AFRICA ENVIRONMENTAL REVIEW Journal

ISSN: 1727-8341

AER Journal Volume 3, Issue 2, pp. 145-155, 2019

RESEARCH ARTICLE

Available Online at *http://www.aer-journal.info*

Trade-off between Agroforestry and Ecosystem Services among Smallholder Farmers in Machakos (Kenya)

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

[1]*Kenya Forest Services, P. O. Box 2501-30100, Eldoret, Kenya; bmkinyili@yahoo.com*

[2]*Department of Environmental Science, Kenyatta University, P. O. Box 43844–00100, Nairobi, Kenya*

Abstract

Agroforestry may provide multiple ecosystem services. Thus, understanding relationships between ecosystem services can help minimize undesired trade-offs. The aim of this study was to determine the trade off between agroforestry and ecosystem services among smallholder farmers in Machakos County, Kenya. The study was conducted using a survey research design from a sample of 248 individual farmers, selected using stratified, random sampling. Data were collected using questionnaires and interviews. Based on calculated percentage rank scores, the most common benefit derived from the local community members was ecosystem supporting functions (82.5%) followed by regulatory functions (80.8%). Provisioning ecosystem service was the third most important function as perceived by the local community members (73.5%) while the least was cultural functions (61.4%). This study demonstrates that smallholder farmers who had adopted agroforestry in the semi-arid areas of Machakos County in Kenya achieved several ecosystem services from the practice. Ecosystem services, supporting functions including nutrient recycling and soil formation was the most important followed by regulatory functions (soil erosion control, water infiltration, micro-climate regulation, flood control and disease / pest control). Provisioning ecosystem services such as livelihood, fuelwood, fruit and nuts, poles, timber and fodder was the third most important function as perceived by the local community members while the least was cultural function that are rarely performed within the agroforestry ecosystems. Given the low knowledge of the entire range of agroforestry ecosystem services in the area, the study recommends a concerted effort to educate the local community on the wide range of ecosystem service to maximize the provision of these services from agroforestry.

Keywords: Agroforestry, Ecosystem Services, Supporting Functions, Regulatory Functions, Provisioning Functions, Cultural Functions, Livelihoods

INTRODUCTION

Smallholder farmers practicing agroforestry integrate woody vegetation (trees or shrubs) with crop and / or animal production in a parcel of land to the benefit of the farmer. To optimize planning and decision-making about smallholder agroforestry adoption and practices, knowledge of the accrued ecosystem services beneficial to the local community members is important (Fagerholm *et al.*, 2016). Evidently, agroforestry provide suits of ecosystem services such as timber, food, fuel wood, fodder, ornamental and medicinal resources, or indirect benefits comprising services such as carbon sequestration, soil and water regulation and habitat for pollinating species and wildlife (Amare *et al.*, 2019; Fagerholm, 2016; Quandt *et al.*, 2018). These ecosystem services are generally in four categories as: provisioning (e.g. production of food or fiber), regulating (control of climate or pests and diseases), supporting (e.g., nutrient cycling and plant pollination), and cultural (e.g. recreational, spiritual or aesthetic). The nature of these ecosystem services and their link with human well-being has been the subject of increasing research undertakings (Brown *et al.*, 2018; Daw *et al.*, 2016; Fedele *et al.*, 2017), stemming from the recognition that economic and social components must be understood jointly, taking cognizance of the feedbacks and trade-offs between them (Hori & Makino, 2018; Mace *et al.*, 2018; Turkelboom *et al.*, 2018). The underlying assumption is that provisioning of these ecosystem services will automatically translate to improvement in livelihood of the smallholder agroforestry adopters (Quandt *et al.*, 2018). However, in some studies, it has been established that ecosystem services tend to only provide marginal sustenance of livelihoods and/or preventing households from falling further to poverty, rather than actively contributing to a steadily improvement of the situation for the household (Feintrenie *et al.*, 2019). Perhaps many of the empirical studies purporting to deal with ecosystems and wellbeing are really valuation studies, for example, demonstrating some kind of (usually monetary) value of ecosystem services or of their utilization (Kay *et al.*, 2019; Mercer *et al.*, 2017; Temesgen *et al.*, 2018). Valuation and monetary contribution of ecosystem services appear to work well in the developed countries where detailed valuation tools are available but rarely work in the developing countries especially in Africa.

