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THE ROLE OF LAND SIZE, USE AND TENURE ON TREE PLANTING AND FUELWOOD AVAILABILITY IN DENSELY POPULATED VIHIGA AND KIRINYAGA COUNTIES OF KENYA

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Abstract
With increasing population densities and closure of the agricultural frontier, traditional sources of fuelwood from bush and trees on common land have been depleted throughout Kenya. At the same time farm sizes have decreased, mainly through population pressure and the land inheritance traditions. The result of these is that households have to find their fuelwood from within the family farm which may sometimes be considered too small to provide adequate supply. This study examined the capacity of household farm holdings to sustainably supply household fuelwood needs. It also determined the relationship between land tenure security, dominant crop land use particularly maize/beans, coffee and tea with tree planting and fuelwood availability in highly populated Vihiga and Kirinyaga Counties of Kenya. The findings revealed that if farm boundaries are utilized optimally, there was sufficient land to supply fuelwood sustainably and this can be enhanced further if energy efficient stoves are used. The choice of tree species and tree management practices can significantly contribute to sustainable fuelwood supply. There was no significant relationship between land tenure and fuel wood supply.

Key Words: *Land size, Land Use, Land Tenure, Tree Planting, Fuelwood Availabilit, Vihiga, Kirinyaga, Kenya.*

INTRODUCTION

With increasing population densities and closure of the agricultural frontier, traditional sources of fuelwood from bush and trees on common land have been depleted throughout Kenya. At the same time farm sizes have decreased, mainly through population pressure and the land inheritance traditions with a commensurate squeeze on the poor. The result of these last processes is that households have to find their fuelwood from

within the family farm which may sometimes be considered too small to provide adequate supply. Households have been planting fast growing exotic tree/shrub species and a good number of them have technically speaking "adequate" trees on their farms, but still they have no fuelwood. Studies show that the trees are rarely harvested for fuelwood. Instead, they are spared for other products such as cash income or timber leaving households with no alternative but to scavenge for whatever combustible biomass material they can find. Besides the small land size and the lack of access to planted trees by women, there are other factors like dominant land uses that have direct effects on tree planting and the subsequent availability of fuelwood. Some parts of the country have designated cash crops such as tea, coffee, and sugarcane that contribute to the household decision to plant or not to plant trees. In addition, although not out rightly documented, there are silent policies barring intercropping of trees with tea and coffee. These policies combined with practical negative experiences that farmers have had with trees, have a net negative effect on tree planting and harvesting. This study examined the capacity of household farm holdings to sustain-ably supply household fuelwood needs. It also determined the relationship between land tenure security, dominant crop land use particularly maize/beans, coffee and tea with tree planting and fuelwood availability in highly populated Vihiga and Kirinyaga Counties of Kenya.

Land size and tenure security on tree planting and fuelwood security

It is estimated that a household requires about a half to one hectare (0.5-1.0 ha) of land under trees to meet its requirements for fuelwood, poles, and other wood needs on a sustainable basis (Pimentel et al., 1986). Considering fuelwood alone, Van Gelder and Kerkhof (1984) classified households in Western, Kenya, with less than one hectare (<1.0 ha.) as having severe woodfuel shortage. Those with one to two hectares (1.0 – 2.0 ha) as having a shortage, and above two hectares (> 2.0 ha.) as self sufficient in fuelwood. Households with very small land holdings are sometimes reluctant to plant trees since they feel that all the land area is needed for food and cash crops. Between 1969 and 1978, the average land holding in Kirinyaga County decreased from 9.1 acres (4.1 ha) to 5.7 acres (2.6 ha) (Castro 1983). Twenty years later (1998), it was 3.5 acres (1.4 ha). In this county, Castro (1983) found that households with two or less hectares (< or equal to 2 ha.) of land felt that it was too small for tree planting. The capacity of land to accommodate trees decreases with decreasing land size (Van Gelder and Kerkhof, 1984; Luciene et al., 1988; ICRAF. 1994, 1995, 1996). In Kenya, 80% of the national population lives on 17% of the land area, the majority of whom own tiny parcels, with the size of the average household land area declining with every subsequent generation.

Annual crop farming, tree planting and fuelwood availability

In Nyanza, Western, and Central provinces for example, the average household parcel size declined from 4.9 to 3.9 acres (2.0 to 1.6 ha) between 1982 and 1992. Over the same period, there was an increase of 15-25% in the number of households with little or no guaranteed access to land (Wahida and Awori, 1996). Given the existing rate of population increase, the problems of landlessness and land poverty are expected to intensify in the future. As the demand for crop land increases, the proportion of rented land also increases. In Indonesia, Luciene et al. (1988) found that farmers with limited land, rented plots for annual crops from their neighbours so that they can plant trees on their own plots since trees cannot be planted on rented land. In Niger (Basden, 1966) and Kenya (Brokensha and Glazier, 1973), tenants were not allowed to plant trees on agricultural land since the trees may be used to claim land ownership. Brokensha et al, (1978) suggests that while the increasing scarcity of fuelwood is likely to encourage tree planting, it is unlikely to occur on borrowed or rented land. In areas where most of the land is farmed by tenants, it is unlikely that much tree planting can occur. Ironically, the poor households that need trees most are the same ones that cannot plant them even if they wanted. For the high agro-ecological potential regions of Kenya, Van Gelder and Kerkorf's (1984) classification appear to consider only big trees. If shrubs as a source of wood are taken into consideration, it should be technically possible to plant and harvest adequate wood on 1.2 acres (0.5 ha) or less of family land. This has been found to be the case in Bangladesh (Abdedin, et al., 1990). In the Castro (1983) study, some

households indicated that tree shade would hurt the coffee crop hence reduce the harvest while others wanted to use all the land area for food production. The underlying reason, however, appear to be the high income from other uses that land is put to. If trees had comparatively similar high monetary value, the chances of it being grown despite the small land size, could be quite high.

