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Original Article

Impacts of Carbon Sequestration Projects on Household Income, and Consumption Expenditure of Smallholder Farmers in Meru County, Kenya

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Carbon Sequestration, Climate Change Mitigation, Agroforestry, Carbon Trading, Propensity Score Matching, Household Income, Consumption Expenditure, Kenya.

ABSTRACT

Mitigation of climate change has led to the initiation of carbon sequestration projects in developing countries in compliance with the Kyoto protocol of 1997. The protocol goal was for industrialized countries to reduce their greenhouse emission by funding carbon projects in developing countries. The study focused on voluntary carbon projects involving smallholder farmer practicing agroforestry. The impacts of these projects on farmers' household income and consumption expenditure were evaluated. A survey and quasi-experimental research design targeting 207 smallholder farmers was conducted in three wards within Igembe South Sub- County namely Athiru Gaiti, Akachiu and Kiegoi/Antubochiu. Data was collected from secondary sources and primary sources. The data was analyzed using propensity matching techniques. The results showed participation in the carbon sequestration program has a significant impact on the income (t= -3.8081 w/df 205, p=0.0002) at a significant level 0.05. Consumption expenditure of the participant was also significant (t= -4.7034 w/df 205, p= 0.0000). Exotic tree species were more preferred to indigenous trees species. Grevillea robusta (A. Cunn. Ex R. Br) although naturalized, was the most preferred exotic tree species (33.9%) while (17%) of the respondents planted Cussonia holstii (Harms ex Engl.) - an indigenous tree species. Income status of majority (86%, f=77/90) farmers participating in the carbon program increased. Expenditure status of majority (68%, f=61/90) of participating farmers in the project also increased. Savings, inflation, alternative uses led to decrease in consumption expenditure. The study recommends the carbon sequestration project be expanded in more areas, conduction of awareness campaigns to reach more farmers, increase of the carbon credit amount paid to the farmer, the project proponent and partners to continue assisting farmers with tree seedlings for free. The study also recommends use of multipurpose exotic tree species since they have a fast growth rate.

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INTRODUCTION

Climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 1992). Climate change is caused by release of GHGs into the atmosphere causing global warming (UNFCCC, 1992). These GHGs are Methane (CH_4), Nitrous oxide (N_2O), Carbon dioxide (CO_2), and fluoride gases (F) (IPCC, 2014). The drivers and factors which contribute to climate change through emissions of the GHGs are population growth, economic growth, energy consumption, trade, urbanization, transport, buildings, industries, AFOLU- agriculture, forestry, other land use, among many (IPCC, 2014).

Kyoto protocol linked to UNFCCC was signed in 1997 and came into force in 2005. The goal of Kyoto protocol was for emissions of greenhouse gases to be reduced by industrialized countries by 5.2% in the first commitment period, 1st January 2008 to 31st December 2012 (UNFCCC, 2008; IPCC 2014). The 1990 level emission was used as the baseline. Within the contexts of the Kyoto Protocol, the priorities of the developing countries were poverty reduction, economic and social development. These countries were therefore not obliged to reduce their emissions in the first commitment period (Fox, 2007; Hoch, 2012).

The Paris agreement was adopted in 2015 under UNFCCC and has been ratified by more than 190 countries. Around 200 countries endorsed global goal of limiting the rise in average temperatures to 2.0 degrees Celsius above preindustrial levels and preferably limit the increase to 1.5 degrees Celsius (Huang, 2019; Blaufelder *et al.*, 2021). To reach the global limit increase to 1.5 degrees, greenhouse gases emissions by 2030 should be cut by 50 percent of current levels and by 2050 the emissions of greenhouse gases should be equal or less than emissions removed from the environment. Rules and procedures for implementing the agreement were adopted in 2018 at the 24th Conference of Parties (COP 24) in Katowice, Poland (Huang, 2019; Blaufelder *et al.*, 2021).

Mitigating climate change aims at reducing GHGs emissions, preserving and expanding carbon sinks. Climate change causes are addressed through climate change mitigation projects. There are a number of climate mitigation projects under AFOLU sector, that individuals, companies and governments engage in as a way of sequestration of GHGs emissions and expanding the carbon sinks. The projects entail energy efficiency, waste disposal, and low carbon enhancing projects, soil carbon enhancement and tree planting. (Blaufelder *et al*., 2021). Agroforestry, forest rehabilitation and regeneration, secondary forest fallows and small-scale pulp/timber plantations are forest carbon projects that highly benefits the local livelihood (Smith & Scherr, 2002). According to May *et al.* 2004, agroforestry systems are the most efficient as carbon project to sequester carbon since they involve smallholders.

