

## Determinants of Tree Planting and Cover Retention in Arid and Semi-Arid Areas of East Africa: The Case of Machakos County, Kenya

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### Abstract

Rapid human population growth, increased demand for land, over-exploitation and the degradation of local natural resources have led to serious socio-economic and environmental challenges in Machakos County, Kenya, East Africa. This has led to a drastic reduction in tree cover in arid and semi-arid areas over the years. To reverse this trend it is important to understand the socio-economic factors that determine household tree planting and cover retention in Machakos County. Based on a structured questionnaire targeting 412 respondents as well as focus group discussions and key informants, we assessed the determinants of tree planting cover retention using a logistic regression model. The study found that socioeconomic variables that significantly influenced tree cover adoption in Machakos County in Kenya included gender ( $p=0.011$ ), household size ( $p=0.030$ ), and title deed ownership ( $p=0.023$ ). The respondents used tree products to enhance their socio-economic resilience. In total, 58 different types of tree species were planted or retained on the farms. The major tree species included *Eucalyptus saligna*, *Grevillea robusta*, *Mangifera indica*, *Persea americana*, *Croton megalocarpus*, and *Terminalia brownie*. Based on our findings we

recommend more involvement of women and youth in tree planting activities in Matungulu Sub-county.

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**Keywords:** Degradation, natural resources, livelihoods, tree cover, climate change

## 1. Introduction

Trees play a critical role from both an environmental and socio-economic perspective. Sufficient trees on farms can enhance socio-economic and environmental resilience and mitigate climate change (Insaidoo *et al.*, 2014). Trees on farm and their goods and services are barely captured in conventional national accounting systems in many countries (Zomer *et al.*, 2016). Although tree cover has been declining generally in the world, it has been necessary for human survival since the creation of humankind (Zomer *et al.*, 2016). According to Wunder *et al.* (2014), the majority of rural communities across the developing world still derive their livelihoods from trees. These wood and non-wood benefits from trees, mainly from public forests, accrue to vulnerable community members. Adopting and establishing trees at the farm level would reduce pressure on public forests and reduce the rates of deforestation (Siraj *et al.*, 2018).

A global study found subsistence crop farming and tree growing, indeed, are complementary economic activities for rural communities (Angelsen *et al.*, 2014). In Sri Lanka, income from trees has been used to strengthen household income and subsistence (Ekanayake *et al.*, 2018). A study in rural Pakistan found gender, household size, age and literacy level of the household head to be strong determinants of tree planting and households with tree were found to have higher incomes, lower poverty levels and consume more tree-based products (Ali & Rahut, 2018). In rural Sub-Saharan Africa, the youth forms the greater majority of the population and their tree planting activities are not well documented, although communities generally have diversified livelihood sources to enhance chances of survival in lean times (Macneil *et al.*, 2017).

Tree cover increases soil minerals and organic matter, improves soil moisture and increases farm production significantly (Shiferaw *et al.*, 2017). Most importantly, trees promote resilience to climate change and future uncertainties facing vulnerable communities in developing countries. (Quandt *et al.*, 2018). Tree acts as safety nets for vulnerable communities and their livestock during times of famine and drought. Research in Kenya by Quandt *et al.* (2018) show that trees help to diversify rural livelihood sources besides improving the overall socio-economic status of the farmers. The immense potential for trees to provide both socio-economic and

environmental benefits simultaneously make them an important vehicle to sustainable development in rural areas (De Leeuw *et al.*, 2014).

To better understand what motivates communities to plant trees and retain tree cover on their farms, context-specific information that differentiates between the diverse characteristics of community groups is necessary. We have chosen Matungulu sub-county, Machakos County in the drylands of South Eastern Kenya to evaluate the socio-economic and cultural factors that influence tree planting and cover retention practices. The area was chosen for this study due to its scanty tree cover, low farm yields, degraded ecosystems, frequent droughts and high levels of poverty. These negative attributes are being compounded by effects of climate change. To plant or maintain tree cover on the farm or not is a deliberate decision made by the farmer according to various circumstances. The quantity and quality of on-farm tree planting is influenced by climatic factors as well as socio economic factors.