Economic value of planted trees on fuelwood availability

Trees planted for fuelwood may not always be used for the purpose. One survey in Kuria, Kenya found that only 5% of the tobacco farmers who had planted eucalyptus for fuelwood used the trees as the principal fuel for curing the crop. The other 95% used trees and shrubs from the natural woodlands as well as agricultural residues. Farmers reported that they did not want to grow good quality construction wood and then burn it to ashes (Kerkof, 1987). One farmer who had 10,000 eucalyptus trees reported that he used the indigenous trees first, when they were all finished, he started buying indigenous wood from neighbours and now that it was too expensive to buy, he has started to use from his own woodlot (Kerkof, 1990). In Kirinyaga, Castro (1983) reported that on most farms, tree planting does not begin until all or almost all, of the natural bush is depleted. It thus seems clear that as long as farmers are able to obtain woodfuel from natural woodlands, regardless of the purpose, they will do so. But planting woodlots does provide farmers with a cash income and in the long-term, it ensures that there are still wood resources available to provide fuel (Castro, 1983; Kerkof, 1991). Knowing that indigenous trees take very long to grow, it appears more logical to encourage planting and harvesting of the fast growing eucalyptus and other planted trees than clearing the very slow growing indigenous trees for use. While there is government regulation against cutting indigenous trees, it appears the households value the exotic fast growing trees more for economic reasons.

MATERIALS AND METHODS

The study was done in the Vihiga and Kirinyaga Counties of Kenya. The criteria for selection of these sites included high agricultural production potential, high population density, and freehold land tenure regime to rule out climatic, land tenure and limited demand constraints to on-farm tree planting. In addition, the two sites were selected to contrast areas with a strong (Vihiga) and a weak (Kirinyaga) cultural barrier to tree planting by women. Due to the high populations that characterize the two Counties, one administrative division was selected from each County for detailed investigations. Luanda and Gichugu Divisions of Vihiga and Kirinyaga Counties respectively, were purposively selected. Within the sites, the land use systems, (i.e., maize/beans for Vihiga and coffee and tea for Kirinyaga) were also considered.

Vihiga County lies between longitude 34^0 30` East and $35^0$ 0` East and between latitudes 0^0 and 0^0 15` North. Luanda Division is located approximately 30km north of Kisumu town. This division was identified by administrators as the one with the highest fuel wood scarcity problem. It is generally flat and at an altitude of about 1300m to 1500m above sea level. It has a warm and semi-humid climate with a bimodal rainfall distribution. Luanda receives between 1800 and 2000 mm of rainfall annually. Rainfall peaks in April to June for the long rains and September to November for the short rains. Mean temperatures range from 14 to 32^0C. Luanda has well drained, dark red friable soils partly covered with humid top soil derived from both volcanic and basement complex rocks and the yellow red loamy sands derived from both sedimentary and basement rocks. The farming system is a subsistence level, mixed food crop/livestock system. The County's average size of a household farm holding is 1.4 acres (0.6 ha). Luanda has one of the highest population densities in the country estimated at 1090 persons/km^2 in 1997 (Republic of Kenya. 1997) and 1,128 persons/km^2 in 2009.

Kirinyaga County is located between Longitudes 37^0 1' and 38^0 East and latitudes 0^0 1' South 0^0 40' South. Gichugu Division forms the eastern part of Kirinyaga County and most of it extends into Mt. Kenya Forest. The division has a tropical type of climate and is interspersed with open U-shaped valleys and ridges. It is at an altitude of between 1310m and 2130m above sea level. Since the County is within the highlands of Kenya near the equator, the pattern of rainfall is typically equatorial. It has two rainfall seasons, the long rains, which

occur from April to June and short rains which occur October to November. Gichugu falls within the high agricultural potential part of the County. The main tea zone receives 1,700mm to 2,150mm of rainfall while the coffee zone receives between 1,220mm and 1,500mm. The area has low annual mean temperatures of 14.5 to 20.6^0 C. Gichugu has rich fertile red clay soils. The Division has three dominant zones, which include tea, coffee and maize. Livestock are raised in all the three zones with the dominant domestic animals being cattle. The County's average size of a household farm was 2.4 acres (1.0 ha) in 1997. In 1997, the Division was estimated to have 635 persons/Km^2, which is almost double the County's population density of 343 persons/Km^2 and almost half of that in Luanda of 1,090 persons per sq. km.

The high population density of both sites creates very high demand for fuelwood hence the need to grow on farm trees for fuelwood supply. On the other hand, the climatic conditions and soils in both Luanda and Gichugu can support fast growth of many tree and shrub species producing high biomass yields hence supply of large quantities of fuelwood. This study examines the situation at the sites.

The study is a longitudinal design that was done for the first time in 1998 and repeated after 14 years in 2012 at the same sites using the same procedures and same research instruments. The same will be repeated in August 2019. One hundred and eighty households were randomly selected from Vihiga and Kirinyaga Counties. In Vihiga, 90 households were selected from six villages, three of which were from Ebukanga Sub-Location and three others from Esaba Sub-location in Central Bunyore Location. The list of households in the village was used as the sampling frame. Systematic random sampling technique was used to select 15 households from each village. In Kirinyaga, the interest was in the coffee and tea zones. Rwambiti and Raimu Sub-Locations were selected to represent the coffee zones, while Thumaita Sub-Location in Karumande Location was selected to represent the tea zone. Three villages, two in Rwambiti (Kagaa and Mucungwa) and one in Raimu (Muthegi) were selected from the coffee zone. As for the case of Vihiga, 15 households were selected from each village using systematic random sampling techniques. For the tea zone, a total of 45 households were sampled from Kibaro, Kamweti and Gaturi villages. Direct observations of the type of tree and shrub species growing on the farm, the niches, spacing and planting orientation (e.g. west-east or north-south) of each of the species, and the type and quantity of fuel wood in storage were made. Physical counting of trees and selected species of shrubs was done on the sampled farms. Measurement of farm boundaries was also done using foot-pacing. Information was also gathered from previous studies done on woodfuel, household gender roles and agro-forestry in general. Vital information was also obtained from government documents, particularly the County development plans of the two Counties.

RESULTS AND DISCUSSIONS

The results of household characteristics, land factors and tree management factors confirm some of the findings of previous studies, but also reveal some new findings specific to the study sites. The findings have provided a lead to possible policy interventions which could contribute to improving fuelwood supply in the rural areas of Kenya.

