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Full Length Research Paper

Assessment of agroforestry in the semi-arid lands of Kenya

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A survey targeting smallholder households was carried out in Mumbuni and Ndovoini sub-locations in the semi arid Makueni County, Kenya, to identify agroforestry types and practices and their level of adoption and socio-economic factors influencing adoption of agroforestry. The study involved a survey of 234 households using a structured questionnaire. The collected data was subjected to descriptive statistical analysis and binary logistic regression model. Results obtained revealed that more than 90% of the households practised agroforestry. It was also observed that significantly (P<0.01) more agroforestry trees in overall were planted at Mumbuni (40 trees/acre) than at Ndovoini (9 trees/acre). Agroforestry annually contributed 41 and 17% of farm-based income in Mumbuni and Ndovoini, respectively. Adoption of agroforestry was significantly influenced by the size of the household, mode of acquisition of land, security of land tenure, size of landholding, gender and the level of education of the head household. Adoption of sustainable agroforestry practices was low in both sites. There were 50 to 58% of households with fruit trees dispersed on crop land; the other practices on fruits were poorly being carried out (<20%). The highest practices on forest wood trees were homestead planting (Mumbuni 40.2% and Ndovoini 70.1%); the rest were poorly adopted (<25%). Agroforestry practices on fodder were least adopted (<16%).

Key words: Agroforestry, agroforestry practices, Makueni County, semi arid lands, socio-economic factors, adoption of agroforestry.

INTRODUCTION

Agroforestry plays an important role in enhancing the resilience of semi arid farming systems by providing a range of products such as human food, fiber, fodder, timber, poles, medicine, and firewood. It also provides

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services which include soil fertility, shade and serves as windbreaks. In the Semi arid lands of Makueni, Kenya, adoption of agroforestry practices is low despite the recognized potential of sustainable agroforestry to contribute to more resilient farming systems, food security and poverty reduction. Although factors affecting adoption of agroforestry have been carried out in Cameroon (Nkamleu and Manyong, 2005), Nigeria (Akpabio et al., 2008), Ghana (Owusu and Parahoe, 2003), Pakistan (Irshad et al., 2011), Uganda (Mutonyi and Fungo, 2011), and in Western Kenya (Odhiambo, 2010), no such studies have been carried out in Makueni County. Results of this study are expected to be different as Makueni is not similar to Cameroon, Nigeria, Ghana, Pakistan, Uganda and Western Kenya in terms of climate and agroecological zone. Socio-economic study of farmers and their relationship to the agroforestry would help to ascertain the opportunities for the development of agroforestry systems in Kenya (Franzel et al., 2002). Analyzing the household and farmer characteristics could help the process of effective planning system for farm forestry. Studies have revealed that growing of trees is a function of socio-economic characteristics of the farming community (Irshad et al., 2011). Agroforestry has not been given much attention as in livestock and agricultural sectors in ASAL (Kinama, 1997). Most of the agroforestry research has been conducted at research stations or research plots near development project sites. Few studies are available on the performance of agroforestry practices under farmer-managed situation' (Franzel et al., 2002).

Research objective

The broad objective of this study was to assess the status of agroforestry in the semi arid lands of Kenya, a case of Makueni.

Specific objectives

1. To identify types of agroforestry and their levels of adoption in the semi arid lands of Makueni County.
2. To determine the household social economic factors influencing the adoption of the practices
3. To identify agroforestry practices and their levels of adoption in the semi arid lands of Makueni County.

Research questions

1. What are the existing types of agroforestry and their levels of adoption in the semi arid lands of Makueni County?
2. How are the household socio-economic factors influencing the adoption of agroforestry in the semi arid lands of Makueni County?
3. What are the agroforestry practices and their levels of adoption in the semi arid lands of Makueni County?