Within this context, the objective of the study was to understand what drives rural tree planting and cover retention. Specifically we are looking at the socio-economic factors that determine the likelihood of tree planting and cover retention in Matungulu sub-county to have a nuanced view of what drives tree planting and cover retention. We hypothesize that mobile phone, gender, age, location, marital status, household size, education, occupation, farm size, title deed ownership, years of tree planting and household income are all factors that influence tree planting and cover retention.

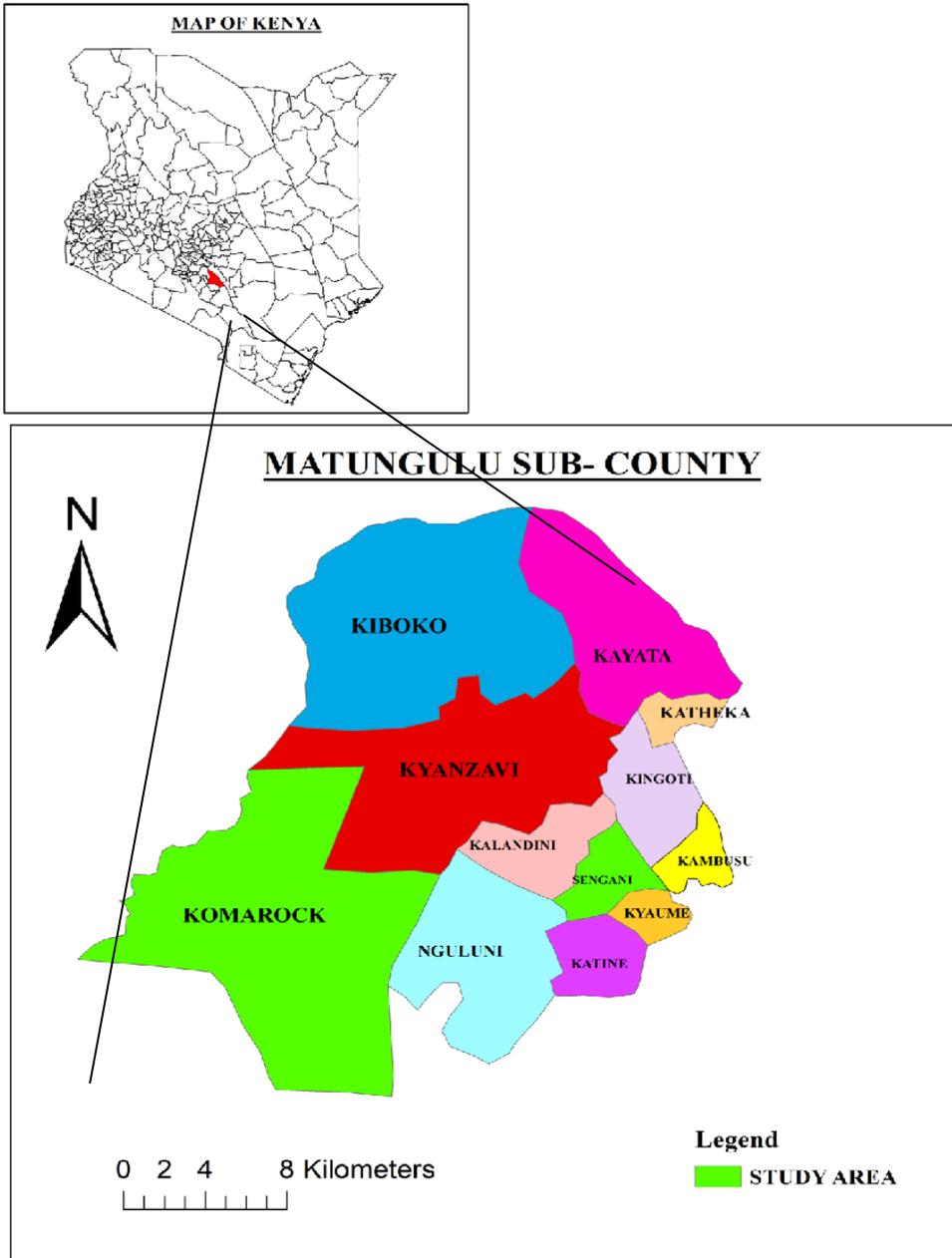
## **2.0 Methods**

### **2.1 The Study Area**

The study was carried out in Matungulu sub county, Machakos County, a semi-arid region of south-eastern Kenya. The Sub-county covers an area of about 610.351 Km<sup>2</sup> and lies between latitudes 1.076<sup>0</sup> and 1.358<sup>0</sup>S and longitudes 37.083 and 37.387<sup>0</sup>E (Figure 2.1). Within the sub county two locations, namely; Komarock and Sengani, which are far apart and of different sizes, topography, soil types, population sizes, ethnic compositions and vegetation types were chosen as study sites.

The area receives a mean annual rainfall is 950mm, with some areas receiving more rainfall than others due to relief (Machakos County Government, 2015). The mean annual temperature is about 22<sup>0</sup> C, with a maximum of 28<sup>0</sup> and a minimum of 12<sup>0</sup> C. The geology of the area consist of quartz-rich granitoid gneisses which resulted in the formation of well drained, reddish brown, stony and rocky sandy clay loam soils. The natural vegetation consists of dispersed mixed indigenous species such as *Terminalia brownie*, *Acacia nilotica*, *Acacia drepanalobium*, *Acacia xanthophloea*, *Acacia brevispica*, *Acacia elatior*, *Acacia melifera*, *Rhus*

*natalensis*, *Lannea schweinfurthii*, *Premna chrysoclada*, *Dovyalis abyssinica*, *Dombeya kirkii*, *Combretum collinum*, *Carrissa spinarum* and *Zanthoxylum chalybeum* (MENR, 2006). The main economic activity in the area is farming both large and small scale. Commonly grown crops include maize, beans, coffee, pigeon peas and horticultural crops.



