ASSESSMENT OF ADOPTION AND IMPACT OF RAINWATER HARVESTING TECHNOLOGIES ON RURAL FARM HOUSEHOLD INCOME: THE CASE OF RAINWATER HARVESTING PONDS IN RWANDA

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DECLARATION AND APPROVAL

DECLARATION

This thesis is my original work and has not been previously presented for an award of a degree in this or any other university

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APPROVAL

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DEDICATION

I dedicated this thesis to my beloved parents, Mr. and Mrs. ZINGIRO, brothers and sisters whose advice and support has given me an inspiration in life. With much gratitude, I salute you all for your encouragement, affection, love, prayers and marvelous sacrifices in the success of my life.

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ABSTRACT

Rainwater harvesting is increasingly seen as a strategy for enhancing agricultural productivity and boosting farm income in many drought prone areas. While extensive efforts are going on in constructing and providing smallholder farmers with water harvesting technologies, such as rainwater harvesting ponds in many developing countries, there is conflicting evidence in the literature about the impact of such technologies on farm households. This study uses propensity score matching technique to assess the impact of rainwater harvesting ponds on farm household income in Rwanda. It then assesses the factors that influence adoption of rainwater harvesting ponds and the pathways through which the use adoption of such ponds influence farm income. This study finds that households with rainwater harvesting ponds have significantly higher income than their counterparts of comparable observable characteristics. The study also finds evidence that increase in farm income occurs via increased input use, and that household size, physical and financial asset endowments and participation in farmer organizations/group condition the decision to adopt rainwater harvesting ponds. The study concludes that the major factors driving the adoption of rainwater harvesting ponds are endowment with physical assets, farm income, membership to a farmer organization, and household size. It also concludes that use of rainwater harvesting ponds has a positive impact on household farm income. The study concludes that adoption of rainwater harvesting technologies has positive benefits to farm households.

The implication of these findings is that adoption of rainwater harvesting ponds presents a pathway for reducing rural poverty. The findings further imply that policies that target increasing farm incomes should promote participation of farmers in farmer organizations. The finding that impact of rainwater harvesting ponds occurs through increased use of purchased inputs suggest

the need to develop the input (fertilizer, manure, improved seed and pesticide) markets in order to reduce the transaction costs so as to make such inputs more easily accessible to farmers. In addition the finding that physical and financial asset endowments affect the adoption of rainwater harvesting ponds imply that there is need for policies and strategies that target the inclusion of poor farmers in adoption of rainwater harvesting ponds. Finally, in order to promote increased adoption of rainwater harvesting ponds and the inclusion of the poorer farmers, research and development interventions should be aimed at finding ways of reducing the cost of constructing the rainwater harvesting ponds and also of adopting the ponds.

TABLE OF CONTENT

LIST OF ACRONYMS

ATE : Average Treatment Effect

ATT : Average Treatment effect on the Treated

ATU : Average Treatment effect on the Untreated

ICRAF : International Center for Research in Agroforestry

KBM : Kernel based Matching

KWAMP : Kirehe community-based Watershed Management Project

MINAGRI : Ministry of Agriculture and Animal Resources

MINECOFIN: Ministry of Economy and Finance

MINIRENA: Ministry of Lands, Environment, Forestry, Water and Mines

NGOs : Non Governmental Organisations

NISR : National Institute of Statistics of Rwanda

NNM : Nearest Neighbor Matching

PSM : Propensity Score Matching

RHSIT : Rainwater harvesting tanks and supplementary irrigation technology

RM : Radius Matching

Rwf : Rwandan Francs

RWH : Rain Water Harvesting

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Rwanda covers an area of 26,338 km^2 with an estimated population of 9.9 million. This translates into an average density of 376 inhabitants per km^2; making it the Africa's most densely populated country (ICRAF, 2010).Population pressure on land has forced people to move from the West which is wet to the East which is warm and dry. Compared to the wet highlands, the culture of improved and sustainable land management has not been adequately adopted in the dry areas and land is under severe degradation problem. There is shortage of soil moisture for crop growth due to recurrent drought and water holding capacity of the soil is also low.

Although Rwanda is known as an equatorial country with high rainfall, poor water management, low soil fertility, unreliable and erratic rainfall have continued to threaten food production in major arid and semi-arid regions of the country. Environmental degradation has further decreased agricultural productivity making inhabitants even more susceptible to drought and other natural disasters. In addition to on-going land degradation due to vulnerable rain-fed, ever-increasing population has accelerated poverty so that 46%, on average, of the rural population is impoverished and food insecure earning an average of 90 dollars/ capita / year (NISR,2006).

In Rwanda, the issue of variability of rainfall is critical for lands on hillsides where water cannot be retained. Farms in the eastern part of the country, where rainfall is lowest, are therefore the most vulnerable (MINAGRI, 2007). Under these conditions, rain-fed agriculture, which is one of the main economic activities, has failed to provide minimum food requirements for the rapidly increasing population although the agriculture sector employs 90% of the labour force, the food and nutrition needs of the population cannot presently be met, as evidenced by the high prevalence of malnutrition of 52% (MINECOFIN,2002).

In such an environment, unless supplementary sources of water are used, traditional farming and animal production activities will not meet the ever increasing demands of the society. Due to the above conditions, development partners argue that there is need for appropriate interventions to address the existing constraints of the poor performance of the agricultural sector using suitable technologies for improved and sustainable agricultural production. Hazell (2009) showed that in Asia, the green revolution enabled Asian countries to break out of its food production constraint by bringing the force of the 20th century scientific revolution in agriculture to its farmers. Governments and their international partners invested heavily in agricultural research and development, extension, irrigation, and fertilizer supplies and farmers made major changes to their traditional and well- honed farming. Asian green revolution would not have occurred without the adoption of new agricultural technology such as the high yielding varieties and irrigation. These technologies spurred significant increases in agricultural productivity in Asia and stimulate the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy (IFPRI, 2002).The Asian experience has informed the search for African green revolution with focus being put on irrigation of which water harvesting can play a major role.

To address the challenges faced by rain-fed agriculture, the government of Rwanda in 2003 under the Rural Sector Support Project implemented large scale water harvesting technologies to store water for irrigation. However, most farmers were unable to exploit the water irrigation system because they were no gravity irrigation control structures which resulted in flooding and also the expense of installing drainage systems was unaffordable (ICRAF, 2010).

In Rwanda, the government and non-governmental organizations introduced in 2007 a national food security strategy that focused on the promotion of small scale irrigation. The initiative involved the introduction of rainwater harvesting technologies at household level as an alternative intervention to mitigate the effects of the erratic nature of rainfall in the arid and semi-arid parts of Rwanda. There is now increasing interest in small scale irrigation systems compared to large scale irrigation, due to the perception that they are easily adaptable to local environmental and socioeconomic conditions unlike the high capital requirement and cost of constructing large scale scheme which can only benefit a fortunate few (Turner, 1994).

According to Ngigi (2003), rainwater harvesting is defined as a technique of collecting, storing and conserving rainwater for some productive purpose such as agricultural production, livestock rearing, household domestic consumption. Although rainwater harvesting techniques broadly include roof water harvesting, runoff harvesting, flood water harvesting and subsurface water harvesting, this study will be limited to runoff harvesting through household ponds.

1.2. Problem Statement

Rainwater harvesting technologies have been used in arid and semi-arid parts of the world because of their potential capacity to enhance agriculture productivity and generate income, under the low rainfall conditions. Amha (2006) for example found that adoption of rainwater harvesting in Ethiopia has a positive effect on value of crop production. Msangi *et al.*(2004) found that those with RWH maize production had higher returns to labor than their counterparts. Other studies that show a positive impact of rainwater harvesting technologies include; Tesfay (2008), Smith *et al.*(2011),Huhua *et al.*(2007).

The impact of rainwater harvesting is not however always positive. A study in Northern Ethiopia by Krusema *et al* (2006) assessed the impact of small scale water harvesting on household poverty and showed that households with ponds were not significantly better off compared to those without. Mintesnot *et al.* (2004), attribute their finding to the fact that irrigation technology introduced pests thus negatively affecting crop yields. Pests which were commonly occurring in the rainy season started occurring during the dry season due to the availability of water on the irrigation fields. A study by Lire *et al.* (2004) indicated that small scale irrigation technology introduced in Tigray (Ethiopia) was associated with important health side effects. There especially were concerns that new sources of water may have increased the prevalence of water borne diseases such as malaria.

Malaria affects agricultural productivity through the impairment of the health of the affected farm workers (i.e., through illnesses). These conflicting findings imply the need for further systematic research on the actual impact of rainwater harvesting technologies. This is especially important because increasing numbers of African countries are focusing attention the use of rainwater harvesting technologies to boost agricultural productivity. This study specifically examines impact adopting rainwater harvesting ponds on farm household's income and input use in Rwanda. The study also assesses the factors that condition the adoption of rainwater harvesting ponds and the impact pathways through which use of such technologies are likely to affect farm households. Yet, the Ministry of Agriculture and livestock (MINAGRI, 2007) is aggressively promoting the use of these technologies, especially the ponds. This study aims to provide the evidence that will fill this gap by assessing the conditioners of adoption and impact of the existing rainwater harvesting ponds on household's farm income in Rwanda.

1.3. The purpose and specific objectives

The purpose of this study was to assess the adoption and impact of rainwater harvesting ponds on rural farm household income in Rwanda.

The specific objectives of the study were as follows:

1. To assess the factors influencing the adoption of rainwater harvesting ponds among the small scale farmers in Rwanda
2. To evaluate the impact of rainwater harvesting ponds on the farm income of the small scale farmers in Rwanda.

1.4. Hypotheses of the study

The hypotheses tested in this study were:

1. Household endowment with physical assets does not affect farmer's decision to adopt the rainwater harvesting pond.
2. Financial capital has no effect on decision to adopt rainwater harvesting ponds.

3. Group membership has no effect on decision to adopt rainwater harvesting ponds.
4. The use of rainwater harvesting ponds has no impact on the farm income of the small scale farmers.

1.5. Justification of the study

The modernization of agriculture is recognized as an essential part of Vision 2020 which is the development blueprint for Rwanda. The government is adopting strategies to increase agricultural production through better technologies that generate higher yields and income. Irrigation has been identified as a key strategic activity for achieving Vision 2020 (MINAGRI, 2009).Increased availability of irrigation water and less dependency on rain-fed agriculture is taken as a means to increase food production and self-sufficiency of the rapidly increasing population of the country. The Rwandese government is promoting lower, more cost efficient irrigation technologies that have a potential to increase and stabilize food production in Rwanda (MINAGRI, 2007).

Since their implementation in 2007, rainwater harvesting ponds are already serving the farmers hence there was a need to undertake an assessment of their potential in poverty reduction. Besides contributing to an understanding of how adoption of rainwater harvesting ponds would change the smallholder farmers' lives, this study will help policy makers to get information on how to take appropriate actions towards up scaling or reforming the rural development strategies. This would enhance smallholder farmers' accessibility to water harvesting technologies services which could potentially increase their income and their agricultural production.

1.6. Organization of the thesis

This thesis is organized in five chapters. Chapter 1 presents the introduction which includes statement of the problem, objective, and hypotheses. Chapter 2 provides a review of literature both on methodology and empirical studies. Chapter 3 presents the study methods. Chapter 4 discusses the results while chapter 5 presents the summary, conclusions and the policy implications

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CHAPTER 2: LITERATURE REVIEW

2.1. Theoretical review

2.1.1. Theory of Adoption

Some studies have attempted to highlight the economic theory underlying farmer behavior in decision-making over a new technology. Hagos et al, (2006) used household model based on utility maximization. Ali and Abdulai (2009) used production theory where a farmer has an objective to maximize profit. In order to adequately determine factors that influence farmers to adopt rainwater harvesting technology ponds:

Let the adoption of rainwater harvesting ponds be a dichotomous choice, where the new technology is adopted when the net benefits from choosing the technology is greater than not adopting the technology. The difference between the net benefits from adoption and non-adoption may be denoted as I^*, such that I^* > 0 indicates that the net benefit from adoption exceeds that of non-adoption. Although I^* is not observable, it can be expressed as a function of observable elements in the following latent variable model:

$$I_i^* = \beta Z_i + \mu_i , \qquad I_i = 1[I_i^* > 0] \tag{1}$$

where I_i is a binary indicator variable that equals 1 for household i in case of adoption and 0 otherwise, b is a vector of parameters to be estimated, Z_i is a vector of household and plot-level characteristics and μ_i is an error term assumed to be normally distributed. The probability of adoption of the new technology can be represented as:

$$\Pr(I_i = 1) = \Pr(I_i^* > 0) = \Pr(\mu_i > -\beta Z_i) = 1 - F(-\beta Z_i) \tag{2}$$

where F is the cumulative distribution function for li. Different models such as logit or probit normally result from the assumptions that are made on the functional form of F.