MATERIALS AND METHODS

The study area

The study was carried out in Makueni County in Kenya. Two sub-locations, Mumbuni and Ndovoini were selected for the study. Makueni County was chosen for the study because it has high food insecurity, high poverty index, high rate of deforestation, inadequate water, high rate of soil erosion, sand harvesting, poor waste management and poor implementation of the Environmental Management and Coordination Act (GoK, 2005). The County lies between Latitude 1°35' and 3°00' South and Longitude 37°10' and 38°30' East. It covers an area of 8,034.7 Km², out of which 474.1 Km² form the Tsavo West National Park and 724.3 Km² form the Chyulu Game Reserve. It has a population of 884,527 (47.7% males; 53.3% females) with an annual growth of 2.8% and poverty index of about 73.5% of the total population (GoK, 2010). Makueni County has two rain seasons: March/April (long rains) and November/December (short rains). June to October is a long dry period, while January to March is a shorter dry season. The hilly parts of the district receive 800 to1200 mm of rainfall per year. The rest of the County receives less rainfall, ranging from 300 to 500 mm per annum. The County has eight AEZ zones ranging from LH2, UM3, UM4, LM3, LM4, LM5, LM6 and IL6 (Jaetzold et al., 2006). LM4, LM5, LM6 and IL6 are the ASAL and form more than 80% of Makueni County (Jaetzold et al., 2006). Mumbuni is in Wote Location of Wote Division in Agro ecological Zone (AEZ) Lower Medium4 (LM4) and Ndovoini is in Nguumo Location of Makindu Division AEZ Lower Medium 4 (LM5). Mumbuni sub-location is within the marginal mixed farming (marginal cotton) zone, ranging from 1200 to 1300 m above mean sea level. It receives rainfall, ranging from 190 to 300 mm in March to April and 250 to 350 mm in November to December. The seasons are very short to short. The soils are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay; a topsoil of loamy sand to sandy loam Ferralo-Chromic/Orthic/Ferric Acrisols and Luvisols; with Ferralsols (Jaetzold et al., 2006). Ndovoini sub-location is under livestock and cotton livelihood (Livestock-millet) zone, an elevation of 1000 to 1080. Rainfall ranges 80 to 160 mm in March to April and 180 to 250 mm in October to December. Ndovoini has well drained soils, deep to very deep, and dark-red to strong brown, friable sandy-clay to clay of Rhodic and Orthic Ferralsols with a very uncertain first cropping season (Jaetzold et al., 2006). Temperatures range from minimum of between 12°C to a maximum of 34°C.

Data collection

Purposive sampling was used to select the AEZ LM4 (comprising of six divisions: Wote, Tulimani, Kisau, Kasikeu, Mbitini and Matiliku) and AEZ LM5 (comprising of six Kibwezi, Mtito Andei, Nguu, Kathonzweni, Kalawa, Makindu). The two AEZ were sampled out for the study because they constitute about 75% of the arable land in Makueni County (Jaetzold et al., 2006). Out of each zone, simple random sampling of a division was used, whereby. Wote and Makindu divisions were sampled for the survey. By a further simple random sampling, Nguumo Location in Makindu and Wote Location in Wote were chosen. Finally, the two sub locations: Mumbuni and Ndovoini sub-locations were selected using simple random sampling out of 8 and 15 sub-locations in Wote and Nguumo, respectively. The target population of this study was 1,273 households in Ndovoini sub-location and 1,060 households in

Table 1. Households (%) with agroforestry trees.

Type	Mumbuni	Ndovoini	χ^2	P
Fruit trees	93.5	90.6	0.658	0.417
Forest wood trees	74.8	89.0	8.114	0.004*
Fodder trees	16.8	32.3	7.362	0.007*

*Significant at 99% level of confidence.

Table 2. Number of agroforestry trees planted by household in the study sites.

Site	Type of trees	Min.	Max.	Mean	Std. error	Std. deviation	Trees/Acre[1]
Mumbuni	Fruit trees	3	1,065	209	21	204	37
	Forest wood trees	1	600	55	13	104	10
	Fodder trees	6	150	69	25	56	12
Ndovoini	Fruit trees	2	250	28	4	42	4
	Forest wood trees	1	300	32	4	42	5
	Fodder trees	1	150	35	6	36	5

[1]Average number of trees per mean size of landholding (acres).

Mumbuni sub-location (as provided by the Assistant Chiefs and village elders). A total of 234 households (127 and 107 households in Ndovoini and Mumbuni sub-locations, respectively, which represented 10% of the households) were sampled. This involved first, listing of all households (as provided by the Assistant Chiefs and village elders) and then sampling the 10% through generation of random numbers using a computer. The sample size was based on the 10% minimum statistics requirement recommended by Gay (1981) and Mugenda and Mugenda (1999). Descriptive research (Kombo and Tromp, 2006) was used whereby a survey targeting small holder households was carried by use of a structured questionnaire for the quantitative data. A structured questionnaire was used to get information on the status of agroforestry (types of trees grown and practices adopted by the small holders). The questionnaire was pre-tested in a pilot survey involving five households from each of the two sub-locations before the main survey. Some questions were modified or removed in cases of repetitions. Ten enumerators were trained for two days and used for data collection.