**Figure 2. 1.** A map of the study area  
Source: Survey of Kenya (2018)

## 2.2 Sampling and interview set up

Non-probability sampling, particularly purposive sampling, was used in the selection of the two administrative locations and key informants for interview. Sample size determination was done following the method of Kothari (2004). In total 412 households were sampled from 4341 households residing in the two sub locations. Both non probability and probability sampling techniques were used to allocate the households determined. Within each of the selected locations systematic sampling was done to identify respondents per location for interview. This was based on records of households kept at the local Chiefs' offices. The respondents were household heads who owned land and practiced some form of farming. An interpreter was used where necessary to ease the problem of language barrier and minimize errors in data collection. The key informants included the Ward Forestry Officers and their frontline extension staff in Koma and Sengani locations, the Ward and Locational Agricultural Extension Officers, Chiefs and Assistant Chiefs, women leaders, area elected representatives, heads of schools, representatives of NGOs and church organizations, as well as other community leaders.

Two focus groups discussions (FDGs) of ten people each were carried out in each location to triangulate the information collected during the household interviews. The FDGs were useful in bridging research and practice, and in providing an insight into different opinions among different parties involved in the tree planting practice. Secondary data was obtained from the internet, office reports, development plans, research theses, pamphlets and other materials found in public offices, libraries and documentation centers. The study adopted a mixed methods research design (Mburu, 2013)

