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# Impact of Disappearance of Lake Haramaya on the Livelihood of the Surrounding Community: The Case of Haramaya District in Oromia National Regional State, Ethiopia

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**Abstract**
This study was initiated with the main objective of measuring the impact of disappearance of Lake Haramaya on the livelihood of the surrounding community; measuring in terms of annual income generated from agricultural production per household. Propensity score matching method was applied to measure the impact of this vanished lake on the outcome variable of the treated household ds. The study shows that the demised lake has resulted in a negative and significant effect on five specific outcomes variable indicators (i.e., income from vegetables, chat, overall irrigated crops, inter-crop cultivation, overall crop and livestock production). The result of the econometric model also revealed that out of 13 variables included in the model, six explanatory variables namely family size, frequency of extension visit, farm machinery ownership, education level, use of animal manure and membership in cooperatives were found to be significant at less than 10% probability level in determining household welfare and livelihood status in the study area. Finally, the sensitivity analysis also showed that the impact result estimates were insensitive to unobserved selection bias. Therefore, the study recommends alternative policy implications to reverse the demise lake Haramaya's adverse effects on the livelihood of the district, mainly for the farming society as it is an alarming issue requiring a positive contribution of everybody in general and the district intellectuals in particular.
**Keywords:** Lake Haramaya, Livelihood, Impact, Propensity score matching.

## 1. INTRODUCTION

The socio-economic values of wetland ecosystems are extremely significant and critically important for all local communities that are dependent on wetland products and resources. Wetlands contribute to the national and local economies by producing resources, enabling recreational activities and providing other benefits (EPA, 2006).

Since the year 1900, one-half of the world's wetlands have disappeared (WWAP, 2011). It is also estimated that by the year 2025 approximately 1,800 million people will experience "absolute" water scarcity with less than 500$m^3$ of available water per year per capita, and two thirds of the world's population could be under "stress" conditions, with only between 500-1000 $m^3$ of available water per year per capita (FAO, 2011). This is alarming, as water is a vital life source, common to all living creatures, and crucial to the survival of any ecological system (Strang, 2005).

The familiarity with existing literature on conflicts, particularly in Africa, suggests that an overwhelming percentage of conflicts are resource-based conflicts (Masari, 2008). The unfolding scenario in the Lake Chad basin is a nodal example in this regard. The rich water resources of this lake have been a source of economic livelihood, sustaining over 20 million people inhabiting the catchments areas. However, in the last few decades, the size of the lake and its resources has continued to diminish. The impact of this depletion is being felt by the Lake Chad basin population who depend on the lake for their livelihood.

Wetlands and their value remain little understood and their loss is increasingly becoming an environmental disaster. While rates of wetland loss are documented for the developed world, the limited study of these ecosystems in countries like Ethiopia is disappointing (Barbier *et al.*, 1996).

Ethiopian lakes are of great importance to Ethiopia's economy and essential to the survival of the local people. However, they are threatened by increasing consumption and environmental degradation. The study district was a mother of four lakes. These lakes were excellent surface water resources utilized for irrigation, drinking, and other domestic consumption for rural and urban communities in the district including Haramaya University and home for different beautiful birds and fishes (Abdulatif, 2004).

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The water treatment of the study site i.e., Lake Haramaya was designed to serve a maximum population of 70,000. However, currently the user population is more than 150,000. It is constantly threatened by anthropogenic interventions rather than the natural phenomenon. As the calculated water balance for this Lake basin shows, annual abstraction of the groundwater is by far greater than annual recharge rate, indicating that groundwater is depleting at an alarming rate (Wagari, 2005). Lake Haramaya has been used as a major irrigation water source and as a local fishery for Haramaya town and the surrounding farming community for over 40 years (Abdulatif, 2004).

Lake Haramaya is shrinking and completely dried up since 2005 (Haramaya Univesity, 2005). However, especially, after complete disappearance of Lake Haramaya, cultivation of the water dried areas continued in a wider rate. Experts believe that such activities may result in serious negative effect on the ecosystem, environmental balance, the economy of the community (reduction in vegetable production[1]), loss of common grazing land and source of conflict among the individuals around the Lake in particular and the district in general (Abdulatif, 2004).