Data analysis

The collected data was subjected to descriptive statistical analysis of cross tabulation frequencies, mean, and binary logistic regression model using Statistical Package for Social Science (SPSS) to explain relationships between different variables and factors affecting and/or influencing agroforestry. Binary logistic regression model (Hailu, 1990; Cramer, 1991; Nkamleu and Adesina, 2000) was used to determine the relationship between household socio-economic characteristics and the level of adoption of the major types of agroforestry trees.

RESULTS

Agroforestry tree types identified in the selected sites

Fruit, forest wood and fodder trees were the three agroforestry tree types planted at the study sites (Table 1). However, most households (about 90%) planted fruit trees. This was followed by forest wood trees and significantly (P<0.01) more households (89%) at Ndovoini compared to Mumbuni (74.8%) planted forest wood trees (Table 1). Further, fodder trees were the least planted compared to other agroforestry tree types and significantly (P<0.01) more households at Ndovoini (32.3%) compared to Mumbuni (16.8%) planted fodder trees.

Results obtained on number of agroforestry trees planted by the households in the study sites revealed that the density of agroforestry trees was higher at Mumbuni than at Ndovoini (Table 2). At Mumbuni fruit, forest wood and fodder trees had a density of 37, 10 and 12 trees per acre, respectively, compared to densities of 4, 5 and 5 trees acre, respectively, at Ndovoini. The average number of trees was also higher at Mumbuni (209 fruit, 55 forest wood and 69 fodder trees) contrast to Ndovoini (which had 28, 32 and 35 fruit, forest wood and fodder trees respectively) (Table 2).

Main sources of household income in the study sites were food crops, livestock and agroforestry (Table 3). Agroforestry significantly contributed to household income in both sites. However, Mumbuni households generated more income (Ksh 10,070,050) from their farms than Ndovoini (Ksh 5,322,700). Further, agroforestry income contributed more to income (41% at Mumbuni than at Ndovoini, 17% (Table 3).

Household socio-economic characteristics and their influence on adoption of agroforestry

Results on socio-economic characteristics of the households in the study sites revealed that there were

Table 3. Annual farm income (Ksh) and the overall contribution of major enterprises to the gross farm income (%).

	Mumbuni				Ndovoini			
Enterprises	**No. of HH**	**Total Annual farm income**	**Farm income per HH**	**Overall contribution**	**No. of house-holds**	**Annual farm income**	**Farm income per HH**	**Overall contribution**
Food crops	82 (77%)	3,780,550	46,104	38	103 (81%)	2,535,900	24,620	48
Livestock	39 (36%)	2,111,950	54,153	21	78 (61%)	1,896,800	24,318	36
Agroforestry	74 (69%)	4,177,550	56,453	41	17 (13%)	890,000	52,353	17
Total		10,070,050		100		5,322,700		100

Percentages of households (HH) are in parenthesis and are on multiple responses.

Table 4. Descriptive statistics (mean) for variables used in the empirical logistic regression model.

Household characteristics	**Mumbuni**	**Ndovoini**	**Chi-Test**	
Continuous variables			χ^2	**P-value**
Respondent's age (years)	45.29	44.57	41.447	0.940
Household size	5.78	6.20	11.847	0.222
Average land size (acres)	5.69	6.58	38.953	0.296
Household annual income from non-agroforestry activities (Ksh)[a]	102,920	97,901	144.151	0.104
Farmers experience in years	19.11	18.21	56.059	0.105
Categorical variables				
Level of education of the household head			1.809	0.613
No formal education	4.7	8.7		
Primary	57.9	58.3		
Secondary	26.2	24.4		
Tertiary	11.2	8.7		
Land tenure			0.928	0.629
With title deed (free hold)	43.9	41.7		
Without title deed	56.1	58.3		
Method of land acquisition [b]			17.097	0.000
Inherited	85.0	60.6		
Purchased	15.0	39.4		
Gender of the household head			5.233	0.062
Male	89.7	83.5		
Female	10.3	16.5		

[a]Household income from non- agroforestry activities is the income from food security crops, livestock, employment, business, casual labour. [b]Method of land acquisition was significantly different at 95% level of confidence (p<0.05) across the two sites.

