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Influence of Agroforestry on Rural Income and Livelihood of Smallholder Farmers in the Semi-Arid Region of Sub Saharan Africa

B.M. Kinyili[1]*, E. Ndunda[2] and E. Kitur[2]

[1]*Kenya Forest Services, Eldoret, Kenya*
[2]*Department of Environmental Science, Kenyatta University, Nairobi, Kenya*

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Abstract

Semi-arid lands typically suffer from sustainable land use challenges including climate variability, declining agricultural productivity, low economic prowess and poor livelihood conditions. In order to sustainably address these challenges, agroforestry has been fronted as a critical entry point allowing for the integration of trees on farms and diversification of production in agricultural landscapes. Nevertheless, the contribution of agroforestry to socio-economic and rural livelihood in several developing countries remains debatable. This study determined the influence of agroforestry on rural income and livelihood of smallholder farmers in Machakos county (Kenya). The study was conducted using survey research design from a sample of 248 smallholder farmers, who were selected using stratified, random sampling. Data were collected using questionnaires and interviews. Results showed that agroforestry was adopted by 82% of the smallholder farmers as a strategy for livelihood improvement in the region. Total income was higher among adopters from timber, fuel wood, posts/poles and fodder. Adopters also had more money to spend on food, clothing, education, medicine and basic needs as a result of revenues from agroforestry. The overall gross revenue, net returns above variable costs and total costs were also higher among adopters compared to the non adopters due to sales of agroforestry products. The study recommends adoption of agroforestry as a strategy to boost rural income and livelihood.

Keywords: agroforestry, socio-economic, rural income and livelihood, machakos, sub Saharan Africa

1. Introduction

Globally, dryland areas characterised by low moisture content due to low rainfall and high rates of evaporation, and a gradient of low agricultural productivity, comprise of approximately 100 countries and cover 42% of the global surface landmass (6.4 billion ha) (Prăvălie 2016; Bastin et al., 2017; Prăvălie et al., 2019). Despite the wide coverage, concern have been raised on human conditions in dryland environments in Africa, calling for significant development assistance and frequent humanitarian aid (De Leeuw et al., 2014). The gravity of the situation in drylands of Africa is clearer since it account for nearly 400 million people who live and derive their livelihood in these areas (Aleman et al., 2018; Gaur and Squires, 2018). The situations within the dryland areas are being orchestrated by innumerable challenges such as climate variability, frequent drought, natural resources degradation, declining agricultural productivity and high population increment (Syano et al., 2016). Therefore, there is a consensus that most of the agro-based activities within these landscapes must be geared towards solving foreseeable challenges (Krishnamurthy et al., 2019). Agroforestry as a dynamic, ecologically based natural resources management system, integrates trees on farms and in agricultural landscapes has been under consideration as an integral component of dryland regions(Ceperley et al., 2016).

**Correspondence: bmkinyili@yahoo.com*
Tel: +25 4723393737

The multiple perceived benefits and merits of agroforestry for providing environmental benefits, economic products and social goods are well known and widely recognised (Franzel, 2004; Jose, 2009; Fanish and Priya, 2013; Gao et al., 2014). In rural households, trees can be used as sources of food, fuel, fodder, construction materials, medicine, to meet subsistence needs (Adekunle and Bakare, 2004; Kumar and Thakur, 2017; Jemal et al., 2018). Historically, agroforestry was narrowly defined in terms of their subsistence production (Somarriba, 1992) but currently seen in light of economic terms stressing the enhancement of the economic return of the system (Kareem et al., 2016; Mercer et al., 2017; Paul et al., 2017; Bruck et al., 2019). In light of recurring food shortages, and rising prices of fossil fuel-based agricultural inputs, economic benefits of agroforestry has recently experienced a surge in interest from the research communities, especially in developing countries (Amejo et al., 2018).