Abdulatif (2004) indicated that, the loss of the Haramaya lake water resulted in loss of wildlife and nesting habitat, different types of fishes habituating in the Lake, drinking and irrigation water, fishing activities, climatic imbalance (such as increased frost during cold time and increase in temperature during hot season), increased cost of production and decreased productivity and creates occurrences of conflicts among farmers due to land ownership and therefore, these adverse impacts of the environment are obviously catastrophic and have an evil consequence on the country's economy in general and the rural livelihoods in particular.

There were various studies on Lake Haramaya focusing on identifying the causes of the deterioration, ultimate death of the lake and its adverse effects. However, there were no empirical studies which analyzed the impact of the disappearance of this lake on the livelihood of farmers using rigorous econometric methods. There is no single study regarding the impact of the Lake that provides possible areas of policy intervention in the district. So this study is aimed at filling this research gap.

## 2. RESEARCH METHODOLOGY

### *2.1. Description of the Study Area*

Haramaya is one of the districts in East Hararghe Zone, Ethiopia. The district is stretching between 1400 and 2340 meters above sea level. Of its total area, 90% is mid-highland while the remaining 10% is lowland agro-climate zones and the mean annual rainfall and temperature are 790 mm and 16.34$^0$c, respectively (BoFED, 2008).

Haramaya is an agriculturally potential area among the districts in East Hararghe zone. Lakes, Rivers, and springs are irrigation water resources in the district. The district was a mother of four Lakes named Tinike, Haramaya, Addele and Harajitu Lakes. Among the four lakes, Harajitu Lake disappeared before many years, Haramaya and Adelle lakes are now disappearing or became seasonal, while Lake Tinkie is the only living and currently utilized lake in the district.

#### 2.1.1. Livelihood characteristics

The livelihood status (income diversification) of the community in the study areas is mainly based on mixed farming systems with crops and livestock production. Other sources of livelihood in the districts are petty trade and other off/non-farm activities (financial capital), daily labor (human capital), food aid in the form of public work and direct support. The district cash crop economy is widespread, but the higher proportion of the household income came from *chat* production which is about 36.5% (HDARDO, 2011).

Crop production is the primary source of income generation in the study area. The production system in the study area can be described in two ways, i.e. rain-fed and irrigated systems. The rain-fed production system is most dominant and is practiced by the majority of the farmers. Horticultural crops are often produced using irrigation. In vegetable production, farmers practice multiple cropping. The dominant crops grown in the study district are sorghum, maize, haricot beans, vegetables and *chat.* Vegetables and *chat* are the two major cash crops grown in the area. However, the farmers are facing market problem when all farmers produce and harvest at similar seasons. Farmers can produce vegetables three times per year using irrigation (Bezabih and Hadera, 2007).

[1] Haramaya was the only vegetable exporting District to Djibouti and Somalia, while this is almost history after the full or partial disappearance of this Lake (Abdulatif, 2004).

### *2.2. Methods of Data Collection and Analysis*

The study used primary data collected from the six targeted *Kebeles*, which surrounds the Haramaya and Tinike lakes.To account for the problem of heterogeneity in the study area, stratified three-stage random sampling technique was employed and a total of 200 households were randomly and proportionately sampled.

The impact analysis used both descriptive statistics and econometric model. Among econometric methods propensity score matching was employed to quantify important empirical results. Statistical Soft-ware STATA was used for this purpose.

#### 2.2.1. Propensity score matching (PSM) method

Rosenbaum and Rubin (1983) were the first to develop the PSM statistical tool. The technique has attracted attention of social program evaluators since the last twenty five years (Jalan and Ravallion, 2003; Dehejia and Wahba, 2002).

PSM matches each participant household with a non-participant household that has almost the same likelihood of participating into the program. This study also applies a propensity score matching technique to address its main objectives, which is a widely applied impact evaluation instrument in the absence of baseline survey data for impact evaluation.

According to Caliendo and Kopeinig (2008), there are steps in implementing PSM. These are estimation of the propensity scores, choosing a matching algorism, checking on common support condition, testing the matching quality and test sensitivity analysis.

The first step in PSM method is to estimate the propensity scores. When estimating the propensity score in the binary treatment case, logit and probit models usually yield similar results. Hence, the choice is not too critical, even though the logit distribution has more density mass in the bounds (Caliendo and Kopeing, 2008). Therefore, Logit model was applied to predict propensity scores for the PSM method in this study.