2.1.2. Theoretical underpinning of Impact assessment

Impact assessment is directed at establishing with as much certainty as possible, whether or not an intervention is producing its intended effects .There are two approaches to study the impact of a given project. These are the 'before and after' and the 'with and without' approaches. Before and after analysis compares the performance of key variables during and after the program, with those prior to the program (Heckman, *et al.*1998).

This approach uses statistical methods to evaluate whether there is a significant change in some essential variables over time. The approach often gives biased results because it does not take into account the effect of the confounding factors on the change. With and without comparisons compares the behavior in the key variables in a sample of program beneficiaries, with their behavior in non-program takings (a comparison group).

This is an approach to the counterfactual question, using the experiences of the comparison group as a proxy for what would otherwise have happened among the program beneficiaries. Impact evaluations are technical exercises that rely on econometric and statistical models. According to Baker (2000), there are three main kinds of impact evaluation designs. These are experimental, quasi-experimental and non experimental that try to establish alternative scenarios to represent the counterfactual. The basic issue is to represent the estimation of the impact as a treatment effects model.

Let Y_i^1 = outcome after treatment, and Y_i^0 = outcome without treatment,

Causal effect of i is given by:

$$Y_i = Y_i^1 - Y_i^0 \qquad (3)$$

Estimated (or average) causal effect is given by:

$$E(Y) = E(Y^1 - Y^0) = E(Y^1) - E(Y^0) \qquad (4)$$

It is however impossible to observe individual treatment effect since we do not know the outcomes for untreated observations when it is under treatment (Y_i^1) and for treated when it is not under treatment (Y_i^0).

Propensity score matching technique which is a non-parametric method proposed by Rosenbaum and Rubin (1983) therefore matches the two groups so as to create a plausible counterfactual. Specifically, it matches a treated individual with a control individual that is similar in all observable characteristics except the treatment and computes the difference in outcome variable. That difference is the impact of treatment (i.e. technology adoption).

Mathematically, the probability that an individual is treated given the observable variables can be expressed as:

$$P(x) = Pr[D=1|X=x] \qquad (5)$$

Where D=1 is the observable treatment and X is a vector of observable characteristics.

2.2. Empirical review

2.2.1 Economic profitability of rainwater harvesting technologies

From the literature, previous studies on rainwater harvesting technologies issues have shown mixed results from different countries.Some studies show that the use of rainwater harvesting technologies is profitable; other assessed the impact of a technology using PSM and also assessed factors influencing adoption rainwater harvesting technologies, but the methodologies applied and the results are not strictly similar.

Yuan *et al.* (2003) conducted a study on the economic feasibility of agriculture with rainwater harvesting and supplemental irrigation in the semi arid regions of Gansu Province in China and found that potato production using rainwater harvesting and supplemental irrigation is found to be the best alternative for cropping systems in the area. The study done by Senkondo *et al* (2004) in Tanzania, used Cost-Benefit model to analyse the impact assessment of RWH on agricultural production in semi-arid areas on three different crop (maize, rice, and onion) and found that return to labor for maize and onion production is significantly higher than that of rice production.

Other studies that show economic feasibility of rainwater harvesting technologies include; Tian *et al* (2003),who evaluated the economic feasibility of agriculture with rainwater harvesting in a semi arid region of china and Pandey (1991) conducted an economic analysis of water harvesting and supplemental irrigation in the semiarid tropics of India. These studies focused on the economic analysis of rainwater harvesting technologies and predicted the farmers' choice of irrigation technology and diffusion. However, they did not assess the factors leading to adoption.

2.2.2 Factors influencing adoption of rainwater harvesting technologies

Hagos *et al,* (2006), have made an impact assessment of small scale water harvesting ponds and wells on household poverty in northern part of Ethiopia. This study used OLS regression analysis tools with an objective of evaluating whether households with ponds and wells are better off compared to those without. It also explored the factors that explain household poverty level. The results showed that households with ponds and wells are not significantly better off compared to households without, even though they are comparable in essential household characteristics. A range of household characteristics, demographics, asset endowments and village level factors were found to be significant in explaining household poverty. However, when the dependent variable happens to be dichotomous logit model has an advantage to estimate probabilities that lies between the logical limit of 0 and 1 unlike OLS used in Hagos's study which leads to biased estimates. Therefore, the focus of the current study is to use a logit model to assess the factors influencing adoption of rainwater harvesting pond.

Amha,(2006) in Ethiopia, used a probit model to assess the determinants of households' adoption of rainwater harvesting technologies and found that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals) and homestead plots explained adoption statistically significantly. Moreover, results also showed that RWH has significant indirect impact on value of crop production through its effect on intensity of input use. Xue-Feng *et al,* (2007) assessed the determinants of adoption of rainwater harvesting tanks and supplementary irrigation technology (RHSIT) in the semi-arid Loess Plateau of China using a binary regression model and found that farmers' educational background, active labor force size, contact with extension, participation in the Grain-for-Green project, and positive attitudes towards RHSIT are some of the variables that have significantly positive effects on adoption of RHSIT, while farmer's age and distance from water storage tanks to farmers' dwellings have significantly negative correlation with adoption.

These findings of the above studies show that factors influencing adoption of rainwater harvesting technologies varies from one country to another, therefore the current study need to know what are the factors influencing adoption of rainwater harvesting technologies in a different agro-ecological zone like Rwanda.

2.2.2 Empirical impact assessment studies applying PSM

According to Ravallion (2006), there is a rapidly growing literature in estimating causal treatment effects and is applied in diverse fields where we have a treated group and a control group. Shiferaw *et al* 2010 applied propensity score matching in evaluating the ex-post impact of adopting groundnuts varieties on crop income and rural poverty in Uganda using cross-sectional farm household data.PSM was used as a treatment effect model to match the adopters and the non adopters. Their study found that adoption of improved groundnut technologies has a positive impact on crop income and poverty reduction.

Yemisrach (2010) used PSM to examine the impact of an input and output development intervention on input use, productivity, total net income, market surplus and market orientation of the participating households. The study found out that the intervention resulted in an increase in the use of input by the participating households. Owusu and Awudu (2009) investigated the impact of non-farm employment on farm household income and way out of poverty, using farm household data in Ghana employed PSM. They found that non-farm employment has a positive and effect on farm household income and a negative effect on the likelihood of being poor. They also found that Self-employment had much higher impacts than wage employment. However, the current study used also PSM and focused on assessing the impact of adoption of rainwater harvesting ponds on smallholder farm income in Rwanda.

CHAPTER 3: METHODOLOGY

3.1. Theoretical framework

3.1.1. Theory on adoption of rainwater harvesting technology

In order to assess the factors influencing adoption of ponds, it is assumed that the use of rainwater harvesting technology is a dichotomous choice; the new technology is adopted when the net benefits from using the technology outweigh those of not adopting the technology. The study assumes that the use of rainwater harvesting technology is expected to affect the demand for inputs such as fertilizers, improved seed, as well as yields and incomes. Following Ali and Abdulai (2009) and Okello et al (2012) to link the adoption decision with these potential outcomes, considered a risk-neutral farmer that minimizes the total cost of production which comprises conventional costs(costs of inputs used), subject to conventional constraints. The farmer chooses rainwater harvesting technology **I** to minimize the conventional costs. Algebraically this can be expressed as,

$$\text{Min } C(\mathbf{WX}) \tag{6}$$

Subject to a production function specified as:

$$Y(X) = Y(\mathbf{V}, \mathbf{I}(\mathbf{T}), \mathbf{L}, \mathbf{K}, \mathbf{z}) \tag{7}$$

where C is the total input cost , **W** is a vector of input prices, **X** is vector of all production inputs, Y is the output produced and sold (as a result of using rainwater harvesting technology among other inputs), **V** is a vector of conventional variable inputs such as, fertilizer, seed, and pesticides used by the farmer, **I** is irrigation water whose use embodies the use of rainwater harvesting technology **T**, **L** is the total labor requirement including both family and hired labor, **K** and **z** are fixed and quasi-fixed capital inputs and institutional factors, respectively.

The farmer's optimization problem is therefore to choose **I** that minimizes the total cost of production subject to a given quantity of output Y_o as expressed below. Stated differently, the farmer will decide to adopt rainwater harvesting ponds if doing so minimizes the total cost of production subject to a target output level. For computational ease, two inputs are used, and the production function is assumed to take the functional form;

$$Y = f(V, I(T)) = Y_0 = (V\ I(T))$$

$$\text{Min } C = W_1 V + W_2 I(T) \qquad (8)$$

Subject to:

$$f(V, I(T)) \geq Y_o \qquad (9)$$

We write out the lagrangian function for this problem as follows;

$$\ell = W_1 1\ V + W_1 2\ I(T) + \lambda(Y_1 o - f(V, I(T)))$$

(10)

and obtain the conditional factor demand for using rainwater harvesting technology.

The solution of the lagrangian function associated with the cost minimization problem yields, among others, I^* which is conditional input demand equation (associated with rainwater harvesting technology) as functions of output Y, input prices W, convectional variable inputs V, fixed factors K and institutional factors z. That is:

$$I^* = I^*(W, Y, V, K, z). \qquad (11)$$

Equation (11) above also gives the technology adoption function. It indicates that adoption of rainwater harvesting technology I is affected by, among others, factor prices (incentives), the fixed and quasi-fixed capital (capacity) and institutional factors. Some of the capacity variables could be farm specific while others are farmer specific.

3.1.2. Estimation of impact of rainwater harvesting ponds

Following Ali and Abdulai (2009), we model the impact of the adoption of new technology in small scale farming on household income as a linear function of explanatory variables (*Xi*) and an adoption dummy variable (R_i).

The linear regression model for assessing the impact of ponds on income can be specified as;

$$Y = \beta X_i + AR_i + \mu_i \quad \text{.......... (12)}$$

Where Y is the mean income of the household, R_i=1 if the technology is adopted and 0 otherwise. μ_i is the error term.

Whether farmers adopt or not is dependent on the characteristics of farmers and farms, hence the decision of a farmer to adopt is based on each farmer's self-selection instead of random assignment.

Assuming a risk-neutral farmer, the index function to estimate adoption is expressed as

$$R_i^* = \gamma X_i + e_i \quad \text{.......... (13)}$$

where R_i^* is a latent variable denoting the difference between utility from adopting U_{iA} and the utility from not adopting the technology (U_{iN}). The farmer will adopt the new technology if $R_i^* = U_{iA} - U_{iN} > 0$. The term γX_i provides an estimate of the difference in utility from adopting the technology ($U_{iA} - U_{iN}$), using the household and farm-level characteristics, as explanatory variables, while e_i is an error term. In estimating equations (12) and (13), it needs to be noted that the relationship between a new technology and outcome such as income could be interdependent. Thus, technology can help increase output and as such richer households may be better disposed toward the adoption of new technologies. Thus, treatment assignment is not random, with the group of adopters being systematically different. Specifically, selection bias occurs if unobservable factors influence both the error terms of the income equation (μ), and the technology choice equation (ε) , thus resulting in correlation of the error terms of the outcome and technology choice specifications. Hence, estimating equation (12) with ordinary least squares will lead to biased estimates. There are at least three strategies that can be used to control for this selection bias. These include implementing the Instrumental Variable (IV), the Heckman two-step method or employing a non-parametric estimator (propensity score matching) method.

The Instrumental Variable method (IV) consists of estimating a two-stage regression model. The method includes the use of an extra variable, known as the 'instrument', in the second stage that introduces an element of randomness into the assignment. Following the procedure yields an unbiased estimate. The main weakness of the IV approach, however, is that it will often be difficult to find a suitable 'instrument'. The instrument should influence the probability to be treated, without being itself determined by any confounding factors affecting outcome, i.e., without being correlated to the error term (Baker, 2000). Since this last condition is difficult to test, the choice of a valid instrument largely depends on intuition and economic reasoning. The difficulty of finding a suitable instrument, therefore, is the main drawback to the instrumental variable approach.

The Heckman two-step method has been widely employed in empirical literature to control for hidden bias or selection on unobserved variables. This method has the advantage of modeling for the differences in both the observed as well as the unobserved attributes of both the treated and control groups by the inclusion of the inversion of mills ratio as an extra regressor in the outcome model. The main drawback to this method is that, the selection estimators are dependent on the strong assumption that the hidden variables are normally distributed resulting to the questioning of the robustness of their results in literature employing both actual and simulated data (Ali and Abdulai, 2009).

The third method that can be used in solving the problem of selection bias is the use of non-parametric propensity score matching. Propensity score matching consists of matching treatment with comparison units (adopters versus non adopters) that are similar in terms of their observable characteristics. The model is suitable for addressing the problem of possible occurrence of selectivity or seletion bias. Selection bias arises when one wants to determine the difference between the participant's outcome with and without the technology. Under cross-sectional data it is not possible to observe both outcomes for a given individual simultaneously.

To evaluate the impact of having water ponds on income all observable characteristics have to be the same between the adopters which in this case is the treatment and the non-adopters which in this case will be the control (Ravallion, 2005). The expected treatment effect of household adoption is the difference between the actual income and the income if they did not adopt rainwater harvesting pond.