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Studies globally, regionally and nationally have found out that carbon projects have impact on the livelihoods of the local communities ((May *et al.* 2004; Fox, 2007; Wimble, 2011; Shirko,2014; Muthuri *et al.* 2023*)*. The ministry of environment in Brazil has programs that compensate small farmers for environmental services provided. The programs emphasize on carbon markets and prevention of deforestation. Payment for environmental services to Brazil farmers is therefore a direct incentive and positive impact to the farmers' wellbeing (May et. al. 2004; Fox, 2007). Local communities in Ethiopia benefited from fodder, fuelwood, medicinal plants, posts and honey as sources of income and for household consumption (Shirko, 2014). **T**he **I**nternational **S**mall Group & **T**ree Planting Program (TIST) program in Uganda has impact on the income of the participating smallholder farmers through sale of carbon credits, tree products such as fruits, nuts and honey, and training on conservation farming (ESI, 2014). Nationally, Meru and Nanyuki community reforestation is a CDM carbon project that was financed by Carbon Neutral Company (Wimble, 2011). The company played a role in offsetting emissions by investing in projects such as planting of trees that acts as carbon stocks. Some of the project impacts are benefits from alternative and new sources of income, wood fuel, timber, and food hence promoting food security, job creation and women empowerment.

Voluntary carbon market is a trading program resulting from cap-and-trade approach advanced from UNFCCC and Kyoto protocol. Companies or individuals in voluntary markets trade carbon credits on voluntary basis. Voluntary carbon market is an avenue for business, individual, state and non-state organizations to offset their emissions by voluntary purchasing of credits, termed as Verified Emissions Reductions (VER), financial incentives issued to emission reduction projects in voluntary carbon markets. There are no established rules and regulations for this market scheme (Seeberg, 2010). Moreover, companies that invest in carbon projects usually aim at reducing greenhouse gas emissions as part of advocacy, public relations and certification of environmental and social benefits (Seeberg, 2010; Donofrio &Thiel, 2018).

Studies have been recommended to evaluate both positive and negative impacts of interventions such as, carbon sequestration projects, on the environment and welfare of the local communities (Prowse & Snilstveit, 2010). This is because much work done on climate mitigation has been on political policies and frameworks, conceptual issues and physical science. TIST program in Kenya, trading under voluntary carbon market, has highlighted on the environmental, social and monetary benefits smallholder farmers gain from the program. However, a quantitative impact evaluation on the household's income and consumption expenditure has not yet been undertaken.

Qualitative methods have been the basis of impact evaluation carried out by a majority of researchers (Prowse & Snilstveit, 2010; Shirko, 2014), this gap has been addressed in this study by undertaking a quantitative evaluation of the impacts of the carbon projects using propensity score matching (PSM). This identified gap has been addressed by basing the study on the TIST program, a climate change mitigation program which began in 1999. The objectives of the study were to determine the preferred indigenous and exotic tree species, planted for carbon sequestration at Igembe South Sub-County, to analyze the impact of carbon projects on total income and consumption expenditure of the participating households at Igembe South Sub-County

MATERIAL AND METHODS

Study Area

The study was undertaken in Athiru Gaiti, Akaciu and Kiegoi/Antubochiu administrative wards within Igembe South Sub- County in Meru County, Kenya. Meru County borders Laikipia County to the West, Nyeri County to the South West, Tharaka Nithi County to the East, and Isiolo County to the North. The county extends across the equator lying within $0^0$6' north and about $0^0$1' south, and latitudes 37^0 West and 38^0 East. The