In africa, agroforestry is currently practiced by many smallholder farmers (Mbow et al., 2014) where there has been increasing adoption by farmers particularly in the sub Saharan Africa (Franzel et al., 2001; Leakey et al., 2005; Meijer et al., 2015; Beyene et al., 2019). Adoption of agroforestry is still rampant despite the persistent attempts at introducing monoculture crop production (Djurfeldt et al., 2005; Altieri et al., 2012). Many of the residents view the option of integrating and managing trees with crops and livestock on the same landscape as an opportunity cost representing a conscious investment due to goods and services derived from the practice (Amare et al., 2019). The suits of goods and services derived from the practice of agroforestry include firewood, building materials (posts and timber), food such as fruits, medicine and invaluable environmental services (Wulan et al., 2008; Kimaro et al., 2019). In rural areas, other additional non-timber products include beeswax, honey, edible fruits, edible insects, wild vegetable, game meat, traditional medicines and fibres, estimated to boost annual income of households (Leakey et al., 2005; Kalaba et al., 2010). Consequently, the insight that trees on farms improve the socio-economic prospects and provide livelihood benefits is increasingly being recognised in the sub Saharan African region (Kalaba et al., 2010; Quandt et al., 2018).

Profitability of the various agroforestry practices has been analysed by various workers and the results show large degree of variation among research as to the overall socio-economic and livelihood impacts (Kang and Akinnifesi, 2000; Roshetko et al., 2007; Steffan-Dewenter et al., 2007; Akinnifesi et al., 2008). Nevertheless, in several drylands of developing countries especially in the Sub Saharan Africa, studies addressing contribution of agroforestry to socio-economic status and rural livelihood are limited (Jama et al., 2006; Iiyama et al., 2014) and therefore may be inconclusive. Therefore more studies on agroforestry adoption and socio-economic conditions are needed. The aim of this study was to determine the influence of agroforestry adoption on the rural income and livelihood in Machakos county in Kenya within the tropical region.

2. Methodology

2.1 The study area

The study was conducted in Machakos county (Figure 1) which covers an area of 5,953 km². It lies between latitudes 0^{o} $45^{/}$ South and 1^{o} $31^{/}$ South and longitudes 36^{o} $45^{/}$ East and $37^{o}45^{/}$ East. Most of the land is semi-arid with population of 1,098,584 as per the 2009 Kenya National census (Kenya National Bureau of Statistics, 2010). Administratively the county is divided into 11 divisions: Kalama, Kangundo, Kathiani, Machakos Central, Masinga, Matungulu, Mavoko, Mwala, Ndithini, Yathui and Yatta. In terms of political structure, the county has eight constituencies including: Kangundo, Kathiani, Machakos Town, Masinga, Matungulu, Mavoko, Mwala and Yatta. There are overlaps between divisions and constituencies were they are in most cases referred to as Sub-Counties. Among the division and constituencies, Kathiani, Mavoko and Machakos Town practice agrofostry. Four siteswhere

agroforestry are practiced included: Mua (Mavoko, Machakos Town and Kathiani) and Iveti Hills (Machakos Central and Kathiani), Kima-Kimwe and Kalama in Machakos Constituency.

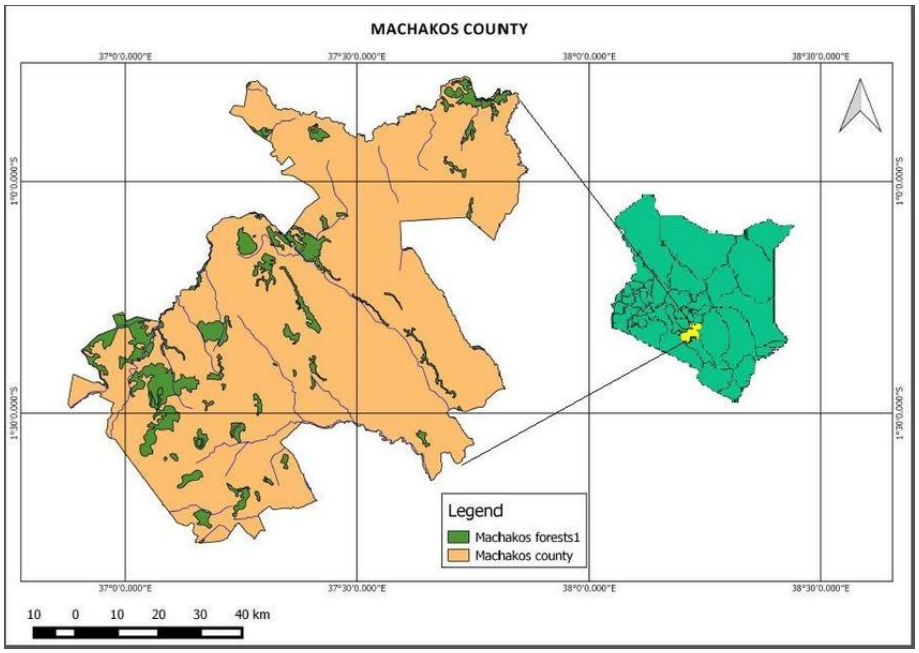

Figure 1. Map of Machakos county showing the study area, Kenya.