This is given as;

$$\mathbf{ATT} = \boldsymbol{E}\left(\boldsymbol{Y}_{1i} - \frac{\boldsymbol{Y}_{0i}}{\boldsymbol{P}_i}\right) \quad (14)$$

Where $\boldsymbol{Y_{1i}}$ denotes the income when i-th household adopts the technology,

Y_{0i} is the income of i-th household that does not adopt the technology, and

$\boldsymbol{Pi}$ denotes as the probability of observing a household adoption, 1=adopt, 0=otherwise.

ATT, so called conditional mean impact or Average Treatment effect on Treatment (ATT), is conditional on household adoption.

The mean difference between observable and control is written as;

$$D = E\left(\frac{Y_1}{P} = 1\right) - E\left(\frac{Y_0}{P} = 0\right) = ATT + \varepsilon \quad \text{.. (15)}$$

Where ε is the bias also given by

$$\varepsilon = E\left(\frac{Y_0}{P} = 1\right) - E\left(\frac{Y_0}{P} = 0\right) \quad \text{.. (16)}$$

The true parameter of ATT is only identified if the outcome of treatment and control under the absence of treatment are the same. This is written as:

$$E\left(\frac{Y_0}{P} = 1\right) = E\left(\frac{Y_0}{P} = 0\right) \quad \text{.. (17)}$$

In a regression framework, the treatment effects model is given by

$$R = a + bP_i + cX_i + e_i \quad \text{.. (18)}$$

Where P_i is a dummy variable that takes the value 1 if household i is treated and takes the value 0 otherwise. **Xi** is a vector of control variables such as farmer characteristics; **b** measures the impact of owning water pond on mean returns. Under the assumption of homogenous treatment effects, **c** identifies the average treatment effect as well as the treatment effect on the treated. Estimation of the average treatment effects on the treated (ATT) group using matching methods such as propensity score matching relies on two key assumptions. To ensure the credibility of the results of the propensity score matching technique, two key assumptions underlying PSM have to be fulfilled.

The first, the Conditional Independence Assumption (or confoundedness assumption), requires that the analyst should observe all variables influencing the adoption decision and outcome variables simultaneously. (CIA) implies that selection into the treatment group is solely based on observable characteristics. This is a strong identifying assumption but has to be met for the results of the PSM to be valid and reliable. Hence, checking the sensitivity of the estimated results with respect to deviations from this identifying assumption becomes an increasingly important topic in the applied evaluation literature.

The second assumption, known as the Common Support (or Overlap Condition), requires the existence of a substantial overlap between the propensity scores of treated and untreated units. If this assumption does not hold, it is impossible to construct a counterfactual to estimate the impact of the technology. The common support is the area where the balancing score has positive density for both treatment and the control units. No matches can be made to estimate the average treatment effects on the ATT parameter when there is no overlap between the treatment and the control groups. Implementing the common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al.*, 2002)

3.2. Empirical method

3.2.1 Discrete choice model

To assess the factors influencing the adoption of rainwater harvesting ponds among the small scale farmers in Rwanda which is the first objective of the study, farmers were asked if they had ever adopted rainwater harvesting pond. The response variable in this case is dichotomous (binary choice variable); includes a "yes" or "no" type (adopter or non-adopters) variable. Thus, the dependent variable in this case is binary; hence either Logit or Probit can be used. Both the Logit and Probit models estimate parameters using maximum likelihood. Probit assumes normally distributed error term whereas the Logit model assumes a logistic distribution of the error term.

Baker (2000) argues that the reason Logit model is often preferred to Probit is because of the consistency of parameter estimation associated with the assumption that error term in the equation has a logistic distribution. Thus the Logit model was used to estimate the probability of household adoption assigned to socio-economic characteristics. Following Maddala (1983, 2001), the probability, *p*, that a household adopts pond is given by:

$$P = e^{z}/1+e^{z} \qquad (19)$$

Where *z* is a latent variable that takes the value of 1 if the farmer adopted pond and 0 otherwise. Central to the use of logistic regression is the logit transformation of *P* given by *Z*

$$Z = ln\ (P/1-P) \qquad (20)$$

Where;

$$Z = Z\ (f, z, a) + \varepsilon \qquad (21)$$

f is a vector of farmer characteristics, *z* is a vector of farm level variables, ***a*** is a vector of asset endowment variables and ε is the stochastic term assumed to have a logistic distribution. The empirical model estimated contains the following variables (letters in parenthesis indicate related category variables from the conceptual model):

1) Farmer specific variables (*f*) = age, gender , title deed, household size
2) Farm specific variables (*z*) = distance to the input market, distance to the agric. extension office and farm size.

3) Asset endowment characteristics (*a*):

   a. Physical asset (income, current value of physical assets, access to credit)

   b. Human capital (education, experience)

   c. Social capital (group member).

Therefore, the probability of household adoption is estimated using the following implicit functional form:

P(X) = Adopt rainwater pond (age, gender, education level, distance to market, farm size, household size, credit access, distance to the agric extension agent, title deed, income, current value of assets, farming experience, group member) + e (22)

3.2.2 Propensity score matching

To address the second objective which is to assess the impact of rainwater harvesting ponds on farm income of the small scale farmers in Rwanda, propensity score matching was used.

Similar to the adoption models, the whole sample from the survey data has to be used in computing the propensity score. Baker (2000) gives the five steps to be followed in applying propensity score matching.

First the propensity scores are estimated using a discrete choice model. This is accomplished using a Probit or Logit model with maximum likelihood method with the latter being preferred due to the consistency of parameter estimates associated with the assumption that error term in the equation has a logistic distribution (Baker, 2000; Ravallion, 2001; Caliendo and Kopeinig, 2008).

In the second step matching algorithm is selected based on the data at hand after undertaking matching quality test. Matching is a common technique used to select control subjects who are matched with the treated subjects based on covariates that the analyst believes need to be controlled. There are several matching methods that can be applied and they include the nearest neighbour matching (NNM) method, the kernel-based matching (KBM), radius matching (RM) and Mahalanobis matching (MM) methods. Ali and Abdulai (2009) discuss these matching algorithms and the circumstances under which they should be used. Asymptotically, all matching algorithms should yield the same results. However, in practice, there are tradeoffs in terms of bias and efficiency involved with each algorithm (Caliendo and Kopeining 2005).

In this study nearest neighbor matching, radius matching and kernel based matching methods were used. Basically, these methods numerically search for neighbors that have a propensity score for non-treated individuals that is very close to the propensity score of treated individuals. NNM method is the most straight forward matching method. It involves finding for each individual in the treatment sample the observation in the non-adopter sample that has the closest propensity score, as measured by the absolute difference in scores (Baker, 2000; Caliendo and Kopeining 2005).

Several variants of the NNM have been proposed in the literature, including NNM matching with 'replacement' and 'without replacement'. In the former case, an untreated individual can be used more than once as a match, whereas in the latter case it is considered only once. Matching with replacement involves a trade-off between bias and variance (Smith and Todd, 2005). Allowing for replacement increases the average quality of matches but tends to reduce the number of distinct non-adopter observations used to construct the counterfactual mean, thus increasing the variance.

Kernel based matching is a non parametric matching estimator that uses weighted average of nearly or all of individuals in the control group to construct the counterfactual outcome depending on the choice of the kernel function. Weights depend on the distance between each individual from the control group and the adopter observation for which the counterfactual is estimated. One major advantage of this approach is the lower variance which is achieved because more information is used (Caliendo and Kopeining 2005). This weighted average is then compared with the outcome for the group of adopters. The difference between the two terms provides an estimate of the treatment effect for the treated case.

Radius matching is a variant of caliper matching suggested by Dehejia and Wahba (2002). NNM faces the risk of bad matches if the closest neighbour is far away. This can be avoided by imposing a tolerance level on the maximum propensity score distance (caliper). Hence, caliper matching is one form of imposing a common support condition. It avoids bad matches and raises the quality of matches. However, if fewer matches can be performed, the variance of the estimates increases. Applying caliper matching means that an individual from the comparison group is chosen as a matching partner for a treated individual that lies within the caliper (propensity range) and is closest in terms of propensity score (Caliendo and Kopeining 2005) .
The basic idea of RM as a variant of caliper matching is to use not only the NNM within each caliper but all of the comparison members within the caliper. A benefit of this approach is that it uses only as many comparison units as are available within the caliper and therefore allows for usage of extra (fewer) units when good matches are (not) available. Hence, it shares the

attractive feature of oversampling mentioned above, but avoids the risk of bad matches (Dehejia and Wahba 2002).

In the third stage of Baker's steps overlap condition or common support condition is identified. Implementing the common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al.*, 2002). According to Caliendo and Kopeinig (2005) the most straight forward way of identifying the common support condition is the visual analysis of the propensity score density distribution for both groups.

In the fourth stage the treatment effect is estimated based on the matching estimator selected on the common support region. Finally, sensitivity analysis is undertaken to check the strength of the conditional independence assumption identified. Sensitivity analysis is normally undertaken to check if the influence of an unmeasured variable on the selection process is so strong to undermine the matching procedure (Owusu and Awudu, 2009). According to Caliendo and Kopeinig (2005), the purpose of this last step of matching analysis is to test the sensitivity of results with respect to deviations from the identifying assumption, e.g. when there are unobserved variables which affect assignment into treatment and the outcome variable leading to a hidden bias. If the results are sensitive and if the analyst has doubts about the validity of the unconfoundedness assumption he should either consider using alternative identifying assumptions or combine PSM with other evaluation approaches. In addition to these, a major objective of propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters.

The balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case the matched comparison group can be considered as a credible counterfactual (Caliendo and Kopeinig, 2008).

Test robustness & unmeasured bias

To check if the matching procedure is able to balance the distribution of the relevant variables in both the control and treatment group, the basic idea of checking the matching quality is to compare the situation before and after matching and check if there remain any differences after conditioning on the propensity score.

Additionally, Sianesi (2004) suggests to compare the pseudo-R^2 before and after matching. The pseudo-R^2 indicates how well the regressors, X, explain the adoption probability. After matching there should be no systematic differences in the distribution of covariates between both groups and therefore, the pseudo-$R2$ should be fairly low. Furthermore, one can also perform an F-test on the joint significance of all regressors. The test should not be rejected before, and should be rejected after matching. To test the sensitivity of estimated treatment effects with respect to unobserved covariates we calculate Rosenbaum-bounds.

Rosenbaum bounds take the difference in the response variable between treatment and control cases. This is reported in percentages; it shows the critical levels of gamma, Γ, at which the causal inference of significant impact of treatment may be questioned. Gamma measures difference in the response variable between treatment and control cases. By considering the lowest critical value of sensitivity analysis, we can concluded the level at which unobserved heterogeneity would alter the inference about the estimated effects of treatment.

3.3 Variables included in econometric models

a) Dependent Variables

1. Adoption of ponds. This was a binary choice variable (1= Adopters, 0=Otherwise).
2. Input use per-acre. This was measured in monetary terms (value of purchased seed, manure, pesticide and fertilizer).
3. Household farm income per-acre. This was measured in monetary terms as the total value of crop and livestock income in 2011.The different crops produced and sold by farmers were vegetables and fruits including cabbage, amaranths, tomatoes, carrots, mangoes. Livestock was considered in the computation of farm income because rainwater harvesting ponds were used to water the animals. Income from livestock was obtained from the sale of milk and animals.

The justification of the explanatory variables included in the model is based on the past studies and innovation diffusion literature.

b) Independent Variables

The independent variables that were hypothesized to influence farmers' adoption and impact of ponds were categorized into three, namely farmer-specific, farm-specific, asset endowment.

i. Farmer specific variables

Age of the of the household head

According to previous studies, age of a household head in years indicate that age of the household head has a positive relationship with adoption of new technologies. Older farmers are likely to have more resources compared to the younger ones. However as a measure of experience age squared, has been found to have a negative relationship with technology adoption (Doss and Morris, 2001). This implies that at some threshold age, adoption of new technology is expected to decline. This may be due to risk adversity that increases with age, younger people are less risk averse and are more willing to make adjustments in their farming by adopting new technologies, unlike the older people. It was hypothesized that a negative correlation exists between age and adoption of the technology.

Gender: This variable was coded as a dummy variable, representing the sex of the household head (1=male,0=female).Doss and Morris (2001) have shown that gender plays a role in decision making regarding adoption of a technology. Generally, in Sub-Saharan Africa, men have greater access to productive recourses than women (Adesina *et al.*, 2001). It was therefore hypothesized that male headed households would adopt the technology more than their counterparts.

Household size: It was measured in number. According to Assefa (2006), since the adoption of the RWH technologies require large amount of labor, especially during construction and watering, household size was expected to have positive relationship with the farm household's decision to adopt RWH technology. Household was therefore expected to take a positive sign.

ii. Farm-specific characteristics

Distance to agriculture extension office

This continuous variable is measured in walking minutes. It was hypothesized that the closer proximity to extension officers (and hence more contact) would enhance adoption of the new technology. Closer proximity to the agricultural extension office would imply regular contact which could facilitate awareness and hence usage of the technology.

