

Table 1 Range of number of trees protected and planted by farmers in the past 3 years

No. of trees protected/planted in previous 3 years	No. of households which protected	Overall percentage (%)	Percentage of protectors (%)	No. of households which planted	Overall percentage (%)	Percentage of planters (%)
Did not protect/plant	64	33.9	–	70	37	–
1–5	46	24.3	36.8	24	12.7	20.2
6–10	30	19.9	24.0	26	13.8	21.8
11–15	17	9.0	13.6	23	12.2	19.3
16–20	11	5.8	8.8	8	4.2	6.7
21–25	10	5.3	8.0	13	6.9	10.9
26–30	1	0.5	0.8	5	2.6	4.2
31–40	3	1.6	2.4	8	4.2	6.7
41–50	3	1.6	2.4	3	1.6	2.5
51–60	2	1.1	1.6	3	1.6	2.5
61–70	1	0.5	0.8	3	1.6	2.5
Over 80	1	0.5	0.8	3	1.6	2.5
Total	189	100	100	189	100	100

Table 2 Comparison of means between planted and protected trees for different utilities

Tree utility pairs	Paired differences					
	Mean	SD	SE Mean	95% confidence interval of the difference		t
				Lower	Upper	
No. of planted charcoal trees− no. of protected charcoal trees	−1.20635	5.87863	0.42761	−2.04987	−0.36282	−2.821*
No. of planted fruit trees− no. of protected fruit trees	4.90476	11.31942	0.82337	3.28054	6.52899	5.957*
No. of planted timber trees− no. of protected timber trees	−0.42857	6.90062	0.50195	−1.41874	0.56160	−0.854
No. of planted medicine trees− no. of protected medicine trees	0.71429	3.15434	0.22944	0.26167	1.16690	3.113*
No. of planted fodder trees− no. of protected fodder trees	−0.39153	2.02777	0.14750	−0.68250	−0.10057	−2.654*
No. of planted live fence trees− no. of protected live fence trees	0.10053	0.84138	0.06120	−0.02020	0.22126	1.643
No. of planted shade trees− no of protected shade trees	0.30159	6.37307	0.46357	−0.61288	1.21606	0.651
No. of planted windbreak trees− no. of protected windbreak trees	0.07937	3.08377	0.22431	−0.36313	0.52186	0.354

* $p < 0.05$

Table 3 Main tree adoption factors extracted and respective factor loadings

Tree utility variable	Extracted factors with factor loading[a]		
	1 (tree planting)	2 (tree protection)	3 (N.A)
No. of planted fruit trees	0.746*	−0.044	0.363*
No. of protected fruit trees	0.068	0.375*	0.518*
No. of planted timber trees	0.538*	−0.100	−0.088
No. of protected charcoal trees	0.000	0.868*	0.028
No. of planted medicine trees	0.757*	0.148	−0.010
No. of planted fodder trees	0.006	−0.036	0.802*
No. of planted shade trees	0.690*	0.176	−0.004
No. of protected shade trees	0.128	0.867*	−0.031
No. of planted windbreak trees	0.731*	0.059	0.052
No. of protected windbreak trees	0.012	−0.058	0.674*

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalization

[a] Rotation converged in 4 iterations

* Factor loading higher than 0.32

variance. The second factor had three tree protection variables loading highly and explaining 16.0 % of the total variance, while the third factor had one variable on tree planting and three variables on tree protection and explained 14.2 % of the total variance. The first factor was thus highly related to tree planting and was named *tree planting* while the second was highly related to tree protection and was named *tree protection,* respectively.

To validate this argument, a linear regression between the saved regression factor scores for the three extracted factors and the overall number of trees planted and protected was done. The saved regression factor scores of factor one (tree planting) were the best predictor of the number of trees planted with $R^2 = 0.903$ $(b = 0.047,\ t\ (187) = 41.6,\ p < 0.05)$. Saved regression factor scores of factor two (tree protection) were the best predictor of number of trees

Table 4 Regression summary for tree planting/protection intensity and household socioeconomic characteristics