#### 2.2.2. Specification of the logit model

Here a question may arise, why Logit model was run for the sampled households, on observable variables. The major concern is that, the logit distribution has more density mass in the bounds and it is the best model to predict the probability of a household to be influenced by the vanished Lake i.e. to predict propensity scores, based on which, the treatment and control groups were matched using the kernel (0.1) estimator. In estimating the logit model, for impact analysis the dependent variable is being near Haramaya Lake that takes a value of 1 and for being near Lake Tinikie that takes the value of 0. Arpino and Mealli (2009) also noted that the logit model which has more density mass in the bounds could be used to estimate the propensity score p(X).

Following Gujarati (2004), the logistic distribution function for the determining factors in livelihood status of the households is specified as follows:

$$P_i = E(Y = 1 / X_i) = \frac{1}{1 + e^{(\beta_0 + \beta_1 \chi_1)}} \quad (1)$$

For ease of exposition, we write (1) as

$$P_i = \frac{1}{1 + e^{-Z_i}} \quad (2)$$

The probability that a given household is affected by the disappearance of the lake (participant) is expressed by (2) while, the probability for not being affected (non-participant) is:

$$1 - P_i = \frac{1}{1 + e^{Z_i}} \quad (3)$$

Therefore, the odds ratio can be written as: $\frac{p_{(i)}}{1 - p_{(i)}} = \frac{1 + e^{Z(i)}}{1 + e^{-Z(i)}} = e^{z_i}$ (4)

Now ($P_i/1-P_i$) is simply the odds ratio in favor of participating (being affected by the dried lake); the ratio of the probability that a household would be influenced by the Lake to the probability of that they are not influenced. Finally, Taking the natural logarithms of the odds ratio of equation (4) would result in what is known as the logit model as indicated below.

$$L_i = \ln\left(\frac{P_{(i)}}{1-P_{(i)}}\right) = In\left[e^{Zi}\right] = Z_i \qquad (5)$$

Where: $Z_i$= is a function of n explanatory variables ($X_i$) which is also expressed as

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (6)$$

Where: $\beta_0$, is an intercept, $\beta_1$, $\beta_2$ . . . ., $\beta_n$ are slopes of the equation in the model. $L_i$ is log of the odds ratio, which is not only linear in X but also linear in the parameters. $X_i$ is vector of explanatory variables. If the disturbance term $U_i$ is taken into account the logit model becomes:

$$Z_i = \beta_0 + \beta_1 \chi_1 + \beta_2 X_2 + \ldots + \beta_n X_n + U_i \qquad (7)$$

**2.2.3. Choice of matching algorithm**

The next stage was to choose the matching algorithm which best estimates the p-score. The choice of matching method involves a trade-off between matching quality and its variance. Various matching estimators have been suggested in the literature. The most commonly used matching methods include the nearest neighbor matching, radius (caliper) matching, and kernel matching estimators. Therefore, the estimated average treatment effect on treated (ATT) was done by implementing kernel matching estimator with band width (0.1) and the already mentioned PSM model.

***2.3. Definition of Variables, Measurements and Hypothesis***

The choice of covariates to be included in the first step (propensity score estimation) is an issue. Heckman *et al.* (1997) argue that omitting important variables can increase the bias in the resulting estimation. Here, pre-intervention characteristics, which bring variation in outcomes of interest among participants and non-participants, were used.

**2.3.1. Dependent variable of the model**

The dependent variable for this model is participation and has dichotomous nature (dummy); it assumes a value of 1 if the household is the previous vanished lake (Haramaya) users and a value of 0 for the living lake (Tinikie) beneficiaries. This was done by relating the previous and current services of these two lakes with the society's livelihood status in the study area.

**2.3.2. The outcome variable** is a variable which show the livelihood impacts/status of the farmers, and it is measured by the value of annual income from (livestock and crop production) per household. The hypothesis is that the demise lake Haramaya has a negative impact in increasing household welfare and reducing poverty.

**2.3.3. Explanatory variable of the model**

Based on the findings of past studies on determinant of community livelihoods, the major endogenous variables were hypothesized to determine farmers' livelihood status include Age of household head (years), Education level by household head (years), family size (AE), Total livestock holding (TLUs), off-farm and non-farm income (EB), frequency of extension visit (per month/year), farm machinery ownership (binary), use of manure (binary), membership in cooperatives (binary), total cultivated land owned (hectares), number of crops grown/cultivated (hectares), average distance from basic services (KMs) and farming experience of the household head (years) .