Distance of the farm to the nearest input market

It is a continuous variable that is measured in walking minutes. Proximity to market creates access to additional income by providing opportunities of selling agricultural products and easy access to inputs and transportation. It was, therefore, expected that households nearer to market center would have better chance to adopt the new technology than those far away from market centers. Proximity to market centers was hypothesized to have a negative influence on household's decision to adopt the new technology.

iii. Asset endowment

a) Physical capital

Current value of assets and household income are a proxy for the household's wealth. Ngugi et al., (2002), observes that although the determination of the influence of the value of assets may be ambiguous *a priori,* ownership of such assets as ploughs and oxen reduce the demand for human labor, hence promote adoption. In this study, a positive correlation between the value of assets and adoption of the new technology was hypothesized. Income was conceptualized to affect the likelihood and intensity of adopting ponds. To take care of big numbers, the study used natural logarithm of these variables.

b) Human capital

Education level of the respondent

It was measured in years of formal learning. Based on previous studies, education level of farmer was expected to have a positive relationship with the decision to adopt a new technology. According to Okello (2009), it was expected that farmers with more years of education would be able to understand the benefits of such new technologies. Education was therefore expected to take a positive sign.

Farming experience

Farmers with longer farming experience are supposed to have better competence in assessing the characteristics and potential benefits of new technology than farmers with shorter farming experience. Moreover, farmers with longer farming experience were expected to be more knowledgeable and skillful. Therefore, this variable was expected to take a positive sign.

c) Social capital

***Group membership*:** Membership to farmer group is a social capital variable that was coded as a dummy variable (1= farmer group member, 0= Otherwise). Farmers form groups for collective action (pool resources together). Collective action affects adoption of new techniques of farming (Salasya et al., 1996).

3.4 Study area

Rwanda is comprised by 30 Districts, including Kirehe District, the study area. This district, which has a population of 292 215 and a surface area of 1225 km^2, is located at the south-east of the Republic of Rwanda at 133 km from Kigali capital. It shares with Tanzania, the eastern border of Rwanda. The Akagera river constitutes the natural limit between the District and Tanzania. In the south, Kirehe District also borders with Republic of Burundi and Tanzania. In the west the District shares border with Ngoma District and Kayonza District in north. Kirehe District has 12 administrative sectors; divided in 60 Cells. It is situated in an arid geographical area. The climate of the District is typically East-African plateau savanna climate. It is a tropical climate, where the temperature ranges from 20 to 24°C with a maximum of between 26 to 29 °C. The District of Kirehe, compared to the remainder of the Country, has a weak rainfall. Rains are very irregular and the rainfall varies between 800 and 900 mm.

The highest monthly rainfall is observed, generally during November-December and March - May periods. Monthly rainfall can reach 250 mm in these months, while the period of June to October is largely dry(KWAMP,2010). Low agricultural productivity caused by variation of rainfall has been endemic in Kirehe district. The high population density; poor climatic conditions and severe soil erosion have been considered as the major contributors to this scenario (MINAGRI, 2007).

3.5 Data collection and Sampling

This study used primary data collected from smallholder farmers located in Kirehe district. The district was purposively selected for the household survey on the basis of the difference in agro-ecology (low land) and was chosen over other districts because, unlike the others, it has a considerable number of rainwater harvesting ponds (up to 161). The study targeted farmers who had worked with rainwater harvesting project.

The aim of the project was to facilitate smallholder farmer to improve agricultural productivity and generate income through the use of rainwater harvesting technologies especially ponds. The respondents in this study were therefore stratified by adoption of rainwater harvesting ponds.

Multi-stage sampling procedure was used to select a sample of respondents for data collection .After selecting the district the next step was identifying sectors that have water ponds. From these sectors, cells were selected from which 18 villages were randomly selected and a list of all farmers registered to have adopted ponds was drawn with the help of Kirehe community-based Watershed Management Project (KWAMP) leaders and farmer leaders. A second list of farmers that did not adopt ponds was also obtained with the help of local administration (village elders and agricultural extension officers).Simple random sampling was then used to select 10 farmers (5farmers with ponds and 5without ponds) from each village. This procedure resulted in 90 farmers who have adopted ponds and 90 non-adopters. A total of 180 farmers were therefore interviewed in this study.

The data was collected through personal interviews using a pre-tested questionnaire. The data collected included farmer characteristics, household asset endowments, farm and use of runoff ponds. The household survey was conducted during March of 2012.

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter presents the descriptive and the econometrics results of the study. The first subsection presents the descriptive statistics; the second subsection discusses the results of the logit model showing the factors influencing adoption of rainwater ponds among the small scale farmers and eventually the last subsection discusses the impact of rainwater ponds on input use and farm income.

4.1 Descriptive Statistics

Table 1 below presents the characteristics of the households interviewed in this study. Of the 180 respondents, 89.4 percent were males while 10.6 percent were females. Of the sampled farmers, the mean age was 44.5 years while the mean household size was 5.9 members. Mean education of respondents was 4.7 years indicating that the farmers have relatively low levels of education. The low level of education has implications for the adoption of a new technology such as rainwater pond. Previous studies identify literacy as an important factor in the use of rainwater harvesting technologies due to their attitude and awareness regarding the new technology (Tesfay, 2008). The average years of experience in farming was 22 suggesting that the respondents had a lot of experience in agricultural production. Results also show that the mean distance to the nearest agricultural extension agent is 62.16 walking minutes, while the mean distance to the nearest input market is 52.51 walking minutes. Hence farmers have poor access to input and agricultural products and services. Results also show that 56 percent of the respondents belonged to at least one farmer group.

Table 1: Characterization of study households by adoption of ponds

Variables	Mean	Std. Dev
Dependent Variables		
Adoption (1=Adopter 0=Non-Adopter)	0.50	0.501
Household input use per acres(Rwf)	37135	32443.22
Household farm income (Rwf)	203752	2.56177E5
Independent Variables		
Farmer level variables		
Age in years	44	11.182
Gender of household head (1=Male 0=Female)	0.89	0.308
Received training on RWH technology(1=yes, 0=No)	0.49	0.50
Household size(number)	5.92	2.06
Own title deed	0.98	148
Farm level variables		
Distance to the nearest input market(walking minutes)	62.16	50.20
Distance to the nearest agric. extension office (walking minutes)	52.51	51.11
Land size in acres	3.97	5.34
Asset endowment		
Natural log of farm income	12.2126	2.64652
Natural log of non-farm income	6.5050	5.8971
Natural log of current value of assets	11.7501	1.38885
Access to credit(1=yes, 0=No)	0.43	0.496
Education (years)	4.77	2.219
Years of experience in farming	22.65	11.77
Group membership (1=Member 0=Non-member)	0.56	0.49

Note; exchange rate at the time of the survey was 1 US dollar = Rwf 609; N=180

Table 2 presents a comparison between households with and without rainwater harvesting ponds. It shows that the average household size between those with rainwater harvesting ponds is statistically significantly different from those without. The average household size for both groups is approximately 6, which is an indication of large households. Average education for households with ponds is slightly more than those without but the difference is marginal and not statistically different. The average age of the households in both groups is not substantially different with an approximate average of 44 years. Results also show that households with ponds have greater experience in farming compared to their counterparts. Table 2 also compares the average distances between different services including extension services, input market. There is no evidence of the differences in distances to these services probably because households with and without ponds were from the same village. Land size is an important factor in farming production since a bigger land size implies that a household is able to diversify to other agricultural production which includes livestock.

From Table 2, households with ponds have on average more land acreage than those without. The difference is statistically significant at 1 percent level of significance. Comparison of value of purchased inputs is also presented in Table 2 below. Households with rainwater harvesting ponds have a larger value of purchased inputs than those without. This difference is statistically significant at 1 percent level of significance. Asset endowment characteristics show that households with rainwater harvesting ponds are more assets endowed than their counterparts. Table 2 also presents a comparison of access to credit between the two groups of farmers. On average households with rainwater harvesting ponds have higher access to credit compared to those without rainwater harvesting ponds. However, this average is not substantially different.

Table2: Summary statistics of households with and without ponds in Kirehe district, Rwanda

Variable	Household with ponds (N=90)		Household without pond (N=90)		t-test of difference in means	
	Mean	std dev	Mean	std dev	t- stat	p value
Farmer-specific characteristics						
Age (years)	46.71	10.47	42.37	11.50	2.65	0.009***
Gender (1= Male , 0= female)	0.[illegible]	0.26	0.87	0.34	1.21	0.228
Receive training(1=yes, 0=No)	0.98	0.14	0.00	0.00	62.57	0.000***
Household size(number)	6.51	2.12	5.33	1.83	3.98	0.000***
Own Title deed (1=yes, 0=No)	0.98	0.14	0.98	0.14	0.00	1.000
Farm-level characteristics						
Distance to agric office agent(min walk)	51.66	48.85	53.36	53.53	-0.22	0.824
Distance to the market (min walk)	64.05	52.74	60.27	47.74	0.50	0.615
Total land size (acres)	5.21	6.70	2.74	3.05	3.18	0.002***
Total value of purchased inputs per acre(Rwf)	46650.23	31829.36	27620.28	30343.70	4.10	0.000***
Asset endowment characteristics						
Ln farm income	12.88	1.93	11.54	3.07	3.49	0.001***
Ln of non-farm income	7.17	6.08	5.83	5.73	1.52	0.130
Ln current value of assets	12.39	1.23	11.10	1.23	6.96	0.000***
Accessed credit(1=yes, 0=No)	0.46	0.50	0.40	0.49	0.75	0.545
Education (years)	4.86	2.30	4.69	2.14	0.50	0.616
Experience (years) in farming	24.10	11.98	21.20	11.43	1.66	0.099*
Group membership(1=yes, 0=No)	0.70	0.04	0.41	0.49	4.05	0.000***

Note: Significance of mean difference is at the *10 percent, **5 percent and ***1 percent levels

Note; exchange rate at the time of the survey was 1 US dollar = Rwf 609

4.2 Factors influencing farmers' adoption of ponds among the smallholder's farmers

Table 3 presents the results of logit regression model estimated to examine the factors influencing adoption of rainwater harvesting ponds. The likelihood ratio reported below indicate a very low p-value (i.e., 0.000) which implies that the model fits the data well. The results show that four factors condition the likelihood of adoption of rainwater harvesting ponds. As hypothesized, household endowment with physical assets significantly affects the decision to adopt rainwater harvesting ponds. Specifically, the marginal effects indicate that an increase in physical assets by 1 unit increases the likelihood of adoption of rainwater harvesting ponds by 0.207, other things being equal. Thus the null hypothesis that physical assets have no effect on adoption of rainwater harvesting ponds is rejected at one percent. This finding means that households with higher levels of assets endowment are more likely to adopt rainwater harvesting ponds than their counterparts and suggests that adoption of rainwater harvesting this technology can exclude poorer farmers.

The other factors that affect the decision to adopt rainwater harvesting ponds are household size, farm income and group membership. Results show that household size is positively related to the farmer"s likelihood of adopting rainwater harvesting ponds. The coefficient on household size had the expected positive sign and is statistically significant at 5 percent. This means that larger households (i.e., those with more family members) are more likely to adopt rainwater harvesting ponds, probably because they are able raise the labor needed to expand production under irrigated system.

The level of household farm income also has a positive and significant effect on the the decision to adopt rainwater harvesting ponds. The marginal effects indicate that a 1 % increase in the farm income increases the likelihood of the household to adopt rainwater harvesting pond by 15.1%, other things being equal. This finding suggests that farmers with financial endowment have higher probability of adopting rainwater harvesting ponds. The finding that households with higher levels of financial capital are more likely to adopt rainwater harvesting ponds than their counterparts further supports the earlier argument that adoption of rainwater harvesting ponds can exclude poor farmers.

Results further show that membership in farmer organizations also positively and significantly affect the probability of adopting rainwater harvesting ponds. This findings suggests that membership of a farmer in farmer organizations increases the capacity of the farm household to adopt rainwater harvesting ponds. This finding is in-line with those of previous studies Salasya et al. (1996) and Odendo *et al.* (2010) which indicate that collective action affects adoption of new techniques of farming. Other studies (Wambugu et al, 2010; Shiferaw et al, 2012) specifically indicate that membership to farmer organizations enables farmers to overcome some of the idiosyncratic market failures that can act as barriers to adoption of agricultural technologies.