## 2.3 Data Analysis and Presentation

The use of both qualitative and quantitative methods ensured that the overall strength of the study is greater than using either method (Guetterman *et al.*, 2015). Descriptive analysis of data was used to determine the frequency distribution and summaries of various sample characteristics. Quantitative methods were used to test for relationships between variables in the results. A logistic regression model was used to estimate the probability of tree planting by farmers using socio-economic predictors (Shrestha *et al.*, 2018). The socioeconomic predictors included ownership of mobile phone, gender, age, location, marital status, household size, education, occupation, farm size, title deed ownership, years of tree planting and household income. These predictors were chosen based on previous studies on tree growing and cover retention in rural areas of sub Saharan Africa. Tree cover was the

dependent variable while all the other parameters were explanatory variables to the logistic model. The Hosmer & Lemeshow test of the goodness of fit was used to test the goodness fit of the model while *Nagelkerke's R<sup>2</sup>* was used to estimate for models' categorical response variables (Hadi, 2018). The Wald test was used to test the statistical significance for each of the independent variables. Table 2.1 below shows the predictors and type of data collected.

**Table 2.1.** Measurement scale and type of data used in the regression model

Parameters	Variable type	Description	Measurement
Mobile phone ownership (X <sub>1</sub> )	Dummy	Farmer owns a mobile phone	0=Does not own phone, 1= Owns phone
Gender (X <sub>2</sub> )	Dummy	Gender of head	0=Female, 1=Male
Age (X <sub>3</sub> )	Categorical	Age in years of head	
Location (X <sub>4</sub> )	Dummy	Location of farmer	-0=Sengani, 1=Koma
Marital status (X <sub>5</sub> )	Categorical	Marital status of head	1=Married, 2= Single, 3= Widowed/Widowed, 4= Divorced,5= Separated
Household size (X <sub>6</sub> )	Numeric	Number of members in a house hold	
Education (X <sub>8</sub> )	Categorical	Highest education of the head	1=None, 2= Primary, 3=Secondary, 4= College, 5=University
Occupation (X <sub>9</sub> )	Categorical	Occupation of house-hold head	1=Farm manager, 2= Farmer 3= Civil servant, 4=Business, 5= Other
Farm size (X <sub>10</sub> )	Numeric	Farm size (Acres)	
Title deed ownership (X <sub>11</sub> )	Dummy	Farmer owns title	0=No title, 1= Has title
TLU (X <sub>12</sub> )	Numeric	Farm livestock units	<i>Calculated. See explanation</i>
Tree cover (natural + planted)	Numeric	Farm trees ≥ 2m	Number
Years of tree planting (X <sub>13</sub> )	Numeric	Duration of tree planting (years)	
Total house hold income (X <sub>14</sub> )	Numeric	Sum of household income (Kshs)	

### 3. Results and discussions

#### 3.1 Socio-Economic Characteristics of the Households

##### 3.1.1 Age distribution of the respondents in the study area

About 57.3% of the respondents were within the productive age bracket of 25-54 years, followed by those over 65 years (22.8%) as shown in Table 3.1 below.

**Table 3. 1.** Age distribution of respondent farmers in Machakos County

Age group	Frequency (F)	Percentage (%)
18-24	3	0.7
25-34	47	11.4
35-44	95	23.1
45-54	94	22.8
55-64	79	19.2
Over 65	94	22.8
Total	412	100.0

According to Focus Group Discussions (FGDs), many young people from the region prefer to go to big towns such as Nairobi, Athi River, Thika, Machakos or Nakuru immediately after secondary school to search for paid work. The involvement of people aged 64 years and above in farming within the study area could therefore be attributed to youth “missing in action”, the compelling rural poverty, and being retired from formal employment. The study findings agree with other studies across Sub-Saharan Africa and the rest of the world, which have shown an “ageing farmer population” (Guo *et al.*, 2015).

##### 3.1.2 Gender of the respondents

The majority (57%) of the respondents were male, while 43% were female. The study findings are similar to those of Wambua *et al.* (2018), which found that although 70% of households in Kenya are headed by women, this figure was only 8% in Machakos County.

##### 3.1.3 Household sizes in the study area

The majority (69.2%) of the respondent households comprised 3 or less members while a minority (2.4%) of households had 7 or more members. That the study found mainly small families could suggest that there may be an acute shortage of household labour in Machakos County. Such households would have to hire additional labour for establishment and management of on-farm trees, depending on their income levels.