89.7 and 83.5% male headed households in Mumbuni and Ndovoini, respectively. In addition, the average age of household heads in the two study sites was 45 years. Further, household size of both sites was about 6. Average land size holding for Mumbuni and Ndovoini was 5.7 and 6.6 acres, respectively (Table 4). Land tenure was freehold but with about 56 to 58% households lacking title deeds. Further, about 85 and 61% households at Mumbuni and Ndovoini, respectively, had inherited land whereas 15 and 39% of the households at Mumbuni and Ndovoini, respectively, had purchased land. Mean annual income from non-agroforestry was Ksh 102,920 and 97,901 at Mumbuni and Ndovoini respectively.

History of farming was 19 and 18 years in Mumbuni and Ndovoini respectively. Household heads either had informal, primary, secondary or tertiary education level. However, majority of the household heads had primary education level, 57.9 and 58.3%, Mumbuni and Ndovoini, respectively (Table 4).

The identified agroforestry practices in the study sites

Agroforestry practices were identified as trees dispersed in crop land, fruit orchards; wood lots; fodder-lots;

Table 5. Logistic regression predicting the adoption of fruit trees.

Variable	Mumbuni				Ndovoini			
	B	Wald χ^2	P	Odds ratio EXP(B)	B	Wald χ^2	P	Odds ratio EXP(B)
Age	0.103	3.025	0.082	1.109	0.194	3.182	0.074	1.215
Size of household	-1.389	3.887	0.049*	0.249	-0.916	2.581	0.108	0.400
Size of land	0.370	1.580	0.209	1.447	0.261	1.337	0.248	1.298
Income from non-agroforestry activities	0.000	0.070	0.792	1.000	0.000	1.959	0.162	1.000
Years in farming	-0.035	0.962	0.327	0.965	0.128	2.107	0.147	1.136
Education								
Primary	-23.220	0.000	0.998	8.24E-11	4.682	0.000	1.000	108.018
Secondary	-18.042	0.000	0.998	8.24E-11	-15.588	0.000	0.998	1.70E-07
Tertiary	-18.737	0.000	0.998	8.24E-11	-13.950	0.000	0.998	8.74E-07
Land tenure (Without title deeds=1)	-2.248	2.980	0.084	0.106	-2.030	2.303	0.129	0.131
Mode of land acquisition (Purchased=1)	-.100	0.002	0.962	0.905	-7.264	5.083	0.024*	0.001
Gender of head of household (male=1)	19.756	0.000	0.999	3.8E+08	6.448	5.192	0.023*	0.002

*Significant at 95% level of confidence.

boundary planting and live fence; homestead/compound planting; on soil conservation structures; range lands or grazing land; wind breaks and planting along streams (Tables 5 to 7). The dependent dichotomous and binary variables used in the logistic regression model were the "fruit tree are planted", "forest wood trees are planted" and "fodder trees are planted", which were coded 0 = no (for not planted) and 1 = yes (for planted or adopted). It was assumed that 'adoption' means that at least an agroforestry tree was planted by a household. Using the model, the logistic linear function is expressed as:

$$\ln\left(\frac{p}{1-p}\right) = \beta_{\circ} + \beta_1\chi_1 + \cdots + \beta_n\chi_n$$

Log-odds {ln (ODDS)} of adoption is modeled as a linear function (Landau and Everitt, 2004; Nkamleu and Adesina, 2000; Cramer, 1991; Hailu, 1990), The regression model predicting the logit, that is, the natural log of the odds of having made one or the other decision, becomes:

$$\ln(\text{ODDS}) = \ln\left(\frac{p}{1-p}\right) = a + B\chi, \text{ and that } p = \frac{\text{ODDS}}{1+\text{ODDS}},$$

where p is the predicted probability of the event which is coded with 1 (adopted the agroforestry) rather than with 0 (not adopted), is the predicted probability of the other decision, and χ is our predictor variable. B is the coefficient for the constant, *a* (also called the "Y-axis intercept") in the null model. Exp (B), the exponentiation of the B coefficient, which is an odds ratio, was used in the SPSS Binary logistic regression model because it is easier to interpret than the coefficient (University of California Los Angeles, 2015). The ODDS ratio was used as the predicted odds of the socio economic characteristics characteristics in deciding to adopt agroforestry in the study area. The predicted value of p, is $0 < p < 1$. The underlying function, which ranks the adoption of the i^{th} farmer, was assumed to be a function of household-specific attributes (the vector χ, the socio-economic characteristics of the household) and a disturbance term assumed to a zero mean. The estimated regression coefficients in the model gives the estimated change in the log-odds corresponding to a unit change in the corresponding explanatory variable conditional on the other explanatory variables remaining constant. The parameters were exponentiated to give results in terms of odds and the coefficients. Wald Chi-square (χ^2) statistic was used as it tests the unique contribution of each predictor (variable), in the context of the other predictors (variables) that is, holding constant the other predictors and eliminating any overlap between predictors. The regression model predicts the logit, that is, the natural log of the odds of having made one or the other decision. The results of the analysis were summarized in Tables 5 to 7.

