Investment in irrigation as a poverty reduction strategy: Analysis of small-scale irrigation impact on poverty in Tigray, Ethiopia

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Abstract

The regional government of Tigray has invested in millions of Birr to develop irrigation schemes as a strategy of poverty reduction. The study was based on a representative sample of 613 farm households (331 irrigators and 282 non-irrigators) drawn using three stage stratified sampling with probability proportional to size. The main aim of this paper is to study the impact of irrigation on household income, therefore, to contribute to the scant literature on irrigation-poverty reduction nexus in Ethiopia, which policy makers can use it as an input to make informed policy decisions in their future endeavors. We found that farming income is more important to irrigating households than to non-irrigating households, while off-farm income is negatively related with access to irrigation. We also found that irrigating households' average income is above the regional average, while non-irrigating households' average income is 50 percent less than the average income of irrigating households. Although there can be other factors, which may contribute to the difference in income, these results are inline with our expectation and supports the decision of the Tigray government to use irrigation as a poverty reduction tool. We have used a stochastic dominance analysis and found that the results are consistent. This result differs from a previous study by Pender et al. (2002), which argues that irrigation has less impact in agricultural yields than expected, reducing returns to investment in modern irrigation.

Keyword: Tigray, Irrigation, Poverty reduction, Matching, Propensity Score

1. Introduction

Ethiopia is one of the poorest economies in the world (Hagos 2003) and Tigray is its poorest and most severely food insecure region as compared to the other regions of the country except to SNNPR (Federal Democratic Republic of Ethiopia (FDRE) 1999). Poverty reduction in Tigray is a core policy agenda of the Ethiopian government in general and the regional government of Tigray in particular. A general consensus was reached that an increase in agricultural production and poverty reduction should come mainly through agricultural intensification and adoption of technologies that improve soil moisture to use more productivity enhancing inputs. The use of productivity enhancing inputs (such as fertilizer and high yielding variety) depends much on availability of moisture in which case, investment in irrigation becomes crucial. Despite the role of irrigation in easing the effect of rainfall uncertainty on agricultural performance, Ethiopia in general having an immense irrigation potential, has remained dependent on rain-fed and less productive agriculture, which resulted in food insecurity and sever poverty. To this end, the Ethiopian government in general and the regional government of Tigray in Tigray has focused on rural investment on small-scale irrigation as a key poverty reduction strategy. Since the establishment of the Commission for Sustainable Agricultural and Environment Rehabilitation of Tigray (CoSAERT) in 1995, 54 micro-dams; 106 river diversion; and a number of spate irrigation projects were constructed with a total irrigation capacity of 3700 hectares benefiting 19,000 households (Abraha 2003). In addition to the government's effort, non-governmental organizations such as Relief Society of Tigray (REST), have invested in irrigation projects. According to Abraha (2003), a micro-dam project, to irrigate 100 hectares, is estimated to cost about 5.84 million Birr (1US$=8.65 Birr), while a river diversion project that can irrigate 45 hectares costs 1.17 million Birr, in which case investment per hectare is estimated at 58,390 and 25,896 Birr, in dam and river diversion projects, respectively.

In spite of the high optimism and the amount of resources committed to develop irrigation, Pender *et al* (2002), argued that in Tigray "irrigation has contributed to intensification of land use and to change in crop choice, but has been associated with less adoption of fertilizer and improved seeds and less improvement in yields than expected. As a result, it appears that the returns to investment in modern irrigation so far have been relatively low". On the other hand, given the experience that irrigation has been an enabling factor for the use of other productivity enhancing agricultural inputs (Dhawan 1988), and the high expectation from irrigation as anti-poverty program, the findings of Pender *et al.* (2002) seem to be paradoxical, which attract the attention of researchers, policy makers and financing agencies.