### **3.1.4 Education level of respondents in the study area**

The majority (57.3%) of the respondents had attained at least secondary education, while about one tenth of the respondents had no formal education. Famines, teenage pregnancies and early marriages were among the key drivers of low levels of education in the study area.

### **3.1.5 Occupation of the respondents**

The majority (60.7%) of the respondents were farmers by occupation, who spent most of their time in the farms although they frequently referred to themselves as ‘unemployed’. Some (2.7%) of the households had employed farm managers to manage their farms, although these assistants alleged inability to make major decisions like planting trees by themselves.

### **3.1.6 Mobile phone ownership of respondent farmers**

About 81% of the respondents owned mobile phones, leaving only 19% without the communication gadgets in Machakos County. Besides a mobile phone being a socio-economic status indicator in the village, it can also be a useful source of learning, information and communication, and capable of influencing tree cover levels and management in the rural areas. Wyche *et al.* (2018) found 54% of respondents in Kenya’s rural semi-arid areas had access to a mobile phone – through either ownership or sharing with neighbours, which is way below the rate in Machakos County. Masuki *et al.* (2010) found that the use of mobile phones improved communication and passage of information among farmers themselves and their extension agents, thereby effectively impacting adoption of farm-improvement technologies.

### **3.1.7 Farm sizes in the study area**

A large majority (83.5%) of the respondents in the study area had 3 acres of farmland or less, making them essentially smallholder farmers. Singh (2018) found that farm size, as a resource factor and a means of production, has a significant influence on adoption of tree cover by farmers in rural India. Permadi *et al.* (2018) found that faster rates of adoption of tree cover are associated with smallholder farmers having larger land holdings.

### **3.1.8 Land ownership in the study area**

Husbands and sons (86.1%) owned most of the land in Machakos County. This means that land ownership and most likely the decision-making that goes with it was patriarchal in Machakos County. A large majority (93%) of the farmers in Machakos County had land title deeds, signifying absolute legal ownership of their properties. Land ownership with title deeds made the farmers more confident to undertake long-term investment plans,

such as planting trees, without the fear of losing the property to other people at a later date.

### ***3.1.9 Years of tree planting by the respondents***

The majority (76%) of the respondent farmers had tree planting experience spanning five years and more. According to Focus Group Discussions, the respondents had learned over the years, from fellow farmers, basic tree planting skills and associated aspects such as common names of tree species and their uses. The learners then honed their skills over time, to the extent that they could prescribe and select tree species to match the local site potential. Meijer *et al.* (2015) found that intrinsic factors (such as knowledge, self-motivation and income) are as critical in the adoption of new innovative technologies by farmers as extrinsic factors. Deressa *et al.* (2009) also found tree planting experience to be one of the determinants of tree cover adoption by farmers in the Nile Basin of Ethiopia.

### ***3.1.10 Income levels of respondents in the study area***

The mean annual income for a respondent in Machakos County was Ksh 88,443.00, compared to a national figure of Ksh 289,800.00 in 2017 (KNBS, 2018). This translates to Ksh 7,370.00 per month per household. The highest income came from livestock and livestock product sales (21.4%). This was followed by income from small and medium businesses (19.9%), tree cover product sales (17%) and monthly wages (17%), followed by farm cereals (8.7%), respectively. Incomes from many of these sources fluctuated with seasons and were not predictable. According to focus group discussions, good harvests (of cereals whether for sale or subsistence) are rare and far apart due to the erratic nature of rainfall in the study area. The main tree products sold included round-wood (such as sawlogs, poles and posts), fruits (such as mangoes and avocados), wood fuel (firewood and charcoal) and animal fodder. Small-scale timber merchants would buy logs from farmers and later convert them to sawn timber for sale in the local retail markets at a higher profit.