Household characteristics

From the household characteristics listed in Table 1 Kirinyaga Sub-County was found to be generally better-off in terms of fuelwood production resources. These are land, labor, education and income. Although income was not recorded due to the respondents' unwillingness to provide information, maize and bean yields and, the number of coffee and tea bushes were used as an indirect measure of income. Considering the main resource, which is land. Vihiga had an average of 2.3 acres while Kirinyaga had 3.5 acres per household in 1998. This had decreased to 1.5 and 1.9 acres in Vihiga and Kirinyaga Sub-counties respectively over the 14 year period. Generally, in the study sites, daughters do not inherit land from their fathers unless there is no son in the home or a daughter is not married. The average number of sons was 3.2 (1998) for Vihiga and 3.6 (1998) for Kirinyaga. As household land holdings become small, their capacity to accommodate trees also decrease. The

challenge of how such small land units can ever supply adequate fuelwood to households gets even bigger.

Table 1: Household characteristics for Vihiga and Kirinyaga in 1998 and 2012

Household characteristics	Mean					
	Vihiga			Kirinyaga		
Year	1998	2012	Change	1998	2012	Change
Household family size	6.7	7.1	+0.4	7.7	5.7	- 2.0
Number of daughters	3.4	-	-	3.9	-	-
Number of sons	3.2	-	-	3.6	-	-
Age of father (years)	51.5	51.7	+0.2	52.8	49.0	- 3.8
Age of mother (years)	44.0	46.4	+2.4	46.2	45.8	- 0.4
Education of father (years)	5.8	8.6	+2.8	7.0	10.6	+ 3.6
Education of mother (years)	4.6	8.3	+3.7	4.6	10.1	+ 5.5
Average household land size (acres)	2.3	1.5	- 0.8	3.5	1.9	- 1.6
Land per capita (acres)	0.34	0.21	- 0.13	0.46	0.34	- 0.12

Land size and tree/shrub planting for fuelwood in Vihiga County

Given yields of wood from tree and shrub species commonly grown in the study sites, Table 2 shows that in Vihiga, 0.2 acres (0.03 acres per capita) of land is required per household if *Eucalyptus saligna* is planted in a woodlot pattern at a spacing of one meter within and between plants and coppiced annually and only one coppice stem left to grow as observed in some homes. If the planting is on the farm boundary, a total of 858 meters of boundary length would be required to provide the 5.6 tons of air-dry wood required per household every year using the three stone fireplace. This could, however be reduced to 286 meters if three coppices are left per stump. For the shrub species considered, the required land was 0.4, 4.5, and 6.8 acres for *Sesbania sesban*. *Tephrosia vogellia* and *Crotalaria grahamiana*, respectively grown in relay with food crops. When grown as single stands or on farm boundaries, the yield could be higher, hence require less land. Given these results, and the average household land size of 2.3 acres in Vihiga, it appears logical to conclude that planting trees/shrubs that have higher woody biomass yields would contribute more to fuelwood availability than those with lower biomass yields.

Table 2: Land requirements for adequate supply of fuelwood for households from one tree and three shrub species spaced one meter apart in woodlot designs

Tree/shrub species	Plants/coppices required per household per year for fuelwood	Land size required/household, per capita (acres)	
		Per household	Per capita
*Eucalyptus saligna***	858	0.2	0.03
*Crotolaria grahamiana**	27,504	6.8	1.01
*Tephrosia vogelli**	18,338	4.5	0.67
*Sesbania sesban**	1,621	0.4	0.06

* Plants, ** Coppices

Land size and tree/shrub planting for fuelwood in Kirinyaga County

In Kirinyaga, 26 ten-year-old trees were harvested and the average yield/per tree was found to be 40 kg of air-dry wood per year. For a sustainable annual household fuelwood demand of 7.8 tons in the tea and 5.3 tons in the coffee zones, 196 and 133 grevillea trees, respectively, would be required. Trees in Kirinyaga were mainly grown on farm boundaries and the common spacing was two meters. If this spacing is used, the required farm boundary length for adequate fuelwood supply would be 392 and 266 meters for the tea and coffee zones, respectively. In a study conducted in Kirinyaga, Tyndall (1995) found that only three quarters of the wood harvested from grevillea is used for fuelwood. The remaining one quarter is used for purposes like construction, fencing, and tomato staking. Under these circumstances, 49 and 33 more grevillea trees for the tea and coffee zones, respectively, would be required per household. The total boundary length required then would be 490 and 332 meters for the tea and coffee zones, respectively, or an average of 411 meters per household for the two sites.

Grevillea grows well in Vihiga and if managed in a similar manner can yield about the same quantity of wood. For Vihiga, 140 grevillea trees would be required to provide the 5.6 tons of air-dry wood required for one household in one year. If the same spacing and boundary planting are used, 280 meters of farm boundary length would be required if all the wood harvested from the trees were used for fuelwood. If Tyndall's (1995) findings can be assumed to be the general wood consumption pattern, 35 more grevillea trees would be required per household bringing the total number of trees to 175 for Vihiga. The corresponding boundary length requirement would be 350 meters. Given the farm boundary utilization results in Table 3, the average farm boundary in Kirinyaga was 674 meters. The proportion utilized was 303 meters which is only 45% of the total. If the Kirinyaga households were to plant trees on the required 411 meter length, this could take only 61% of the total farm boundary. In other words, there was more than adequate boundary space to accommodate enough trees for household annual fuelwood supply.

Table 3: Farm boundary utilization for tree planting in Vihiga and Kirinyaga

Category	Vihiga		Kirinyaga	
	Meters	Proportion (%)	Meters	Proportion (%)
Average farm boundary length planted with trees	67	18	303	45
Average farm boundary length not planted with trees	301	82	371	55
Average total farm boundary length	368	100	674	100

For Vihiga, if grevillea trees were to be planted for adequate annual fuelwood supply, 95% of the current farm boundary space could be utilized. Technically, if other variables were held constant, both Vihiga and Kirinyaga households have adequate land space to provide all their fuelwood needs, but Vihiga households will run out of land sooner than Kirinyaga. However, this could be delayed if households could reduce their fuelwood consumption levels by adopting energy conservation measures.