The existing literature and empirical studies dealing directly with irrigation-poverty linkage are not only dominantly of Asian origin, but they are few, recent origin and polarized. On the other hand, although there are many studies, which indirectly deal with the linkages of irrigation and household income as a proxy of household wellbeing or poverty, most of them are like a by-product of a general analysis of the phenomenon of agricultural growth and/or poverty (Saleth *et al*. 2003). Literature review pertinent to the linkages of irrigation-household income and poverty reduction is presented in the next section. In general, we note that there is a knowledge gap whether small-scale irrigation contributes to increase household income and poverty reduction. To our best knowledge, Hagos et al. (2006) is the only recent research output from Tigray which deals with the impact of small-scale water harvesting (ponds and shallow-wells) on household poverty. This study is the first of its kind anywhere in Ethiopia in addressing and comparing three irrigation systems (i.e., earth dam, river diversion and shallow wells) under different agro-ecological settings. Furthermore, it has made an effort to address the complete pathways and layers that could exist between irrigation and poverty reduction.

Accordingly, the main objectives of this paper are:

1) To study the impact of small-irrigation on household income in Tigray, so that policy makers can use the research outcome to make informed policy decision. To this end, we investigate irrigation's impact on household income. We also test whether irrigation has an effect on off-farm employment and income diversification.

2) This paper seeks to contribute to the empirical literature on irrigation-poverty reduction linkages, through a better understanding the pathways of irrigation-household income and poverty reduction from the experience of Tigray, Ethiopia.

To achieve the main objectives specified above, we develop an analytical framework that depicts the linkage between irrigation-household income and poverty reduction (see Figure 1). The framework shows how the linkage works between four inter-linked systems (which are: irrigation, socio-economic, household characteristics and agro-climatic systems).

The structure of the paper is as follows: section 2 reviews related literature, while in section 3; we describe the conceptual framework that captures the pathways. In section 4, we briefly discuss data, sampling procedure and the study area. Section 5, is dedicated to discuss the empirical method. In this section, we have discussed factors that determine participation; hence, we identify varibles that are used to match participants with non-participants. Furthermor, we have brifley discussed the advantges and limitations of PSM as an estimation method. We use section 6 to presents results and discussions followed by conclusion in section 7.

2. Literature review

Among the existing literature on irrigation and its impact on poverty reduction, some are based on empirical research, which focuses on specific locations. These types of literatures use primary or secondary data and are methodologically rigorous. On the other hand there are literatures, which are based on perceptions and logic based arguments (e.g Lipton and Litchfield, 2003;), while the third type of literature is based on project evaluation, which mostly is based on the interest of funding organization (Hussain and Hanjra, 2004). Among these, one of the studies that attempt to deal with irrigation poverty linkages is (Hussain and Wijerathna, 2004), which is a wide-ranging study that covers six major Asian countries (i.e., Pakistan, India, Bangladesh, China, Vietnam and Indonesia). Although highly aggregated and review based, Hussain and Wijerathna (2004) argued that irrigation reduces poverty both directly and indirectly, where the direct impacts are realized through labour and land augmentation effect that ultimately translates to improved productivity, employment, income and consumption, while the indirect impact is realized through enhanced local economy and improved welfare at macro level (Hussain and Wijerathna, 2004).

Regardless of the methodologies applied, most of the studies carried to investigate the impact of irrigation on poverty reduction are classified as comparative analysis, such as before and after, with and without or more or less comparisons Hussain and Hanjra (2004) is one of the descriptive/comparative type study, which attempts to study the irrigation-poverty linkage, and argued that access to irrigation reduces poverty. Furthermore, Hussain et al. (2006) has used primary data to make a comparative analysis of irrigation impact on household income in the marginal areas of Pakistan, where it concludes that small-scale irrigation is positively correlated with household income and then reduces poverty. Similarly, Bhattarai and Narayanamoorthy, (2003) has used both cross section and time series data to study the effect of investment in irrigation in poverty reduction in India, where they found that investment in irrigation as compared to investment in rural letracy was more effective poverty reduction instrument, but since they used a single equation and highly aggregated data it makes it difficult to capture the layers and linkages between irrigation, agricultural growth and poverty reduction (Saleth *et al.* 2003).