Table 3: Factors affecting adoption of rainwater harvesting ponds: Logit regression results

Maximum likelihood estimates			Marginal effects	
Dependent Variable=1 if a farmer has adopted rain water ponds, 0 otherwise	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Independent Variables				
Farmer-specific characteristics				
Gender	0.199	0.767	0.049	0.765
Household size	0.219**	0.033	0.054 **	0.033
Title deed	-0.456	0.734	-0.112	0.726
Farm-level characteristics				
Distance to market	0.003	0.372	0.008	0.372
Land size	0.071	0.155	0.017	0.155
Asset endowment				
Ln farm income	0.151*	0.083	0.037*	0.083
Ln assets value	0.830***	0.000	0.207 ***	0.000
Credit access	-0.056	0.885	-0.014	0.885
Education	-0.052	0.546	-0.012	0.546
Farming experience	0.016	0.332	0.004	0.332
Group membership	0.646*	0.092	0.160*	0.084
Cons	-13.625	0.000		

*significant at 10% **significant at 5% and *** significant at 1%

Pseudo R2 0.2772
LR $\chi2$ (P value) 69.18 (0.000)
Hosmer-Lemeshow $\chi2$ (8) = 3.49 Prob > $\chi2$ = 0.9000

4.3 Impact of ponds on household's farm income and household's input use per acre

4.3.1 Estimating propensity scores and the common support condition

To assess the impact of adoption of rainwater harvesting ponds on the household's farm income and input use per acre, propensity score matching (PSM) technique was applied using STATA statistical package. The results of the initial step in PSM namely estimation of the propensity scores via a Logit model are shown in Table 4.

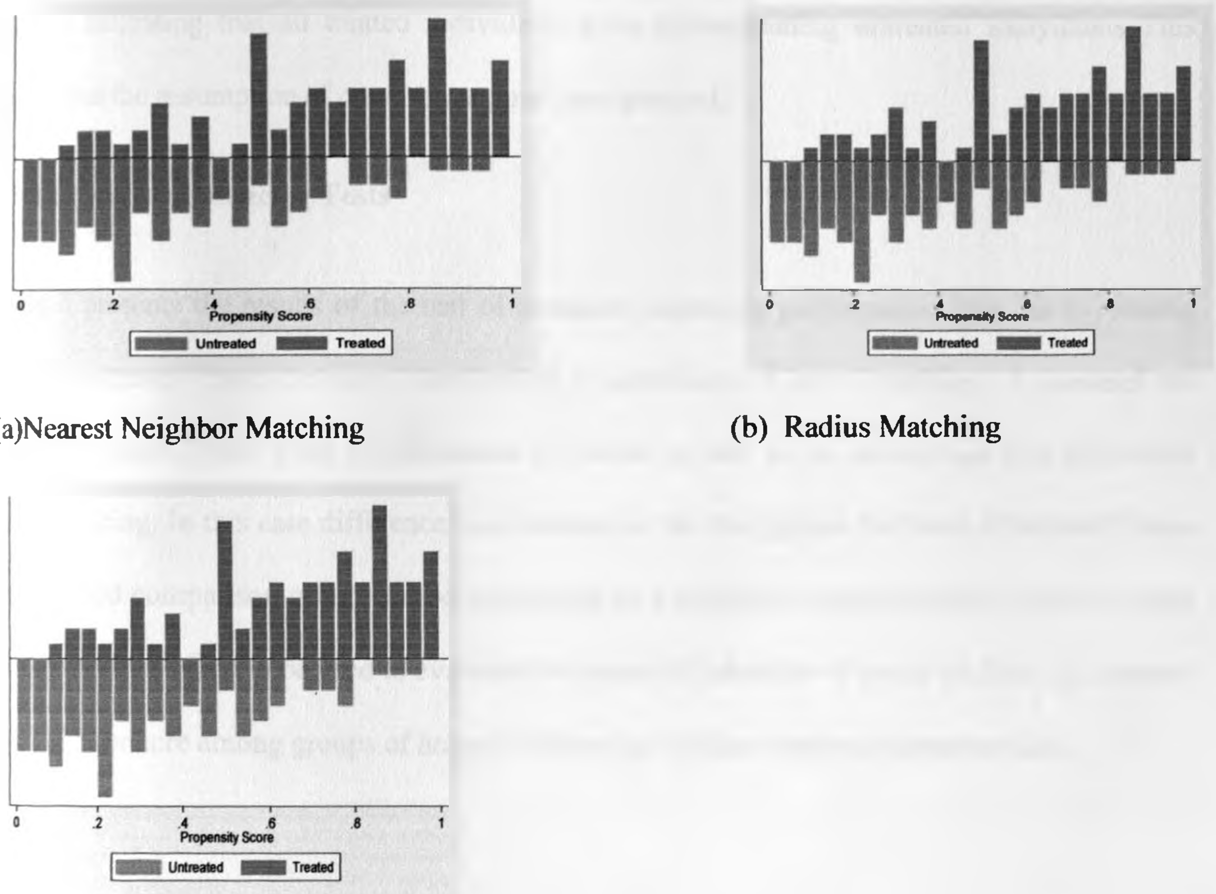
Table 4: Maximum likelihood estimates of the Logit regression used in estimating the propensity scores

Variable definition **Dependent variable** = Adoption of rainwater harvesting pond		
Independent Variables	Coefficient	p-value
Farmer specific variables		
Age	0.135	0.338
Age square	-0.001	0.416
Gender	0.247	0.704
Farming experience	-0.002	0.933
Farm specific variables		
Distance to nearest input market(minute walk)	0.002	0.489
Household size	0.179*	0.100
Asset endowment variables		
Natural log of current value of assets	0.841***	0.000
Credit access	-0.152	0.705
Land size (acres)	0.084*	0.097
Education	-0.027	0.742
Group membership	0.718*	0.057
Constant	-15.36	0.000
No. of observations: 180 Pseudo R^2 : 0.2695 p-value : 0.000 Log Likelihood: -91.147		

*significant at 10% **significant at 5% and *** significant at 1%;

The likelihood ratio test of goodness of fit has a p -value of 0.000 indicating that the model fits the data well. Furthermore results of the maximum likelihood estimation of the Logit show that household size, group membership and land size and current assets affect the likelihood of household's adoption of ponds. As such the individuals adopting rainwater harvesting ponds differ significantly from the non-adopters with respect to observable characteristics. Therefore comparing two groups as they are could have resulted in a selection bias and thus the need to correct for selection bias is in this case justified. Propensity score matching is one such technique that controls for such bias by reducing imbalances between covariates for both groups and making them comparable.

The density distributions of the propensity scores for adopters and non adopters are shown in Figure 1. The bottom half of each graph shows the propensity score distribution for the non-treated, while the upper-half refers to the treated individuals. The y-axis indicates the frequency of the propensity score distribution. Visual inspection of the density distribution of the propensity scores in both groups is the most straight forward way of checking the overlap and the region of common support between the treatment group and the comparison group. As indicated earlier, the treatment effects are only defined in the region of common support hence Heckman *et al.* (1997) argues that a violation of the common support condition is a major source of evaluation bias in conventional approaches. The graphs depict that there is a high chance of getting good matches and large number of matched sample size from the distribution as the propensity score distribution is skewed to the left for adopters and to the right for the non-adopters.



(a)Nearest Neighbor Matching

(b) Radius Matching

(c)Kernel Based Matching

LEGEND
Y axis = frequency of propensity scores

X axis = propensity scores

Figure1: Distribution of the propensity scores on the region of common support.

Source: Own calculation

From the graphs , all the treated and the untreated individuals were within the region of common support indicating that all treated individuals have corresponding untreated individuals This shows that the assumption of common support was attained.

4.3.2 Covariate Balancing Tests

Table 5 presents the results of the test of covariate balancing performed to test the hypothesis that both groups have the same distribution in covariates x after matching. It presents the covariates means, their t-test of differences in means as well as the percentage bias before and after matching. In this case difference in covariates in the two groups has been eliminated hence the matched comparison group can be considered as a plausible counterfactual. Therefore these results can authentically be used to evaluate the impact of adoption of ponds on farm income and input use per acre among groups of households having similar observed characteristics.

Table 5: Covariate balancing tests for propensity score; NNM, RM and KBM methods

		Nearest Neighbor Matching (NNM)					Radius Matching (RM)					Kernel Based Matching				
		Mean			%rdt	test	Mean			%rd	test	Mean		%	%rd	test
Variable	Sample	Treated	Control	%bias	|bias|	p>|t|	Treated	Control	%bs	|bs|	p>t	Ttd	Ctl	bias	|bs|	p> t
Age	Unmatched	46.7	42.3	39.5		**0.009**	46.7	42.3	39.5		**0.009**	46.7	42.3	39.5		**0.009**
	Matched	46.7	45.0	15.1	61.7	0.278	46.7	46.2	3.8	90.3	0.776	46.7	46.0	5.3	86.1	0.132
Age squared	Unmatched	2290.4	1925.7	34.4		**0.022**	2290.4	1925.7	34.4		**0.022**	2290.4	1925.7	34.4		**0.022**
	Matched	2290.4	2129.4	15.2	55.8	0.272	2290.4	2229.4	5.7	83.4	0.672	2290.4	2073.4	20.5	40.5	0.143
Farm exp	Unmatched	24.1	21.2	24.8		**0.099**	24.1	21.2	24.8		**0.099**	24.1	21.2	24.8		**0.099**
	Matched	24.1	22.6	12.6	49.2	0.389	24.1	22.4	14.1	43.1	0.329	24.1	22.4	14.2	42.5	0.334
Gender	Unmatched	0.9	0.8	18.1		0.227	0.9	0.8	18.1		0.227	0.9	0.8	18.1		0.227
	Matched	0.9	0.9	-8.3	54.3	0.492	0.9	0.9	-9.9	60.0	0.540	0.9	0.9	-5.7	68.4	0.492
Education	Unmatched	4.8	4.6	7.5		0.616	4.8	4.6	7.5		0.616	4.8	4.6	7.5		0.644
	Matched	4.8	4.7	6.5	13.2	0.663	4.8	4.5	14.0	51.8	0.350	4.8	4.7	3.6	51.8	0.807
Hhld size	Unmatched	6.5	5.3	59.4		**0.000**	6.5	5.3	59.4		**0.000**	6.5	5.3	59.4		**0.000**
	Matched	6.5	6.1	20.3	65.8	0.199	6.5	6.1	9.7	83.7	0.535	6.5	5.9	28.4	52.1	0.268
Credit	Unmatched	0.4	0.4	11.2		0.454	0.4	0.4	11.2		0.454	0.4	0.4	11.2		0.454
	Matched	0.4	0.4	10.7	14.0	0.472	0.4	0.4	10.1	10.0	0.501	0.4	0.4	13.2	17.6	0.378
Dist.mket	Unmatched	64.0	60.2	7.5		0.615	64.0	60.2	7.5		0.615	64.0	60.2	7.5		0.615
	Matche d	64.0	60.6	6.1	21.7	0.549	64.0	60.4	6.7	22.4	0.284	64.0	60.7	5.3	50.6	0.465
Current asset	Unmatched	12.3	11.1	103.8		**0.000**	12.3	11.1	103.8		**0.000**	12.3	11.1	103.8		**0.000**
	Matched	12.3	12.0	27.7	73.3	0.494	12.3	12.1	18.3	82.4	0.190	12.3	11.9	37.5	63.9	0.308
Grp Mshp	Unmatched	0.7	0.4	60.4		**0.000**	0.7	0.4	60.4		**0.000**	0.7	0.4	60.4		**0.000**
	Matched	0.7	0.74	-9.7	83.9	0.488	0.7	0.8	-10.1	86.7	0.490	0.7	0.7	-2.1	96.5	0.884
Land size	Unmatched	5.2	2.7	47.5		0.122	5.2	2.7	47.5		0.321	5.2	2.7	47.5		0.264
	Matched	5.2	3.4	34.1	28.3	0.254	5.2	3.6	30.7	35.5	0.415	5.2	3.4	33.6	29.3	0.327

(Figures in bold shows significant covariates)

As shown in Table 5, the matched sample means were almost similar for both the treatment and the control which was not the case prior to matching for all the 11 covariates. This means that propensity score matching adequately served the role of reducing imbalances between the covariates for both groups and that of selection bias and that the outcomes between the two groups can thus be compared with the matched covariates.

The second matching statistic employed to assess the quality of matching was the pseudo-R2 from the logit estimation of the conditional probabilities of adoption. The results in Table 6 indicate that the pseudo-R2 after matching was lower than before matching for all matching algorithms, as required (Ali and Abdulai, 2009). This implies that after matching there were no systematic differences in the distribution of covariates between adopters and non-adopters.
The p-values of the likelihood ratio tests indicate that the joint significance of the regressors could not be rejected at any level of significance before matching, however after matching the joint significance of the regressors were rejected. This further suggests that there was no systematic difference in the distribution of covariates between adopters and non-adopters after matching.

Together, the results of these tests imply that the matching procedure using PSM was able to balance the characteristics of the treated and the matched comparison groups. This in turn implies that the comparison group is a credible counterfactual and also indicates the absence of bias. Hence the computed estimates of the project impact (technology adoption) are valid given

Table 6: Other Covariate Balances Indicators Before and After Matching with NNM, RM and KBM.