Reasons for limited use of farm boundaries for tree planting

Fifteen different reasons were given for the limited utilization of the farm boundary for tree planting (Table 4). The three most outstanding reasons in Vihiga County were: lack of the desired tree seedlings, avoiding interference with neighbors, and the fact that the boundaries were already planted with live fences. For

Kirinyaga, the three outstanding reasons were; to avoid interference with neighbors, land had not yet been subdivided among heirs, and land had just been recently subdivided. Households in Vihiga indicated that to plant trees on farm boundaries, they would require tree species that do not interfere with food crops. Since eucalyptus was the dominant species planted by most households at this site, it is not surprising that the unavailability of the appropriate tree species was the leading constraint for Vihiga households. When compared to Vihiga, Kirinyaga had a higher proportion of households reporting fear of boundary disputes. The reason for this situation could be the fact that most of the Kirinyaga households were planting trees on farm boundaries and already had more incidences of farm boundary conflicts when compared to Vihiga.

Table 4: Reasons for limited planting of trees on farm boundaries

	Proportion of households (%)	
	Vihiga (n=90)	Kirinyaga (n=90)
To avoid interference with neighbors	20	31
No seedlings to plant	21	6
Plan to plant soon	10	16
Planted trees normally stolen	7	1
Have no time to plant	1	1
Have a live fence already planted	10	0
Trees are browsed by livestock	1	0
Wants light to penetrate into the home stead	2	2
Has planted napier grass on the boundary	9	0
Family land not yet subdivided.	1	10
Family land recently subdivided	0	8
The planted seedlings tried up	0	7
To avoid damage to crops	0	8
Has enough trees on the farm	0	1
Has no reason	2	1
Not applicable	10	5

The big difference of land related constraints between Vihiga (1%) and Kirinyaga (18%) could be due to the fact that once the farm boundary is fixed. Kirinyaga households want to plant trees while in Vihiga they do not. The willingness of households to plant trees on farm boundaries if tree seedlings are provided was sought. Eight nine percent in Vihiga and 75% in Kirinyaga indicated their willingness to plant trees. The remaining 11% and 25% gave various reasons why they would not plant trees even if the seedlings were provided. These reasons are as reported in Table 5. Kirinyaga had ten households fearing to plant trees because of boundary disputes when compared to only two in Vihiga. In addition, Kirinyaga had one third more households reporting land shortage for tree planting when compared to Vihiga. The reasons for the first observation could be due to the experience that Kirinyaga households have had over time with regards to farm boundary disputes. The average land size in Kirinyaga was higher (3.5 acres) than that of Vihiga (2.3 acres). The reason for the reported land shortage being higher in Kirinyaga when compared to Vihiga could be due to the higher

value given to cash crops (coffee and tea) in Kirinyaga when compared to maize and beans in Vihiga.

Table 5: Reasons for households not wanting to plant trees

	Proportion of households (%)	
	Vihiga	Kirinyaga
Not applicable	89	76
May bring dispute	2	10
Trees do not establish well	1	0
Has inadequate land	6	9
Has enough trees	0	5
Land does not belong to the household	2	0

Role of tree spacing on wood yield

One of the factors that contribute negatively to the quantity of wood harvested from trees in Vihiga was the close spacing of the eucalyptus trees. Trees are planted in woodlots at a spacing of about one meter or less. They, therefore, grow straight with few, thin, or no branches at all. Previous studies have suggested that since branches can be obtained from trees planted for other purposes, there is no need to encourage tree planting specifically for fuelwood. In a situation where the trees are not producing branches, fuelwood scarcity will continue in the midst of plenty of trees. In fact this may be the case in Vihiga. While the most common spacing in both Vihiga and Kirinyaga was two meters (Table 6) there was no significant difference between the yield of prunings from ten year old grevillea trees spaced at 2.0, 2.5, and 6.0 meters apart on farm boundaries.

Table 6: The most common between tree spacing on farm boundaries

Spacing in meters	Proportion of households (%)	
	Vihiga	Kirinyaga
0.5	9	8
1.0	18	18
1.5	0	16
2.0	27	23
2.5	0	9
3.0	9	12
3.5	0	3
5.0	9	5
>5.0	9	7

The second most common spacing for both Vihiga and Kirinyaga was one meter. It is possible that over time, households have established that the two spacings (one and two meters between trees) work well for them suggesting that if recommendations for tree/shrub planting were to be made, a between tree spacing of one to

two meters could be both appropriate and acceptable to the land owners. A close observation of the grevillea tree management appears to indicate that the yield of prunings was determined by the way the tree is pollarded (i.e. The more the positions from which the pollards grow, the more the wood). Therefore, unless for other purposes, wider spacing was not an advantage when considering the wood yield. In Vihiga discriminant harvesting of eucalyptus trees was found to reduce the yield of coppices because the older trees were found to shade the coppices. In cases where a row of trees or trees in a particular block were harvested at the same time, growth of the coppices was more uniform and vigorous than where they were harvested discriminantly. A few households had double rows of grevillea alternately arranged along the farm boundary. Where the two were planted around the same time, growth was good for both rows, but where one was planted long after the first row had established, growth in younger rows had been suppressed. Where double rows were planted, it had been expected that the inner branches would be suppressed, but this did not appear to occur. It may be because after pollarding, grevillea pollards grow upwards and not side ways.

Occurrence of farm boundary disputes

An examination of the occurrence of farm boundary disputes showed that only 16% of the households in Vihiga had disputes with their neighbors as compared to 30% in Kirinyaga (Table 7). This could be due to the fact that very little (18%) of the Vihiga boundaries have been utilized for tree planting. With increased use of farm boundaries for tree planting, more boundary related disputes can be expected. Apparently, almost all the disputes in both Vihiga and Kirinyaga were tree-related. All the households with disputes complained of low crop yield due to their neighbor's trees and indeed from direct observation of the situation on the ground, their complaints were genuine. If households are encouraged to utilize farm boundaries for tree planting, clear solutions to potential disputes should be identified.