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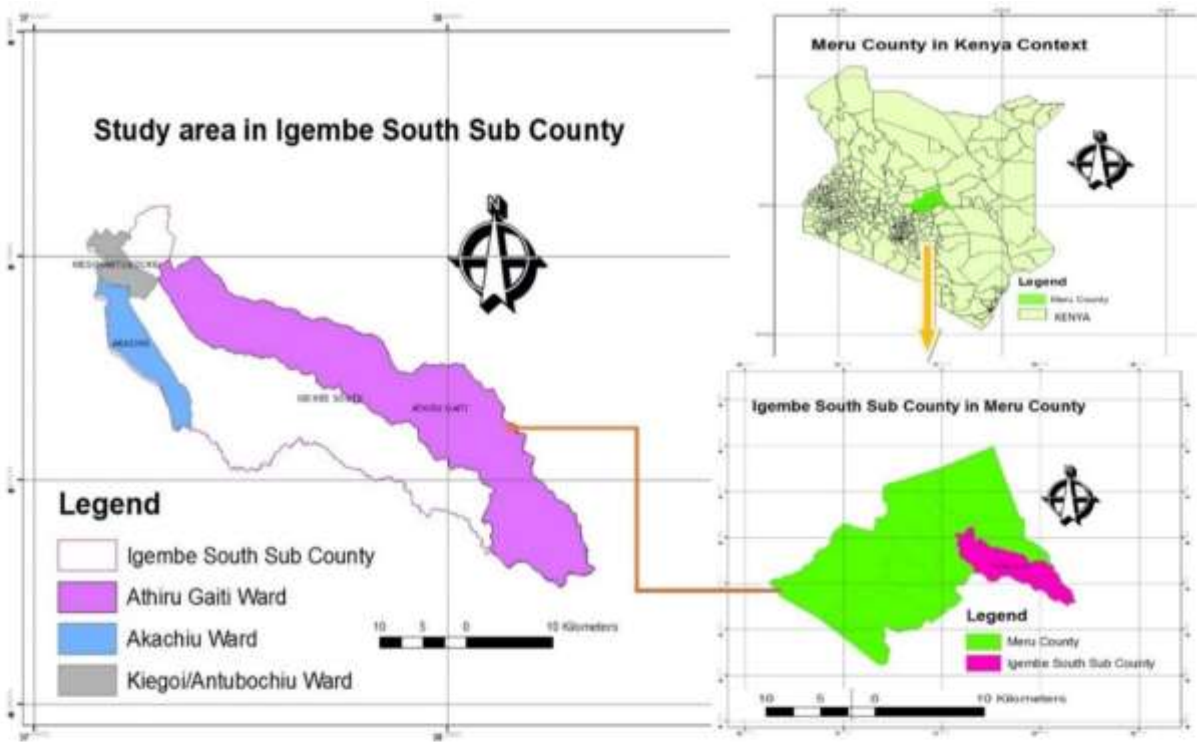
total area of the county is 6,936.2 km^2 from which 1,776.1 Km^2 is gazetted forest. Major economic activity is agriculture and the major cash crops are tea, coffee, bananas and *Catha edulis* (*miraa*). Farmers specialize in *miraa* as a major source of income (Meru County Government, 2013). The county has a population of 1,545,714 people (KNBS, 2019).

Lower Highlands, Upper Midland and Lower Midlands are among Agro-ecological zones in Meru County as detailed in *Table 1* (MoALF, 2016).

Table 1: Agro-ecological Zones in Meru County

Agro-ecological zones	Rainfall	Temp	Altitude
LH-(Lower Highlands)	800mm-2600mm	17.40^{0}C-14.90^0 C	1830- 2210 m
UM-(Upper Midland)	500mm-2400mm	20.60^{0}C-17.60^{0}C	1280- 1800 m
LM-(Lower Midlands)	580mm-1600mm	24.0^{0}C - 20.90^{0}C	750- 1300 m

Figure 1: Study Map



Source: Njogu (2016)

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Research Design

The study adopted survey and quasi-experimental research designs. Quasi experimental design mimics experimental designs and has been used by various researchers in different studies (Danso-Abbeam & Baiyegunhi 2018; Fox, 2010; Jiang &Yan, 2021, Abo *et al.*, 2017, Alem & Eggert, 2015 and Alene & Manyong, 2006). Target population comprised of households practicing agroforestry comprising of farmers participating in TIST program assigned as treatment group and farmers' non-participant in the program as comparison group.

Propensity score matching (PSM) was used to help in identification of a comparison group reducing bias. The study targeted 1236 household farmers. The sample size was calculated using the formula by Yamane, (1967).

$$n = \frac{N}{1+N\,(e)^2}$$

Where: n is sample size **(302)**; e is the margin of errors (0.05) and N the target population of the study (**1236**) (TIST,2020).

Purposive sampling, was used to select key informants and participants in the FGDs. Stratified random sampling was used to

choose the small farmer groups to be involved in the study in the three wards. To get sample size in the three wards (strata), the following formula was used;

$$N_S = P_S\, x\, S$$

Where: N_S= Sample in each stratum

S = Total sample size

P_S= Percentage of each stratum in the target population.