It is evident that adoption and practice of agroforestry has increased among smallholder farmers in the developing countries especially in the Sub Saharan Africa (Garrity, 2004; Owombo *et al.*, 2018). There are several reports that indicate that African agroforestry systems improve energy, food and housing through tree domestication (Benjamin *et al.*, 2018; Ofori *et al.*, 2014; Temesgen *et al.*, 2018). Yet there is little attention which has been paid to understanding whether the local community members comprehend the ecosystem services and the tradeoff between ecosystem services and livelihood in smallholder agroforestry.

Large parts of African landscape fall under the arid and semi arid area characterized by prolonged droughts and scarcity of water and food (Huang *et al.*, 2016). There are several studies that have established that there are more agroforestry adoption in the semi arid areas (Iiyama *et al.*, 2017; Quandt *et al.*, 2017). In the semi arid areas of Kenya, there has been concerted efforts to encourage adoption of agroforestry to help in building livelihood resilience to floods and drought (Maluki *et al.*, 2016; Quandt *et al.*, 2017). However, there has been little attempt at establishing the trade off between adoption of agroforestry and knowledge of the ecosystem services. Further, while the multi-dimensionality of livelihood is increasingly recognized, analyses to date remain heavily focused on income and assets, rather than in combination with non-income dimensions of poverty (Benjamin & Sauer, 2018). Few studies have examined relationships at anything less than a macro or aggregate level and mostly ignore whether there is actually any ecosystem benefits to the poor especially in developing countries. Consequentially, questions remain about the nature of the links between adoption of agroforestry, ecosystem services and links to the multiple dimensions of poverty, and about the mechanisms and consequences of changes in ecosystem provision on different aspects of well-being. Determining these causal pathways is particularly important with respect to developing appropriate and effective policies to achieve both the sustainable management of ecosystem services and poverty alleviation (Liebenow *et al.*, 2012). Therefore, the aim of this study was to determine the indigenous knowledge of the ecosystems services from agroforestry and its links to rural livelihood in semi arid area in Kenya.

MATERIALS AND METHODS

Study Area

The study was conducted in Machakos County (Figure 1) which covers an area of 5,953 km². It lies between latitudes 0º45´South and 1º31´South and longitudes 36º45´East and 37º45´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 agroforestry. Four sites where agroforestry are practiced included: Mua (Mavoko, Machakos Town and Kathiani) and Iveti Hills (Machakos Central and Kathiani), Kima-Kimwe and Kalama in Machakos Constituency.

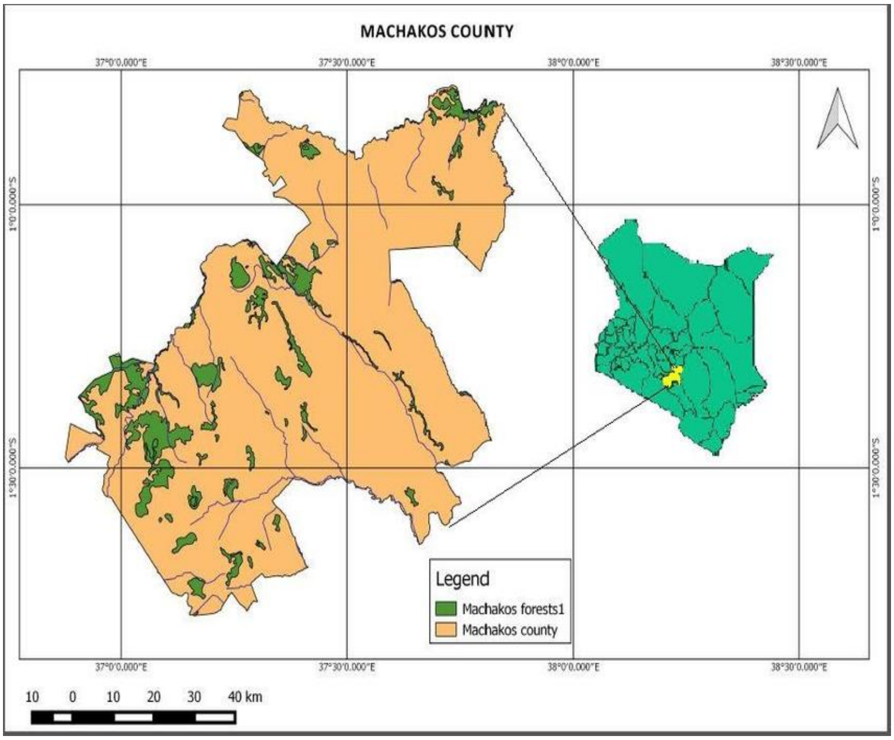

Figure 1: Map of Machakos County showing the Study Area.