Independent variables	Tree planting[a]		Tree protection[b]	
	Standardized coefficients β	t	Standardized coefficients β	t
(Constant)		0.400		−1.392
Access to natural woodland	−0.039	−0.550	0.177	2.320*
Gender of household head	0.005	0.066	0.060	0.822
Livestock index	0.218	2.770*	−0.167	−1.968
Information access index	0.041	0.569	0.014	0.181
Community org membership	0.030	0.454	−0.029	−0.397
Income (KES[c])	−0.161[d]	−2.339*	0.013	0.175
Distance to nearest domestic water source	−0.015	0.222	−0.032	−0.443
Distance to nearest motorable road	−0.134[d]	−2.044*	0.149	2.102*
Distance to nearest market	−0.230[d]	−2.916**	−0.130	−1.529
Education level of household head	0.310	0.401	0.087	1.051
Household size	0.216	2.335*	0.101	1.014
Land size in ha.	−0.079	−1.144	0.385	5.208**
Charcoal production	−0.006	0.315	−0.0032	−0.423
Donkey ownership	−0.013	−0.177	−0.108	−1.336
Bicycle ownership	0.174	2.275*	−0.080	−0.972

[a] Dependent variable: tree planting, model fit (R^2) = 0.383

[b] Dependent variable: tree protection, model fit (R^2) = 0.224

[c] KES- Kenya Shillings

[d] Significant with negative Beta

* $p < 0.05$ ** $p < 0.01$

protected with $R^2 = 0.899$ ($b = 0.090$, $t(187) = 40.77$, $p < 0.05$).The saved regression factor scores of the third factor were not a good predictor of neither the number of trees planted with $R^2 = 0.045$ ($b = 0.010$, $t(187) = 2.96$, $p < 0.05$) nor protected with $R^2 = 0.066$ ($b = 0.024$, $t(187) = 3.647$, $p < 0.05$). The third factor was therefore not considered for further analysis.

Multiple regression

The results of the standard multiple linear regression presented in Table 4 show that socioeconomic factors significantly influence tree planting patterns in the study area ($F(15,165) = 6.83$, $p < 0.05$, $R^2 = 0.383$). Six variables were found to significantly explain the intensity of tree planting. Livestock index, household size and ownership of a bicycle had a positive correlation with the intensity of tree planting, while income, distance to the market and distance to motorable road had a negative correlation. Access to natural woodlands, gender of household head, information access, community organization membership, distance to water source, household head education level, land size, charcoal production and ownership of a donkey did not significantly influence the intensity of tree planting.

The model for tree protection showed that socioeconomic factors significantly influence the intensity of tree protection (F $(15,165) = 4.46$, $p < 0.05$, R^2 $281 = 0.224$). Access to natural woodland, distance to motorable road and land size were found to have a positive correlation with the intensity of tree protection. Land size was the most highly significant variable at $p < 0.01$, while the other two were significant at $p < 0.05$. The other socioeconomic factors, namely: household head gender, livestock index, information access, household income, distance to domestic water source, community organization membership, distance to the market, household head education level, household size, charcoal production, ownership of a donkey and ownership of a bicycle did not significantly influence the intensity of tree protection.

Discussion

Tree adoption and management

This study captures the complexity of the agroforestry systems adopted by households in terms of species utility and mode of tree establishment and management. Though many households are involved in both tree planting and FMNR, the species utility plays an important role in selecting the mode of establishment and management. The results show that fruit and medicine trees were mostly adopted through planting while charcoal and fodder trees were adopted through FMNR. Fruit trees were favored in agroforestry systems because of their nutritional and commercial value (Fifanou et al. 2011) and the ability to be intercropped (Bucagu et al. 2013). However, as most of the preferred trees are exotic, establishment was through planting of seedlings procured from friends or tree nurseries. These included *Citrus aurantium* (orange), *Persea americana* (avocado), *Mangifera indica* (mango), *Carica papaya* (papaya) and *Citrus limon* (lemon).

The community in the study area is well known for its use of traditional herbs collected from the natural woodlands. The fact that medicine trees were adopted through planting means that the resources are getting scarce in the natural woodlands. Indeed, Vallejo et al. (2014) and Fentahun and Hager (2010) pointed out that a community that is reliant on resources from natural woodlands may adopt those trees in their agroforestry systems if they become scarce. The mostly planted medicinal tree is *Azadirachta indica* (Neem tree), which is exotic and believed to treat over 40 diseases.

Charcoal is produced from indigenous tree species famed for being dense and having high calorific value (Ndegwa et al. 2016a; GOK 2009). These are mostly *Acacia* and *Combretum* spp. usually harvested from the natural woodlands (GOK 2013). The seeds from the parent trees of the natural woodlands can therefore be easily dispersed into the farmlands, while stumps from trees cleared during preparation for cultivation coppice readily. As the trees are already valued, the households readily tolerate these trees as an investment (Tambara et al. 2012; Fifanou et al. 2011). Some of these species are: *Acacia gerrardii, Acacia mellifera, Acacia nilotica, Acacia lahai, Acacia senegal, Acacia seyal, Acacia tortilis, Albizia amara, Berchemia discolor, Balanites aegyptiaca, Cassia abbreviata,* and *Combretum collinum*.