Table 7: Frequency and type of farm boundary disputes

	Proportion of households (%)	
Type of dispute	Vihiga	Kirinyaga
No dispute	84	68
Tree disputes	16	30
Coffee disputes	0	1
Farm boundary dispute	0	1

Examples of some of the ways in which some of the disputes have been solved show that most of them ended up uprooting the trees (Table 8). If households are being encouraged to plant trees, it appears contradictory to uproot the trees. Solutions that could lead to both households retaining their trees could be preferred. This suggests the need for some arrangements between neighbors even before the initial planting of trees is done. This also means that the species have to be appropriate that is, they should have minimal negative effects on crops. When considering the aspect of disputes with neighbors, households that border public road reserves have no reason what so ever for not having trees on their farm boundaries. All the same, in general, most households had no boundary problems with their neighbors suggesting that the potential for optimizing the use of farm boundaries for tree planting is substantial.

Table 8: Households' farm boundary dispute settlement options

	Proportion of households (%)	
Nature of settlement	Vihiga	Kirinyaga
Not applicable	85	66
Uprooted trees	7	19
Pruned excess branches	1	0
Pruned roots	1	0
The Government surveyed and confirmed land boundaries	0	10
Surrendered the tree to neighbor	1	1
Dispute still there	5	4

Land tenure

Eighty one percent of households in Kirinyaga as opposed to 47% in Vihiga had land title deeds (Table 9). There appear to be no clear explanation as to why more households in Kirinyaga own titles as compared to Vihiga. This could be because most fathers in Kirinyaga had not given out land to their sons, as compared to Vihiga where the land could have been given out to sons, but they had not gone through the official demarcation. Alternatively, the sons in Kirinyaga who had been given land could have gone through the official demarcation and had titles for their land. Households in the Kirinyaga study site had been resettled in the area so immediate acquisition of land titles was necessary for tenure security. Vihiga households on the other hand were living in their ancestral land which carries higher security. Vihiga had a higher percentage of households who had purchased the land they were living on. This could be due to a higher level of immigrants, but given the high population in Vihiga, this is unlikely. A higher level of emigration appears the most likely suggesting that more households were buying land from those emigrating from the area.

Table 9: Land acquisition and tenure status

	Proportion of households (%)	
	Vihiga	Kirinyaga
Inherited the land	84	91
Bought the land	16	9
Have land title deeds	47	81

Based on finding of previous studies (Fortman, 1985; Mugo, 1997) it was expected that because of having a secure land tenure, households with land title deeds could have more trees per capita and per acre than those without titles. But T-test results in Table 4.10 show no significant difference in the number of trees per capita. Contrary to the expectation, the households with no title deeds in Vihiga had significantly more trees per acre than those with titles.

Table 10: T-test for mean of number of trees between households with titles and those without

Security of tenure	Vihiga		Kirinyaga	
	Trees/acre	Trees/capita	Trees/acre	Trees/capita
With title	62	28	40	19
With no title	96	25	57	21
Significance	*	ns	ns	ns

There appear to be no clear explanation for these results. The households with titles had an average group age of 54 years while those without had an average age of 44 years. One possibility could be that younger people plant more trees than older people. Alternatively, the older households could have harvested their trees before the survey as it was found in some Kirinyaga homes. Such a situation, however is not possible for eucalyptus because they are always coppiced. Suggestions from previous studies, that households with insecure land tenure plant more trees as a way of laying claim on land did not appear likely for this situation. In the past when land was plenty and people were few, such practice could occur and other members of the family could not be disappointed. In both study sites, the land issues appeared to be so sensitive that no son would dare to plant a tree anywhere on his father's land without the permission of the father and probably the brothers too. This impacts negatively on tree planting.

In Kirinyaga, there was no significant difference in the number of trees per capita and per acre between households with titles and those without titles. This suggests that security of tenure is not a major determinant factor in the household tree population for the study areas. The households with no land title deeds in Kirinyaga had half the land size of those with titles (probably representing sons and father), but there was no significant difference between the number of trees per capita for the two groups of households again suggesting that land size *per se* was not a major factor in determining the household tree population. As for the case of Vihiga, in Kirinyaga, the group with no land title deeds were younger than those with titles by an average age difference of 10 years, suggesting that the age of the head of household had no significant effect on per capita tree population. In Kirinyaga, it was observed that households that had temporary farm boundaries had no trees on them.

Tree tenure and fuelwood availability

Various studies for example (Mugo, 1997; Warner, 1995; and Kerkof, 1990; Warner, 1995) have reported that generally women have more access to naturally growing trees for fuelwood than planted trees. Most naturally growing trees are of poor form for the market and they tend to have very few alternative uses. The planted exotic trees on the other hand tend to be straight in form and quite attractive for the market. Because of the higher economic value associated with the planted exotic tree species, men tend to assume the control of such trees even if they were planted by women. Examination of the occurrence of naturally growing trees revealed that 78% of households in Vihiga and 74% in Kirinyaga were found not to have any indigenous trees on their farms. In households where some indigenous trees were found, they had very few, between one and 14 mature trees. In Vihiga, the species were mainly *Psidium quajava* and *Markhamia lutea* while in Kirinyaga the species were mainly *Cordia abyssinica* and *Croton macrostarchys*. *Sesbania sesban* shrubs were found on many farms in Vihiga, but in some homes, they were not being managed to grow to suitable sizes for fuelwood.

It is therefore, possible that despite the physical presence of many trees on given household farms, there may be no fuelwood due to the inaccessibility of the trees to women who generally have the responsibility of providing fuelwood for their families. A number of studies have proposed the planting of crooked trees so that women can be assured of fuelwood supply. This does not appear necessary since in the event of fuelwood

scarcity increasing, even the crooked wood will be sold on the market for income. Such an incident was witnessed in one of the homes where the man was found preparing *Sesbania sesban* (usually not sold) wood to take to the market to sell. Given the continuing reduction in the land size, it appears more logical to promote a diversity of multipurpose agroforestry tree species for the products required most. A good example is grevillea which can be managed for fuelwood, timber, small poles, all at the same time.