Logistic regression model predicting the adoption of fruit trees revealed that fruit tree adoption was significantly ($p<0.05$) influenced by the size of the household in Mumbuni and by the method of land acquisition and gender of the household head at Ndovoini (Table 5). However, adoption of agroforestry wood trees was significantly ($p<0.05$) influenced by the level of education at Mumbuni and security of land tenure at Ndovoini (Table 6). Further, adoption of fodder trees was significantly ($p<0.05$) influenced by land size at Ndovoini (Table 7).

Adoption of agroforestry practices on fruit trees

Fruit trees in the study sites were planted as either

Table 6. Logistic regression predicting the adoption of forest wood trees.

Variable	Mumbuni sub-location				Ndovoini sub-location			
	B	Wald χ²	P	Odds ratio EXP(B)	B	Wald χ²	P	Odds ratio EXP(B)
Age	-0.013	0.334	0.564	0.987	-0.017	0.370	0.543	0.983
Size of household	0.265	1.489	0.222	1.304	-0.176	0.915	0.339	0.839
Size of land	-0.045	0.441	0.507	0.956	-0.028	0.712	0.399	0.972
Income from non-agroforestry activities	0.000	2.803	0.094	1.000	.000	.727	0.394	1.000
Years in farming	0.020	0.915	0.339	1.021	.030	.596	0.440	1.030
Education								
Primary	1.077	0.892	.345	2.935	-0.286	0.000	1.000	0.751
Secondary	1.736	3.200	.074	5.674	-19.278	0.000	0.999	0.000
Tertiary	3.260	6.087	.014*	26.060	-18.845	0.000	0.999	0.000
Land tenure (Without title deeds=1)	-0.285	0.218	0.640	0.752	-1.561	4.822	0.028*	0.210
Mode of land acquisition (Purchased=1)	-0.571	0.383	0.536	0.565	0.103	0.026	0.872	1.108
Gender of head of household (female=1)	0.093	0.009	0.923	1.097	-1.057	0.798	0.372	0.347

*Significant at 95% level of confidence.

Table 7. Logistic regression predicting the adoption of fodder trees.

Variable	Mumbuni				Ndovoini			
	B	Wald χ²	P	Odds ratio EXP(B)	B	Wald χ²	P	Odds ratio EXP(B)
Age	-0.018	0.292	0.589	.982	0.019	0.951	0.329	1.019
Size of household	-0.208	0.679	0.410	.812	0.091	0.502	0.479	1.095
Size of land	0.120	2.354	0.125	1.128	0.054	40.327	0.038*	1.055
Income from non-agroforestry activities	0.000	0.710	0.399	1.000	0.000	0.162	0.687	1.000
Years in farming	-0.030	0.840	0.359	0.970	0.008	0.142	0.706	1.008
Education		0.703	0.872			0.728	0.867	
Primary	0.395	0.043	0.836	1.484	0.032	0.001	0.979	1.032
Secondary	0.768	0.213	0.645	2.155	0.505	0.325	0.568	1.657
Tertiary	1.153	0.506	0.477	3.169	0.216	0.057	0.811	1.241
Land tenure (Without title deeds=1)	0.401	0.247	0.619	1.494	0.318	0.517	0.472	1.375
Mode of land acquisition (Purchased=1)	-0.260	0.070	0.791	0.771	-0.173	0.148	0.700	.841
Gender of head of household (female=1)	0.409	0.104	0.747	1.505	0.165	0.061	0.805	1.179

*Significant at 95% level of confidence.

Table 8. Adoption of agroforestry practices on fruit tree (%).