Furthermore, the success stories of China's food self sufficiency in the 1960s and 1970s, was attributed to a massive investment in irrigation (Huang et al., 2005; and Huang et al., 2006) implying that irrigation plays an important role in poverty reduction. Huang et al. (2005) has used household level cross sectional data to apply a multivariate analysis method, where it found a strong positive correlation between access to irrigation and household income, leading to poverty reduction and equitable income distribution.

As mentioned above, the literature on irrigation and its impact is polarized. For example, unlike to the above stated literature, different studies which manly used aggregated data (e.g., Rosegrant and Evenson, 1992; Jin *et al.,*2002; and Fan *et al.*,2000) have found negative and/or weak relationship between irrigation and agricultural productivity implying negative or no impact on household income and poverty reduction at large. According to Rosegrant and Evenson (1992), for example the effect of irrigation on agricultural productivity in India was found negative. Moreover, Jin et al. (2002) uses aggregated nation wide data of China's major crops but cannot find a relationship between irrigation and total factor productivity (TFP). On the other hand, Fan *et al*.(2000) has made a comparative analysis of impact of public expenditure in irrigation, research & development, road, education, electrification and rural telephone networking, where "investment in irrigation was found to have the least impact on both production and poverty alleviation" (Fan *et al*.,2000). Most of the studies that used aggregate data could not identify a positive contribution of irrigation to poverty reduction, implying that the direct effect of irrigation could be undermined by other factors which could have been observed at household and/or plot level.

In general, the lack of consensus regarding the linkages between irrigation and poverty reduction seems to mirror the general debate regarding the role of investment in agriculture. For instance, Christiaensen et al. (2006) argue that although the majority of poor people in developing countries, especially in Sub-Saharan Africa (SSA), depend directly on agriculture for their livelihood, there is no common view about the role of agriculture in economic development and poverty reduction. For example, the dual economy model inspired by Lewis in the 1950s, argue that resources have to be diverted from agriculture to the industrial sector, while a positive view that emerged in the early 1960s argue about investment in agriculture and its contribution to economic growth and poverty reduction is more than an equal amount of investment in non-agriculture (Christiaensen et al. 2006). The experience of the Green Revolution in Asia, where traditional agriculture was rapidly transformed substantiates the role of investment in agriculture in economic growth and poverty reduction (Christiaensen et al. 2006). Empirical evidences show that in areas where irrigation is widely used, agricultural yields and household income are higher, and less poverty and undernourishment are observed (FAO 2003). In the framework we made clear that the impact of irrigation comes through its multi-dimensional effect.