Tree planting

Overall, Vihiga had more trees per acre (80) when compared to Kirinyaga (44). It is not clear why this situation exists, but from the observations made during the survey it may be more because of the size of the tree species. In both Vihiga and Kirinyaga, shrubs planted as live hedges were not counted because of their close spacing. In Vihiga, *Sesbania sesban* (a shrub) was counted since it was found on farm in woodlots while in Kirinyaga there was no outstanding shrub species. It was mainly grevillea trees which were counted. The shrubs in Kirinyaga were mainly *Euphorbia turicalli* and *Tithonia diversifolia*, but both had been planted as hedges.

Future tree species planting preferences

Vihiga was found to have more tree species (15) that could be considered dominant on the farms where they were found than Kirinyaga which had only five species (Table 11a). An examination of the type of tree species that households wished to plant in the near future revealed that most would want to plant the species that are dominant in their areas (i.e., *Eucalyptus saligna* for Vihiga and *Grevillea robusta* for Kirinyaga) (Table 11b).

Table 11a: The dominant tree species growing on the farm

Species	Proportion of households with species (%)	
	Vihiga	Kirinyaga
Grevillea robusta	none	86
Eucalyptus saligna	67	5
Cupressus lusitanica	8	1
Markhamia lutea	9	1
Persea americana	1	1
Others (11 different species)	18	none

This gives a strong indication that introducing new tree species in the two sites in particular may not be easy. Farmers appear to want to plant the trees whose growth characteristics they already know. This calls for some demonstration sites where the performance of trees unknown to farmers can be viewed before consideration for planting can be made. If the desired tree species are known to grow in other parts of the country, farmers can be taken to see. Where none exist, demonstration plots in research stations or chiefs' centres could play a major role in creating awareness to households.

Table 11b: Priority number one tree which households want to plant

	Proportion of households (%)	
	Vihiga	Kirinyaga
Eucalyptus saligna	74	6
Cupressus lusitanica	8	0

Grevillea robusta	7	77
Sesbania sesban	4	0
Various fruit trees	1	20
Others	5	7

Despite the fact that many households rarely plant trees specifically for fuelwood, most of the wood from the trees is used for fuelwood. A good example of this is grevillea which is usually pollarded first at six years after which, it is harvested yearly or every two years. If the yield of fuelwood pruning from all the years the trees are harvested (about 12 or more) and the off-cut remains from sawing timber is compared to the actual timber yield from the same tree, it is logical to propose that grevillea trees are planted for fuelwood as a number of farmers have indicated (Table 12). The same applies to eucalyptus in Vihiga. Very few farmers plant eucalyptus for their subsistence use for fuelwood, but they harvest the trees and sell if for fuelwood. Therefore, despite the fact that eucalyptus is planted mainly for cash income, it still ends up being used mainly as fuelwood by those purchasing its wood. Eucalyptus' high economic rating may be because of its limited supply.

Table 12: Reasons for preferring tree number one above for planting

	Proportion of households (%)	
	Vihiga	Kirinyaga
Good for fuelwood	41	53
Has good timber	18	3
Is fast growing	10	16
Multipurpose	11	4
Preserves soil fertility	4	0
Seedlings are easily available	4	0
For poles	7	1
Fruits	2	5
Does not affect crops	3	8
Good ornamental	0	2
For income generation	0	8

It is possible that if there was no market for eucalyptus trees, they could be harvested by households for subsistence use for fuelwood. Such a situation can be brought about through flooding the eucalyptus market. To a limited extent, this is the situation witnessed in Kirinyaga where almost every household has its own grevillea trees to the extent that it is not easy to find fuelwood being sold on the market. Although not necessary and it appears wrong from the economic point of view, planned flooding of the poles' market in Vihiga might lead to the availability of more fuelwood for the households. End use product analysis indicated that in Vihiga, it is now more profitable to sell trees as fuelwood instead of poles.

Sources of tree/shrub planting material

Lack of tree planting materials has appeared in the findings of many studies (e.g. Warner, 1995; Mugo, 1997) as one of the major constraint to tree planting. Households were found to plant many trees and shrub species ranging from 3 to 16 different types. Seedlings for most of the species were obtained from different sources. Only sources of seeds and seedlings for the dominant species on the farms have been reported in Table 13. In Vihiga, the combination of neighbors, friends and relatives was the source of planting material for the majority of the households. This category was followed by supply from commercial sellers, and households' own tree nurseries. Most of the sellers were selling potted seedlings while the on-farm nurseries were producing bare root seedlings. In Kirinyaga, most of the households were buying seedlings from individual private nurseries. This was closely followed by use of wildlings which are naturally growing seedlings that were uprooted and planted in the desired part of the farm.

Table 13: Source of seed/seedlings for the various trees planted on the farms

	% of households	
Source	Vihiga	Kirinyaga
Wildlings	5	30
Neighbors, friends, and relatives	35	10
Individual private tree nurseries	-	31
Own tree nursery	27	8
Forest Department	-	14
Door to door seller	31	8
ICRAF	2	-
Prison's nursery	1	-

Location of trees on the farm and availability of fuelwood

Table 14 shows the location of the dominant species on the farm. It was observed that trees/shrubs planted on farm boundaries and within the crop land were more likely to be harvested than those planted within the homestead and in woodlots. The main reason appears to be the need to prune trees to reduce the shade effect on the crops. Trees planted in the homestead are planted mainly for shade so little if any pruning can be expected. This leads to a suggestion that in farming systems where trees are planted on farm boundaries, within farms, and on borders more fuelwood can be expected.

Table 14: Location where the dominant tree species was planted on the farm

	Proportion of households (%)	
	Vihiga	Kirinyaga
Farm boundary	37	69
In homestead	41	1
Scattered on farm	12	17
Woodlot	10	3
In cropland	1	3

As shown in Tables 15 and 16, the primary function for the dominant tree species planted in Vihiga was fuelwood followed by poles while in Kirinyaga it was fuelwood followed by timber. Poles were the main tree products used in household construction in Vihiga while in Kirinyaga it was timber. The functions for which the trees are planted is, therefore, not a surprise. Households' species preferences for various purposes have to be taken into consideration when proposing the tree species to be planted.

