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Full length Research

Impact of Terraces in Maize and Pigeon pea Intercrop on Wellbeing of Smallholder Farmers in Semi-arid lands in Kenya.

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Climate change is expected to have economic impacts on semi-arid lands of Kenya, particularly on rural farming households whose livelihoods depend on rain-fed agriculture. Fanya juu terraces have been promoted for soil and water conservation and as an adaptation strategy to climate change in semi-arid lands of South Eastern Kenya. However, the impact of adoption of terraces as an adaptation strategy has not been explored. Propensity Score Matching approach was used to evaluate impact of adopting *fanya juu* terraces in maize and pigeon pea production on farmers' per capita income and poverty. Survey data was gathered from Machakos, Makindu and Mutomo Sub-counties. Results showed that adopters would have increased cost of production; significant increase in per capita income and reduction of poverty compared to non adopters. The study recommends government involvement in facilitation of establishment of terraces on the farms by providing technical knowhow of rainwater harnessing and harvesting; improve farmers access to seeds and other farm inputs to enhance their adaptation to climate change; improvement of market environment as an incentive to adopt the adaptation strategies to enable yields have easy access to functioning markets.

Keywords: Adaptation; Climate change; Fanya juu terraces; Semi-arid; Kenya: Propensity Score Matching.

INTRODUCTION

In agriculture, a terrace is a piece of sloped plane that has been cut into a series of successively receding flat surfaces or platforms, which resemble steps, for the purposes of more effective farming . This type of landscaping, therefore, is called terracing. Graduated terrace steps are commonly used to farm on hilly or mountainous terrain. Terraced fields decrease both erosion and surface runoff, and may be used to support growing crops that require irrigation, such as rice, maize (UNESCO, 2016). Climate change is expected to have serious economic impacts on semi-arid lands of Kenya, particularly on rural farming households whose livelihoods depend on rain-fed agriculture. The ability of the farming households to adapt to changing patterns of yield, productivity, production cost, and resource availability is important for sustained livelihood as the climate incessantly changes (ILRI, 2007; IPCC, 2007). Agricultural research in Kenya has continuously developed drought tolerant varieties of the maize and pigeon pea which are the staple crops in semi-arid areas to withstand the climate change adversity (Dalton and Lutta, 2011), however, realization of high crop yield has been frequently hampered by inadequate water supply to the plants during critical stages of growth (Cooper *et al.,* 2008).

Terraces have been promoted in South Eastern Kenya to reduce soil erosion, conserve water and as an adaptation strategy to climate change (Recha et al., 2013). However, the impact of adoption of terraces as an adaptation strategy has not been explored.

Past impact evaluation studies that have used survey samples drawn from non-experimental methods experienced a technical limitation of selection bias (Nyangena and Köhlin, 2008). Selection bias occurs due to non-randomization of sampling (Dehejia and Wahba, 1998) which provides wrong estimate of the casual effects of the subject under investigation (Rosenbaum and Rubin, 1983). This study addresses the knowledge gap by evaluating the impact of adoption of fanya juu terraces on crop yield, cost of production, per capita income and poverty while controlling selection bias in variables used in the analysis.

METHODOLOGY

Survey data was obtained from maize and pigeon pea producing sub-counties in semi arid areas of South Eastern Kenya that were purposefully selected. Multistage sampling technique was employed to select the villages to be sampled. A total of 450 households were randomly selected from three Sub-Counties for interviews.

Data collected were on households demographic and farm characteristics, yields, cost of production, net farm returns, access to credit, agricultural extension services and weather information membership in farmers associations. Propensity score matching was used to analyze the impact of adoption of fanya juu terraces on net farm returns, per capita income in maize and pigeon pea production as an adaptation strategy to climate change.

Analytical approach

A farmer making a rational decision adopts a technology if the expected benefits of adoption are larger than those of not adopting. Letting adopters of fanya juu terraces in maize and pigeon pea production be (A = 1); (A = 0) for non adopters; the causal effect of adoption on net farm returns, per capita income and poverty be represented by a variable K , y_{1ik} be the level of outcome variable K, for an individual i who adopts and y_{0ik} for non adopter. The average treatment effect (ATE) which is the average of individual treatment effects across the whole population of interest. Following Dehejia and Wahba, (2002) the ATE was defined as:

$\tau_{ATE,k} = (y_{1ik}|A_i\text{=}1) - E(y_{0ik}|A_i\text{=}0)$ .... (1)

However, the *ATE* only controls for self selection but does not address the counterfactual situation.