3. Conceptual framework

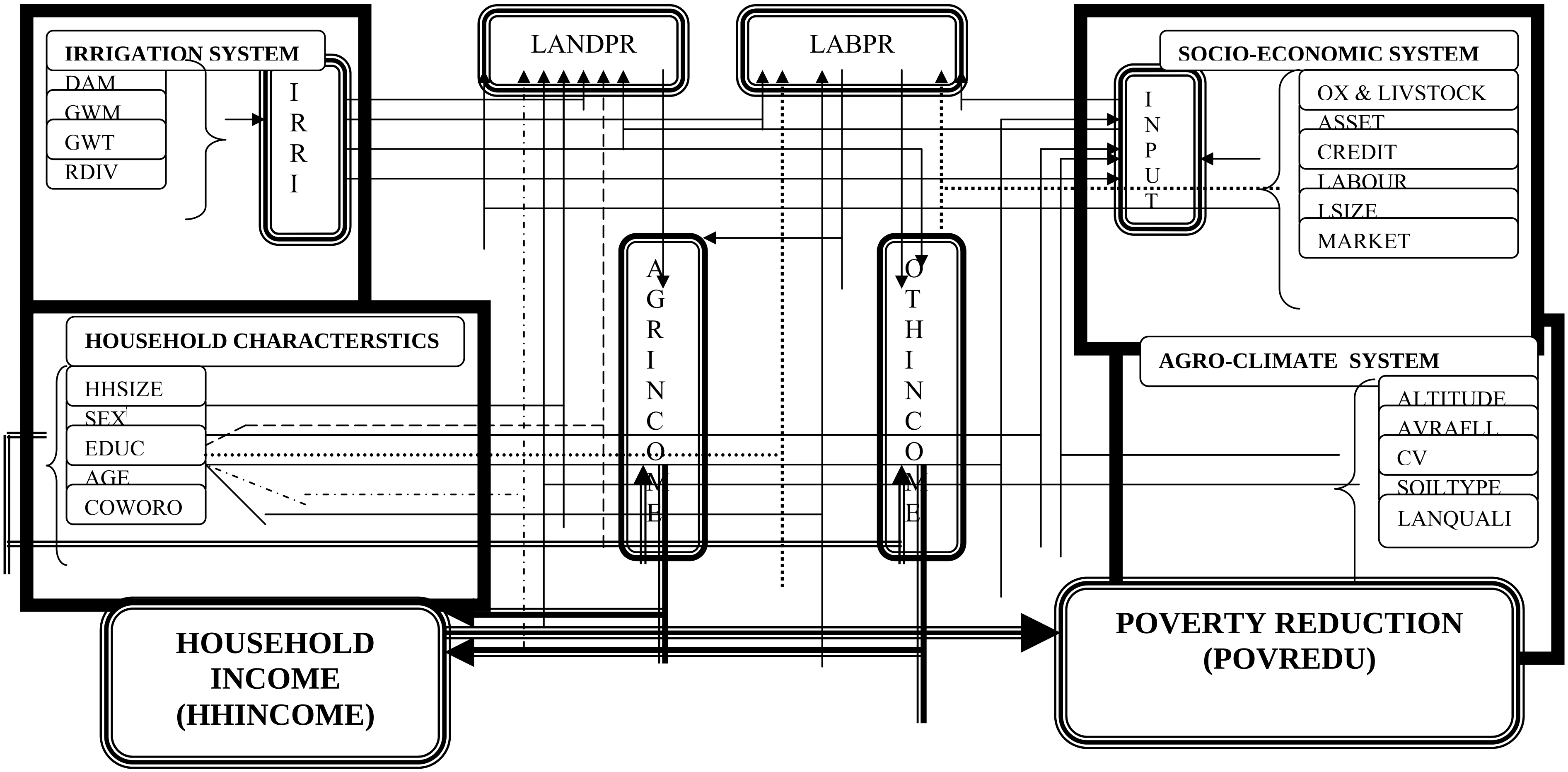
We hypothesize that irrigation had a significant impact on agricultural performance and poverty reduction in Tigray. We assume that the effect of irrigation on production is ultimately translated to household income and poverty reduction. Although it may differ from location to location and irrigation technology/system, the pathways through which irrigation can impact on poverty reduction are complex and diverse. Hence, if researchers and policy makers have to understand how irrigation affects poverty, it is essential to understand the complexity and diversity of pathways and linkages. Accordingly, we developed a conceptual framework (see Figure 1) as a guide to our research. Figure 1 illustrates the basic relationship capturing the major pathways and layers inherent in irrigation-poverty linkage, which helps to net out the impact of irrigation on poverty reduction. The framework makes clear that the impact of irrigation comes through its multi-dimensional effect, such as its effect in input use, crop intensity, land and labour productivity.

In rural areas where most of the people depend on agriculture for their food and income, water and food security are closely related (FAO 2003). In the framework, the impact of irrigation on household income and poverty reduction is captured through two major pathways (i.e., land and labour productivity). Irrigation enhances the use of agricultural inputs (such as fertilizer and HYV), which in turn improves the productivity of land and labor (especially, agricultural labor) ultimately resulting in high household income and poverty reduction. Such an agricultural performance could result either because of the input use effect or simply due to the external shock minimizing effect of irrigation.