The local climate is semi-arid with hilly terrain and an altitude of 1000 to 2100 Metres above sea level. The area is composed of hilltops rising to 1594-2100 m above sea level. The annual average rainfall is 1000 mm (range, 500 mm to 1300 mm), and is bimodal; short rains occur in October to December and long rains in March to May. Temperatures range between 18.7°C and 29.7°C. The soils are well drained shallow dark red volcanic on hilltops and clay soils in the plains. Irrigation farming is practiced utilizing 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.

Research Design

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 generalize the findings to the populations from which the sample was drawn.

Target Population, Sample Size and Sampling

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.

Since the actual population was not easy to determine due to changes in the rate of adoption with respect to time, the sample size utilizing proportion 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 therefore computed using the formula described in Mugenda and Mugenda (Mugenda and Mugenda, 2003): $n = \frac{z^2 p(1-p)}{d^2}$

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 adopters

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

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

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.

Samples were selected through stratified, random sampling at each of the selected spatial units and used to identify the adopters. Adopters were households practicing any form of agroforestry.

Research Instruments and Data Collection

This study used primary data collected through a questionnaire. Data on ecosystem goods and services among the respondents was collected using structured researcher administered questionnaires. The designing of the instruments were such that they endeavored to ensure 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 the data collection. The questionnaires were administered by physical drop and pick by the researcher and two research assistants. The researcher personally administered the instrument. The researcher made prior visits to assist in defining timings and distribution of research instruments.

Validity and Reliability of the Instruments

The researcher developed the research instruments based on examining the research objectives and the related literature. The salience of the instruments was sought through expert judgment. The experts 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 researcher and thus their expert judgments ensured validity of the instruments.

The reliability of instruments was established through a pilot study among 12 household members who did not participate in this study. The results of the study were used to compute the reliability of the instruments. Cronbach's coefficient alpha was used to determine the reliability of the instruments (Bonett & Wright, 2015). The study considered the instrument 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 determined to be suitable for the research.

Statistical Analyses

All questionnaire data were coded into Statistical Package for Social Sciences (SPSS 23) for analysis. Differences in ecosystem goods and services were evaluated using likert scale and percentage rank scores.

RESULTS AND DISCUSSION

The ecosystem services by the small holders who adopted agroforestry practices are shown in Table 1, while the computed percentage ranks scores of the value of the aggregated ecosystem services obtained by the local community members are provided in Figure 2.

Table 1: Ecosystem Services by the Small Holders Farmers who Adopted Agroforestry Practices

Category of services	Specific ecosystem services	Frequency of responses				
		Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Provisioning	Fuel wood	9	0	7	68	40
	Timber	29	2	7	63	23
	Poles	19	4	8	75	18
	Fodder	21	4	9	71	19
	Fruits and Nuts	13	8	16	61	26
Regulatory	Soil erosion control	4	1	11	76	32
	Water infiltration	3	2	10	79	30
	Micro climate influence	3	1	12	68	40
	Flood control	6	14	16	61	27
	Disease/pests control	7	18	17	59	23
Supporting	Nutrient Recycling	3	1	14	79	27
	Soil formation	3	4	22	72	23
Cultural	Spiritual	76	8	10	25	5
	Recreation	9	2	17	74	21
	Education	40	5	14	56	9
	Aesthetic	34	2	10	58	20

Based on calculated percentage rank scores, the most common benefit derived from the local community members was ecosystem supporting functions (82.5%) followed by regulatory functions (80.8%). Provisioning ecosystem service was the third most important function as perceived by the local community members (73.5%) while the least was cultural functions (61.4%). Smallholder agroforestry contribution to multiple ecosystem services that support rural livelihood of smallholder farmers is widely recognized.