Non-experimental samples used in impact assessment lead to self selection bias resulting from non-randomization the treated and non-treated groups may not be the same before receiving treatment (Rosenbaum and Rubin, 1983). The propensity score which is the conditional probability of receiving treatment given pre-treatment characteristics is defined as *p(X);*$(X)\text{=}p(\mathrm{A}i\text{=}1|X)$. (Becker and Ichino, 2002) has been used to solve the self selection bias problem (Rosenbaum and Rubin, 1983, Lechner, 2002).

The validity propensity score matching method (PSM) depends on two conditions; the unconfoundedness or conditional independence assumption that state that, conditional on a set of observables, X, the respective treatment outcomes $y1_i$, $y0_i$are independent of the actual treatment status A(Rosenbaum and Rubin 1983) and the common support which states that for each value of observed variable X there should be both treated and untreated cases).

The Average Treatment Effect on the Treated (ATT) is the average gain from treatment for those who actually were treated that was evaluated in terms of "how much did the adopters of the fanya juu terraces in maize and pigeon pea production benefit from adoption, compared to the situation if they would not have adopted"? Following (Rosenbaum and Rubin 1983) the ATT can be expressed as:

$$\tau_{ATT} = E\big(y_{1i} - y_{01}|p(X)\big) = E(y_{1i}|p(X), A_i = 1) - E(y_{0i}|p(X), A_i = 0)$$

Where $\boldsymbol{p(X)}$ is the propensity score and $\boldsymbol{X}$ is a vector of pre-treatment characteristics.

The propensity scores were estimated using probit model.

The ATE on the treated units was estimated by averaging within-match differences in the outcome variable between the treated and the untreated using nearest neighbor, radius and kernel matching methods. The multiple matching methods were used to reduce the variance and bias in estimates.

The study also compared the results from difference of means, Heckman's two-stage method and PSM to describe the difference in means between ATT and ATE.

RESULTS AND DISCUSSIONS

The propensity scores in table 1 showed that probability of adopting fanya juu terraces on maize and pigeon pea production in the study area was 78.

Years of experience of the household head, number of male adults in the household, ownership of land, access to weather forecast information and membership in farmer's association significantly influenced adoption of *fanya juu* terraces. Level of education of household head and access to credit facilities also influenced adoption in Mutomo.

The results imply that with time farmers acquire more experience and knowledge about the appropriate use and operation of the technology which increase productivity. The results also imply that establishing and maintaining terraces of farm is labour intensive; requiring masculine labour force and that most farming household rely on family labour. Households with no male adult working on farm are therefore constraint in adopting terraces.

The importance of membership in farmer group to adoption of terraces is attributed to importance of farmer

Table 1: Propensity Score estimates of adoption of fanya juu terraces (probit estimates)

	Machakos		**Makindu**		**Mutomo**		**Whole sample**	
Covariates	Coeff	z value	Coeff	z value	Coeff	z value	Coeff	z value
Age	0.169	3	0.115	3.9	0.105	4.78	0.079	1.98
Experience	0.078**	0.87	0.171*	1.31	0.08**	1.14	0.096**	1.23
Education level	1.155	2.31	0.067	0.25	0.389*	2.02	0.334	2.72
Adult male	0.776*	2.05	0.518*	2.38	0.054**	0.58	0.17*	2.74
Non farm income	1.147	1.41	0.346	0.71	0.139	0.39	0.244	1.07
Farm size	-0.409	-1.93	0.001	0.02	-0.149	-1.62	-0.067	-1.66
Own land	2.509*	1.76	0.039**	0.08	0.265*	0.75	0.028*	0.23
Access to Extension	0.536	0.6	0.92	1.16	0.609	1.67	0.476	1.18
Access to credit	0.985	1.2	0.971	1.64	0.49**	0.14	0.154	0.68
Climate information	1.541**	2.36	1.068***	2.84	1.45***	3.81	1.137***	5.76
Permanent house	0.48	0.67	0.665	0.13	0.252	0.7	0.109	0.84
Own car	4.558	2.68	1.182	2.3	0.867	2.3	1.168	4.98
Association	1.50**	1.71	0.645*	0.99	1.019***	3.81	0.904**	3.49
No. of observations	145		148		150		443	
Log likelihood	-13.97		-23.99		-39.68		-91.789	
LR chi square (df=12)	70.12***		76.1***		64.2***		70.36***	
Pseudo Rsquare	0.31		0.25		0.34		0.28	
Predicted probability	0.85		0.74		0.81		0.78	

