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Climate Change Mitigation in Ethiopia: To What Extent Do Carbon Sequestration Projects Put Impact on Smallholder Farm Households' Income?

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Abstract
Environment friendly programslike carbon sequestration can play a positive role in enhancing household income for the resource scarce smallholder farmers. This paper sets out to assess whether a programme of climate-change mitigation through carbon sequestration initiated in Wolaita Zone (Ethiopia) is incentive compatible for smallholder farm households. It uses a quasi-experimental analytical method to analyze cross sectional data gathered from 199 randomly selected households to estimate its effect on per capita income of the project beneficiaries. Propensity score matching estimatessuggested thatmembership in the carbon sequestration projectput significant impact on the annual income of the participants, as compared to the non-participants. The article concludes by arguing for the promotion of such platforms of Clean Development Mechanism (CDM).
Keywords: carbon sequestration, climate change, income, mitigation

1. Introduction

Human activities such as burning of fossil fuels, deforestation and intensive farming have caused a substantial increase in the concentration of carbon dioxide (CO_2) in the atmosphere. This increase in atmospheric CO_2 - from about 280 to more than 400 parts per million (ppm) over the last 250 years- is causing measurable global warming (Reyer, 2009). Adverse effects like sea-level rise; increased frequency and intensity of wild fire, floods, recurrent droughts and tropical storms; erratic and ever changing amount and distribution in rain fall; snow and runoff; and disturbance of coastal marine and other ecosystems are among the impacts of the climate change (Tubiello, 2012).

Concern about human driven global warming and deforestation trends have motivated scientific efforts to quantify the role of forests in the global carbon cycle and political efforts to make forest preservation more socio-economically attractive(Brown, et al.2002; Watson *et al*., 2000). The United Nations Framework Convention on Climate Change (UNFCCC, 2006) and the Kyoto Protocol (Santilli, *et al*. 2005) provide the legal framework for the supranational strive against dangerous climate change. Among the several mechanisms they defined to climate change mitigation, "Clean Development Mechanism (CDM)" is one of the actions which contribute to emission reduction or carbon sequestration all over the world and thus to climate change mitigation (Aukland, *et al*. 2002; Moura-Costa and Stuart, 1998; UNFCCC, 2007).

The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from the emission sources and stored in water bodies and terrestrial environments (vegetation, soils and sediments). Such terrestrial sequestration is accomplished through forest and soil conservation practices that enhance the storage of carbon (such restoring and establishing new forests, wetlands, and grass lands) or reduce CO_2 emissions such as reducing agricultural tillage and suppressing wildfires and deforestations. Carbon dioxide is absorbed by vegetation through photosynthesis and stored carbon in biomass and soils (Watson, 2005). Preventing further deforestation and encouraging forest regeneration not only preserves biodiversity and other local ecosystem services, but also mitigate global climate change by preventing the carbon stored in trees and soils from being released into the atmosphere. Moreover, reforestation and forestation activities could attract funds for sustainable development from emerging international carbon markets (Warren, *et al*. 2004).

Interest in and awareness of the multiple environmental, economic and social benefits provided by carbon sequestration projects has greatly increased in recent decades. This is particularly true in developing countries including Ethiopia where adaptive capacity is low. Moreover, their economies predominantly depend on climate-sensitive agricultural production. In an agrarian country, Ethiopia, about 85% of the total population lives in rural areas, 90% of which are small-scale peasants depending mainly on crop production for its livelihood (Tesfaye, 2003). Household access to agricultural land has become an ever growing problem due to population growth. Continuous parceling, diminution of holdings and landlessness are pushing the small scale farmers and their newly married sons to till slops and hill sides which were once covered by vegetation and bushes.

There is strong dependence and competition among these land scarce and land less farmers, which puts increase stress on the scares natural resources in the country. Besides, the current disaster stresses area very high in the country. Like the other Sub Saharan nations, Ethiopia is experiencing disaster-related loss with devastating consequences on lives and livelihoods of poor communities (Maerag, *et al.* 2013). Researchers assert that the country loses from 2- 6% of its total production due to climate change every year (IMF, 2011). This is higher than the projected economic cost of 1.5- 3% of Africa's GDP of climate change by 2030 (Clements, 2009).