For example, crop production in the highlands of Tigray requires more than 90 days (for vegetative and flowering), but usually the rain stays effectively for about 60 days (during July-August), where agricultural crops are grown once a year, therefore, farmers are not willing to invest in fertilizer and other agricultural inputs, because of the risk of crop failure. As a result agricultural productivity is low and poverty is high. FAO (1999) argued that higher productivity and production is associated with high input use, therefore, the main constraint to increase food production is limited uptake of new technologies by risk-averse farmers. The uncertainty caused by unreliable moisture availability is the main factor behind the risk aversion behavior of farmers. Since the exogenous component of production uncertainty is reduced with assured access to irrigation, we assume that production and income difference between irrigating and rain-fed households is observed even if there is no difference in input use.

Another dimension through which irrigation can impact on household income and poverty reduction is through its spillover effect. The economic integration (linkage) effect of irrigation on poverty reduction is important, but in most cases remains masked. As discussed above, irrigating households benefit directly through increased and stable income or because of the higher value of irrigated land. On the other hand, even landless laborers and small farmers who have no access to irrigation often benefit through higher wages, lower food prices and a more varied diet (FAO 2003). Therefore, in areas where there is irrigation project, we assume that more jobs and informal businesses (such as family based petty trade) are created. Since irrigation creates demand for small scale implements, credit, marketing and extension services, every job created due to irrigation may trigger another job in the non-agricultural sector. Figure 1 depicts the relationship between irrigation and poverty in more detail. The keys to the acronyms used in the figure are presented in table 1.

Figure 1 Impact of Irrigation on Household Income and Poverty Reduction: Irrigation-Poverty Linkages



4. Data and the study area

The data used in this paper was obtained from a survey made to study small-scale irrigation in the Tigray region, Ethiopia as part of a PhD study program. The study area covers six communities (*tabias*), each of which consists of about 4 villages. As presented in Figure 2, of the six sites, two each are in the southern and North-west zones, while the others are one each in Eastern and Central zone of Tigray; therefore, we believe that our data is representative of the region of *Tigray*.