The sample size was distributed in the three wards proportionally between non-participants and participants' sub-groups as shown in *Table 2*. Data and information were collected from secondary and primary sources. The study incorporated use of participatory survey methods namely questionnaires, semi-structured interviews, focused group discussions and field visit.

Table 2: Sampling Frame

Ward	Study Population (N)	Sample Size (n)	Non-participants (n^0)	Participants (n^1)
Akachiu	588	142	71	71
Kiegoi/Antubochiu	480	118	59	59
Athiru Gaiti	168	42	21	21
TOTAL	**1236**	**302**	**151**	**151**

Methods

Descriptive statistics used in the analysis were means, frequencies, percentage and standard deviation. Propensity Score Matching estimation by psmatch2 probit regression model and teffect psmtach estimators, and validity tests were performed by Stata 15.0 version- a statistical software for data science and Microsoft excel computer package. Nearest-neighbour (NN) matching method was employed in this study. Participants were therefore matched to non-participants based on propensity scores. The treatment effect on household income and consumption expenditure was estimated using this technique. Propensity score matching analysis was therefore done in two stages.

Stage one was selection of farmers by binary probit model. For this study, farmers already in the carbon

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project were assumed to have been selected using a binary model expressed in a dichotomous equation of participation.

$$C = 1\ if\ C^{*} > 0$$

$$C = 0\ if\ C^{*} < 0$$

The assumptions were that farmers would decide to participate in carbon project (C^{*}_{1}) if the expected impact was greater than the value received if household did not participate (C^{*}_{0}). *Stage two* entailed estimation of the treatment effect of participating in the carbon project on household income and consumption expenditure. Therefore, average treatment effect on the treated (ATET), was performed, defined as;

$$\tau_{ATT} = E[Y_i\ (1) - E[Y_i\ (0)|C_i = 1]$$

Where Y_i (1) is outcome for participating in the carbon program, Y_i (0) is outcome for farmers not participating in the carbon program, E(.) is mathematical expectation operator and C_i is participation in carbon project. This was to tackle the counterfactual problem that one cannot obtain a Y (0) outcome when the treatment condition C=1. The treatment effect was the mean difference between the outcome of the treated and control groups.

The estimates of the psmatch2 in *Table 3* below indicates that the probit model is statistically significant at 5 % confidence level. This significance is indicated by likelihood values (LR chi^2 (6) = 24.99 P=0.003). P value tests the hypothesis that the regression co-efficient are 0.0003 for each predictor in the model.

Nearest-neighbour matching methods was performed by matching each treatment unit (farmers participating in the carbon project) to 3 units (farmers not participating) in the control group, as shown in *Table 4.* Yearly income of participating farmers was 100,879.4 KES more than farmers not participant in carbon program. Consumption expenditure was 86,277.61 KES more than non-participating farmers.

Table 3: Estimates of the psmatch2 of the determinants of the participation in the carbon project

PARTICIPATION	Coef.	Std. Err.
Gender	-0.47	0.24
EDUYRS	0.01	0.02
MARITAL	0.69	0.34
HHMEMBERS	0.06	0.04
FARMSIZE	0.19	0.79
AGE	0.01	0.01
LRchi2 (6) = 24.99		
Prob> chi2= 0.0003		
Pseudo R2 = 0.0882		

The propensity score graph was generated to check the quality of matching procedure and shows the distribution of propensity score of both treatment and control groups. *Figure 2* shows both distributions are quite similar and ranges from 0 to 1. The common support condition is satisfactory met with upper and bottom sections of the histogram for treatment and control groups respectively.

A balancing test by pstest command was performed on the covariates to check if the mean propensity scores is equivalent in both treatment and comparison group as shown in below *Table 4.* This shows farmers participating in the carbon program and their corresponding non-participant farmers have no significant difference between their mean

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covariates after matching hence both are comparable.

Reduction in bias, the insignificant *p-value* of the likelihood ratio (LR), low *pseudo* R^2 and high total bias reduction after matching shows that the propensity score estimator used is successful hence effective in assessing the impact of carbon projects to farmers with similar observed characteristics.