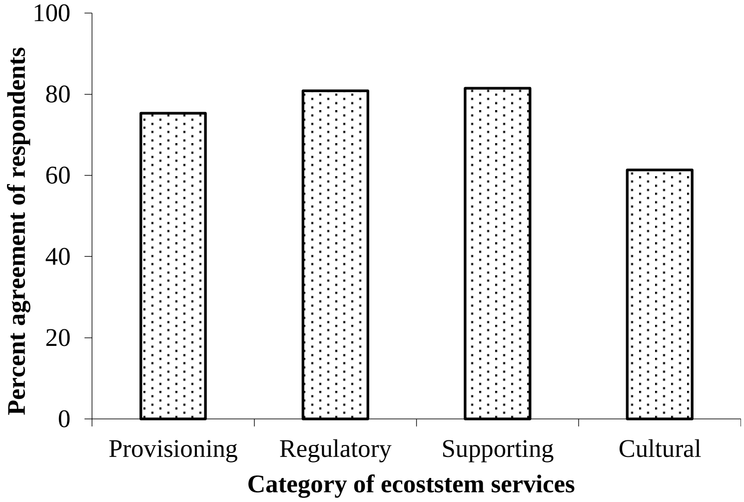

Figure 2: Percent Rank Scores for the Value of Aggregated Ecosystem Services Obtained by the Local Community Members.

Given the dearth of information on local knowledge of the ecosystem services in semi arid drylands within the Sub Saharan Africa, this study determined the local community understanding of the ecosystem benefit derived from smallholder agroforestry in Machakos County in Kenya. The study established that ecosystem supporting functions which included nutrient recycling and soil formation was the most important. This is one of the reasons often stated for the adoption of agroforestry with a view of provision of service such as climate regulation and restoration of soil quality (Edwards *et al.*, 2014; Lal, 2015). A study by Edwards *et al.* (2014) established that improved soil fertility was perceived as the main benefit derived from practicing agroforestry. However, in other studies in the Sub Saharan Africa, ecosystem supporting function is often lowly ranked by local community members due to lack of knowledge about nutrient recycling and soil formation (Corbeels *et al.*, 2019; Jose & Bardhan, 2012), which also concur with other studies in the Amazon basin (Pinho *et al.*, 2012). Therefore, it is inherent that due to the poor quality of soil and nutrient levels in the area (Maluki *et al.*, 2016) makes local knowledge of any activity that help to improve the soil as a priority.

The study also determined the percent rank scores for each of the individual provisioning ecosystem services among the local community respondents (Figure 3). According to computed aggregated Likert scoring scheme used, the highest percentage rank on ecosystem provisioning services among the local community members was fuelwood (84%), followed by fruit and nuts (75%), poles (74%), timber (72%) and least for fodder (64%). Provisioning ecosystem services such as fuelwood, fruit and nuts, poles, timber and fodder was the third most important function as perceived by the local community members. These ecosystem goods and services have been highlighted as of great importance when it comes to fuelwood for energy in the region (Maingi, 2019) and within the sub Saharan Africa (Toth *et al.*, 2017). In support of the current study, provisioning functions including the provision of fuel wood, timber, poles, fodder and fruits is often ranked as the most important services derived from agroforestry (Waldron *et al.*, 2017).

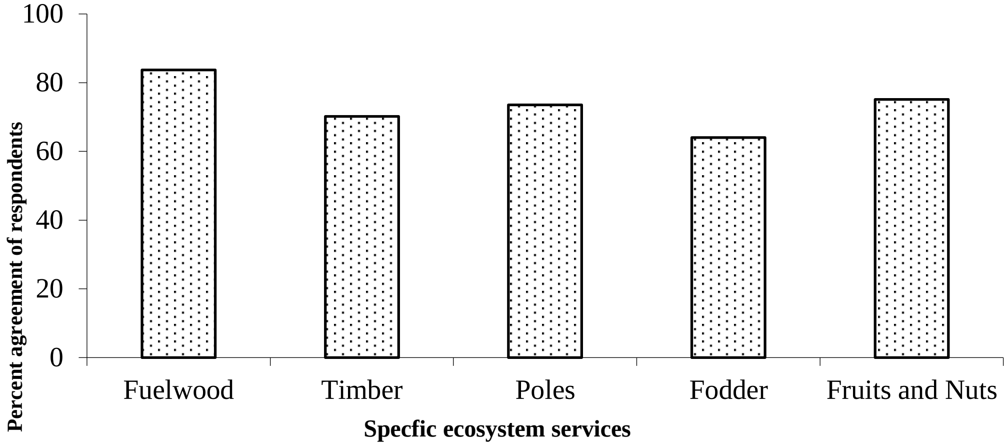

Figure 3: Percent Rank Scores for Individual Provisioning Ecosystem Services.