The local climate is semi-arid with hilly terrain and an altitude of 1,000 to 2,100 m above sea level. The area is composed of hilltops rising to 1,594-2,100 m above sea level. The annual average rainfall is 1,000 mm (range, 500 to 1,300 mm), and is bimodal; short rains occur in October to December and long rains in March to May. Temperatures range between 18.7^{o} C and 29.7^{o} C. The soils are well drained shallow dark red volcanic on hilltops and clay soils in the plains. Irrigation farming is practiced utilising the permanent rivers and streams that flow from the hilltop catchment areas towards South Eastern to join Athi river. Crop such as maize, beans, pigeon peas, vegetables are dominant. Dairy and beef cattle, sheep, and goats are the major livestock kept.

2.1 Data collection

This study was conducted through an exploratory survey design. Surveys are normally used to systematically gather factual quantifiable information necessary for decision-making (Nardi, 2018). Surveys are efficient methods of collecting descriptive data regarding the characteristics of populations, current practices and conditions or needs. They also help gather information from large populations by employing use of samples hence cutting down on costs. Survey study research design was adopted in this study in order to capture descriptive data from selected samples and generalise the findings to the populations from which the sample was drawn.

The study targeted household heads from Mua Hills (Mavoko, Machakos Town and Kathiani), Iveti Hills (Machakos Central and Kathiani), Kima-Kimwe and Kalama Hills in Machakos Constituency. The sample size of the households adopting agroforestry as earlier established in the region was used. According to (Nzilu, 2015), 80% of the households had adopted agroforestry in Mwala (Machakos county). The appropriate sample size was computed using the formula described in Mugenda and Mugenda (Mugenda and Mugenda, 2003) (equation 1).

$$n = \frac{z^2 p(1-p)}{d^2} \quad (1)$$

where: n=the desired sample size
z=the z score at the required confidence level α=0.05 (1.96)
p=the proportion in the target population assumed to be adopter
d=permissible marginal error (the level of statistical significance, set at α=0.05).

Using the values of *z*, *p* and *d*, the value of *n* was computed as follows (equation 2).

$$n = \frac{1.96^2 \times 0.8(1-0.8)}{0.05^2} = 245.86 \approx 246 \quad (2)$$

The sample size was 246 but the two research assistants who hail from the area also provided additional information resulting in a total of 248 respondents. Adopters who were included in the study were households practicing any form of agroforestry while non adopters were those who had no form of agroforestry or tree growing in their farms. Samples were selected through stratified, random sampling at each of the selected spatial units and used to identify the adopters and non adopters.

This study relied on primary type of data. Primary data on income, expenditure and rural livelihood among the respondents was collected using structured researcher administered questionnaires. The designing of the instruments were such that they ensured an in-depth exploration of personal views, feelings and opinions on agroforestry and benefits accrued. Before data collection, the respondents were contacted in advance and asked to organize their time for the research. Two research assistants were recruited and trained to aid in data collection. The questionnaires were administered by physical drop and pick by the researcher and two research assistants. The researcher personally administered the instrument and made prior visits to assist in defining timings and distribution of research instruments.

Research instruments were developed by examining the aim of the research. The validity of the instruments was sought through expert judgment who examined the face, content and construct validities in order to determine whether items measured what they were supposed to determine. They established whether the numbers of items are adequate for the purpose intended research and thus their expert judgments ensured validity of the instruments.

The reliability of the instruments was established through a pilot study of 12 household members from the study area who did not participate in this study. The results of the study were used to compute the reliability of the instruments through Cronbach's coefficient alpha (Bonett and Wright, 2015). The study considered the instrument as reliable and acceptable if the computation yielded a reliability coefficient of 0.7 and above. For this study, the reliability coefficient was 0.83 which was suitable for research.

All questionnaire data were coded into Statistical Package for Social Sciences (SPSS 23) for analysis. Differences in rural income, expenditure and livelihood were evaluated using chi-square analysis and ANOVA. All analyses were declared significant at $p<0.05$.