Thus, the need of adaptation and mitigation to the imminent environmental changes directly or indirectly caused by climate change is obvious. To address the high and potentially rising levels of vulnerability in the smallholder farm community, climate mitigation needs to be livelihood-based (Workneh*et al.* 2009). Investments in the form of carbon sequestration projects can help alleviate rural poverty and improve local livelihoods in developing countries (Tefera, 2011). Carbon sequestration projects may thus provide a win-win situation between environmental conservation and increased opportunity for economic development in poor countries (UNFCCC, 2006).

Correspondingly, the consortium of NGO and higher education institution: World Vision, Ethiopia and WolaitaSodo University, Ethiopia recognized the importance of a comprehensive approach and that climate change mitigation requires the connectedness of environmental, social, and economic elements and conditions. Their joint ventures on these milieus particularly focus on three key elements: disaster risk reduction, environmental conservation, and enhancing household's economic capacity.

In fact, very few and scanty published works and grey literature existing make claims aboutdiverse socio-economic and environmental benefits of the carbon sequestration programmes (Brown, *et al*. 2007; Maereg, *et al*. 2013). The most valuable outcome categories were: 1) increased assets in the form of tree stocks could serve as a 'carbon sink' absorbing and storing greenhouse gases from the atmosphere to help mitigate climate change.; 2) increased wild resources (especially wild foods like fruits and seeds, apiculture and construction inputs) for household consumption and sale, and associated dietary health benefits; 3) improved psycho-social wellbeing as a result of a more aesthetically pleasing and comfortable community and work environment, enhanced leadership capacity of FMNR group members, and a more positive outlook; 4) improved soil fertility and crop yields, and 5) regeneration of the native forests provide important habitat for many species of wild life and enhances biodiversity, which in turn could be an attraction for ecotourism.

The value of carbon sequestered by increased tree cover was also identified by stakeholders as important and validated by carbon calculations, which contributed to the overall value created by the FMNR project. However, to date, no study has provided a measure of the aggregate impact of community adoption of FMNR on per capita income. This study has attempted exactly this by calculating the net income of households. This case study, therefore, aims at investigating how much this project influences the per capita income of the project participants. To do so, the paper presents quantitative methods of impact analysis by analyzing the extent that the project participation puts impact on per capita income of the project participants.

2. Materials and Methods

2. 1. Location and context of the project

Sodo Community Management Reforestation Project (SCMRP) is a Clean Development Mechanism (CDM) project in southern Ethiopia registered with the United Nations Framework Convention on Climate Change (UNFCCC). Situated at310km southwest of the Ethiopian capital- Addis Ababa-this forestry and agro-forestry regeneration project started in 2006 and being implemented on 503 hectare of land at two adjacent districts:SodoZuria and Damote Gale districts of Wolaita Zone with a total population of 28,668. The area is situated at approximately 6°54°N37°45°E through to 6.5°N 37.5°E (*Fig 1*). Topographically the zone lies on an elevation ranging from 1200 to 2950 meters above sea level.

The natural vegetation of Sodo Community Conservation Forest ishighly diverse and inhabited by various plant species likegrassy vegetation with scatteredbush and shrubs, montane moorlands, broad leaf bushyvegetation and ericaceous vegetation. It is characterized by mix of vegetation with dominant species such as *Albiziagummifera, Erica arborea, Croton macrostachyus, Premnaschimperi, MaesallanceolataRhamnusprinoides, Embeliaschimperi, Juniperusprocera, Hypericumrevolutum, Carissa edulis ,Rhamnusstaddo, Syzygiumguneense, Oleaeuropaea, Phoenix reclinata, Podocarpusfalcatus, Luxiacankesta,Pittosporumviridflorum, Erythrinaabyssinica, Bruceaantidysenterica, Arundinaria alpine, Ximenia Americana, Bamboo, Vernonia amygdalin, Prunus Africana* (WVE, 2006).