The percent rank scores for individual ecosystem regulatory services among the respondents were also determined (Figure 4) where it was established that the highest percentage rank on the ecosystem regulatory functions was micro-climate regulation (85%), followed by soil erosion control (83.5%), water infiltration (83%), flood control (51%) and least for disease and pest control (44%). Regulatory functions (soil erosion control, water infiltration, micro-climate regulation, flood control and disease / pest control) were the second most important ecosystem services. The use of agroforestry as a mitigation for climate change among smallholder farmers is a practice now gaining much relevance (Mbow *et al.*, 2014) which has also been practiced within the region in the past (Quandt *et al.*, 2018). The region also has incidences of soil erosion which is high due to the hilly terrain of the study area (Baaru and Gachene, 2016; Karuma *et al.*, 2014), the climate in the region is also quite hot and dry and therefore agroforestry practices will modify these micro-climate to noticeable levels. Moreover, frequency of flooding was often high and therefore any action of the agroforestry crops towards control of floods would easily be noticed by the local community members.

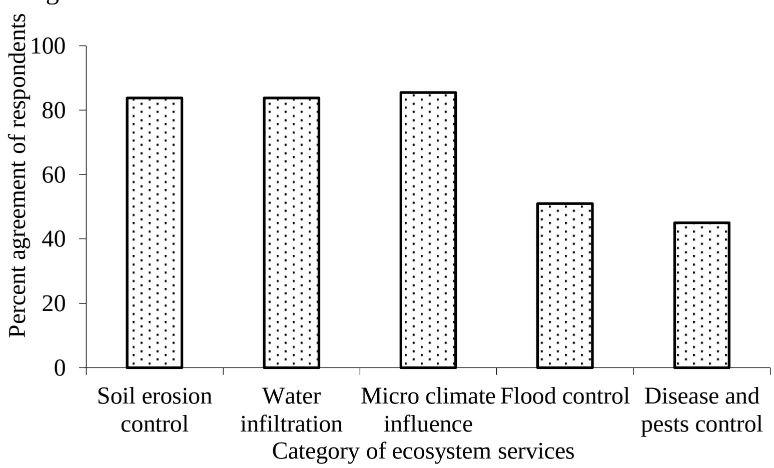

Figure 4: Percent response for regulatory ecosystem services.

Percent rank scores for individual ecosystem supporting services among the respondents are provided in Figure 5. The highest percentage rank on the ecosystem supporting functions among the local community members was for nutrient cycling (83%) followed by soil formation (81%).

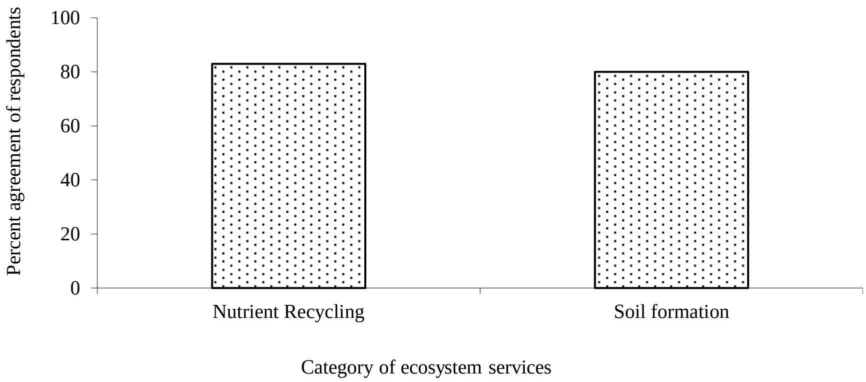

Figure 5: Percent Response for Supporting Ecosystem Services.