Matching algorithm	Mean std bias before matching	Mean std bias after matching	Pseudo - R^2 unmatched	Pseudo - R^2 matched	p-value Unmatched	p-value matched
Nearest Neighbor Matching	37.6	15.3	0.270	0.079	0.000	0.310
Radius Matching	37.6	17.4	0.270	0.067	0.000	0.119
Kernel Based Matching	37.6	15.4	0.270	0.052	0.000	0.292

4.3.3 Treatment effect (impact)

The impact of adopting ponds on household farm income and household input use per acre was computed using three matching methods namely, the nearest neighbor matching (NNM), radius matching (RM) and kernel based matching (KBM).The results from all three matching approaches indicate that adoption of water ponds had a positive and significant effect on level of household farm income and household input use per acre.

The average treatment effect on the treated (ATT) of household farm income was Rwf 90985(US$149).The amount is significantly higher than what is realized by the non- adopters at 5 percent with Nearest Neighbor Matching technique, Radius and Kernel Matching techniques. The null hypothesis that use of rainwater harvesting pond has no effect on farm income was therefore rejected at 5 percent level of significance.

Table 7: Impact of adopting pond on household farm income and input use per acre

Matching Algorithm	Outcome Variable	ATT	Number of treated	Number of control	Critical level of Hidden bias (Γ)
Nearest Neighbor Matching	Household input use per acre	19814.78*** (2.70)	90	90	2.00-2.05
	Household farm income per acre	90985.96** (2.45)	90	90	1.60-1.65
Radius Matching	Household input use per acre	21147.98*** (3.37)	90	90	2.2-2.25
	Household farm income per acre	87748.69 ** (2.05)	90	90	1.70-1.75
Kernel Based Matching	Household input use per acre	20141.28*** (3.32)	90	90	2.5-2.55
	Household farm income per acre	89409.45** (2.28)	90	90	1.45-1.50

Note: Numbers in parentheses are t-values. Values are significantly different from zero at ***1 percent, **5 percent and *10 percent level. Note; exchange rate at the time of the survey was 1 US dollar = Rwf 609

Results of the analysis of the impact of adopting ponds using NNM, RM and KBM indicate that the adoption of rainwater harvesting ponds has a positive effect on household farm income per acre. The NNM, RM and KBM causal effects were about Rwf 90985(US$149), 87748(US$144) and 89409(US$147) respectively. This implies that average household farm incomes per acre of adopters of ponds were higher than that of non-adopters.

In order to assess the pathway by which adoption of ponds affected household income, the study examined the effect of adopting ponds on input use as well. Results from NNM, RM and KBM show that the adoption of ponds increased household input use per acre by between Rwf 19814 (US$ 32) and Rwf 21147(US$ 35). This suggested that input use is higher among adopters of ponds than the non-adopters. As expected, adopting ponds increases use of purchased inputs.

Sensitivity tests on the results of this study were performed. The purpose of the sensitivity analysis is to assess whether inferences about adoption effects may be altered by factors not observed in the dataset (unobserved variables).Rosenbaum bounds (rbounds) test which tests the null hypothesis of no effect on the treatment effect for different values of unobserved selection bias was used. This test computes the gamma level which is defined as the odds ratio of differential treatment assignment due to an unobserved covariate.

From Table 7, the lowest critical value of sensitivity analysis in all the three matching algorithms was 1.45–1.50, whereas the largest critical value was 2.5-2.55.A gamma level of 1.45–1.50 for the adoption of rainwater harvesting ponds on farm income basically it implies that the unobserved variable would have to increase the odds ratio by 45 – 50 percent before it would bias the estimated impact, i.e. if the individuals that had the same characteristics (X vector) were to differ in their odds ratio of adoption of ponds by a factor of 45 to 50 percent then the significance of the estimated adoption impact on household farm income would be questionable. We therefore concluded that even large amounts of unobserved heterogeneity would not alter the inference about the estimated effects of use of ponds on level of household input use and household farm income per acre.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and conclusions

Water harvesting is increasingly seen as a strategy for enhancing agricultural productivity and boosting farm income in many drought prone areas. While extensive efforts are going on in constructing and providing smallholder farmers with water harvesting structures, such as ponds in Rwanda, there is limited knowledge of the factors that influence adoption of such structures and their impact on households' input use and farm income.

The study assessed the factors that influence adoption of rainwater harvesting ponds and impact of adoption of ponds on household input use and farm income in Kirehe district, Rwanda. The study used cross sectional data collected from 180 households in Kirehe district through personal interviews using pre tested questionnaires.

A binary Logit regression model was used to assess the factors influencing adoption of water ponds with the dependent variable taking the value of 1 for adopters and 0 for non-adopters. The study found that factors influencing adoption of rainwater harvesting ponds include household size, membership to a farmer organization (a proxy collective action), farm income and endowment with physical assets. The null hypothesis that household endowment with physical and financial assets does not influence farmer's decision to adopt the rainwater harvesting pond was rejected. Additionally, the null hypothesis that group membership does not influence farmer's decision to adopt the rainwater harvesting pond was also rejected.

The study also found that use of rainwater harvesting ponds had a positive and significant impact on level of household input use and farm income per acre. The null hypothesis that use of rainwater harvesting ponds has no effect on household farm income was therefore rejected.

The study concludes that the major factors driving the adoption of rainwater harvesting ponds are endowment with physical assets, farm income, membership to a farmer organization and household size .Further the use of rainwater harvesting ponds has a positive impact on household farm income per acre by about US$ 149. The positive impact of the adoption of rainwater ponds on farm income per acre occurs via increased in input use. Indeed, as results demonstrate, the use of rainwater harvesting ponds increases input use per acre by at least US$ 32.

5.2 Recommendations

The implication of these findings is that adoption of rainwater harvesting ponds presents a pathway for reducing rural poverty. The findings further imply that policies that target increasing farm incomes should promote participation of farmers in farmer organizations. The finding that impact of rainwater harvesting ponds occurs through increased use of purchased inputs suggest the need to develop the input (fertilizer, manure, improved seed and pesticide) markets in order to reduce the transaction costs so as to make such inputs more easily accessible to farmers. The finding that physical and financial asset endowments affect the adoption of rainwater harvesting ponds imply that there is need for policies and strategies that target the inclusion of poor farmers in adoption of rainwater harvesting ponds. In addition , in order to promote increased adoption of rainwater harvesting ponds and the inclusion of the poorer farmers, research and development interventions should be aimed at finding ways of reducing the cost of constructing the rainwater harvesting ponds and also of adopting the ponds. Finally, future research is needed to determine whether increase in income causes greater input use or vice versa. That is to determine the cause and effect in the findings of impact analysis

REFERENCES

Adesina, S.K., O. Idowu, A.O. Ogundaini, H. Oladimeji, T.A. Olugbade, G.O. Onawunmi & M. Pais, (2004). Antimicrobial constituents of the leaves of *Acalypha wilkesiana* and *Acalypha hispida*. Phytotherapy Res., 14: 371-374.

Ali and Abudulai (2010). The Adoption of Genetically ModifiedCotton and Poverty Reduction in Pakistan. *Journal of Agricultural Economics*, Vol. 61, No. 1, 2010, 175–192.

Amha R (2006).Impact assessment of rainwater harvesting ponds: the case of alaba woreda, Ethiopia. M.Sc Thesis, University of Addis Ababa, School of Graduate Studies.

Assefa (2006). impact assessment of rainwater harvesting technologies: the case of astbi womberta woreda, tigray, Ethiopia. M.Sc Thesis, University of Addis Ababa, School of Graduate Studies

Baker. J. (2000). Evaluating the Impact of Development Projects on Poverty. "A handbook of Evaluation".*The World Bank Economic Review* 15(1): 115-140

Becker, S. O., and Ichino, A. (2002). Estimation of Average Participation Effects on Propensity Scores. *The Stata Journal*, 358-377.

Bryson A., Dorsett R. and Purdon. S. (2002).The use of propensity score matching in the evaluation of labour market policies. Working Paper No. 4, Department for Work and Pensions.

Caleindo M. and Kopeinig. S. (2005). Some Practical Guidance for the Implementation of Propensity Score Matching. IZA Discussion Paper, no. 1588. Bonn, Germany: IZA.

Caliendo M. and Kopeinig S.(2008) . Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, Vol. 22, (2008),31–72.

CIMMYT. (1993). The Adoption of Agricultural Technology: A Guide for Survey Design. Mexico, International Maize and Wheat Improvement Center.

Dehejia, R.H. and Wahba, S. (2002). Propensity score matching methods for non experimental causal studies. Review of Economics and Statistics 84(1): 151–161.

Doss, C. and Morris, M. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agric. Econ. 25: 27–39.

Faltermeier, L. and Abdulai, A.(2009).The impact of water conservation and intensification technologies: Empirical evidence for rice farmers in Ghana, Agricultural Economics, Vol. 40, pp. 365–379.

FAO, (2009).Transboundary Agro-ecosystem Management Program for the Kagera River Basin(Kagera TAMP).

Greene H. W. (2003). Econometric Analysis: Pearson Education Inc. New York University

Guijt I. and Thompson J.(1994).Landsape and livelihoods: environment and socioeconomic dimension of small scale irrigation land use policy 11 294-308

Gujarati, D.N.(1995). Basic Econometrics. 4th Edition. Tata McGraw-Hill, New York.

Hazell(2009).The Asian Green Revolution. IFPRI Discussion Paper 00911.Washington,D.C

Heckman, J, Hidehiko, and Todd P .(1998). Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a job training program, *Review of Economic studies* 64:4, 605-654.

Huhua Cao, Xue-Feng H, , Feng-Min L.(2007). Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China.

IFPRI (2002). International Food Policy Research Institute, Green revolution Curse or Blessing?

Krusema G., Zenebe A., Linderhof V., Afeworki M. and Girmay G .(2006). Impact of small scale water harvesting on household poverty: evidence from Northern Ethiopia.

Lee,Myoung_Jae.(2005).Micro-Econometricsfor Policy, Program and Treatment Effects.Advanced Texts in Econometrics. Oxford University Press.

Lire Ersado, G.S. Amacher and J. Alwang(2004).Productivity and land enhancing technologies in the northern Ethiopia: Health, public investment and sequential adoption, American *Journal of Agricultural Economics*, 86(2):321-331.

Maddala, G.S. (1986). Introduction to Econometrics. London: Macmillan.

Maddala,A.S. (2001).Limited Dependent and Quantitative Variables in Econometrics.Cambridge University Press, Cambridge, UK.

Msangi, A. S. K., Xavery, P., Lazaro, E. A., and Hatibu, N. (2004). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-Arid Areas of Tanzania. *Journal of Applied Irrigation Science*, Vol. 39. No 1/2004, pp. 65 – 81. ISSN 0049-8602.

Mendola M.(2006). Agricultural technology adoption and poverty reduction: A propensity – score matching analysis for rural Bangladesh. *Food policy* 32 (2007) 372-393

MINAGRI(2007). Ministry of Agriculture and Animal Resources in collaboration with World Agroforestry Center(ICRAF), Agricultural Rainwater Harvesting Interventions (ARWHI)Manual Final Report. Published also by Hortfresh Journal, 17: 14-15.

MINAGRI (2009) Strategic Plan for the Transformation of Agriculture in Rwanda – Phase II. Final Report

MINIRENA (2009). Ministry of Lands, Environment, Forestry, Water and Mines Rainwater collection and utilization in Rwanda, Project completion report

Mintesinot Behailu, Mohammed Abdulkedir, Atinkut Mezgebu and Mustef Yasin(2004). Preliminary report community based irrigation management in the Tekeze basin: Impact assessment a case study on three small-scale irrigation schemes (micro dams).

Ngigi N.S.(2003).Rainwater Harvesting for improved food security: Promising Technologies in the Greater Horn of Africa Rainwater Partnership (GHARP), Lino Printers, Nairobi, Kenya.

NISR (2006) National Institute of Statistics of Rwanda: Comprehensive Food Security and Vulnerability Analysis (CFSVA) report conducted in March and April 2006.

Odendo, M., Obare, G., and Salasya, B., (2010). Determinants of the speed of adoption of soil fertility enhancing technologies in western Kenya. Contributed Paper presented at the Joint 3rd AAAE and 48th AEASA Conference, Cape Town, South Africa, September 19-23, 2010.

Okello, J., Ruth M.O., and Edith O. (2009). Awareness and the use of mobile phones for market linkage by smallholder farmers in Kenya,

OkelloJ, Gitonga Z., Kirui O., Njiraini W.(2012).Drivers of use of information and communication technologies by farm households: The case of smallholder farmers in Kenya.

Owusu A. and Awudu L.(2009).The impact of non-farm employment on farm household income and way out of poverty, using farm household data from Brong-Ahafo region of Ghana

Pandey, S.(1991). The economics of water harvesting and supplemental irrigation in the semiarid tropics of India. *Agriculture System.* 36, 207–220.