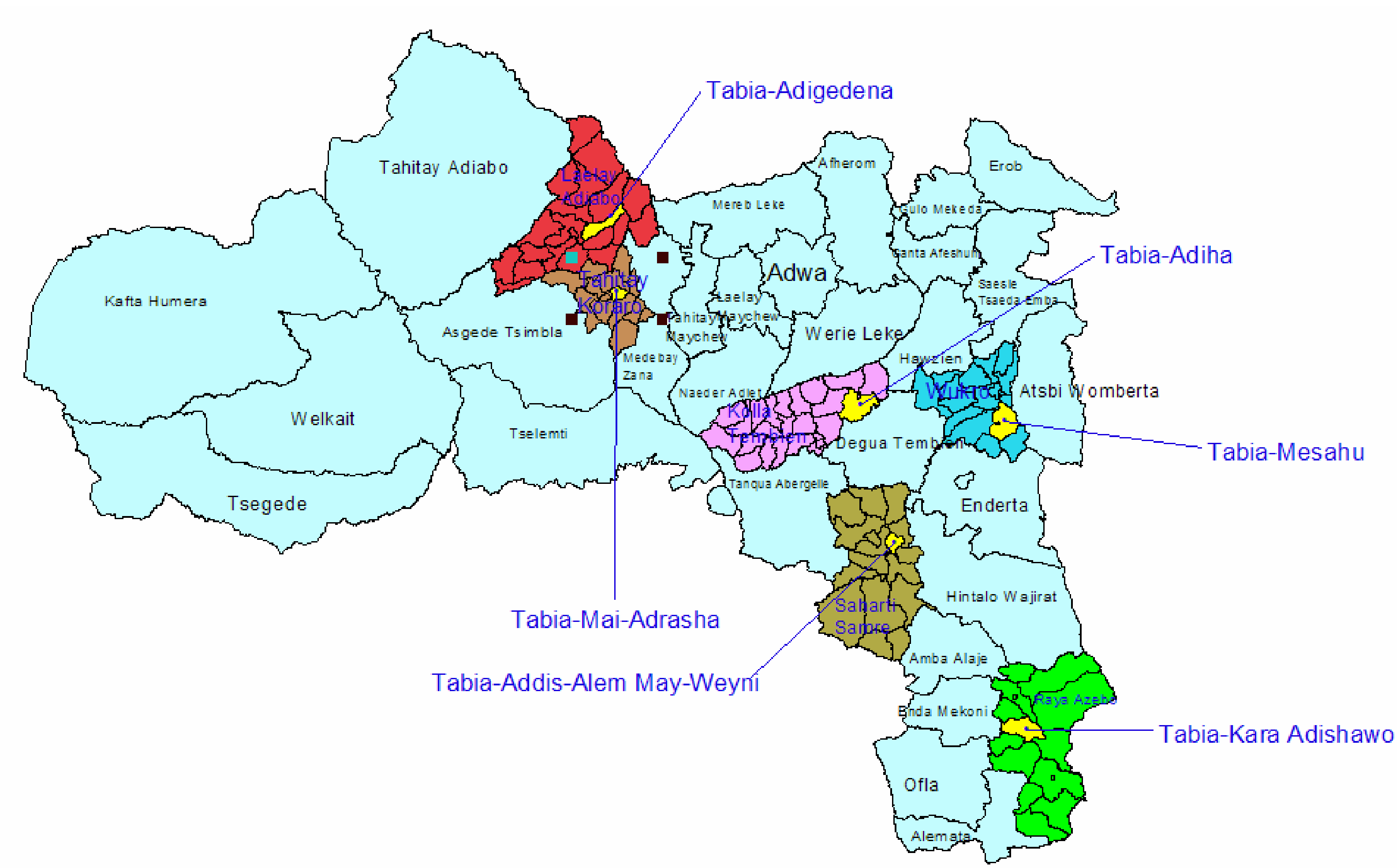


Figure 2: Map of Tigray, Ethiopia and study sites.

The sample selection process involved three stage stratified random sampling. First, all *tabias* in the region having irrigation projects were stratified based on the type of irrigation. Six sites were selected among which two of them use micro-dam, two river diversions and the rest two use ground water as a source of irrigation. Among the two ground water sites *Kara-Adi-Shawo* irrigation project located in *Golgol Raya* uses pressurized tube (drip/sprinkler) irrigation systems.

In the second stage, we stratified all farm households in each *tabia* based on their access to irrigation. Access to irrigated plot through any other means (such as formal or informal land rental contract) was not considered in the stratification process. Finally, we randomly selected 613 farm households (100 sample households from each of the five *tabias* and 113 households from *Kara-Adi-Shawo*). The proportion of sample households with and without access to irrigation mirrors the proportion of total households in the respective *tabia*. This approach enables us to collect information about non-irrigating households who are comparable in basic characteristics to the irrigators that can serve as counterfactual. From the total of 613 sample households, 331 of them had access to irrigation and 282 of them were purely rain-fed cultivators.

We asked our respondents about their household specific information. We have also collected data on farm input and output by asking each household head to recall his activities and production on a particular plot during the immediate past harvest year, that includes multiple cropping, especially in irrigated plots. Data collection was carried during October-December, 2005. Detailed plot level data was also collected. A plot is defined as a distinct management unit based on the type of crop planted during the 2004/2005 agricultural year. Plot size was not physically measured, but we ask farmers to tell us in local measurement unit (i.e., in *tsimdi)*. Four *tsimdi* is equivalent to one hectare. We have asked each respondent about the prices of input and output, but we have also randomly checked in the nearby market from which we calculated an average price for each product type in order to control the effect of price difference. The empirical method of analysis is outlined below.