The percent rank scores for individual ecosystem cultural functions among the respondents are shown Figure 6.

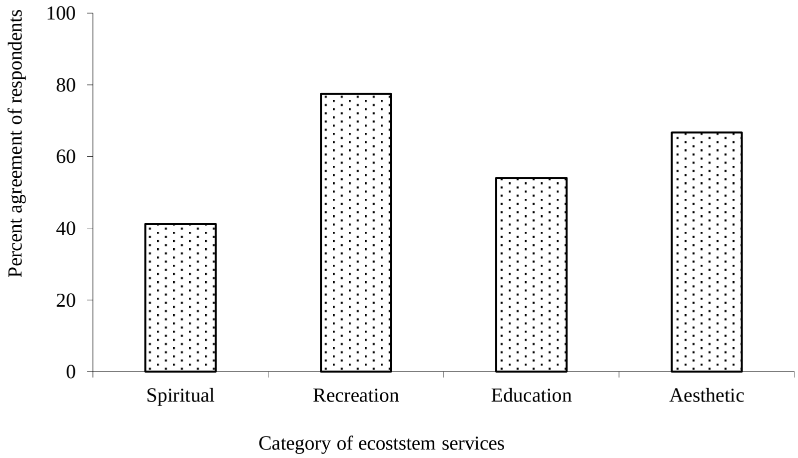

Figure 6: Percent Response for Cultural Ecosystem Services.

Based on the aggregated Likert scoring scheme, the highest percentage rank on the ecosystem cultural functions among the local community members was for recreation (77.5%), followed by aesthetic function (66.7%), education (54%) and least in spiritual functions (41.2%). A general tendency in ecosystem service assessments, depicted by the recent literature, is that the measurement of cultural services lags behind the regulating, provisioning, and supporting services categories (Meijer *et al.*, 2015). Most households in the area are currently moving away from several cultural undertakings and therefore it seems that there was not much importance attached to the cultural practices except for recreation which is not considered a very strong cultural value.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study demonstrates that smallholder farmers, who had adopted agroforestry in the semi-arid areas of Machakos County in Kenya, achieved several ecosystem services from the practice. Ecosystem supporting functions including nutrient recycling and soil formation was the most important followed by regulatory functions (soil erosion control, water infiltration, micro-climate regulation, flood control and disease / pest control). Provisioning ecosystem services such as fuelwood, fruit and nuts, poles, timber and fodder was the third most important functions as perceived by the local community members while the least was cultural functions that are rarely performed within the agroforestry ecosystems. Adoption of agroforestry increased agricultural productivity and addressed the Sustainable Development Goals (SDGs) in poverty and hunger reduction. Improved health, nutrition and education, reduced inequality and spurred economic growth while tackling climate change and preserving forests. Agroforestry adoption tackles Kenya Vision 2030 priority sectors on agriculture and livestock production in economic and social equity for clean and secure environment. With agroforestry adoption the smallholder farmers are able to address the government Big Four Agenda on nutrition and food security, affordable housing, affordable health care and manufacturing industries. Given the low knowledge of the entire range of agroforestry ecosystem services in the area, there should be concerted effort to educate, create awareness, training and sensitize the local community members, smallholder farmers, stakeholders and County and National Governments the wide range of ecosystem service to maximize the provision of these services from agroforestry practices.

ACKNOWLEDGEMENTS

The Kenya Organization for Environmental Education (KOEE) through Faith Based Climate Change Education for Sustainable Development (FBCCESD) financed this study while Kenya Agricultural and Livestock Research Organization (KALRO) helped in providing information on areas with previous agroforestry projects. The Kenya Forest Service (KFS) assisted in identification of active agroforestry adopters who participated in this study. We thank the local community members who agreed to sacrifice their time to respond to the questionnaires.

REFERENCES

Amare, D., Wondie, M., Mekuria, W. & Darr, D. (2019). Agroforestry of Smallholder Farmers in Ethiopia: Practices and Benefits. *Small-scale Forestry, 18,* 39-56.

Baaru, M. & Gachene, C. (2016). Community empowerment through participatory resource assessment at Kathekakai settlement scheme, Machakos County, Kenya. *International Journal of Sociology and Anthropology, 8,* 15-22.