Table 4: Average Treatment Effect on the Treated

Participation (participant vs non-participant)	Treatment effect	Co-efficient	Std. Err	Z	p>z
Onfarm income	ATET	90460.12	36166.01	2.50	0.01
	NN (3)	100879.4	29240.34	3.45	0.00
HH Expenditure	ATET	86286.8	21933.72	3.93	0.00
	NN (3)	86277.61	19348.66	4.46	0.00

Figure 2: Propensity score graph

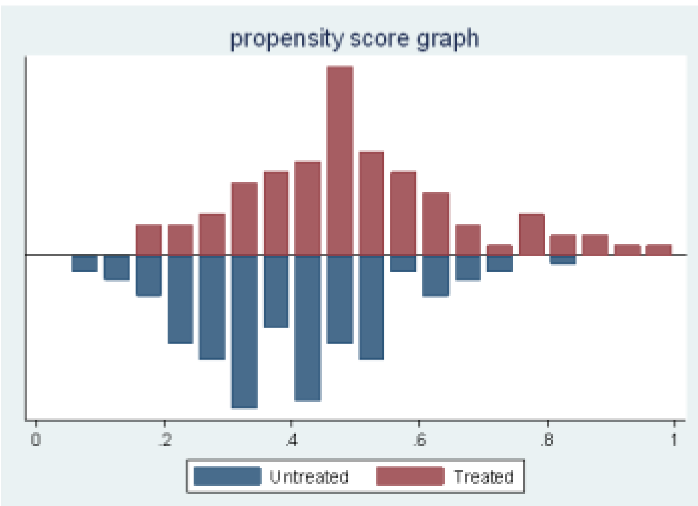

Table 4: Test of the mean equality of the covariates before and after matching

	Unmatched	Mean		% reduction		t-test		V(T)/
Variable	Matched	Treated	Control	Bias	|bias|	T	p>t	V(C).
Gender	U	0.70	0.75	-11.70		-0.83	0.41	.
	M	0.70	0.64	12.40	-6.60	0.79	0.43	.
EDUYRS	U	5.81	5.61	5.00		0.36	0.72	1.02
	M	5.81	6.96	-28.20	-460.30	-1.84	0.07	0.93
MARITAL	U	0.92	0.85	23.80		1.67	0.10	.
	M	0.92	0.86	20.90	12.40	1.42	0.16	.
HHMEMBERS	U	6.40	5.57	35.10		2.51	0.01	1.09
	M	6.40	6.83	-18.40	47.60	-1.18	0.24	0.86
FARMSIZE	U	2.07	1.28	46.90		3.47	0.00	3.28*
	M	2.07	1.80	16.00	65.80	0.96	0.34	1.58*
AGE	U	55.91	50.17	42.90		3.04	0.00	0.83
	M	55.91	54.93	7.30	83.00	0.50	0.62	0.85
Sample	Ps R2	LR chi2	P>chi2	Mean Bias	Med Bias	B	R	%Var
Unmatched	0.09	24.99	0.00	27.6	29.5	66.1*	2.05*	25
Matched	0.05	11.87	0.07	17.2	17.2	52.1*	0.99	25

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RESULTS AND DISCUSSIONS

Questionnaire Response Rate

The study administered 302 questionnaires, out of which 207 questionnaires comprising of 117 non participants and 90 participants, were filled and returned. This response rate was 69% which was within the significance rate response rate for statistical analysis established at a minimal value of 50% (Sekaran & Bougie, 2010 cited by Koome, 2020).

Socio-economic Characteristics of the Respondents

Majority (65%) of the respondents reached primary school level. Twenty-nine per cent (29%) of the respondents were aged between 51-60 years old. More males (73%) participated in the study compared to females. Majority (88%) of the respondents were married. The average farm size was 1.62 acres while majority (74%) of the land was acquired through inheritance. The household size of the majority of the respondents was 4 members. The study found out that majority (89%) of the respondents' source of income was from the farm. Majority (87%) of the participating farmers learnt of the program through an awareness campaign carried out by the implementing organization (TIST). Many farmers (44%) did not participate in the carbon sequestration project since they never heard of the program while 31.6% heard of the program but never met TIST trainer.