Fodder trees were managed more through FMNR than planting as most were *Acacia* spp. readily found in the natural woodlands. As the area is characterized by cyclic droughts, fodder trees, which easily survive the drought due to adaptation to harsh climatic and soil conditions guarantee animal feed security during dry periods (De Leeuw et al. 2014). This confirms Kang et al.'s (1990) argument that in Africa fodder is rarely planted with people relying on natural browse and crop residues.

There was no difference between the means of protected and planted trees for the other utilities, namely: timber, shade, live fence and windbreak. *Melia volkensii*, an indigenous timber species, is highly valued for its quality timber and is adopted through planting and FMNR. Other valued indigenous timber tree species include *Delonix elata, Dombeya rotundifolia, Terminalia prunioides* and *Berchemia discolor*, which are mostly managed through FMNR. *Eucalyptus* spp. are the only exotic trees adopted in the area and are mostly established through planting. The dual approach adopted in establishment and management of *Melia volkensii* therefore means that it is difficult to categorize timber trees as being adopted through planting or FMNR.

For shade trees it was also difficult to clearly establish if they are adopted through planting or FMNR, even though all the species are indigenous: *Acacia tortilis, Delonix elata, Erythrina abyssinica, Salvadora persica, Cassia abbreviata* and *Commiphora africana.* The fact that some shade trees may not always regenerate where shade is needed-especially around the homesteads-means the households have to procure the seedlings and plant them in preferred locations as well as protect those regenerating naturally. Clear lack of categorization for live fence and windbreak trees is due to the minimal numbers adopted for these purposes. Many of the fences are made by layering branches of thorny trees mostly *Acacia* and *Commiphora* species cut from the natural woodlands.

Socioeconomic factors affecting tree adoption

This study was able to establish the influence of socioeconomic factors on the mode of tree adoption and management in Mutomo District. Accessibility through road infrastructure is the only common factor that influenced adoption through planting and protection. However, while accessibility increased the intensity of tree planting ($\beta = -2.044$, $p < 0.05$), it reduced the intensity of protection ($\beta = 0.149$, $p < 0.05$). This is in line with Gibreel (2013) and Abebe et al. (2013) who reported that households with access to transport infrastructure and markets invest more in commercial oriented agroforestry as they can easily transport the produce as well as farm inputs (Gibreel 2013). In contrast, households with poor accessibility prefer to adopt trees mostly for locally used products, thus engaging in protection of the well understood regenerating indigenous trees. This concurs with the argument of Winterbottom and Hazlewood (1987) that households faced with poor infrastructure and market access opt for low investment subsistence based technologies like FMNR for subsistence products. Consequently therefore, the intensity of tree planting reduced with increase in distance to the market ($\beta = -0.230$, $p < 0.05$), but had no influence on the intensity of tree protection.

In the absence of a good road network, a majority of the households use donkeys at the local level for transport of goods while bicycles are the main means of transport from one village to another and to the market centers. However, ownership of a donkey had no influence on both tree planting and protection as they are mostly used for domestic chores. On the other hand, ownership of a bicycle had a positive influence on tree planting, suggesting a household with a bicycle is able to transport products as well as farm inputs to and from the market. Sood and Mitchell (2009) also state that mobility has a positive influence on adoption of agroforestry as it exposes the people to contacts who can enlighten them on new farming practices, tree management procedures and demand–supply relations of products. From another point of view, Belem et al. (2011) argue that even though a bicycle provides mobility, it is also a symbol of wealth, and therefore a household owning a bicycle would be able to afford investment in technologies like tree planting.

Livestock is a symbol of farm-based wealth in many rural areas (Gijsbers et al. 1993) and income derived from their sale or sale of products can support tree investment activities and soil conservation. This explains the positive relationship between livestock and the intensity of tree planting (Sebastian et al. 2014; Abebe et al. 2013). In contrast, income alone has a negative relationship with the intensity of tree planting ($\beta = -0.161$, $p < 0.05$) and no influence on tree protection. A further examination of the data showed that about 65–73 % of the upper and the third quartiles by income are charcoal producers (see Appendix II) suggesting that most charcoal producers do not engage in tree planting. According to the findings of Ndegwa et al. (2016b), 54 % of the producers are small-scale and depend almost entirely on income from charcoal for survival, while 34 % are medium-scale producers with relatively less but significant dependence. Lack of investment in trees by the charcoal producers does not only lead to degradation of woodlands (Ndegwa et al. 2016a; Iiyama et al. 2014), but also reduces the households' coping capacity in dry periods (De Leeuw et al. 2014). This study also found that charcoal production had no influence on either tree planting or protection.