### ***3.1.11 Tree planting behavior of farmers in Machakos County***

The majority (97%) of the respondents acknowledged that they had planted some trees on their farms. There was a reasonable level of tree planting of both indigenous and exotic species by farmers in Machakos County although the long-term rate of wood utilization appeared to have out-paced new plantings.

During Focus Group Discussions, it came out that more farmers had planted or maintained more tree cover in Sengani Location than in Koma Location - a discrepancy they attributed to unfavourable black cotton soils.

Sengani Location has largely arable red loamy soils. Another reason given for reduced tree cover in Koma Location was that there were too many roaming animals in the location, both domestic and wild, which were destructive to newly planted tree seedlings.

### 3.2 Effects of Socio-Economic Factors on Tree Cover in the Study Area

A logistic regression model was used to estimate factors that influenced tree planting and cover retention in Machakos County (Table 3.2).

**Table 3. 2.** Logistic regression model affecting tree cover in Machakos County

Parameters	B	S.E.	Wald	df	Sig.	Exp (B)
Mobile phone ownership	-0.362	.469	.595	1	.440	.696
Gender	-0.936	.370	6.401	1	.011	.392
Age	0.017	.014	1.444	1	.229	1.017
Location	0.315	.451	.488	1	.485	1.370
Marital status	0.273	.256	1.137	1	.286	1.313
Household size	0.282	.130	3.735	1	.030	1.326
Education	0.133	.216	.383	1	.536	1.143
Occupation	0.230	.242	.904	1	.342	1.258
Farm size	-0.429	.151	8.042	1	.005	.651
Title deed ownership	1.169	.513	5.186	1	.023	3.220
TLU	-0.049	.048	1.017	1	.313	.952
Years of tree planting	-0.016	.165	.009	1	.924	.984
Total household income	0.000	.000	1.093	1	.296	1.000
Constant	-3.514	1.767	3.954	1	.047	.030
Percentage correct cases	76.1					
Nagelkerke R <sup>2</sup>	51.0					
Hosmer and Lemeshow test	Chi-square =11.8, df = 8, sig = 0.159					

The logistic regression model was statistically significant, explaining 51% (Nagelkerke  $R^2$ ) of the variance in tree planting behavior and correctly classified 76% of cases (Table 3.2). Parameters which affected tree cover included gender, household size, farm size and title deed ownership.

There was a non-significant relationship ( $p = 0.229$ ) between the age of respondents and tree cover in the study area (Table 3.2). This finding contradicts Gyau *et al.* (2014) and Ali & Rahut (2018) who found a positive significant relationship between the age of respondents and adopters of tree cover, with younger generations being more likely to plant and maintain tree cover. Results could differ due to influence of a strong training and advocacy

policy and age group priorities in a given area (Kaakkurivaara & Stampfer, 2018).

Gender had a negative but significant influence ( $p = 0.011$ ) on tree cover (Table 3.2). Male-headed households were 0.392 times more likely to plant exotic tree species than female-headed households, while increasing household size by one member increased the odds of planting exotic trees by 1.326 times. This could be explained by the glaring household labour, gender and land tenure imbalances in Machakos County as there are more male-headed households and males owned more land than the females. Gender, as a fundamental aspect of social organization determines the distribution of land titles in developing countries (Kiptot & Franzel, 2011).

Nkamleu and Manyong (2005) found that male farmers were likely to plant exotic trees suggesting that male-managed farms were more likely to engage in tree planting activities. Women involvement in tree planting in the rural villages will continue to be low as they are passed over during selection for sensitization and training - unless there is a change in policy by the relevant institutions and technical service authorities (Kristjanson *et al.*, 2017). Marital status had no significant influence on tree cover in Machakos County. However, when the study sites were split in the model, it was found that marital status significantly influences tree cover in Sengani Location ( $p = 0.038$ ) but not in Koma Location ( $p=0.856$ ). Thus marital status of respondents was significantly linked with location, and was more significant in Sengani Location. Sengani Location, which is mainly ancestral land, had higher proportions of married (82.2%), widowed (9.1%) and divorced (2.2%) respondents than Koma Location (married 79.7%; widowed 6.8%; and divorced 0.8%), which was occupied by relatively more modern settlers who were heterogeneous and less culturally inclined. A similar study by Verkaart *et al.* (2017) in Kitui and Embu Counties in Eastern Kenya showed that married respondents were more likely to intensify and diversify agriculture as a pathway from poverty than respondents of other marital statuses.