3. Results

The socio-economic profile of the respondents in Machakos county during the study is shown in Table 1. Majority of the respondents were aged 36-55, most being females with primary and secondary

levels of education. Household size for the majority was 6-10. The land size ranged between 0.4 to 24 acres with majority having land size ranging between 2-5 acres followed by those with less than 2 acres.

Table 1: Socio-economic profiles of the respondents.

		Agroforestry adopters		Agroforestry non adopters	
Variable	Response category	Frequency (n=204)	Percent (%)	Frequency (n=44)	Percent (%)
Age (years)	18-25	11	5.4	6	6.9
	26-35	28	13.7	8	18.2
	36-55	84	41.2	14	31.8
	>55	81	39.1	16	36.4
Gender	Female	116	56.9	26	59.1
	Male	88	43.1	18	40.9
Marital status	Single	12	5.9	1	2.3
	Married	192	94.1	43	97.7
Level of education	None	5	2.5	7	15.9
	Primary	112	54.9	18	40.9
	Secondary	73	35.8	14	31.8
	Tertiary	14	6.8	5	11.4
Household size	<3	3	1.5	0	0.0
	3-5	75	36.8	27	61.4
	6-10	105	51.5	17	38.6
	>10	21	10.3	0	0.0
Land size	<2 acre	72	35.3	14	31.8
	2-5 acres	106	52.0	26	59.1
	5.1-10 acres	26	12.7	4	9.1

The computed average income from crops, livestock and total income from the adopters and non adopters of agroforestry in Machakos are provided in Table 2. The income derived from crop, livestock, tree seedlings and tree products as well as the farm and total income of the farmers were all significantly higher for the adopters than non adopters ($p<0.05$).

Table 2: Average income from crops, livestock and total income computed between adopters and non adopters of agroforestry in Machakos (Values are in US $).

Income	Adopters	Non adopters	t value	p value
Average annual farm income from crop proceeds*	278.39	154.16	30.1281	0.0000
Average annual farm income from livestock*	228.38	156.05	9.531	0.0021
Average annual income from tree seedlings*	205.18	109.83	17.391	0.0001
Average income from wood/wood products*	271.34	142.91	16.680	0.0001
Average farm income per annum*	253.44	195.61	5.985	0.0056
Total income from agroforestry*	1236.73	758.56	60.104	0.0000

*Differences are significant at $p<0.05$
NS denotes not significantly different

The average income wood and wood products from the adopters and non adopters of agroforestry in Machakos are provided in Table 3. The income derived from timber and fuel wood as well as the total income derived from wood/wood products was significantly higher for the adopters than non adopters

($p<0.05$). However, the income derived from posts/poles and from fodder was similar for the adopters and non adopters.

Table 3: Income derived from wood and wood products between the adopters and non adopters in Machakos county (Values are in US $).

Wood income	Adopters	Non adopters	t value	p value
Income realised annually from timber*	162.00	77.73	14.088	0.0000
Income realised annually from fuelwood*	96.06	67.15	3.184	0.0413
Income realised annually from post/polesNS	60.16	53.61	0.248	0.6193
Income realised annually from fodderNS	63.00	64.72	0.005	0.9546
Total annual income from wood/wood products*	271.34	142.91	16.680	0.0001

*Differences are significant at $p<0.05$
NS denotes not significantly different

Annual expenditure on basic needs adopters and non adopters of agroforestry in Machakos County are shown in Table 4. The annual expenditure on food, clothing, education, medicine and total household expenditure on basic needs were all significantly higher for the adopters than non adopters ($p<0.05$).

Table 4: Annual expenditure on basic needs between adopters and non adopters of agroforestry in Machakos county (Values are in US $).

Expenditure on basic needs	Adopters	Non adopters	t value	p value
Annual household expenditure on food*	222.27	86.82	74.954	0.0000
Annual household expenditure on clothing*	157.02	69.89	62.944	0.0000
Annual household expenditure on education*	206.28	151.09	11.389	0.0014
Annual household expenditure on medicine*	92.42	57.55	9.304	0.0034
Annual household expenditure on basic needs*	646.55	329.52	111.851	0.0000

*Differences are significant at $p<0.05$
NS denotes not significantly different

The annual expenditure budget for wood and wood products between adopters and non adopters are shown in Table 5. The household annual expenditure on timber, poles as well as the total expenditure on wood and wood products was significantly higher for the non adopters than adopters ($p<0.05$).

Table 5: Annual expenditure budget for wood and wood products between adopters and non adopters. (Values are in US $).