5. Empirical Method

5.1. Estimation Method

The difficulty in impact evaluation is, identifying the comparison group (the counterfactual). To make an impact evaluation, we need to know what the outcome (in our case the income of households who actually have access to irrigation) would have been in the absence of irrigation (i.e., the counterfactual). Once the problem of identifying the counterfactual is resolved, the difference between the actual and the would be income is the impact of irrigation. However, since the counterfactual income is not observed, resolving such missing data problem requires feasible method of estimation that is based on economic theory. In other words, in studying the impact of irrigation, a methodological problem that is frequently observed is the tendency to assume every income and poverty difference observed between households with and without access to irrigation solely attributed to the irrigation factor (Dhawan 1988), therefore, to insure methodological rigorousness, estimating the counterfactual is at the core of impact evaluation (Baker 2000). In line with this, we used matching method to form a counterfactual against which comparison can be made. To analyze the impact of small-scale irrigation in Tigray, we consider irrigation as a treatment and rain-fed as a control. A dummy variable I is used to denote access to irrigation, where (I=1) if household i has access to irrigation, and (I=0) otherwise. Variables Y_1 and Y_0 represent household's income with and without access to irrigation, respectively. Subscripts 1 and 0 indicate income with and without access to irrigation, respectively. In line with this, the impact of irrigation on income of household i is given by:

$$\Delta_i Y = Y_{1i} - Y_{0i} \qquad [1]$$

For a household who have access to irrigation, we only observe Y_{1i}, while for those who have no access Y_{0i} is observed, implying that a household can not be in both situations at a, therefore, we only observe Y_{1i} or Y_{0i}, which can be written as:

$$Y_i = IY_{1i} + (1-I)Y_{0i} \qquad [2]$$

In Equation [2] if I = 1, (1-I) = 0, thus $Y_i = IY_{1i}$ and the reverse is also true. When we say impact, we mean the change in income due to access to irrigation, thus by rearranging equation [2], we get

$$Y_i = Y_{0i} + \Delta_i I \qquad [3]$$

If household i has no access to irrigation, I = 0, Δ_iI = 0, therefore, $Y_i = Y_{0i}$.

In summary, we draw three basic points about the whole process of examining the impact of irrigation. Firstly, the framework differentiates between outcomes (Y_{1i} and Y_{0i}) and impact (Δ_i). The former is simply about describing the outcomes (Y_{1i} and Y_{0i}), while the second is about impact (Cobb-Clark and Crossley 2003). Secondly, the analytical framework allows for heterogeneity in impact as well as in income (income without irrigation). This point is very important in an empirical impact study and differentiates the analytical framework adopted in this study from other models which assume homogeneity. The assumption of heterogeneity is important, because in practice, all households who have access to irrigation can not benefit equally due to heterogeneous characteristics. Thirdly, the framework is restrictive, because it assumes a Stable-Unit-Treatment-Value (SUTV). As explained in the second point, the impact of irrigation varies across households due to their heterogeneous characteristics, and it assumes that any impact is confined within that household which implies SUTV, thus it rules out the possible interaction effect, however, this may not be plausible assumption, because of the spillover effect of irrigation.

The assumption of heterogeneity is important to frame our analysis. According to Cobb-Clark and Crossley (2003), population average treatment effect (ATE) [E(Δ_i)] and average treatment effect on the treated (ATT) $\left[E\left(\Delta_i \middle| I=1\right)\right]$ are different, but are frequently estimated impact parameters, which can be specified as in equation (4) and (5), respectively.

$$ATE = E\left(\Delta_i\right) = E\left[Y_{1i} - Y_{0i}\right] = \left\{E\left[Y_{1i} - Y_{0i} \middle| I=1\right]\Pr\left(I=1\right)\right\} + \left\{E\left[Y_{1i} - Y_{0i} \middle| I=0\right]\Pr\left(I=0\right)\right\} \quad [4]$$

Since the objective of this paper is to estimate the average treatment effect on the treated (ATT), Equation (4) is irrelevant. Hence, the average effect of the treatment (irrigation) on the income of the treated (ATT) can be written as:

$$ATT = \left[E\left(\Delta_i \middle| I=1\right)\right] = E\left[Y_{1i} - Y_{0i} \middle| I=1\right] = E\left[Y_{1i} \middle| I=1\right] - E\left[Y_{0i} \middle| I=1\right] \quad [5]$$

The difference between equation (4) and (5) is that Equation (4) estimates the average treatment effect of irrigation on the income of the whole population irrespective of household's access to irrigation, i.e., E(Δ_i), while Equation (5) estimates the average treatment effect conditional on access to irrigation, i.e., E(Δ_i| I = 1), which is ATT. The most common evaluation context is one of ex-post evaluation, where we wish to know what change in outcomes an intervention delivered for those who were subject to the intervention (Cobb-clark and Crossley 2003).