Agroforestry practice	Mumbuni (N=107)	Ndovoini (N=127)	Chi-square (χ²) value	P-value
Dispersed in crop land	58.9	50.4	1.685	0.194
Fruit orchard	16.8	29.1	4.896	0.027*
Soil conservation	17.8	3.1	13.981	0.000***
Homestead/compound planting	4.7	25.2	18.376	0.000***
Boundary planting and live fences	3.7	16.5	9.966	0.002**
Windbreaks	4.7	0.0	6.064	0.014*
Along streams	0.0	1.6	1.700	0.192

*Low level of significance **Significant *** highly significant at 95% level of confidence.

Table 9. Adoption agroforestry practices on forest wood trees (%).

Agroforestry practice	Mumbuni (N=107)	Ndovoini (N=127)	Chi-square (χ²) value	P-value
Dispersed in crop land	3.7	19.7	13.602	0.000***
Wood lots	3.7	3.1	0.061	0.805
Soil conservation structures	3.7	6.3	0.783	0.376
Homestead/compound planting	40.2	70.1	21.103	0.000***
Boundary planting and live fence	19.6	24.4	0.769	0.382
Windbreaks	12.1	15.0	0389	0.533
Along streams	2.8	0.8	1.405	0.236
On range land or grazing land	4.7	3.1	0.364	0.546

*Low level of significance ***High.

dispersed in crop land, fruit orchards; on soil conservation structures, homesteads, boundary plants, wind breaks, or along streams. However, most fruits were planted in the farms under two major agroforestry practices; fruits dispersed in the crop land and fruit orchards (Table 8). Mumbuni had relatively higher numbers of households (59%) with fruit trees dispersed on farm land than Ndovoini (50%). However, Mumbuni had significantly ($p<0.05$) higher number (29%) of fruit orchard than Ndovoini (17%).

Adoption agroforestry practices on forest wood trees

Results obtained on forest wood trees indicated that trees were planted as dispersed in crop land, wood lots, on soil conservation structures, homesteads, boundary planting and live fences, wind breaks, along the streams and on range land or grazing land (Table 9). In addition, significantly ($p<0.01$) more trees were found on homesteads. This was followed by boundary planting and wind breaks, respectively.

Adoption of agroforestry practices on fodder trees

In the study sites fodder trees were found dispersed in crop land, fodder lots, boundary planting and live fences, homesteads, on soil conservation structures and on range lands or grazing lands (Table 10). However, significantly ($p<0.01$) more fodder trees were found at Ndovoini dispersed on crop land (11.8%) and on range lands or grazing lands (12.6%).

DISCUSSION

Agroforestry trees types identified in the study sites

Fruit, fodder and forest wood trees were the three types of agroforestry trees identified. The higher adoption of agroforestry in Mumbuni compared to that found in Ndovoini was because Mumbuni lies in the AEZ LM4 and receives more rainfall and has lower temperatures than Ndovoini in agreement with the categorization of AEZ by (Jaetzold et al., 2006). Adoption of fruit farming in Mumbuni is higher than in Ndovoini (mean density for fruit trees was 37 trees/acre in Mumbuni and 4 trees/acres in Ndovoini) which can be attributed to the favourable climate in Mumbuni for fruit farming and Mumbuni being classified as high fruit production zone and Ndovoini was under low production zone, according to a report on Makueni County fruit baseline survey (Ministry of Agriculture, Kenya-ASDSP, 2014). Further, farmers in

Table 10. Adoption of agroforestry practices on fodder trees (%).

Agroforestry practice	Mumbuni (N=107)	Ndovoini (N=127)	Chi-square (χ^2)	P-value
Dispersed in crop land	1.9	11.8	8.520	0.004**
Fodder lots	3.7	1.6	1.088	0.297
Boundary planting and live fences	0.0	7.1	7.886	0.005**
Homestead/compound planting	1.9	15	12.184	0.00***
On soil conservation structures	6.5	2.4	2.480	0.115
Range land or grazing land	1.9	12.6	9.415	0.00***

*Low level of significance, **Significant, ***Highly significant.