Subsistent agriculture with small-scale farming is the base for the livelihood of Sodo community. Crops like Irish potato, sweat potato, wheat, barley, *inset*, cassava and taro are dominantly produced in the area. The annual average temperature of the zone is 15.10°c. The soiltypesare fertile and acidic, and highly exposed to erosion; as a result the agricultural farms are often highly depleted. The climatic condition of the areais bimodal with long rainy season extending from June to October, with a short rainy season in March and April. Theaverage annual rainfall is 1365.

The implementing partnersof SCMRPinvolve fiveforest cooperatives which have been legally established with local smallholder farmers. The forest cooperatives having a total of 1,560 members and have

User Right certificates, thereby they recruit securities from the community members, provide incentives and engaged with sense of ownership. Institutional arrangements involve representatives of the NGO (World-Vision, Ethiopia) and a focal person from the Forestry Department of the local government structure. Each cooperative has its leader elected democratically, executive committee, credit sub-committee, and forest management sub-committee.

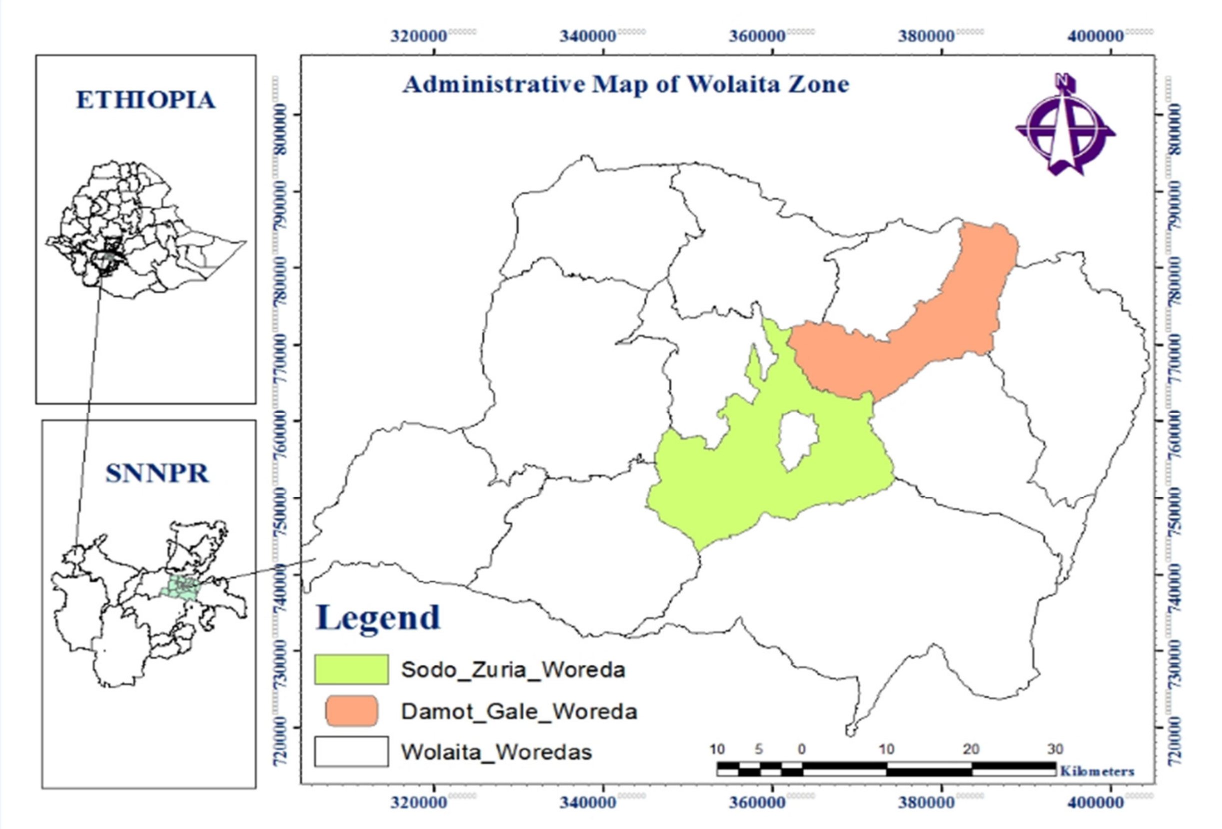

Figure 1: Study area map

The project uses a technique called Farmer-Managed Natural Regeneration (FMNR) which is a system of farm tree and forest regeneration that has been developed and refined in West Africa. Through FMNR and prudent stewardship, rural communities own their forests and forest products and see significant restoration over a short period.