**3. RESULTS AND DISCUSSION**

***3.1. Descriptive results***

The study results indicate that the before matching difference between the two groups with regard to the agricultural outcome variables (the total mean income from livestock and crop production) per household in the study area were 342472.00 Birr per household per year. Accordingly, the mean income of treated household is 273415.30 Birr and non-treated mean income is 411528.80 Birr.The difference in mean incomes of the treated and non-treated groups is around 138113.60 Birr which is significant at 1 % probability level.

### *3.2. Econometric Model Results*

#### 3.2.1. Estimation of propensity scores

A logistic regression model was used to estimate the propensity scores of respondents which help to put into practice the matching algorithm between the treated and control groups in the study area. In estimating the propensity scores, data from both groups were pooled such that the dependent variable takes a value of 1 if the household was participant and 0 otherwise.

In this section, the selected explanatory variables were used to estimate the logit regression model to analyze the determinants of household income and livelihood status. Therefore, the model is a binary logit where the test for linear correlation of covariates is irrelevant and no statistical software is needed to determine the best subset of explanatory variables that are good predictors of the dependent variable.

The pseudo-$R^2$ indicates how well the regressors explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo-$R^2$ should be fairly low (Caliendo and Kopeinig, 2008).

The pseudo-$R^2$ value of 0.29 shows that, the estimated model performs well for the intended matching exercise. A low pseudo-$R^2$ value means participant households do not have much distinct characteristics over-all and as such finding a good match between participant and non-participant households becomes easier. The statistical significance of the different variables varies widely; some are statistically significant at less than 1%, 5% and 10% level of significance while others are not significant even at 10% level of significance. In general, the model performs well. Therefore, it is possible to interpret the model results meaningfully.

Looking into the estimated model coefficients presented in AppendixTable 1 among the 13 variables considered in the model, six variables were found to have a significant impact on determining the participant groups and hence livelihood status of households at 1%, 5% and 10% probability levels. These variables include household family size, education level, use of manure, membership in cooperatives, frequency of extension visit and farm machinery ownership. However, the sign of the last two variables was not as expected. Seven of the 13 explanatory variables were found to have no significant influence on household income and hence livelihood status of households.

#### 3.2.2. Estimating treatment effect on treated (ATT)

After the distributions of treated and non-treated units were located in the same domain, the pre-intervention differences were controlled.The estimated average treatment effect was done by implementing kernel matching estimator with band width (0.1) and the already mentioned PSM model. Therefore, in order to attain the objective of this study the following aggregate level impact indicator of the treatment effect was performed using the PSM model.

After controlling for differences in socio-economic characteristics of the participant and non-participant households, it has been found that the average treatment effect on treated (ATT) and/or the average total impact difference on the outcome variable of the treated group is nearly 126480.04 Birr (31%) decreased by average annual total income. In other words, the impact of vanished Lake Haramaya has minimized the mean annual total income of the treated households nearly by 31% where the mean total impact differences on this outcome variable of the two groups is statistically significant at 1 % probability level (Appendix Table 2).

### *3.3. Sensitivity of the evaluation results*

Sensitivity analysis was undertaken to detect whether the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or the estimated ATT is robust to specific failure of the CIA. As indicated in Appendix Table 3, we can conclude that our impact estimates (ATT) are insensitive to unobserved selection bias and are a pure effect of vanished lake interventions by participant households.

## *4. Conclusions*

The study used cross-sectional data collected from both group of households. The demise Lake Impact was measured as both continuous and categorical levels. Descriptive statistics and econometric techniques (PSM) were applied to analyze the empirical data collected.

The result of the econometric model analysis revealed that out of 13 variables included in the model, 6 explanatory variables were found to be significant up to less than 10% probability levels. Accordingly, family size (<0.05), frequency of extension visit (< 0.01) and farm machinery ownership (<0.05) were found to have a negative association with the dependent variable. Whereas, education level in years (<0.01), use of manure (<0.05) and membership in cooperatives (<0.1) were found to be significant and have a positive relationship with the households' probability of participation.

After controlling for differences in demographic, location, institutional and asset endowment characteristics of the participant and non-participant households, it has been found that, average annual total income (from crop and livestock production) for participant and non-participant farmers were 282795 and 409275 Birr, respectively, in the study area. This implies that irrigation access contributes to household income and poverty reduction.