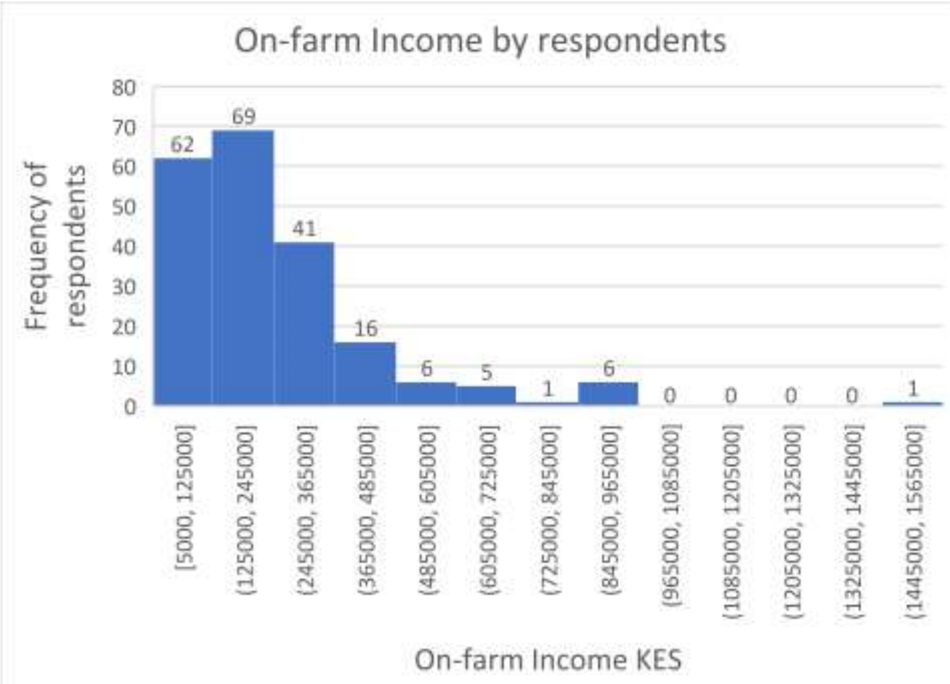
Preferred Tree Species Planted for Carbon Sequestration

The study established that, both exotic and indigenous trees were planted by the respondents. The trees were planted with a combination of crops (Agrisilvicultural), with domesticated animals (Silvopastoral) and a combination of crops and animals (Agrosilvopastoral). *Grevillea robusta* (A. Cunn. Ex R. Br) although naturalized, was the most preferred exotic tree species (33.9%). The findings established that 17% of the respondents planted *Cussonia holstii (*Harms ex Engl.) - an indigenous tree species. Exotic trees most of which were fruit trees were the mainly preferred tree species due to fast growth and other multipurpose uses. The findings agree with studies by Muthuri *et al.* (2023) who noted that exotic tree species are highly preferred by farmers compared to indigenous species. The findings further agree with studies by Gemechu *et al.* (2021) & Nath *et al.* (2016) that mention other reasons for tree preferences by farmers as fast growth rate, fewer pests, reduced competitions with crops, higher economic value, management practices and land use types.

Impacts of the Carbon Project on Household Income

Majority (33%, f=69) of the respondents earn on-farm income between 125,000 – 245,000 KES (*Figure 3*). According to Meru County CIDP, (2014), overall mean on-farm income is 97,740 KES per year. Findings further showed that participant farmers in the carbon sequestration project earn more income from on- farm activities compared to non-participant farmers. This is attributed to farming activities due to the benefits derived from trainings and, payment of carbon credit, sale of crops, livestock products and tree products. These findings agree with Muthuri *et al.* (2023) study which states that participants in agroforestry projects earn more income compared to non-participants.

Figure 3: On-farm Income Earned by the Respondents



Findings showed that majority (78%, f=161) of the respondents in the study earned an off-farm income between 0- 50,000 KES followed by farmers (8%, of f=17) earning between 102,000- 153,000 KES. (*Figure 3*). These figures lie in range to the annual off-farm income earning of KES 86,576 reported in the first Meru County Integrated Development Plan (Meru County Government 2013).

Moreover, findings showed that non-participants earned more from off-farm income than farms participating in the carbon project. This is attributed by less involvement in farm activities compared to farmers participating in the carbon sequestration project.

The income status of a great number of the farmers (86%) participating in the program increased compared to others (*Table 5*). The income status increased due to a number of incentives that benefits the farmers from the carbon sequestration program. These benefits are sale of tree products and carbon, trainings, increased harvests, decreased expenses, cost cut for purchase of goods and services and table banking.

Farmers (10%) whose income remained same was due to increased household members, had not received carbon payment, carbon payment received is very little, increased expenditure while some admitted benefiting from the training despite no income increase. The findings agree with report by Machingawuta *et al.* (2022) report that financial incentives from carbon projects are fairly small compared to their farm incomes. The findings agree with study done by Bass *et al.* (2000) stating that cash income is not enough for rural poor.