Wood/wood product expenditure category	Adopters	Non adopters	t value	P value
Household annual expenditure on timber*	71.00	164.62	4.276	0.0225
Household annual expenditure on fuel wood*	45.81	49.91	0.4254	0.0432
Household annual expenditure on poles/postsNS	50.09	52.30	0.0452	0.8323
Household annual expenditure on fodderNS	31.03	37.51	2.796	0.3422
Total expenditure on wood/wood products*	199.93	302.34	10.672	0.0001

*Differences are significant at $p<0.05$
NS denotes not significantly different

The enterprise budget for adopter and non adopters of agroforestry practices in Machakos county are shown in Table 6. Based on the table, gross revenue for the adopters (US $ 1,236.73) was higher than the non adopters (US $ 758.56). Also the overall expenditure on variable cost by the adopters (US $ 890.16) was consistently higher than the non adopters (US $ 663.86). The total fixed cost of the

agroforestry adopters was nevertheless similar to the non adopters (US $ 70.80). As a consequence, there were higher net returns above Total Variable Costs (TVC) for the adopters (US $ 346.57) compared to the non adopters (US $ 94.70), which resulted in positive higher net returns above Total Cost (TC) for the adopters (US $ 275.77) compared to the non adopters (US $ 23.90). The computed margins above TVC (%) was therefore higher for the agroforestry adopters (28.02%) than the non adopters (12.48%) and margins above the total cost for the adopters was 22.30% and 3.15% for the non adopters.

Table 6: Computed enterprise budget for adopter and non adopters of agroforestry practices in Machakos county (Values are in US $).

Parameters	Adopters	Non adopters
Revenues		
Average annual farm income from crop proceeds	278.39	154.16
Average annual farm income from livestock	228.38	156.05
Average annual income from tree seedlings	205.18	109.83
Average annual income from wood/wood products	271.34	142.91
Average annual farm income per annum	253.44	195.61
Total income from agroforestry	1236.73	758.56
Variable costs		
Household expenditure on food per year	222.27	86.82
Annual household expenditure on clothing	157.02	69.89
Annual household expenditure on education	206.28	151.09
Annual household expenditure on medicine	92.42	57.55
Total Annual household expenditure on basic needs	646.55	329.52
Household annual expenditure on timber	71.00	164.62
Household annual expenditure on fuel wood	45.81	49.91
Household annual expenditure on poles/posts	52.09	50.30
Household annual expenditure on fodder	31.03	37.51
Total expenditure on wood/wood products	199.93	302.34
Miscellaneous	43.68	32.00
Total variable cost (TVC)	890.16	663.86
Fixed costs		
Amortisation	60.00	60.00
Interest on fixed cost	10.80	10.80
Total fixed cost	70.80	70.80
Total cost (TC)	960.96	734.66
Net returns above TVC	346.57	94.70
Net returns above TC	275.77	23.90
Margins above TVC (%)	28.02	12.48
Margins above TC (%)	22.30	3.15

The indicators of improved livelihood among the adopters and non adopters of agroforestry were also determined (Table 7). There were significant differences in the responses to the contribution of agroforestry to livelihood between the adopters and non adopters (χ^2=45.2312, df=8, p<0.001). Among the adopters of agroforestry, majority attested that indeed there was increased food supply, improved educational attendance and increased energy in the household.

Table 7: Indicators of improved livelihood among adopters of agroforestry.

Livelihood indicators	Adopters		Non adopters	
	Frequency	Percent (%)	Frequency	Percent (%)
Reduced use of fertilizers	168	82.4	15	34.1
Increased energy in the household	174	85.3	17	38.6
Increased food supply	178	87.3	11	25.0
Increased household income	124	60.8	15	34.1
Improved educational outcomes	101	49.5	15	34.1
Improved medical attendance	78	38.2	12	27.3
Improvement in employment	122	59.8	8	18.2
Improved educational attendance	177	86.8	11	25.0
Increase in land sizes	106	52.0	7	15.9

The scores of the indicators of household livelihoods was also determined among the adopters and compared with the non adopters. The results are as shown in Figure 2. Based on the scores from the figure, there were consistently higher rank scores for all the livelihood indicators among adopters compared to the non adopters except for improved educational outcomes, improved medical attendance, and increased land sizes.