Ravallion. M. (2001).The Mystery of the Vanishing Benefits: An Introduction to Impact Evaluation. The World Bank Economic Review 15(1): 115-140.

Rosenbaum, P. R. (2002). *Observational Studies*. Second Edition. Springer-Verlag. New York.

Rosenbaum, P.R., and Rubin D.R.(1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects, Bometrika 70, 41-55.

Sadoulet, E. and A. de Janvry (1995). Quantitative Development Policy Analysis. Baltimore, Maryland, The Johns Hopkins University Press.

Salasya B, Odendo M, Odenya J.(1996).Adoption of Improved Sorghum Varieties and other Production Technologies in Busia District Kenya, Proceedings of the 5th KARI Scientific Conference.

Shiferaw, B., Kassie, M and Muricho. G.(2010). Adoption and impact of improved groundnut varieties on rural poverty. Evidence from Rural Uganda. Discussion paper May 2010,Enviroment for development.

Sianesi, B. (2004). An evaluation of the Swedish system of active labour market programmes in the 1990s. Review of Economics and Statistics 86(1): 133–155

Sisay Y.(2008). Determinants of smallholder farmers access to formal credit: the case of metema woreda, north gondar, Ethiopia. MSc Thesis, Haramaya University.

Smith R., Hildreth L., and Kimsey S.(2011). Evaluating the Economic Impacts of water harvesting in Burkina Faso. Ecosystem Services Economics (ESE) working paper series.Division of Environmental Policy Implementation paper N0 6.

Smith, J. A., and Todd, P. E.(2005). Does matching overcome LaLonde's critique of nonexperimental estimators? *Journal of Econometrics*, 125(1–2), 305–353.

Tesfay.H.(2008), Rain water harvesting in Ethiopia: Technical and socio-economic potentials and constraints for adoption in Wukro district. MSc Thesis, Wageningen University.

Tian, Y., Li, F.M., Liu, P.H.(2003). Economic analysis of rainwaterharvesting and irrigation methods, with an example fromChina. Agric. Water Manage. 60, 217–226.

Turner V.(1994).Increasing food production in Sub-saharan Africa through farmer managed small-scale irrigation development Ambio 23 524-6

Woodridge J.M. (2002). Econometric Analysis of Cross sectional and panel Data, MIT Press.

Yemisrach. G. (2010). Impact assessment of input and output market development interventions of the IPMS project: the case of Alaba and Dale Woredas, Snnprs, Ethiopia.

Appendix 1: Partial correlation test for multicollinearity

Control variables	Dst to the market	Dist to the agent	Farming experience	Gender	Age	Edcation	Group member	Farm size	Title deed	Credit access	Hhld size	Lncurval assets	Ln farminc	Lnnon farminc
Distance to the mkt	1.000													
Distance to the extension agent	**.568**	1.000												
Farming experience	.057	.049	1.000											
Gender	-.105	-.062	-.001	1.000										
Age	-.012	.014	**.713**	-.092	1.000									
Education	-.101	-.055	-.026	.076	-.124	1.000								
Group member	.071	.109	.021	.032	.035	.040	1.000							
Farm size (acres)	-.096	.099	-.100	-.005	-.056	-.048	-.143	1.000						
Title deed	.063	.033	-.001	-.052	-.006	.087	.018	-.126	1.000					
Credit access	-.110	-.192	-.050	.073	-.056	-.142	.059	.026	-.022	1.000				
Household size	-.050	-.053	.237	.143	.279	.051	.127	-.179	-.044	.069	1.000			
Lncurvalassets	-.161	-.150	-.116	.046	-.066	.150	.160	-.133	.049	.066	.073	1.000		
Lnfarminc	-.087	-.043	-.035	.173	-.129	.165	.160	-.192	.068	-.071	.016	.173	1.000	
LNnonfarminc	.098	.036	-.123	-.134	.051	-.053	.112	-.030	-.054	.268	.015	.258	.080	1.000

Appendix II: Variance inflation factor for continuous explanatory variables in the Logit

Variable	Variance inflation factor(VIF)
Age*	36.78
Distance to extension agent	3.21
Farming experience	4.85
Gender	7.50
Education	4.83
Household size	9.36
Credit access	1.84
Distance to market	2..36
Ln farm income	9.7 5
Ln assets value	6.80
Group membership	2.39
Land size	1.71

* Had the problem of multicollinearity since VIF >10 and hence was dropped

Appendix III: Questionnaire

Questionnaire No:			

SURVEY QUALITY CONTROL

Enumerator's name: ____

Date: __/__/____ Start time: __h __ End time: __h __

Approved: OK / NOT OK

Date entered: __/__/____ Entered by: ______________________________

1.0. GENERAL INFORMATION ABOUT THE HOUSEHOLD AND SITE IDENTIFICATION

1. Respondent name (in full) ____________________Phone number ________
   (Amazina yombi) *(Nomero ya telefoni)*
2. District/*Akarere*______________
3. Sector/*Umurenge*______________
4. Village/*Umudugudu*______________
5. Distance to the nearest main market centre ___ minutes' walk.
   (Mukora urugendo rungana gute kugera ku isoko riri hafi? (iminota ugenda n'amaguru.)
6. Name of market ____________
   (Izina ry'isoko ribegereye)
7. Type of road to main market centre[1] for selling produce and buying most of your agricultural inputs/*Ubwoko bw'umuhanda mukoresha iyo mujya ku isoko kugura cg kugurisha umusaruro wanyu* __
8. Quality of road to main market: [2] __
   Umuhanda ujya ku isoko umeze gute?
9. What is the distance to the nearest agricultural office agent ___ minutes' walk
   (Mukora urugendo rungana iki kugirango mugere kuri agoronome; iminota......)
10. Experience (years) in farming ___
    (Imyaka umaze mu buhinzi)
11. Did you participate in rainwater harvesting project? **1.** Yes **0.** No
    Waba warigeze ugira uruhare mu gikorwa cyo gukusanya/gufata amazi y'imvura?
12. If Yes to Q11.at what level is it? **1.** Individual **2.** Community
    Niba ari yego, icyo gikorwa cyari icyawe bwite cyangwa mwari mu ishyirahamwe?

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[1]. **Type of Road:** 1. Non-paved dirt road, 2. Paved dirt road, 3. Paved gravel road, 4. Paved asphalt (tarmac)
2. Quality of road: 1. Bad, but passable all year round *(Ni mubi ariko tuwugendamo buri gihe)*
2. Bad, and passable only parts of the year *(Ni mubi ku buryo tutawugendamo buri gihe mu mwaka wose)*
3. Good (all weather) *(Ni mwiza)* 4. Very Good (all weather) *(Ni Mwiza cyane)*

2.0 Household Composition and characteristics

Name of HH member (start with respondent)	Gender Codes A	Marital status Codes B	Age (Years)	Years of Education	Highest education level Codes C	Relationship to HH Codes D	Main Occupation Codes E	Secondary Occupation Codes E
Amazina y'abatuye mu rugo (Guhera k'urimo gusubiza)	*Igitsina*	*Yarashatse*	*Imyaka*	*Amashuri yize*	*Aho yagarukirije Amashuri*	*Icyo bapfana*	*Icyo Ukora*	*Akandi kazi ukora*
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								

Codes

Codes A	Codes B	Codes C	Codes D	Codes E
1. Male 0. Female	1. Married living with wife/husband 2. Married but wife/husband away 3. Divorced/separated 4. Widow/widower 5.Single 6. Other, specify………..	1.None 2.Primary 3.Secondary 4.University/college	1. Household head 2. Spouse 3. Son/daughter 4. Parent 5. Son/daughter in-law 6. Grand child 7. Other relative(grand- parent) 8. Hired worker 9. Adopted child 10.Other(specify)......	1. Farming 2. non farming(*Ubucuruzi*) 3. School/college child 4. Salaried employment(*Umwarimu)* 5. Other, specify………

3.0 Social Capital Endowment: Membership to farmer organizations/cooperative

1. Are you a member of farmer org/association? *Waba uri umunyamuryango w'ishyirahamwe ry'abahinzi?*		**1.** Yes **0.** No
2. Year first joined / *Wabaye umunyamuryango mu wuhe mwaka?*		
3. Functions of farmer organization/association. *Ishyirahamwe ryanyu rikora iki?* ***[Circle all that apply]***	**1.** Production and marketing(Seed production ,Farmer research group, Livestock(poultry, beekeeping) *Ubuhinzi n'ubworozi & ubucuruzi bw'ibikomokamo* **2.** Input access(Savings and credit, Input credit, Merry go round) *Ubucuruzi bw'inyongeramusaruro* **3.** Natural resource conservation(Soil & Water conservation, Tree planting/Nursery) *Gufata neza umutungo kamere(Ubutaka, amazi, amashyamba,...)* **4.** Welfare/funeral club *Ubusabane no gutabarana* **5.** Other (specify).................................... *Ibindi(bisobanure)*	
4. Does the group involved in rainwater harvesting activities? *Ishyirahamwe ryanyu ryaba rifite ibikorwa byo gufata/gukusanya amazi y'imvura?*		**1.** Yes **0.** No
5. If YES to Q4, list any activity involved*[Circle all that apply]* *Niba ari yego watubwira ibyo bikorwa?*	List **1.** Diging the pond *(gucukura ibidamu)* **2.** Lining up *(Gushyiramo igisashe mu kidamu)* **3.** Silt trap(icyobo kiyungurura amazi mbere yo kujya muri damu) **4.** Repair the pond *(gusana ibidamu)* **5.** Other(specify) *(ibindi/ bisobanure)*................................	

4.0. Household Farm assets other than Land

4.1. Does your household own any of the following assets? *Mu rugo rwawe mwaba mutunze ibi bikurikira?*

Asset name	Number currently owned	Year bought/built	Current value(RFW)
Izina	*Umubare*	*Igihe mwabiguze*	*Agaciro gifite*
1.Ox-cart /*Ikinyabiziga gikururwa n'amatungo*			
2.Chemical Sprayer(pump)/*Ipompu itera umuti ibihingwa*			
3.Wheel barrow/*Ingorofani*			
4.Bicycle / *igare*			
5.Motorbike /*ipikipiki*			
6. Plough/*Imashini ikoreshwa mubuhinzi*			
7. Harrow/ *Imashini ikoreshwa mu gutera intabire*			
8. Mobile phone /*telefone*			
9.Hoes/*isuka*			
10.Machete/*umupanga*			
11. Standard weighing scale/*Umunzani usanzwe*			
12. Store for farm produce/*ububiko bw'imyaka*			
13.Radio/radio cassette / *radiyo*			
14. Television (TV)) /*televisiyo*			
15. Water pump/*Ipompu y'amazi*			
16. Other (specify)/*ibindi sobanura*			

4.2 Land holding (acres) during 2011 planting seasons
Ubutaka wari ufite mu gihe cy'ihinga cya 2011

1. How much land do you own in acres? ....
Ubutaka bwawe bungana gute muri ari

2. Do you have a title deed for this land? 1. Yes **0.**No

Waba ufite icyemezo cya burundu cy'ubwo butaka bwawe?