Note: The dependent variable is the decision to adopt fanya juu terraces, which equals one, zero otherwise. ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively; z-values are calculated from robust standard errors; df is degrees of freedom= 12

group meetings as local forums for information sharing, which therefore enhances adoption of agricultural technologies. Most producers change their input use patterns only when they observe or gain access to information regarding production yields from neighboring farmers or members of their farmer groups. Access to weather forecast is important to enable make informed decision during their farm planning especially on what, where and when to plant.

The pseudo R^2 was 0.28 indicating that 28 percent variance in the adoption is explained by the independent variables. Following Caliendo and Kopeinig (2008), low values of pseudo R^2 suggest that the estimated model provided an adequate fit for the data and that both the adopters and non-adopters had the same distribution in covariates, which was good for matching the scores.

Impact of adoption of *fanya juu* terraces in Maize pigeon pea production

The impact of adoption was estimated through the Average Treatment Effect on the Treated (ATT). The study analyzed the impact of adopting *fanya juu* terraces on the wellbeing of the farmers. The hypotheses that were tested to assess the impact of adoption were:

1) Cost of production is higher for maize, pigeon pea production on terraces than without terraces.
2) Adoption of *fanya juu* terraces gives higher crop yield per acre compared to non-adopters.
3)Net returns is higher for adopters of *fanya juu* terraces relative to non-adopters.
4) Adoption of *fanya juu* terraces reduces poverty head count.

The nearest neighbour, radius and kernel matching methods were used in estimating the impact of adoption on net farm returns and income-based poverty.

The results showed that adopters experienced significant increase in total cost of production relative to non-adopters. The cost increase ranged from KES 26, 270 to 28,447per acre (exchange rate of 1USD = KES 100). The increase in cost of production emanates from establishment and maintenance of terraces which is labour intensive. The labour demand increased by a range of 34.14 to 36.37 man-days per acre. Adopters also experienced an insignificant reduction in seed rate. The seed rate of both maize and pigeon pea reduced because terraces increase crops access to water thus enhancing crop growth; while non-adopters increased the seed rate as a risk reduction strategy to limit the crop

Table 2: Average treatment effect of the treated across different matching methods South Eastern Kenya

Variable	Nearest Neighbour	Radius	Kernel
Cost of production	26270(1.83)*	27750*(2.13)	28447*(2.26)
Seed rate maize	-4.43(-1.58)	-3.9(-2.43)	-4.7(-2.23)
Seed rate pigeon pea	-3.03(-1.08)	-3.37(-0.83)	-3.7(-0.64)
Maize yields/acre	248.37**(2.32)	250**(2.71)	260.1**(2.62)
Pigeon pea yield/acre	186.4(3.5)	173.77(2.92)	164.07(3.05)
Labour demand	36.37***(0.24)	34.14***(0.28)	34.27***(0.25)
Household income	52243**(2.58)	53303**(2.68)	52910**(2.49)
Per capita income	5,276*(1.47)	5, 374(1.62)	5,104*(1.92)
Poverty head count	-0.04 (-1.53)	-0.03(-1.58)	-0.04*(-1.57)
Common support region imposed	Yes	Yes	Yes
Balancing property satisfied	Yes	Yes	Yes
No. of treatment units	186	188	180
No. of control units	230	231	235

Note: The analysis is conducted using pscore command in STATA Version 12.
***, **, *denote statistical significance at the one percent, five percent, and ten percent levels, respectively; t-values (in parentheses) are calculated from bootstrapped standard errors

Table 3: Comparison of average treatment effect of the treated across different estimation methods

Variable	PSM NN	Heckmans two step	Difference in means
Cost of production	26270(1.83)*	28287(2.37*)	30020 (3.05**)
Seed rate maize	-4.43(-1.58)	-3.47(-2.14)	-4.50(-2.75)
Seed rate pigeon pea	-3.03(-1.08)	-3.77 (-1.51)	-4.15 (-1.24)
Maize yield/acre	248.37**(2.32)	274.13(2.15)***	293.67(1.75***)
P. pea yield/acre	186.4(3.5)	190.03(2.98)	217.73(3.23)*
Labour demand	36.37***(0.24)	42.90(1.82)***	35.54(1.89)
Household income	52243**(2.58)	59940 (2.65***)	61797 (2.15***)
Per capita income	5,276*(1.47)	5861(2.62**)	6150(1.51***)
Poverty	-0.04 (-1.53)	-0.05(-1.76)	0.06(-1.50)*

Note: The analysis is conducted using pscore command in STATA Version 12.
***, **, *denote statistical significance at the one percent, five percent, and ten percent levels, respectively; t-values (in parentheses) are calculated from bootstrapped standard errors.