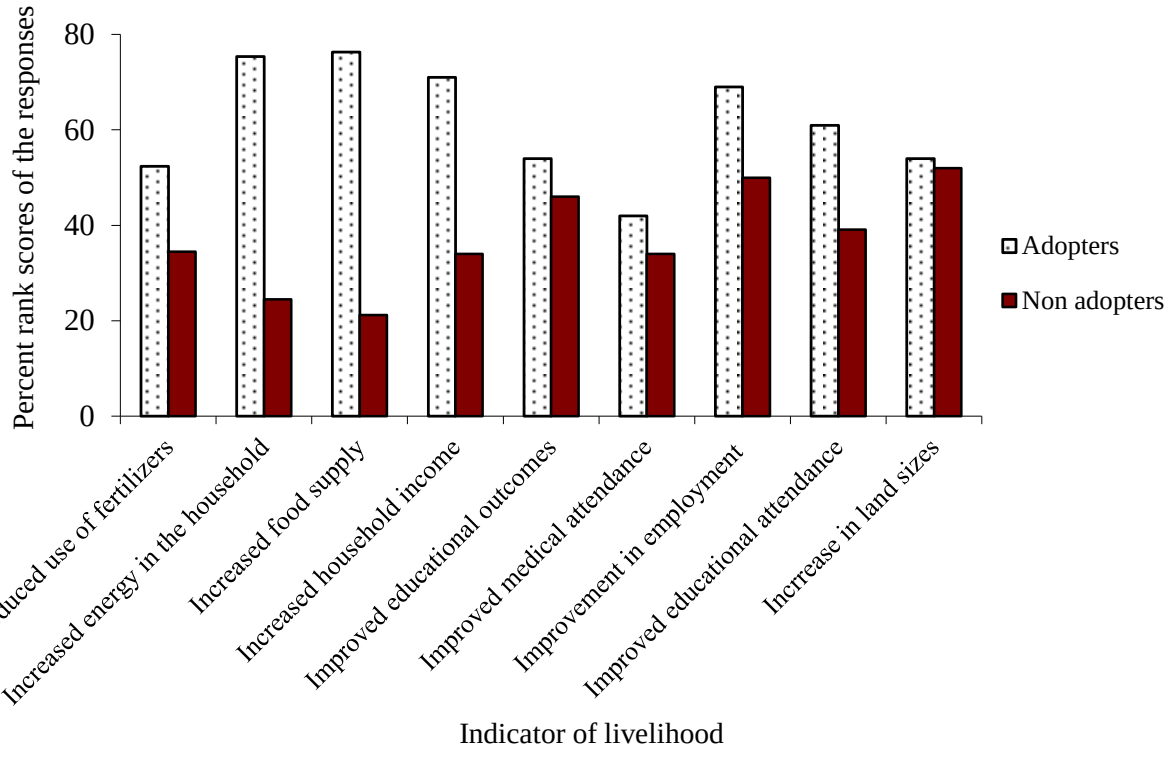

Figure 2. Scores of the indicators of household livelihoods among adopters and non adopters in Machakos county.

4. Discussion

During the study, the income derived from crop, livestock, tree seedlings and tree products as well as the farm and total income of the farmers were higher for the adopters than non adopters. This concurs with other studies which indicated that earning from crops, livestock and trees among agroforestry adopters is often higher owing to the income earned from sales of the crops, livestock and trees from the agroforestry (Neupane and Thapa, 2001; Franzel, 2004; Namwata et al., 2012; Kareem et al., 2016; Kassie, 2018). Indeed agroforestry increase livelihood benefits for people such as food security, employment, income generation among others. Meanwhile the average annual farm income from livestock proceeds displayed significant differences since it was established that agroforestry adopters did keep higher number of animals than those not practicing agroforestry and therefore the earnings from livestock were similar. The study also established a higher income from timber, fuel wood and wood/wood products due to agroforestry adoption which concurs with several other studies (Scherr, 2004; Bertomeu, 2006). Apart for domestic use of the timber and fuel wood, there are instances where farmers with larger scale practice of agroforestry can sell some of their products and earn income higher than those without any form of agroforestry. Nevertheless the income derived from posts/poles and from fodder were similar for the adopters and non adopters which may be attributed to low production of these wood products among farmers and the fact that they do not sell posts/poles and fodder.