Mumbuni have commercialized fruit farming, especially grafted mangoes. Moisture stress and termite attack have negative effects on forest tree performance (Kidane and Tesfaye, 2006), hence realizing lower number of trees per households. Mumbuni had 74.8% households practicing forest wood tree farming while Ndovoini had 89%. However, the mean number of forest wood trees was 55 in Mumbuni and 32 in Ndovoini (mean density for forest wood trees was 10 trees/acre in Mumbuni and 5 trees/acres in Ndovoini). Unlike in Ndovoini (AEZ LM5), the more favorable climate in Mumbuni. Households who planted fodder were significantly higher in Ndovoini (32.3%) than in Mumbuni (16.8%). However, the mean density for fodder trees was higher in Mumbuni (12 trees/acre) than in Ndovoini (5 trees/acre). Both sites had low adoption of fodder trees which may be associated with inadequate knowledge of the farmers, the narrow species choice and inadequate knowledge on the utilization of fodder trees due to low extension services accessible by the smallholders in the study area in agreement with results by Oino and Mugure (2013). The fodder crops, *Calliandra* spp*.* and Leucaena spp. require more humid climate for better growth than that is found in both Mumbuni and Ndovoini. However, *Calliandra* spp. was more grown in Ndovoini than in Mumbuni. Ndovoini had more livestock than Mumbuni, and the former had a higher mean of fodder trees due to expected higher demand by livestock. The species of trees identified were in agreement with a study by Gichuki (2000), which pointed out that in SAL preferred species include fruit trees, live fences, and neem and that the mango and pawpaw are preferred due to their drought resistance. Agroforestry contributed to 41% of farm income at Mumbuni and 17% at Ndovoini because more commercial fruit trees (grafted mangoes) were grown at Mumbuni than at Ndovoini, and contributed to higher income observed at Mumbuni in agreement with fruit survey of Makueni County (Ministry of Agriculture, ASDSP, 2014).

Although there was no statistically significant differences in the mean annual income from agroforestry in the two sub-locations (Ksh 56,688 in Mumbuni and Ksh 52,352 in Ndovoini), only 13% of households in Ndovoini were realizing monetary benefits from the sale of agroforestry products (fruits, timber, wood fuel) compared to 69% in Mumbuni.

Influence of household socio-economic characteristics on adoption of agroforestry trees

The logistic regression was chosen to show the influence of farmer or household socio-economic characteristics towards adoption of the three types of agroforestry trees: Fruit, forest wood and fodder trees. Binary logistic regression was chosen because of its ability to utilize both the continuous and categorical variables and or if they are not nicely distributed (Landau and Everitt, 2004). Using the model, the adoption of agroforestry was significantly influenced by the size of the household in Mumbuni; mode of acquisition of land in Ndovoini), security of land tenure in Ndovoini, size of the landholding in Ndovoini, gender of the head household in Ndovoini and the level of education in Mumbuni. This agrees with findings from other studies whereby, similar socio-economic characteristics of the small holder farmers affected the adoption of agroforestry (Nkamleu and Manyong, 2005; Irshad et al., 2011; Akpabio et al., 2008).

Adoption of fruit trees was influenced by the size of the household in Mumbuni. The probability of adoption is more as we move from large to small household. This, however, disagreed with the conventional argument that large family relates to higher availability of labour (Akpabio et al., 2008) Adoption of fruit trees was also influenced by the mode of acquisition of land in Ndovoini. The odds of adopting agroforestry by those who inherited land were higher than they are for those who purchased the land. This could be due to the fact that those who inherited land are more likely to also inherit agroforestry trees from their predecessors and security of guaranteed ownership influenced investment in agroforestry. Gender of the head the household in Ndovoini influenced adoption of fruit trees. The ODDS of adopting of agroforestry by the male headed households were higher than that of the female headed households. Males are more likely to provide adequate manual labour needed for establishment of agroforestry trees than the females, hence higher likelihood of adoption by the male headed households. Adoption of forest wood trees was significantly influenced by the level of education in Mumbuni. The ODDS for adopting agroforestry wood trees was 26 times more for those in tertiary level. The ODDS of adoption increased as we move from lower levels towards tertiary level of education. It is expected that the higher the educated the head of a household is, the more likelihood to adopt forest wood trees due to improved knowledge, access to information and positive consideration of the expected long term benefits of agroforestry. Adoption of forest wood trees was also significantly influenced by security of land tenure in Ndovoini. The ODDS of adopting forest wood by those with title deeds were higher than those without title deeds. There was higher likelihood of those with title deeds adopting forest wood trees, as they enjoy security of land tenure and right to utilize land resource. This makes one invest with confidence or even access credit for investment with title deed as security. Households can be sure that tree ownership will not change soon and there is continuous flow of expected benefits. Adoption of fodder trees was significantly influenced by the size of landholding Ndovoini. The bigger the land, the higher the likelihood to invest in fodder trees suitable in the SALs and that the farmer can plant in parts of the land deemed suitable without restrictions. Among other farmer characteristics, size of land, land tenure, gender and level of education were also found to affect adoption of agroforestry in Cameroon (Nkamleu and Manyong, 2005) and at Busia in Kenya (Oino and Mugure, 2013).