Table 15: Primary use of the dominant tree species on the farm

	Proportion of households (%)	
Function	Vihiga	Kirinyaga
Fuelwood	53	82
Construction poles	21	0
Timber	9	9
Fencing	5	1
Fruits	5	1
Marking farm boundary	5	3
Multiple purposes	3	3

Table 16: Main secondary use of the dominant tree species

	Proportion of households (%)	
Function	Vihiga	Kirinyaga
Timber	26	73
Fuelwood	31	18
Construction poles	16	10
Shade	20	0
Others (Marking boundaries, fencing, furniture and tools, erosion, cash income)	8	0

THE ROLE OF EXTENSION SERVICES ON TREE PLANTING

Limited extension services to farmers have been blamed for the poor response of farmers to tree planting initiatives. An assessment of the role of extension services in initiating tree planting revealed that most of the planting is from farmers own initiatives as shown in Table 17. Combined efforts of extension services from government and Non governmental organizations were reported to have initiated tree planting in only 15% of the households in Vihiga and 22% in Kirinyaga.

Table 17: Initiator of the decision to plant trees

	(%) of households	
Initiator	Vihiga	Kirinyaga
Self	81	75
Govt. Extension Officer	10	19

NGO Extentsion Officer	5	3
Relative	2	1
Friend	1	1
Neighbor	1	1

A comparison of the extension services provided for tree farming, livestock, and crops showed that 52% of the households in Vihiga and 70% in Kirinyaga had never received any advice on tree farming (Table 18). Agricultural extentionists were reaching 52% of the crops and 41% of the livestock farmers in Kirinyaga. Of the two counties, Vihiga households were receiving more tree related extension services than Kirinyaga households while the Kirinyaga ones were receiving more livestock and crop advice when compared to those in Vihiga. The difference in the tree extension services could be due to the presence of ICRAF in Vihiga. While there is no clear explanation for the limited livestock and crops extension services in Vihiga. The limited tree extension services calls for action to improve the exchange of useful information with farmers.

Table 18: Source of advice for tree planting and management

Source of advice	**Households getting advice on tree planting and management**	
Source of advice	Vihiga	**Kirinyaga**
No advice	52	**70**
Forest Department	14	**19**
Livestock extension	-	**-**
Agricultural extension	-	**-**
Chief's baraza	9	**6**
ICRAF	14	**-**
Friends and Relatives	7	**-**
Other NGOs	-	**4**
Mass Media	2	**-**
School Knowledge	1	**1**
Community Groups	1	**-**

DOMINANT RURAL LAND USES, TREE PLANTING AND FUELWOOD AVAILABILITY

The examination of land use practices shows that in most cases, there is no documented policy statement indicating what should be done on the farms, but previously, agricultural officers advised farmers to cut trees from crop land and this tradition appears to be fixed in farmers' minds. In addition, the farmers themselves have observed over time what crop combination and arrangements are best for them.

Maize and beans growing, tree planting and fuelwood availability

There was no documented policy statement indicating whether trees should be planted in maize and bean fields or not. But from experience, farmers have observed how eucalyptus, cyprus, and pine trees have harmed their maize and bean crops. As such, they are not willing to take chances. *Sesbania sesban* shrubs were left on the farm, but generally the numbers were not adequate for household fuelwood requirements. In almost all cases where there was a mature eucalyptus tree on a farm boundary, there was a boundary dispute and this adds to the well known poor relationship between eucalyptus and crops. Surprisingly, all the potential “appropriate” tree species that one could consider recommending were found within Vihiga, but they were very few in number and were planted by very few individuals.

Coffee growing, tree planting and fuelwood availability

In Kirinyaga district, it was observed that the coffee zone had the highest number of trees, but the least fuelwood. Direct observation of the trees on the farm showed that trees in this area are not harvested as frequently as expected. Almost all trees in Kirinyaga are planted on farm boundaries. The coffee trees flower in May and the berries are harvested from November to January. It was also observed that whether planted on farm boundaries or within the coffee farm, when trees are harvested, the tree branches break the coffee stems together with the berries. This is not acceptable to coffee farmers since within the coffee zone, coffee is a chief source of income for households. Research on the best way the coffee/tree interaction can be managed is going on at the Coffee Research Foundation. The findings may contribute towards increasing trees and tree harvesting frequencies on coffee farms.

Tea growing, tree planting and fuelwood availability

Grevillea is the main tree grown in the tea area. It sheds very many leaves which make a blanket sort of cover on the tea plants, hence preventing or limiting the photosynthetic process from occurring. This can greatly reduce the yield of tea leaves. For this reason very few farmers are willing to plant grevillea along the farm boundaries if there is tea in the particular area. Besides this, the Kenya Tea Development Agency does not encourage farmers to plant trees next to the tea crops. In this particular case, grevillea trees can be managed in such a way that the leaves are harvested frequently for other purposes like mulching while the sides facing the roads are left to produce fuelwood. Alternatively, species that do not have shedding problems can be screened for planting in association with the tea plants. Grevillea also acts as a secondary host to the amelaria fungi which can infect and destroy tea bushes. To reduce the possibilities of infection, farmers are not allowed to plant grevillea trees where tea is growing. In this case, other trees which are known not to threaten the tea plants can be screened and the suitable ones planted in association with tea bushes.

ROLE OF HOUSEHOLD FACTORS ON TREE POPULATION

As indicated in Table 19, only one out of the 14 variables considered was positively and significantly contributing to the per capita number of trees on farms in Vihiga. Other variables that were contributing positively, but not significantly, were: if father was employed, if land was inherited, if father was living home, large family size, high education of mother, high number of cattle, higher age of mother, and high level of participation of wife in tree resource activities. The negative and significant variables were high education and age of father. All the other were negative, but not significant. For Kirinyaga, only large land size had a positive and significant contribution (Table 20).