The annual expenditure on food, clothing, education, medicine and total household expenditure on basic needs were all significantly higher for the adopters than non adopters due to the higher disposal income from agroforestry that enabled them spend more on food, clothing, education and medicine. Given one of the largest costs of most rural areas is on fuel wood as a source of energy (Sharma et al., 2016; Waldron et al., 2017), most of the farmers with trees in their farms will save the income and use it to purchase food, built better houses and spend more on quality education as well as search for better healthcare (Borish et al., 2017).

The household annual expenditure on timber, poles as well as the total expenditure on wood and wood products was significantly higher for the non adopters than adopters which concurs with other studies (Leakey et al., 2005) due to the fact that most of the adopters have these products in their farms and therefore they don't need to buy these products from outside their farms. During adoption of agroforestry, farmers have access to wood and wood products and therefore the amount of money going towards purchase of such are expected to be lower than those who have no wood from any agroforestry practice. However, expenditure on fodder was not different between the adopters and the non adopters mainly because most of the agroforestry practices were not planting fodders in their farms.

Analysis of enterprise budget yielded several observations. First the gross revenue for the adopters (US $ 1,236.73) was higher than the non adopters (US $ 758.56) indicating higher income derived from agroforestry practices. Similarly the overall expenditure on variable cost by the adopters (US $ 890.16) was consistently higher than the non adopters (US $ 663.86) which was attributed to the adopters having higher disposal incomes. The total fixed cost of the agroforestry adopters was nevertheless similar to the non adopters (US $ 70.80) suggesting that fixed cost for the adopters and non adopters tend to be somewhat similar. As a consequence, there were higher net returns above TVC for the adopters (US $ 346.57) compared to the non adopters (US $ 94.70), which resulted in positive higher net returns above TC for the adopters (US $ 275.77) compared to the non adopters (US $ 23.90). Based on the above statistics, the computed margins above TVC (%) was therefore higher for the agroforestry adopters (28.02%) than the non adopters (12.48%) and margins above the total cost for the adopters was 22.30% and 3.15% for the non adopters. These results suggest that income was higher for the adopters resulting in overall profitable operational margins that render adoption as a good enterprise.

This study also determined the influence of adoption of agroforestry practices on rural livelihood of smallholder farmers and found that adopters of agroforestry had increased food supply, improved educational attendance and increased energy in the household, which concurs with several studies among agroforestry adopters (Quandt and McCabe 2017; Quandt et al., 2018). The diversification of crops, keeping of livestock and trees in the same farm which can be sold by the farmers is expected to create opportunities for achieving a steady and sometimes higher rural income through the more efficient use of resources and the exploitation of comparative advantages (Kassie 2018). Agroforestry systems have also been determined to combine short-term and long-term benefits for the farm households with the aim of livelihood protection and sustainability in the use of resources in semi arid areas (Quandt et al., 2017). The mango-based alley cropping that was practiced by majority of the farmers played a vital role in rural livelihood strategies.

The scores of the indicators of household livelihoods were consistently higher rank scores for all the livelihood indicators among adopters compared to the non adopters except for improved educational outcomes, improved medical attendance, and increased land sizes. Improvement of livelihood among agroforestry adopters have been identified in several studies. The land use systems in the study area are generally agro-crop production along with timber and fruit tree species and livestock production systems. Here, the farmers practice agroforestry include woodlot, alley cropping, windbreaks/shelterbelts and intercrop. Most of the farmers intercropped grain, vegetables and tree crops. The grain crops cultivated in the land use system included maize, bean, millet, sorghum, pigeon peas, peas, green chili, etc. with horticultural produce such as avocado, carrot, kales, oranges, mangoes, pawpaw, onions, tomatoes, cabbages, gourd, bitter gourd, pumpkin, and pineapple, which are often sold to increase livelihood indices. Nevertheless it was found that income generating activities in the study area were not diversified as compared to other regions of the world (Burgess et al., 2017; Mosquera-Losada et al., 2018). From above results, it is clear that agroforestry plays a major role in supporting the socio-economic needs and improving the livelihood conditions of the people in Machakos, Kenya.

5. Conclusion

The study shows that in the dryland area of Machakos in Kenya, adoption of agroforestry improved the socio-economic and livelihood indicators of the local communities by enhancing income and expenditure. Agroforestry adoption generated more money to adopters to send their children to schools, buy medicine, buy clothes and other necessities that eventually improved the livelihood. It can be concluded that agroforestry adoption had a significant impact on the livelihood of most agroforestry adopters and their households

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