The study established that a household that had access to natural woodland was more likely to protect naturally regenerating trees while this had no influence on tree planting. This observation signifies the importance the household attach to the products from these trees thus they tolerate them as a part of their investment (Fentahun and Hager 2010). Most of the trees planted are exotic fruit species while those regenerating naturally tend to be indigenous species and are mostly phenotypically similar to those in the natural woodland (Fifanou et al. 2011; Haglund et al. 2011). This may explain why households leaning towards tree planting are not influenced by natural woodlands to plant trees.

Household size had a significant impact on the intensity of tree planting but no influence on tree protection, probably because the latter is not labor intensive. According to Mukungei et al. (2013), household composition dictates how responsibilities are allocated to different family members. Indeed, Sebastian et al. (2014) state that the more the family labor, the higher the probability that some can be allocated to intensive tree silvicultural practices while less labor means more emphasis on subsistence food production. Sood (2006) also reported greater adoption of agroforestry practices through planting by households with enough labor, while households with less labor opted for less labor intensive practices like FMNR.

Land size had no influence on the intensity of tree planting but had a positive relationship with tree protection probably because small land sizes reduce the area within which trees can naturally regenerate (Barranche et al. 2006). For this reason, households with large parcels of land have more regenerating/coppicing trees to choose from on what to remove or retain when cultivating (Fentahun and Hager 2010). This further supports the findings by Ruheza et al. (2012) and Mahapatra and Mitchell (2004) that land size has no influence on the intensity of tree planting even though Sebastian et al. (2014) and Gibreel (2013) reported a positive correlation between tree planting and land size.

A factor said to impact on the level of tree adoption is social capital, mostly expressed through membership to community organizations (FAO 2013; Assé and Lassoie 2011). However, in the study area this had no influence in tree adoption either through planting or protection. This could be attributed to lack of any environmental or agricultural based organizations in the area with all the households who reported belonging to a community organization being members of either church or saving groups.

Land tenure has been extensively cited as a major factor influencing the level of long-term investments like trees (Elias 2013; FAO 2013; Barranche et al. 2006) even though it has not been found to affect the level of agricultural productivity or profitability (Place 2009). However, with all the respondents in this study indicating they did not have a title deed, it was not possible to test the impact of land tenure on tree adoption. In spite of this, it cannot be ruled out as one of the causes of low tree adoption levels as insecure land tenure is a major disincentive to agroforestry adoption in East Africa (Jama and Zeila 2005).

Other factors that did not have any influence on tree adoption are education level of the household head and information access even though they would be expected to enable the households make an informed decision on adoption of new technology (agroforestry), products, market dynamics and other related tree investment aspects (Fentahun and Hager 2010; Barranche et al. 2006). Access to water sources was also found to have no influence on tree adoption, most likely because all the households practice rain-fed agriculture. Gender of household heads did not have any impact on tree adoption either through planting or protection, probably because the women who are heads of their households have the freedom to make independent decisions.

Conclusion and way forward

This study shows how utility of a species together with the socioeconomic factors influence the mode of tree establishment and management. A household that adopts commercial-based agroforestry of exotic species is more likely to be engaged in tree planting. This is an advantage since they also get to procure improved seedlings which can guarantee better yields as compared to the indigenous fruit varieties (Kehlenbeck et al. 2011). On the other hand, households engaging in FMNR mostly adopt indigenous species valued locally for their products or environmental services. A wealthy household with enough labor, good transport infrastructure and market access is more likely to invest in tree planting for products destined for the market. However, households with a large size of land, poor transport infrastructure and poor market access are more likely to be engaged in FMNR for subsistence products or environmental services.

The study also demonstrates the importance of FMNR in tree adoption in drylands which needs to be embraced and integrated by policy makers and development organizations promoting agroforestry in these lands. The ease of tree establishment, traditional knowledge of the species and low labor requirement makes them especially suited in these lands where most of the households are poor. More research therefore needs to be done on specific tree species already under this system with a view of their improvement, maximization of outputs and exploitation of all their utilities for both subsistence use and markets in case of surplus.

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