5.0 Crop Production

5.1. Characteristics of crop production plots in the 2011 season / *Record for ALL crops in 2011 season [Record separately by variety]*

Plot code (number starting from nearest plot to house)	Crops grown (Codes A)	Crops Variety (Codes B)	Is it intercropped? Yes or No	Plot size (acres)	Plot ownership (Codes C)	Soil fertility (Codes D)	Soil depth (Codes E)	Soil type (Codes F)	Land slope (Codes G)
Kodi y'umurima	*Imyaka yahinzwemo*	*Ubwoko bw'Igihingwa yahinzemo*	*Imyaka yahinzwe ivanze?*	*Uko umurima ungana*	*Nyir'umurima*	*Ubutaka burera?*	*Ubujyakuzimu*	*Ubwoko*	*Ubuhaname bw'umurima*

Codes A	Codes B	Codes C	Codes D	Codes E	Codes F	Codes G
	1.Improved/*Indobanure* 0.Local/ *Isanzwe*	1. Owned/ *Ni uwanjye* 2.Rented/ *Ndakodesha* 3.Borrowed/*Narawutijwe*	1. Poor/ *Oya* 2.Medium /*Biringanye* 3. Good/ *Neza*	1. Shallow/*Hagufi* 2. Medium/*Hararinganiye* 3. Deep/*Ni harehare*	1. Black (loam)/ *Umukara* 2. Brown(sandy)/ *Ikigina* 3. Red / *Umutuku* 4. Grey (clay)/ *Ibumba*	1. Gently slope (flat)/ *Buhoro* 2. Medium slope/ *Biringaniye* 3. Steep slope/ *Cyane*

5.2. Crop production inputs and output in 2011 planting season *[Record separately by plots]*

Plot code (starting from plot nearest to house)	Plot size/*Ubuso* Acres	Crop grown/igihingwa **Code A**	Crop variety **Code B**	Purchased seed/(*imbuto yaguzwe*)			Fertiliser type 1 (DAP)*ifumbire yaguzwe*			Fertiliser type 2 (Urea)/*ifumbire yaguzwe*			Farm manure/ *imborera yaguzwe)*			Pesticides/ *umuti wica udukoko)*			Do you hire labour to do the treadling?	If you hire, what was the cost of irrigation	How many times do the labour do the treadling ?	Crop Output/ *umusaruro w'ibihingwa)*	
				Qty	Unit	Price	Qty	Unit	Price	Qty	Unit	Price	Qty	Unit	Price	Qty	Unit	Price	**Codes C**	RFW	Times/week	Qty	Units **Code D**
Rainy season																							
Dry season																							

Codes A	**Codes B**	**Codes C**	**Codes D**
[Use the CROP CODE sheet]	1. Improved 0. Local	1. Yes 0. No	1. Piece 2.Kg 3.Litre 4.Bag/*umufuka* 5. Wheelbarrow/ingorofani 6. Grams 7. Pick up/*ikamyonete* 8. Bunch/*umufungo* 9. Bundle/*Igitoki* 10. Head load/*ku mutwe* 11. Crate/*Agatebo* 12. Other (specify)……………

5.3. **How did you utilize the crops you harvested in 2011?** ***/umusaruro wavuyemo wawukoresheje iki?***

Crop type (Codes A)	Production/*umusaruro* (From last column Table 5.2)		Sales/*ibyagurishijwe*		Gift,title,donation,paid as wages/*impano watanze*		Price obtained/*Agaciro* (RFW)
Rainy season	Qty	unit Codes D	Qty	unit Codes D	Qty	unit Codes D	
Dry season							

Codes D 1. Piece 2.Kg 3.Litre 4.Bag/*umufuka* 5. Wheelbarrow/ingorofani 6. Grams 7. Pick up/*ikamyonete* 8. Bunch/*umufungo* 9. Bundle/*Igitoki* 10. Head load/*ku mutwe* 11. Crate/*Agatebo* 12. Other (specify)...............

5.4. **Household Food security indicators (January to December 2011)** *[Limit to staple crops only]*

	Beans/ *Ibishyimbo*	Maize/ *Ibigori*	Cassava/ *Imyumbati*	Banana s/*Ibitoki*
1. During which month did you harvest this staple crop **(Codes A)** *Ni mu kuhe kwezi weza bimwe muri ibi bihingwa?*				
2. Did your stocks of harvested crops from last season last household consumption need until the following season **(Codes B)** *Umusasuro wahunitse(wasaruwe mugihembwe cyihinga cyashize) waba warageze mu kindi gihe cyihinga?*				
3. If **NO** to **Q2** above, for how many <u>months</u> was the harvest enough to meet the household needs? *Niba ari OYA ni igihe kingana iki umusaruro waba waramaze (umusaruro wawumaranye ameze angahe)?*				
4. How much (kg) did you buy to meet the deficit? Waba waraguze umusaruro ungana iki kugirango ugere kuwundi musaruro wawe(Kg)?				
5. How much (kg) did you borrow or receive as gifts? Mugihe utarufite umusaruro wawe, waba wagurijwe cyangwa warahawe umusaruro ungana iki?				

Codes A						**Codes B**
1. January	3.March	5.May	7. July	9. September	11.November	1. Yes
2. February	4. April	6. June	8.August	10. October	12. December	0. No

5.5. **Rainwater harvesting technologies.** *[Circle the right answer]*

1. Are you aware of rainwater harvesting ponds? 1. Yes 0. No
(Waba uzi uburyo bwo gufata/gukusanya amazi y'imvura mu bidamu)

2. How did you first hear about it? 1. Neighbour 2.Radio 3. Extension agent 4.Newspaper 5.Others (specify)
Mwabimenye gute? Abaturanyi Radiyo Agoronome Ibinyamakuru (ibindi,sobanura)

4. Did you know the costs of installing rainwater harvesting pond? 1. Yes 0. No
(Waba uzi ikiguzi ko gushyiraho ikidamu cyo gufata amazi y'imvura)

5. How did you know it? 1. Neighbour 2. Radio 3. Extension agent 4. Asked to the project 5.Other (specify)....................
(Mwabimenye mute) (abaturanyi) (radiyo) (agoronome) (umushinga) (ibindi,sobanura)

6. Do you currently use rainwater harvesting pond? 1. Yes 0. No
(Kuri ubu mwaba mukoresha ubu buryo bushya bwo gufata no gukusanya amazi y'imvura)

7. If Yes to Q6, when did you start to use rainwater harvesting technology? 1. 2008/09 2. 2009/10 3. 2010/11 4.N/A
(Mwatangiye kubukoresha ryari)

8. What is the size (capacity) of the water pond? 1. 120 m^3 2. 250 m^3 3. 480 m^3
(Ikidamu mukoresha cyaba kingana gute)

9. Were you ever visited by an extension agent in 2011? 1. Yes 0. No
(Mwigeze musurwa na Agoronome muri 2011)

10. If Yes to Q9, give the number of extension contacts per month....................................contact/month
(Niba ari yego,abasura kangahe mu kwezi)

11. For what purpose do you use the water collected in pond? 1. Irrigation 2.Domestic use 3.Other (specify)................
(Amazi yakusanyirijwe mu kidamu muyakoresha iki) Kuvomera Ibihingwa Muyakoresha mu rugo Ibindi (sobanura)

12. If for irrigation, which crops do you grow using water from the pond? *[Refer to crop sheet A]* ______
(Niba ari kuvomera ibihingwa , ni ibihe bihingwa muvomera)

13. How long does the collected water last after rain stops? 1. 1month 2. 2 month 3. 3 month
(Amazi mwakusanyije yaba amara igihe kingani iyo imvura irikeyaho kugwa) Ukwezi kumwe Amezi abiri
Amezi atatu

14. What are the advantages of water ponds facilities? 1. Access to water 2.Reduce erosion 3. Increase yield
(Ese ni akahe kamaro ubona ibidamu byaba bifite) Kubona amazi Kugabanya Isuri Kongera Umusaruro
4. Increase income 5.Other (specify)................
Kongera inyungu Ibindi (sobanura)

15. What are the disadvantages of water ponds facilities? 1. Lack of land/*Kubura ubutaka*

(Ese ni izihe mbogamizi ubona ziterwa n'ibidamu) 2. Lack of access credit/ *Kubura inguzanyo*

3. Accident on animals and kids/ *Impanuka ku bana no ku matungo*

4. Demand high household digging and construction cost/ *Bisaba ingufu nyinshi mu gucukura n'amafaranga menshi kubyubaka*

5. Other (specify)/ *Ibindi (sobanura)*.............................

16. Have you ever received any kind of training on rainwater harvesting technology?
1. Yes 0. No
(Mwigeze muhabwa amahugurwa ku bijyanye no gufata no gukusanya amazi y'imvura)
17. If Yes to Q16, Please complete the table below for training in runoff ponds. *[Only for adopters]*

Items	Trained? /*Wahuguwe* Codes A	Are you applying the training?/*Gukore ibyo wahuguwemo* Codes A
1. How to dig *(uburyo bwo gucukura)*		
2. How to line up*(Gushyiramo igisashe mu kidamu)*		
3. How to silt trap*(icyobo kiyungurura amazi mbere yo kujya muri damu)*		
4. How to fence the pond *(uburyo bwo guzitira)*		
5. How to repair the pond(gusana ibidamu)		
6. Water lifting and application *(kuzamura amazi no kuyakoresha)*		
7. Water conservation*(kuyabika no kuyakoresha neza)*		
8. Other (specify) *Ibindi(Sobanura)*........................		

Codes A
1. Yes
0. No

6.0. **Livestock production activities/ *(ubworozi bw'amatungo)*** *[Record for January to December 2011]*

Livestock type	Stock at start of the year	Number sold during the year	Price /head **(RFW)**	Number bought during the year	Stock at end of year	Value of stoc at the end c year **(RFW)**
	Uko amatungo yanganaga umwaka utangira?	*Ayagurishijwe mu mwaka hagati*	*Amfaranga/ umubare*	*Ayaguzwe mu mwaka hagati*	*Uko amatungo yanganaga umwaka urangira/mu mpera z'umwaka*	*Agaciro amatungo yaw yari afi umwaka urangiye/mu mpera z'umwaka*
1. Cows / *inka*						
2. Calves / *inyana*						
3.Trainedoxen/*inkazihinga*						
4. Goats/ *ihene*						
5.Sheep/ *(intama)*						
6.Pigs/ *ingurube*						
7.Chicken/ *inkoko*						
8. Rabbits/ *urukwavu*						

7.0. Other sources of income (January – December 2011)

Sources	**Quantity**	**Unit(qty) Codes D**	**Price/igiciro (FRW)**	**Total income (FRW yinjiye)**
1. Milk*(amata)*				
2. Eggs*(amagi)*				
3. Other livestock product (specify...............................) *(ibindi bikomoka ku matungo nga organic manure,sobanura)*				
4. Rented out land/ *ubutaka bwakodeshejwe*				
5. Crop residues (e.g. stover)/*ibisigazwa by'imyaka*				
6. Rented out oxen for ploughing /*inka zakodeshejwe mu buhinzi*				
7. Off-farm labour income/ *indi myuga nku bwarimu*				
8. Non-farm agribusiness NET income (e.g., shop, tailoring, etc)/*Urwunguko rwavuye mu bindi bikorwa bitari ubuhinzi/ubworozi(urgero: iduka,ubudozi)*				
9. Pension income/ *imperekera y'izabukuru*				
10. Drought relief / *Imfashanyo igenerwa abagizweho ingaruka n'izuba*				
11. Remittances(sent from non-resident family living elsewhere) / *Yoherejwe n'umwe mu bo mu muryango ubaha hanze/ahandi*				
12. Marriage gifts (e.g., dowry) Frw /*yaturutse ku nkwano*				
13. Sale of own trees/timber/firewood, etc / *Kugurisha inkwi cg ibiti*				
14. Sale of communal resources (charcoal, bricks, stones, sand, etc)/*Mu kugurisha imitungo kamere (amabuye, umucanga,)*				
15. Other (specify)/ *Ibindi sobanura)*				

8.0 **Financial Assets and Sources of Credit.** *[Record for 2011 planting season]* Need and access to credit

Purposes for borrowing *(impamvu y'inguzanyo)*	Needed credit? **(Codes A)**	If YES, did you get it **(codes A)**	If you got **credit**, how much was it?	From where did you get the credit? **(codes B)**
1. Buying seeds/*kugura imbuto*				
2. Buying fertilizer/*kugura ifumbire*				
3. Buy other agricultural inputs/*Kugura ibindi bikenerwa mu buhinzi* (pesticide)				
4. Farm equipment/*kugura ibikoresho by'ubuhinzi(cement, isuka..)*				
5. Buying oxen for traction/*Kugura inka zihinga*				
6. Buy other livestock/*kugura amatungo*				
7. Invest in irrigation/*gushora mu bikorwa byo kuhira(ipompu, imipira)*				
8. Non-farm business or trade/*Ibikorwa bitari iby'ubuhinzi/ubworozi cg se ubucuruzi(kubaka ishuri)*				
9. Buying food /*kugura ibiribwa*				
10. Children's education/*uburezi bw'abana*				
11. Family Health/medical/ *Kwita k'ubuzima bw'umuryango*				
12. Buy land/*Kugura isambu*				
13. Improve your house/*Kuvugurura inzu*				

Codes A	Code B
1. Yes (yego) 0. No (oya)	**1** Commercial bank/*(banki y'ubucuruzi)* **2.** Rural micro-finance/ *(ibigo by'imiari iciriritse)* **3.** SACCO/ *(amashyirahamwe yo kubitsa no kugurizanya* **4.** Money lender/*(abaguriza amafaranga)* **5.** Merry go-round/*(ikimina)* **6.** Other, specify/*(ibindi,sobanura)*

14. Social obligations/*Inshingano z'umuryango(ubukwe,gutabara)*				
15. Other(specify)/*Ibindi (Sobanura)*				

Codes A	**Crop code Sheet**
1	Mangoes/ *imyembe*
2	Pawpaw/ *(papaya)*
3	Banana fruit /*imineke*
4	Avocado/ *Avoca*
5	Bananas/ *ibitoki*
6	Cabbage/*Amashu*
7	Carrots/ *icaroti*
8	Onions/ *ibitunguru*
9	Tomatoes/ *inyanya*
10	Sweet Peppers/ *pilipili*
11	Green beans /*imiteja*
12	Maize/ *ibigori*
13	Beans/ *Ibishyimbo*
14	Sorghum / *Amasaka*
15	Cassava/ *imyumbati*
16	Egg plant/ *ibiringanya*
17	Beetroot/ beterave
18	Amaranthus/ dodo
19	Bitter lemon/ citoro
20	Other(specify)

Thank you/*Murakoze*