Finally, from the discussion that has been made so far and experiences from around the world, it is possible to conclude that the disappeared lake Haramaya by itself is not a problem or threat as such. The problem lies on the presence or absence of appropriate and sustainable management practices of this natural resource. The completely dried up Lake Haramaya follows the most dramatic changes on the wetland degradation and has profound socioeconomic impacts on the lives of the surrounding community; and the case of Lake Haramaya can be also an example of the serious threat and alert for other existing lakes in Ethiopia and even in Africa. It is very clear from this study that irrigation access has an important impact on poverty reduction through high income and improved well-being of the farming households.

Lastly, given the limitations of this study, undertaking comprehensive impact studies by incorporating subsequent effects of wetland loss on livelihoods, environment, socio-economic and spill-over aspects by having relatively large sample size and coverage is very important.

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Appendix Table 1: **Estimated Logistic regression results for determinants of participation and livelihood status**

| Model variables | Coefficients | Std. Err. |
|---|---|---|
| Age | 0.03 | 0.06 |
| Education | 0.21*** | 0.07 |
| Family size | -0.22** | 0.11 |
| Cult. Land holding | -1.23 | 0.82 |
| Livestock Owned in TLU | -0.11 | 0.09 |
| Off/Non farm income | 0.00006 | 0.00005 |
| Frequency of extension visit | -0.15*** | 0.03 |
| Avg. distance from basic services | 0.04 | 0.09 |
| Number of crops grown | -0.15 | 0.11 |
| Farm experience | -0.05 | 0.06 |
| Farm machinery ownership | -0.76** | 0.36 |
| Use of manure | 0.86** | 0.40 |
| Membership in cooperatives | 0.65* | 0.36 |
| Constant | 2.95* | 1.66 |

Number of obs = 200
LR chi2(13) = 81.31
Prob > chi2 = 0.00
Log likelihood = -97.98
Pseudo $R^2$ = 0.29

Source: Own estimation result, 2012
***, **, & * indicates significance at 1%, 5% and 10% probability levels, respectively

**Appendix Table 2:** Estimation of ATT for average total impact on livelihood outcome variable (total annual income) estimated in Birr

| Outcome-variable | Treated | Controls | Difference | t-value |
|---|---|---|---|---|
| Average total annual income | 282795.39 | 409275.43 | -126480.00 | -2.76*** |

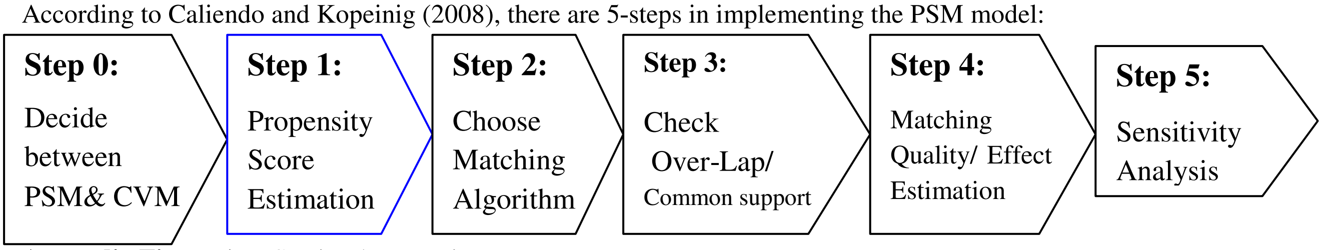
Source: Own survey data result, 2012 ***, indicates significance at 1% probability level

**Appendix Table 3:** Result of sensitivity analysis using Rosenbaum bounding approach

| | | p-critical values( the upper bound of Wilcoxon significance level (Sig+) at different critical value of Gamma($e^{\gamma}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Outcomes | $e^{y}=1$ | $e^{y}=1.25$ | $e^{y}=1.5$ | $e^{y}=1.75$ | $e^{y}=2$ | $e^{y}=2.25$ | $e^{y}=2.5$ | $e^{y}=2.75$ | $e^{y}=3$ |
| 1 | Anual Income | P< 4.3e-08 | P< 1.2e-10 | 3.2e-13 | 8.9e-16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Source: Own estimation, 2012
$e^{y}$ (Gamma)=log odds of differential due to unobserved factors where Wilcoxon significance level for the significant outcome variable (Annual income) is calculated.

According to Caliendo and Kopeinig (2008), there are 5-steps in implementing the PSM model:




**Appendix Figure 1:** PSM implementation steps