2.2.Sampling Procedures and Instruments

The study is based on a rural household survey conducted on randomly selected 199 households defined within the two neighboring districts (SodoZuria and Damot Gale) of Wolaita Zone, southern Ethiopia. The study subjects were selected amongst the inhabitants of the project covered districts with total number of 28,668 households. For such a large population again we set the confidence interval at 5% and set the confidence level at 95% (Kothari, 2004). Homogeneity (in terms of topography, soils, received rainfall, and critical vulnerability and impacts of climate change) was considered among the two districts. In order to maintain the manageability of the size of the survey participants, the desired sample size of 199 households was determined using a formula by Yemane(1967) with 10% variability level. The formula is expressed as:

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

where, $N$is the population size; n is sample size and e refers to the level of precision (P=0.7 in this study).

Then, four Peasant Associations (PAs), two from each district, were taken as intact strata, based on the existing traditional classification. Next, the households were randomly selected and a proportional random sampling procedure was followed to draw 199 households. A household in this study is defined as a farm family. It is composed of all the individuals or family living in a farm plot.

Semi-structured quantitative interview- schedule was used for the household survey. Apart from basic household/demographic characteristics, the survey generated data on annual household income (on-farm, off-farm and non-farm).However, the data did not include income from labour migration and remittances (perhaps because the two districts are not equally close to the urban areas where rural households typically migrate in search of wage labour). Thus, it was not assumed that migration as a diversification strategy initiated by the carbon project participation.

2.4. Analytical procedures

In order to estimate the average impact of project participation on household income, a quantitative approach with matching method was employed. As households enrolled into the carbon sequestration projecthad been selected on the basis of predefined criteria, this rules out the use of randomization to evaluate the project. This article uses propensity score matching (PSM) as a quasi-experimental technique to overcome selection bias by controlling for relevant observable characteristics (Abadie and Imbens, 2006). PSM involves constructing a counterfactual comparison group in order to address the evaluation problem. It enables to generate the probability (or the propensity score) of each household participating in the project. It then matches beneficiary and non-beneficiary units that have similar propensity scores. Specifically, PSM estimates the average impact of project participation on participants by constructing a statistical comparison group on the basis of the probability of participating in the treatment T conditional on observed characteristics X, given by the propensity score (Khandker*et al.*, 2010).

$$P(X) = \Pr(T = 1/X) \quad (1)$$

The approach operates with the following two assumptions:

$$E(Y_0/X, T = 1) = E(Y_0/X, T = 0), \text{ and} \quad (2)$$

$$0 < P(X) < 1 \quad (3)$$

The first assumption, conditional mean independence, is that after controlling for$X$, mean outcomes of non-beneficiaries would be identical to outcomes of beneficiaries if they had not participated in the project. The second assumption is the assumption of 'common support' given by expression (3). Common support ensures there is sufficient overlap in both treatment and control propensity score distributions (Khandker*et al.,* 2010). Units that fall outside the region of common support area were dropped. The assumption of common support was fulfilled by dropping units whose propensity scores lie outside the area of overlap between treatment and control groups. Since the nature of the data used in this study is such that there are more participants than non-participants, a Kolmogorov-Smirnov test for equality of distributions for both treatment and control groups was implemented.

Binary logistic regression is appropriate when the observed outcome for a dependent variable can have only two possible values (Gujarati, 2004). For the purpose of this study, it is assumed that participation in the carbon sales cooperatives is program intervention(participant) and households who don't engage in the cooperatives are assumed to be a controlled group (comparison group). Hence, the dependent variable is participation in the project value 1 if the household participates and 0 if the household doesn't participate.