Table 19: Predictors of per capita number of trees on the farm in Vihiga

Variables regressed	Un-standardized Coefficients	T-Value
Age of father	-1.011*	-1.853
Age of mother	0.396	0.828
Education of father	-2.921*	-1.886
Education of mother	2.262	1.495
Number of cattle	1.067	0.373
Number of daughters	-15.455	-1.010
Number of sons	-16.584	-1.149
Family size	13.088	0.903
Family living home	14.325	1.251

Father employed	15.066	1.358
Land size	-2.060	-0.755
Land inherited	14.794	1.243
Ownership of title	18.239**	2.169
Level of participation of wife	0.105	0.198
Constant	41.837*	1.691
R-squared	48%	-
R-squared adjusted	25%	-
Regression, Residual, Total (df)	14, 32, 46	-

*, **, Significant at 10% and 5% level of probability respectively

Table 20: Predictors of per capita number of trees on the farm in Kirinyaga

Variables regressed	Un-standardized Coefficients	T-Value
Age of mother (father)	-0.0698 (0.352)	-0.124 (0.720)
Education of father	1.248	1.378
Education of mother	1.008	1.121
Number of cattle	-0.299	-0.144
Number of daughters	-1.093	-0.232
Number of sons	-1.900	-0.406
Family size	0.041	0.010
Father living home	-3.544	-0.766
Father employed	-7.485	-1.005
Land size	2.000	1.327
Land inherited	-0.138	-0.016
Land size under maize and beans	5.995*	1.673
Number of coffee & (tea) bushes	0.006 (-0.0004)	0.477 (-0.269)
Closeness to the forest	-6.259	-0.766
Wife allowed to sell poles	11.279	1.319
Wife allowed to sell fuelwood	-6.777	-1.035
Level of participation of wife	-0.0101	-0.016
Constant	14.331	1.691
R-squared (adjusted)	40% (18%)	-
Regression, Residual, Total (df)	19, 52, 71	-

* Significant at 10% level of probability.

SUMMARY AND CONCLUSIONS

This paper reported on the role of land size, tenure, land use policy and utilization of farm boundaries for tree planting. This section provides the summary and policy recommendations that could contribute towards improved on-farm tree growing.

Land size, tree planting and fuelwood availability

The land size required for sustainable supply of wood products for a household depends on the tree/shrub species, planting arrangements, spacing and management patterns. The average land size of 2.3 and 3.5 acres for Vihiga and Kirinyaga, respectively, is adequate for tree planting for sustainable supply of fuelwood. Homesteads particularly in Vihiga, could be planned to accomodate a substantial number of trees, including fruit trees. The land size could be enhanced by planting high yielding tree/shrub species on farm boundaries.

Land tenure, tree planting and fuelwood availability

Farmers' priorities are food production and cash income. Fathers give land to their sons for planting maize and beans, coffee, and tea. Since trees in Kirinyaga are planted on farm boundaries, and the land given for other crops is on temporary basis, it is difficult to plant trees on temporary boundaries. Even where the final boundaries have been identified, it is expensive to do official demarcation by the government. This greatly delays the finalization of farm boundaries along with the planting of trees. Of particular concern to the younger men was if they mark their boundaries by planting the trees, how will their father's land be divided when he is no longer there.

The issue of women having access to land did not arise. Men, particularly in Vihiga, could not, imagine a situation where women could be allowed to share in the land of their fathers. The Kirinyaga men, on the other hand, appeared more accommodating by responding that “their land belonged to both of them (husband and wife)” and they did not have a lot of the differentiation of the land belonging to their fathers.

Tree tenure and tree planting

Men were generally referred to as the owners of trees like eucalyptus and grevillea. Women could harvest from indigenous trees and shrubs more freely than the men's trees. Here, the issue was not so much the trees but their economic value. As witnessed in one household, even shrubs like sesbania which had a market value could slowly change hands of ownership to become men's shrubs. A similar result was observed in Bungoma where combretum molle trees that used to be harvested freely by women changed to being men's trees when they were identified as good sources of charcoal for sale. While it is almost taboo for a man to be involved in firewood collection, very many men could be seen with fuelwood on bicycles taking to the market, suggesting that they can also be involved at the household level.

Dominant land uses, tree planting and fuelwood availability

There was no particular land use policy stating what should happen on the farm, but farmers would not plant trees because of the negative effect they had observed over time. The Coffee Research Foundation is conducting research to identify the most suitable species and planting arrangements that could enable farmers to incorporate trees into their coffee farms. No information was obtained on what the Tea Research Foundation was doing to include trees in/or near the tea farms.

RECOMMENDATIONS

Based on the findings of this study and the various hints to alternative options, recommendations to improve utilization of the small land sizes, land tenure, and land use policy arrangements for sustainable supply of fuel wood and tree products in general, have been made as follows:

Land size, tree planting and fuelwood availability

- All farm boundaries should be considered for tree planting, but farmers have to be assisted to identify appropriate tree species.
- Farm boundaries should be considered for shrub planting and they could be managed for fodder, mulch, or fuelwood. All these management purposes will allow the shrubs to assist in reducing water run-off and soil erosion.
- Farmers should be assisted to plan their homesteads so that where possible, they can plant more trees, particularly fruit trees, in their home compounds.
- Research into locally available and viable alternative sources of livelihood for the rural populations should be conducted to reduce the pressure on land. This could limit sub-division of the already small land sizes.
- Houses should also be designed to use minimum space (e.g. Having one house per household instead of three). These could release some land that could in turn be used for planting trees.

Land tenure, tree planting and fuelwood availability

- Ways of speeding up the use of farm boundaries after land subdivision should be sought.
- The sharing of farm boundaries requires mutual agreement between the households affected. One possibility is to initiate community meetings to discuss how this can be promoted.
- Under the current tenure arrangements, it appears easier to convince men to plant and harvest trees for fuelwood than to ask them to give women land to plant trees for the same, but the better option is where the household could be treated as one unit.

Dominant land use, tree planting and fuelwood availability

- There are multipurpose tree and shrub species that grow well in association with maize and beans. These species should be identified for specific sites and farmers assisted to plan and incorporate them in their farming systems.
- Harvesting of grevillea can be done during the months of February and March to reduce the carnage to coffee plants. On-farm tree management studies should be done to develop appropriate harvesting techniques.
- The Tea Research Foundation should be approached to consider screening tree species that could grow well with tea bushes.

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