Loss.

Adopters experienced a significant increase in maize yield ranging from 248.4 kg to 260.1 kg per acre. Amplification of yields results in more than what households subsist on, therefore creating surplus for sale. The adopters experienced an increase in net farm income ranging from KES52, 243 to 53,303 per year and per capita income of KES 5,104 to 5,374 per house hold member per year. This translated to a reduction in poverty by 3-4 percent per household; the increase in per capita income was not large enough to cause a significant reduction in the poverty level. This could be due to a greater quantity of green maize and pigeon peas harvested for home consumption and therefore not adequately captured in the yield data; this is in addition to the high per unit transport cost to the market. The results of the impact of adoption of *fanya juu* terraces on farmers wellbeing is presented in table 2.

To quantify the differences in outcome variable after accounting for self selection bias, the results showed that the difference between adopters and non-adopters for the difference of means method were over-estimated for most of the variables. The effect of adoption on cost of production was significantly higher for adopters when considering the difference of means with per acre rates of KES 30,020. However, after controlling for selection bias and accounting for both self selection and counterfactual situation the cost of production was slightly significant but increased by KES 27,287 and KES 26,270 respectively as presented in table. The labour demand insignificantly increased by 35.54 man-days per year in difference of means method but significantly increases by 42.9 and 36.37 man-days per year when controlling for self selection and when considering both self selection and counterfactual situation respectively as shown in table 3.

The results also show a significant increase in both net farm income and per capita income in all the methods. The results reveal a significant reduction in head count poverty of 6 percent in difference in difference method and an insignificant reduction of poverty of 4 per cent and 5 percent when accounting for self selection bias and both self selection bias and counterfactual situation respectively. The results imply that adoption of the terraces in maize and pigeon pea production contributes towards reduction of the households living on US $1.25 per day.

CONCLUSION AND RECOMMENDATIONS

This study evaluates the impact of adopting *fanya juu* terraces on maize and pigeon pea producers net farm income, per capita income and poverty in South Eastern Kenya. Propensity Score Matching approach was employed in examining the counterfactual situation on how adopters benefit from adoption of *fanya juu* terraces compared to the situation if they would not have adopted. Survey data collected from Machakos, Makindu and Mutomo Sub-Counties was used for the empirical analysis.

The propensity score results showed that experience in farming; adult males in the household; membership in farmers association and access to weather forecast information in terms of onset and cessation of rainfall the temperatures variation increased the adoption of fanya juu terraces in maize and pigeon pea production as adaptation strategy to climate change.

Causal effect of *fanya juu* terraces adoption was overestimated when the issue of self-selection bias was not addressed: Addressing the issue of selection bias reduced the size of outcome variables obtained in the difference of means method. This indicates that the estimates of the effect of the outcome variables that do not control for self-selection effects exaggerate results that could give wrong advice to policy makers.

Adoption of *fanya juu* terraces was projected increase crop yields, farm income and per capita income. Farm income and per capita income significantly increased by KES 52243 and KES 5276 per year respectively. The labor demand was projected to increase by 36.37 man-days per year to establish the structures on the farm raises which would raise the cost. However, proper layout of the structure reduces the annual maintenance cost which in the long run increases the cost of production at a reducing rate. The terraces were projected to reduce head count poverty rate by 4 percent.

The study recommends that those involved in policy intervention should design policies that support farmers' access to machinery to alleviate the labour demand that could constraint adoption of terraces. Policies should aim to improve timely provision of advisory information on weather forecast especially early warnings to reduce the loss caused by climate change given that farm-level decision making occurs over a very short time period influenced by seasonal climatic variation. Policies designed should improve formation of farmers associations through facilitation of sensitization of the farmers on the socio-economic benefits associated with farmers associations.

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