According to Gujarati (2004), the functional form of logistic regression model is specified asfollows:

$$L_i = L_n\left[\frac{Pi}{1-Pi}\right] = \beta_{0+}\beta_1.X_1 + \beta_2.X_2 + \cdots + \beta_i.X_i + \varepsilon(4)$$

Where, $Li =$ logit means log of the odds ratio. It shows how log odd in favour of change in decision to participate in the project as respective independent variable (Xi) change by a unit.$Xi =$ the individual i;Pi= the probability that a household is being participant;$(1 - Pi)$= the probability that a household will not be a project participant;$\beta_0 =$ intercept or constant term; and $\varepsilon =$ error term.

3. Results and Discussion

3.1. Descriptive analysis before matching

Statistically there was a significant difference between the two groups in terms of household size, age, size of farm land and farm experience of household head. The difference on the average mean values of the household sizeand age of the household head were found to be significant at less than 10% and 5% probability levels; whereas that of farm experience of the household head and the household agricultural land size were significant at 1% probability level.

Table 1: Descriptive statistics of sample households (Continuous Variables)

Covariates	Total *Mean (SD)*	Participants *Mean (SD)*	Non-part. *Mean (SD)*	Mean differ.	t-value
Household size	6.2 (2.51)	6.94 (2.1)	5.32 (2.5)	1.7	4.802*
Age	44.2 (11.8)	45.2(10.3)	43.05 (13.2)	2.1	1.265**
Livestock ownership	3.43 (2.6)	4.2 (2.4)	2.64 (2.6)	1.5	4.386
Land size	.59 (.45)	.74 (.51)	.43 (.304)	.31	5.076***
Farm experience	20.1 (9.5)	16.1(7.7)	24.26(9.4)	184.5	6.76***
Market distance	4.9(3.7)	4.7(4.8)	5.21(1.9)	137.3	-.919

Note: *p<0.05, **p<0.01 and ***p<0.001.

According to the survey result, it was found that the project participants' group had significantly higher percentage of male headed households as compared to non-participant households (X^2=3.752),though the mean difference is significant only at 10% probability level. With respect to marital status, the statistical results revealed that the difference is significant at 5% probability level with ($X^2 = 13.773$). But in both groups of comparison, the married category highly overweighed than the rest three: single, widowed and divorced.

It was found that there was considerable difference in terms of occupational status between the treatment and control groups with 10% probability level. Meanwhile, majority of the households in both the participant and nonparticipant groups were unemployed, which make up 93.7% of the total sample.

Table 2. Descriptive statistics of sample households (categorical variables)

Covariates	Category	Participant	Non-part.	Total	Chi-Squ.
		f(%)	*f* (%)	*f*(%)	
Sex of household head	Male	84(81.5)	67(69.8)	151(75.9)	3.75*
	Female	19(18.5)	29(30.2)	48(24.1)	
Education status	Illiterate	56(52.3)	51(47.7)	107(53.8)	.031
	Literate	47(51.1)	45(48.9)	92 (46.2)	
Marital status	Married	89(57.1)	67(42.9)	156(78.4)	13.773**
	Single	5 (55.6)	4(44.4)	9(4.5)	
	Divorced	6(46.2)	7(53.8)	13(6.5)	
	Widowed	3(14.3)	18(85.7)	21(10.6)	
Employment	Employed	3(25)	9(75)	12(6.03)	3.662*
	Unemployed	100(53.5)	87(46.5)	187(93.7)	
Off-farm participation	Yes	91(57.9)	30(42.1)	42(21.1)	11.463**
	No	12(28.6)	66(71.4)	157(78.9)	
Institutional membership	Yes	73(62)	68(57.8)	141(70.9)	87.52***
	No	38(65.5)	20(34.5)	58(29.1)	
Extension contact	Yes	54(66.7)	55(67.3)	109(54.8)	.491
	No	49(51)	41(48)	90(45.2)	

Note: *p<0.05, **p<0.01 and ***p<0.001.

Participation in off-farm activities and membership in local institutions (like *edir, equb*, marketing cooperatives, saving and credit cooperatives and etc) were another explanatory variable which describe the socio-economic characteristics of the research participants. The statistical analysis revealed that there was highly significant difference (at the probability levels of 5% and 1%, respectively) between the project participants and non-participants with respect to engagement in off-farm activities and membership to social organizations and networks.