Agroforestry practices identified in the study sites

Agroforestry practices identified in the study sites were under the categories described by Tengnas (1994), who outlined the major agroforestry practices in Kenya as trees dispersed in cropland, boundary planting, live fences and hedges, trees on soil conservation structures, improved fallows, highway planting, alley cropping, trees as windbreaks, ornamental trees, wood lots, fodder lots, trees in rangeland, and trees along streams. More than 50% (Mumbuni 58% and Ndovoini 50.4%) had their fruit trees dispersed on cropland. This was evident that the farmers were not equipped with the knowledge for other sustainable practices such as the orchards. Management of pests and diseases is easier when fruit trees are planted as an orchard (Griesbach, 2003). Adoption of fruit orchards was low (16.8% in Mumbuni and 29.1% in Ndovoini). The difference in adoption between the two sites was based on the fact that purchasing of land as opposed to inheriting was more common in Ndovoini, and such households were more likely to adopt sustainable agroforestry practices such as the fruit orchard. This could be motivated by the drive to recover the money used in acquisition of land. Adoption of fruit trees on or for soil conservation purposes was very low (Mumbuni 17.8% and Ndovoini 3.1%). Mumbuni has more slopes and with deep erosive soils, and its households were perhaps more conscious of the need for soil conservation than those in Ndovoini. Though the adoption of fruit trees planted at homestead was low, the adoption was significantly higher in Ndovoini (25.2%) than in Mumbuni (4.7%). The difference was high because households in Ndovoini preferred shade trees at homestead due to higher temperatures in the area. The practice of live boundary was low in the study sites, Ndovoini (16.7%) and Mumbuni (3.7%). The difference was because more households used agroforestry trees for farm boundary establishment (for control of livestock interference with crops) in Ndovoini than in Mumbuni, Ndovoini being a livestock livelihood zone as described by Jaetzold et al. (2006). Fruit tree planting as windbreaks and along stream were below 5% adoption). Except for dispersion of fruit trees in the farms and along streams, the other agroforestry practices on fruit trees were poorly adopted.

Forest wood trees were planted in homestead, boundaries or live fences, windbreaks, dispersed in crop land, wood lots, on soil conservation structures, wind-breaks, along streams, and range land. In the study sites, the commonest practice was planting at the homestead or compound. This was perhaps due to temperatures in Ndovoini being higher than in Mumbuni. Many households preferred sheltering themselves under trees than inside a house under hot weather, which is more in Ndovoini. Moreover, in ASALs, trees are easily cared for when at compounds than when far away. The adoption of other practices on forest wood trees, boundary or live fence, was very low, less than 25% in both locations. The 3 to 4% adoption of the environmentally resilient agroforestry practices, such as wood lots, in study sites of Makueni was lower than that of Nyando, which was 22% (Odhiambo, 2010). However, the adoption of shade trees in the compound was higher in study sites of Makueni (Mumbuni was 40% and Ndovoini 70%) than in Nyando, which was 20% according to Odhiambo (2010). Very few respondents (less than 33%) in both sites planted fodder trees. Therefore, there was very low adoption of fodder trees. This is far different from Embu County of eastern Kenya, where more than 3,000 farmers (Franzel et al., 2002) planted tree legumes in fodder banks for use as an inexpensive protein supplement for their dairy cows as recommended by Snyder (1996).

Conclusion

Fruit, forest wood and fodder trees were grown in Mumbuni and Ndovoini sub locations. However, there was higher adoption of fruit farming in Mumbuni (AEZ LM4) because the climate is suitable for fruit growing and that many farmers have commercialized fruits. In Ndovoini (LM5), households with fruits farming (though fewer) are earning almost the same income as those in Mumbuni (LM4). Adoption of agroforestry was significantly influenced by the size of the household, mode of acquisition of land, security of land tenure, and size of landholding, gender of the head household in and the level of education. There was low adoption of sustainable agroforestry practices (such as fruit orchards, wood lots, fodder lots, boundary planting, live fences and hedges, trees on soil conservation structures, improved fallows, alley cropping, trees as windbreaks, ornamental trees, trees in rangeland, and trees along streams).

Conflict of Interests

The authors hereby declare that no conflict of interest exists among them.

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