Table 5: Income Status of Farmers Participating in the Carbon Project

Income Status	Frequency	Percent (%)
Increased	77	86
Decreased	4	4
Same	9	10
Total	**90**	**100**

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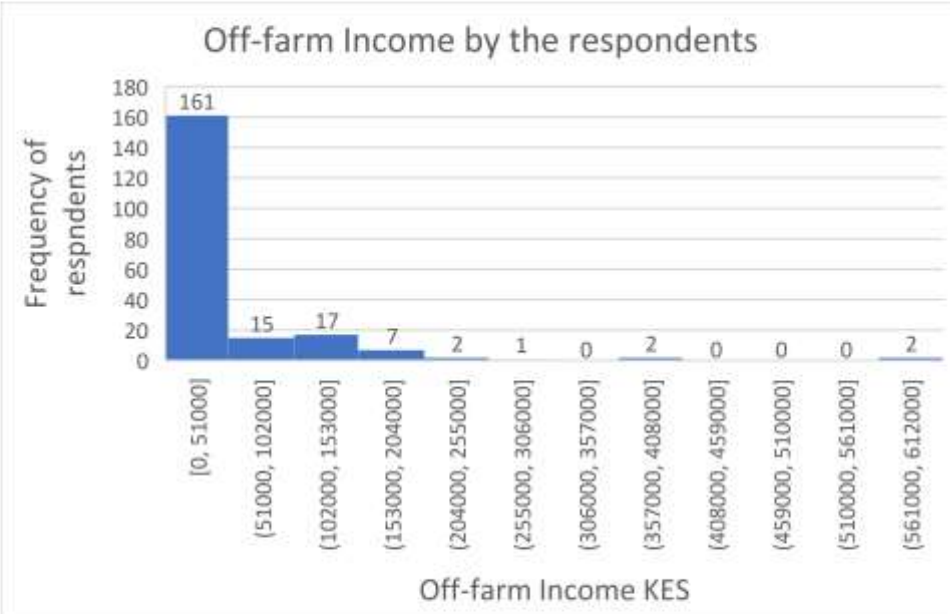
Figure 3: Off-farm Income Earned by the Respondent



T-test analysis indicated a difference between the mean values of participating and non-participating farmers (t= -3.8081 w/df 205, p=0.0002) at a significant level of 0.05. The mean income of the participants was more than that if the non-participants by 105136. Therefore, the alternative hypothesis was accepted indicating that the carbon program has a positive effect on the farmers income.

Table 4: T-test analysis for income

Outcome variable		non-participant (117)	participant (90)	n-Total (207)	Diff	t(df)	p
Income	Mean	190942.1	296078.5	236654	-105136	t= -3.8081 (205)	0.0002
	Std. Err	13462.45	26177.65	14127.8	27608.6		
	Std. Dev.	145618.7	248343	203263			

Impacts of Carbon Project on Household Consumption Expenditure

The findings in *Figure 4* shows that majority of the farmers (f=74.36%), incurred a household expenditure between 96,000- 182,000 KES. Moreover, expenditure for participants was more than for non-participants. This is due to high income hence more money available to be spend.

Majority (68%, f=61/90) of the farmers expenditure increased (*Table 5*). The reasons for increase in household expenditure were; farms that are far from the dwelling place, employment of more workers to plant and manage the trees hence more wages to pay, and increase in income. This finding agrees with the study by Lipper& Cavatassi (2003), that mentions carbon sequestration project may likely change labor allocation to land use such as in this case a respondent planting more trees on his farm will incur high wages to pay the workers. The reasons for increase in expenditure is an indicator more money is being spent compared to savings. Moreover, household expenses increase with household income (Hartoyo *et al.*, 2021). The report by Kazmiercyzk *et al*. (2007) agrees with the study

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findings, that households with more people have higher consumption of goods and services.

Household expenditure decreased due to cutting cost of buying fuel by collecting firewood from their farms, cost of fencing cut by using timber from matured trees on their farms, trained on savings-hence regulates them from incurring unnecessary expenditure due to availability of income, hence spending what is needed (Muthuri *et al.*, 2023). Access to savings services by farmers through table banking and loans from cluster Sacco has contributed to reduced expenditure. The findings agree with report by CRS, (2022) which states that savings are monies not spent. The carbon sequestration project has provided various incentives as alternative uses hence the farmers have cut cost such conservation farming, and use of manure has led to cut cost of buying fertilizers. It was noted that expenditure remained the same for some of the interviewed farmers (8%) due to price fluctuation, increase in expenses, had not yet received carbon payment and very little payment from sale of carbon hence no financial change.