3.2. Empirical results of matching

A set of key variables describing the socioeconomic conditions and household characteristics are presented in Table 3. A subset of these was included in the binary logistic model to estimate the propensity score used for matching. These variables were selected on the basis of economic theory and supported by the qualitative information gathered during the survey. As a basic approach, the covariates should determine the participation decision, in our case participation in carbon sequestration programme or cooperatives, and the outcome variable (per capita income) simultaneously (Smith and Todd, 2005). Furthermore, only variables that are unaffected by participation should be included (Caliendo and Kopeinig, 2008). In our case, for instance, a covariate 'engagement in off-farm activities' was dropped from the model so as to avoid possible endogenityproblem with the dependent variable. The presented features of each participant of the programme were compared and statistically tested and the results revealed a number of significant differences highlighted in the table.

Table 3. Logistics estimations of variables used in the PSM

Variables	Coefficient B& (Exp(B))
Constant	7.791 (2419.406)
Household size	-.122 (.885)
Sex of household head (1=M, 0=F)	.380 (1.462)
Age of household head	-.006 (.994)
Educational status of household head (dummy)	.061** (1.063)
Marital status of household head	.493 (1.638)
Employment (dummy)	-1.380 (.252)
Variables	**Coefficient** B& (Exp(B))
Farm size of the household	-1.827** (.161)
Livestock ownership (in TLU)	.014 (.986)
Membership to institutions	-1.201*** (.301)
Per capita income in 2015 (Excluding carbon sales income)	.01* (1.000)
Extension contact (dummy)	-.269 (.764)
Farm experience of household head	.158*** (1.171)
Distance to market	-.153* (.858)

Note: *p<0.05, **p<0.01 and ***p<0.001.

To stay focused on matching and evaluating the average treatment effect on the treated (ATT), we do not discuss the binary logistic regression results thoroughly in this study. However, the model's predictive powers are generally high and the variables included show the expected signs.

Four important tasks were carried out during conducting the matching work. First, the predicted values of project participation (propensity score) for all the sample households of both treatment and control groups was estimated. Second, imposing a common support condition on the propensity score distributions of participant and nonparticipant households is another important task that was done. Third, discarding observations whose predicted propensity scores fall outside the range of the common support region is the next work. Fourth, conducting a sensitivity analysis to check the robustness of the estimation (whether the hidden bias affects the estimated average treatment on treated or not) is the final task.

By choosing radius matching, we restrict ourselves to an area of common support which is defined by caliper width set to a quarter of standard deviation of the balancing score. The distribution of the estimated propensity scores and the overlap between the groups are displayed in table 4.

Table 4. Distribution of estimated propensity scores

Groups	Observations	Mean	St. Dev.	Minimum	Maximum
Total sample	199	0.51	0.501	0.0364	0.960
Participants	99	0.61	0.180	0.139	0.960
Non participants	87	0.41	0.213	0.036	0.927

Source: Own estimation result

As shown in the above table, the estimated propensity scores vary between 0.139 and 0.96 (mean = 0.61) for participant households and between 0.036 and 0.927 (mean = 0.41) for non participant (control) households.

The common support region would therefore, lie between 0.139 and 0.927 which means households whose estimated propensity scores are less than 0.139 and larger than 0.927 are not considered for the matching purpose. As a result of this restriction, 13 households (4 participants and 9 non participants) were discarded.

3.3. The impact of the carbon sequestration project participation on household income

The main goals of propensity score analysis is to balance two non-equivalent groups: treated and non- participant households, on observed covariates to get more accurate estimates of the effects of participation (average participant effect on the treated) on which the two groups differ (Luellen*et al.,*2005). In line with this, this section presents the participant effects of participation in carbon sequestration project. The table below shows the econometric estimation results of the effects of dependent variable on the outcome variable of interest (household annual income).