The study found that there was a significant relationship ( $p = 0.030$ ) between household size and tree cover in the study area (Table 3.2). Bigger families were more likely to establish tree cover than smaller ones - because big households are driven by bigger household livelihood needs and they have the requisite labour to do so. Household labour was found to be an important factor in the rehabilitation of waste lands and enhancement of food security using a combination of tree cover establishment, soil, and water conservation activities ((Nkamleu & Manyong, 2005; Etongo *et al.*, 2018).

Education did not significantly influence ( $p = 0.536$ ) tree cover in Machakos County (Table 3.2). This is most likely due to lack of training, extension and sensitization opportunities in tree cover in Machakos County. Education level in the adoption of technologies is effective when coupled

with the relevant technical training and extension services (Ekanayake *et al.*, 2018). While investigating the effects of climate change on dry-land agriculture and the adaptation strategies by small-scale farmers in the neighbouring Yatta Sub-county, Mburu (2013) observed that education was a significant factor in climate change adaptation as it enabled farmers to diversify their sources of livelihood.

Mobile telephony did not have a significant influence on tree planting and cover retention in the study area (Table 3.2). That there were no known promotional mobile phone-based policy, advocacy or software packages in tree cover technologies for farmers in Machakos County explains the insignificance of mobile phone ownership in relation to tree cover. Meijer *et al.* (2015) found that technology and knowledge play a key role in the uptake of agricultural and agroforestry technologies among smallholder farmers in Sub-Saharan Africa.

The study found a weak positive relationship ( $p = 0.005$ ) between farm size and tree planting and cover retention in Machakos County (Table 3.12). Farmers with a larger farm size by 1 acre were 0.651 times more likely to plant trees than farmers with a lesser land area. Farm size is also an indicator of household economic resources and farmers with larger parcels of land are more likely to possess other resources required for tree growing, even under situations of multiple competing land uses. Simotwo *et al.* (2018) found that farm size is significantly linked to adaptive capacities of farmers in Transmara County, Kenya. Trinh *et al.* (2018), indeed, found farm size to be the most important factor affecting farmers' decision on adaptation to climate change.

There was a significant relationship ( $p=0.023$ ) between title deed ownership and tree cover (Table 3.12). Households who had title deeds were more likely to adopt tree cover in their farms than those without. Households with titles deeds were 3.2 times more likely to plant exotic tree species than farmers without land titles. Our findings agree with Lawin and Tamini (2018) who found that land tenure significantly influences farmers' decision to adopt new long-term agricultural innovations. Nkamleu and Manyong (2005) identified land ownership as a key driver for tree cover development in Sub-Saharan Africa, because the latter is a long-term capital investment. Our findings contradicts that by Muriu-Nganga *et al.* (2017) who found a negative relationship between land tenure and adoption.

#### **4. Conclusion and recommendations**

Socio-economic variables that significantly influenced tree cover included gender ( $p= 0.011$ ), household size ( $p=0.030$ ), and title deed ownership ( $p=0.023$ ). Gender had a negative significant influence on tree cover. Male-headed households were more likely to plant trees than female-

headed households. Age, marital status, education level, occupation, mobile phone ownership, years of tree planting experience and household income did not have significant influence on tree management in Machakos County. Based on these results we conclude that some socio-economic factors do significantly affect tree planting and cover retention in Machakos County.

We recommend more involvement of women and youth in tree planting activities in Matungulu Sub-county. Women are held back from tree planting activities by cultural factors while the youth migrate to towns. We also recommend on leveraging of mobile phone technology to reach out to more farmers with the message of tree growing and cover retention on their farms.

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