A t-test analysis was performed to check the difference of mean values of household expenditure between the participant and non-participant farmers. *Table 6* indicate there was a difference between the means (t= -4.7034 w/df 205, p= 0.0000) at a significant level of 0.05. The mean household consumption expenditure of the participants was more than that of the non-participants by 90806. Therefore, the alternative hypothesis was accepted hence the carbon project has a positive effect on the household consumption expenditure.

Table 5: Expenditure Status of Participating Farmers

Expenditure Status	Frequency	Percent (%)
Increased	61	68
Decreased	21	23
Same	8	9
Total	**90**	**100**

Figure 4: Household Expenditure Incurred by the Study Population

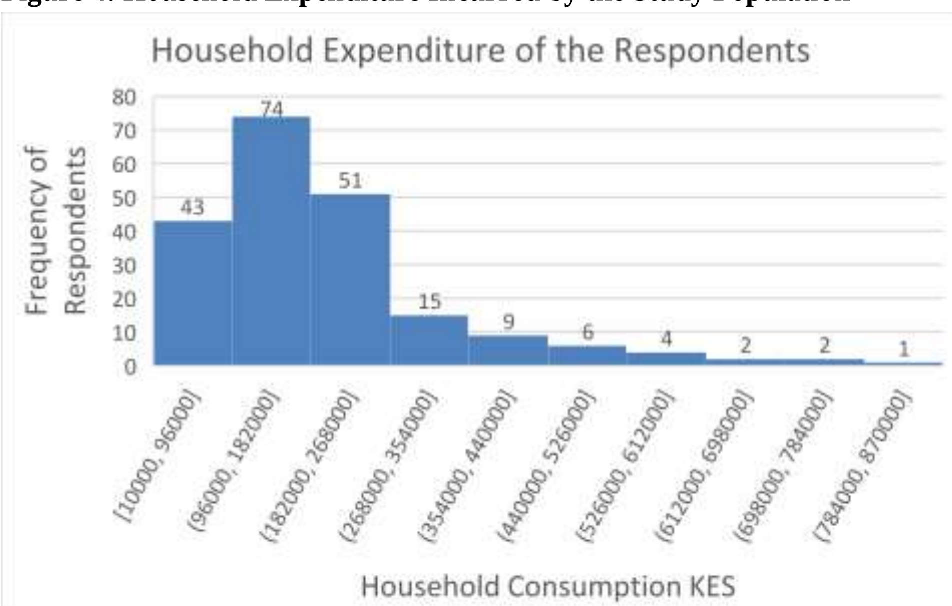

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Table 6: Test of Significance of the Difference of Means

Outcome variable		non-participant 117	participant 90	n-Total (207)	Diff	t(df)	p
HH Expenditure	Mean	156361.2	247166.8	195842	-90806	t= -4.7034 (205)	0
	Std. Err	12130.35	15360.44	10049.4	19306.3		
	Std. Dev.	131209.8	145721.9	144585			

From the findings, participation in the carbon sequestration program has immense environmental, financial and social benefits to the farmers. It can therefore be concluded; tree preferences by farmers for planting was determined by growth rate, and multipurpose uses. Therefore, both exotic and indigenous tree species with multiple uses and faster growth rate were preferred by the farmers. The carbon sequestration project had a positive impact on household income of the farmers. This is attributed by income earned from sale of carbon credit, tree products; fruits, firewood, fodder, and incentives such as conservation agriculture. The carbon sequestration project has positively impacted the household consumption expenditure of the majority of the respondents. This is due to increase in income, alternative uses derived from trees and project incentives enabling savings.

RECOMMENDATIONS

The project proponent (TIST) and partners (CAAC & I4EI) to continue assisting farmers with tree seedlings for free, mostly the preferred exotic tree species with multiple uses since they have a fast growth rate. TIST carbon sequestration project be expanded in more areas through awareness campaign due to its immense benefits on farmers income. TIST should continue to emphasize on income benefits derived from diverse tree products and services, and other incentives the program offers to farmers on savings, alternative uses, education on conservation agriculture, social network creation, administration and general health. Designated National Authority of Kenya government, to emphasize not only environmental benefits but also meaningful social and financial benefits to participants of the carbon projects in the design of carbon projects by the proponents.

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