Benjamin, E. O. & Sauer, J. (2018). The cost effectiveness of payments for ecosystem services—Smallholders and agroforestry in Africa. *Land Use Policy, 71,* 293-302.

Benjamin, E. O., Ola, O. & Buchenrieder, G. (2018). Does an agroforestry scheme with payment for ecosystem services (PES) economically empower women in sub-Saharan Africa? *Ecosystem Services, 31,* 1-11.

Bonett, D. G. & Wright, T. A. (2015). Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *Journal of Organizational Behavior, 36,* 3-15.

Brown, S. E., Miller, D. C., Ordonez, P. J. & Baylis, K. (2018). Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: a systematic map protocol. *Environmental Evidence, 7,* 24.

Corbeels, M., Cardinael, R., Naudin, K., Guibert, H. & Torquebiau, E. (2019). The 4 per 1000 goal and soil carbon storage under agroforestry and conservation agriculture systems in sub-Saharan Africa. *Soil and Tillage Research, 188,* 16-26.

Daw, T., Hicks, C., Brown, K., Chaigneau, T., Januchowski-Hartley, F., Cheung, W., Rosendo, S., Crona, B., Coulthard, S. & Sandbrook, C. (2016). Elasticity in ecosystem services: exploring the variable relationship between ecosystems and human well-being. *Ecology and Society, 21,* 11.

Edwards, D. P., Tobias, J. A., Sheil, D., Meijaard, E. & Laurance, W. F. (2014). Maintaining ecosystem function and services in logged tropical forests. *Trends in Ecology & Evolution, 29,* 511-520.

Fagerholm, N. (2016). *Importance of ecosystem services from agroforestry for local people*. Paper presented at the 3rd European Agroforestry Conference Montpellier, 23-25 May 2016. EURAF.

Fagerholm, N., Oteros-Rozas, E., Raymond, C.M., Torralba, M., Moreno, G. & Plieninger, T. (2016). Assessing linkages between ecosystem services, land-use and well-being in an agroforestry landscape using public participation GIS. *Applied Geography, 74,* 30-46.

Fedele, G., Locatelli, B. & Djoudi, H. (2017). Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. *Ecosystem Services, 28,* 43-54.

Feintrenie, L., Cifuentes Espinosa, J. A., Dos Santos Moreira, N., Bustillo Vazquez, E., Sibelet, N., Gutiérrez-Montes, I. & Vermeulen, C. (2019). *Forest or agroforestry systems, farmers value trees for ecosystem services provision in Nicaragua*. CIRAD.

Garrity, D. P. (2004). Agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems, 61,* 5-17.

Hori, J. & Makino, M. (2018). The structure of human well-being related to ecosystem services in coastal areas: A comparison among the six North Pacific countries. *Marine Policy, 95,* 221-226.

Huang, J., Ji, M., Xie, Y., Wang, S., He, Y. & Ran, J. (2016). Global semi-arid climate change over last 60 years. *Climate Dynamics, 46,* 1131-1150.

Iiyama, M., Derero, A., Kelemu, K., Muthuri, C., Kinuthia, R., Ayenkulu, E., Kiptot, E., Hadgu, K., Mowo, J. & Sinclair, F. L. (2017). Understanding patterns of tree adoption on farms in semi-arid and sub-humid Ethiopia. *Agroforestry Systems, 91,* 271-293.

Jose, S. & Bardhan, S. (2012). Agroforestry for biomass production and carbon sequestration: an overview. *Agroforestry Systems, 86,* 105-111.

Karuma, A. N., Gachene, K., Charles, K., Msanya, B., Mtakwa, P., Amuri, N. & Gicheru, P. (2014). Soil morphology, physico-chemical properties and classification of typical soils of Mwala District, Kenya. *International Journal of Plant & Soil Science, 4*(2), 157-170.

Kay, S., Graves, A., Palma, J. H., Moreno, G., Roces-Díaz, J. V., Aviron, S., Chouvardas, D., Crous-Duran, J., Ferreiro-Domínguez, N. & de Jalón, S. G. (2019). Agroforestry is paying off–Economic evaluation of ecosystem services in European landscapes with and without agroforestry systems. *Ecosystem services, 36,* 100896.