Table 5.Propensity Score Matching of ATT Effect of NNM, RM, SM and KM

Matching algorithm	Number of Treated	Number of controlled	ATT	Str. Error	t-value
NNM	99	49	1062.667	519.959	2.044**
SM	99	87	1077.854	389.106	2.771***
KM	99	87	1004.172	366.090	2.743***
RM	99	87	1959.602	350.752	5.587***

Where;
ATT = average impact of treatment on the treated*** and ** significant at less than 1% and 5% level of Significance, respectively
NNM= nearest neighbor matching

SM = stratification matching

KM = kernel matching, and
RM= radius matching ,

On the basis of the four matching algorithms, the Nearest Neighborhood matching (NNM), Radius matching (RM), Stratification Matching and Kernel Matching, the PSM results are reported in table 5. The analysis reveals that participation in the carbon project has a significant positive impact on value of household annual income. Participation in the carbon project has increased the household total income by about 1,062 Birr per year for NNM, which is significant at 5% probability level, by about 1,077 birr per year for SM which is significant at 1% probability level, by about 1,004 birr per year for KM which is significant at 1% probability level and by about 1,959 birr per year for RM which is significant at 1% probability level, as compared on average to the non-participants. It is the average difference between the total household incomes of similar pairs of the households who belong to the non-participant group. In other words, the annual income of householdswhojoined the carbon sequestration project is significantly higher than that of the non-participants. This finding is consistent with Menale, *et al* (2008). According to Khandker,*et al.*2010 comparing different matching methods results is one approach to check robustness of average treatment effect. Since at least the findings of the already applied above, three matching methods estimation results are quiet similar the researcher concluded that the consistency and robustness of PSM analysis.

4. Conclusion and policy implications

This paper identifies the economic benefits of climate-change mitigation strategies initiated by the consortium of government and non-government organizations in WolaitaSodo, Ethiopia. A package including mitigation practices like reforestation, soil and water resources management, and livestock management as coping strategies for small holder farmers in selected vulnerable districts could provide a wide varietyof diversified income generating activities, and facilitate environmental amelioration, which would benefit farmersdirectly, to ensure sustainable livelihoods. The study applied a propensity score matching technique which is widely applied to evaluate non experimental social programs.From this case study, it is concluded that the participation in the carbon sequestration project brought highly significant effect on household annual income earnings in the study area. The annual net income of the project participant households was significantly greater than those of the non-participant households.

This study gives us a clear understanding and measure of the impacts that Farmer-Managed Natural

Regeneration (FMNR) mitigation can contribute to vulnerable rural smallholder farm households. The study validated the importance of economic outcomes of carbon sequestration programmes found by previous studies (e.g. Brown, *et al*.2011). Previous studies on FMNR make claims about diverse socio-economic and environmental benefits in general and qualitative terms. Yet, to date, all published original research has focused on economic indicators, and/or tree-counting as an assumed contribution to human wellbeing. Some studies have described other benefits; though have not quantified their values. Thus, to date, no study has provided a measure of the aggregate impact of community adoption of FMNR on per capita income.This study has attempted exactly this by calculating the net income of households and using quasi-experimental approach to estimate whether there is significant difference between the project participants and non-participants in terms of their annual income earnings.

It is highlighted that climate change has relationship with agriculture in one or another way. This relationship becomes strong in developing countries like Ethiopia because their livelihood depends on agricultural activities and these activities mostly depend on climatic conditions. In relation, the impact of climate change is very serious in developing counties due to their limited adaptive capacity and lack of technology and also they are the main emitters of non-carbon GHGs.

On the other hand, by the help of the right farming practice,agriculture could be the main solution for climate change bymitigation response. Given the large contribution of land use conversion and the forestrysector to GHG emissions, reforestation presents an opportunity tocounter the adverse impacts of climate change through the joint actionof adaptation and mitigation. FMNR enhance the copingcapacity of small farmers to climate risks through diversification of income sources, which in turn decreases the mere dependence of the smallholder farmers on the limited farm land and natural resources, and to enhance the livelihood resilience of the members so that they can cope up with the economic and environmental shocks. Thus, the mutual balance between climate mitigation and household livelihood security could be maintained through such plat forms which demonstrate environment friendly and green economic growth. Finally, additional researches should be carried out using much larger sample size at different locations to acquire more empirical findings on the impact of the carbon sequestration cooperatives on smallholder farm households' income.

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