Kenya National Bureau of Statistics. (2010). *Population census results of Kenya by the year 2009.* Nairobi: Government Printers.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability, 7,* 5875-5895.

Liebenow, D. K., Cohen, M. J., Gumbricht, T., Shepherd, K. D. & Shepherd, G. (2012). Do ecosystem services influence household wealth in rural Mali? *Ecological Economics, 82,* 33-44.

Mace, G., Schreckenberg, K. & Poudyal, M. (2018). *Ecosystem services for human wellbeing: trade-offs and governanc*e. Taylor & Francis.

Maingi, L. N. (2019). *Sustainable utilization of woodfuel in selected rural sites of Mwala sub-county, Machakos County, Kenya*. Unpublished MSc Thesis, South Eastern Kenya University

Maluki, J., Kimiti, J. M., Nguluu, S. N. & Musyoki, J. (2016). Adoption levels of agroforestry tree types and practices by smallholders in the semi-arid areas of Kenya: A case of Makueni County. *Journal of Agricultural Extension and Rural Development, 8*(9), 187-196.

Mbow, C., Smith, P., Skole, D., Duguma, L. & Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability, 6,* 8-14.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W. & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability, 13,* 40-54.

Mercer, D. E., Li, X., Stainback, A. & Alavalapati, J. (2017). Valuation of agroforestry services. In S. Michele, B. Gary and P. Toral (Eds.), *Agroforestry: Enhancing resiliency in US agricultural landscapes under changing conditions. Gen. Tech. Report WO-96*. Washington, DC: US Department of Agriculture, Forest Service, 63-72.

Mugenda, O. M. & Mugenda, A. G. (2003). Research methods: *Quantitative and qualitative approaches*. Nairobi: ACTS Press.

Nardi, P. M. (2018). *Doing survey research: A guide to quantitative methods*. Routledge.

Nzilu, W. B. (2015). Farmer's perception and its impacts on adoption of new agroforestry tree (*Gliricidia sepium*) in Mwala Division, Kenya. Unpublished Thesis, Kenyatta University.

Ofori, D. A., Gyau, A., Dawson, I. K., Asaah, E., Tchoundjeu, Z. & Jamnadass, R. (2014). Developing more productive African agroforestry systems and improving food and nutritional security through tree domestication. *Current Opinion in Environmental Sustainability, 6,* 123-127.

Owombo, P., Idumah, F. & Adepoju, A. (2018). Analysis of Farmers' Perception and Adoption of Agroforestry Technology as Climate Change Mitigation Strategy in Edo State, Nigeria. *World News of Natural Sciences, 21,* 16-27.

Pinho, R. C., Miller, R. P. & Alfaia, S. S. (2012). Agroforestry and the improvement of soil fertility: a view from Amazonia. *Applied and Environmental Soil Science,* Vol 2012, Article ID 616383, 11 pages.

Quandt, A., Neufeldt, H. & McCabe, J. T. (2018). Building livelihood resilience: what role does agroforestry play? *Climate and Development,* 1-16.

Quandt, A. K., Neufeldt, H. & McCabe, J.T. (2017). The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya. *Ecology and Society*. **22**.

Temesgen, H., Wu, W., Shi, X., Yirsaw, E., Bekele, B. & Kindu, M. (2018). Variation in ecosystem service values in an agroforestry dominated landscape in ethiopia: Implications for land use and conservation policy. *Sustainability, 10,* 1126.

Toth, G. G., Nair, P. R., Jacobson, M., Widyaningsih, Y. & Duffy, C. P. (2017). Malawi's Energy Needs and Agroforestry: Adoption Potential of Woodlots. *Human Ecology, 45,* 735-746.

Turkelboom, F., Leone, M., Jacobs, S., Kelemen, E., García-Llorente, M., Baró, F., Termansen, M., Barton, D. N., Berry, P. & Stange, E. (2018). When we cannot have it all: Ecosystem services trade-offs in the context of spatial planning. *Ecosystem services, 29,* 566-578.

Waldron, A., Garrity, D., Malhi, Y., Girardin, C., Miller, D. & Seddon, N. (2017). Agroforestry can enhance food security while meeting other sustainable development goals. *Tropical Conservation Science*, *10*, 1940082917720667.