ATT could have give a policy idea about the possible impact of irrigation if more investment is made to expand the program and more households get access to irrigation. However, the basic problem in estimating ATT is the missing data problem. For example, in Equation (5), $E\left[Y_{1i} \middle| I=1\right]$ is observed, while $E\left[Y_{0i} \middle| I=1\right]$ is missing. If we assume that the impact of irrigation is homogenous, it would imply that Equation (4) is equal to Equation (5), i.e., ATE = ATT. Thus the missed data would have been estimated by $E\left[Y_{0i} \middle| I=0\right]$ in Equation (4), because homogeneity assumes that $E\left[Y_{0i} \middle| I=1\right] = E\left[Y_{0i} \middle| I=0\right]$. However, since different households have different characteristics, they respond quite differently to the same treatment. Hence, the realistic assumption about the impact of irrigation is heterogeneity, which invalidates the possibility that the missed data $E\left[Y_{0i} \middle| I=1\right]$ in Equation (5) can be approximated by $E\left[Y_{0i} \middle| I=0\right]$ as in Equation (4). Therefore, the basic question is, how can we estimate the income of those households who actually have access to irrigation in the absence of irrigation.

One possibility to handle such a problem is to use the income of households who have no access to irrigation to estimate what the income of those households who have access to irrigation would have been in the absence of irrigation which can be written as:

$$E\left[\Delta_i \middle| I=1\right] = E\left[Y_{1i} - Y_{0i} \middle| I=1\right] = E\underbrace{\left[Y_{1i} \middle| I=1\right]} - E\underbrace{\left[Y_{0i} \middle| I=1\right]}$$

[6]

Observed Missing

If we use income of non-participating household to estimate the unobservable/missing data, equation (6) can be rearranged as:

$$E\left[\Delta_i \left| I=1\right.\right] = E\left[Y_{1i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]$$

[7a]

By subtracting and adding $E\left[Y_{0i}\left| I=1\right.\right]$ to equation (7a) we get

$$E\left[Y_{1i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right] - E\left[Y_{0i}\left| I=1\right.\right] + E\left[Y_{0i}\left| I=1\right.\right]$$

[7b]

By rearranging the above specification, we obtain

$$E\left[Y_{1i}-Y_{0i}\left| I=1\right.\right] + E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right] =$$

$$E\left[\Delta_i \left| I=1\right.\right] + \left\{E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]\right\} = ATT + BIAS$$

[7c]

Therefore, it is now clear that Equation (7c) suffers from bias because the income of households with and without access to irrigation would be different in the absence of irrigation, why identifying a counterfactual is the core of impact evaluation. While experimental design method is theoretically ideal for establishing a counterfactual, it is practically impossible, hence, it has been shown that non-experimental design methods, particularly the matching method is considered as the best solution in practice (Cobb-Clark and Crossely 2003). In Equation (7c), $ATT = E\left[\Delta_i \left| I\right.\right]$ and $BIAS = \left\{E\left[Y_{0i}\left| I=1\right.\right] - E\left[Y_{0i}\left| I=0\right.\right]\right\}$, therefore if a parametric regression method is applied, the assumption will be no selection bias in program placement, however, when the program is policy induced (such as placement to irrigation), it is purposive placement, then the outcome will depend on treatment status implying selection bias (Ravallion, 2005).

Specifically, matching is used to estimate the expected counterfactual $\left\{E\left[Y_{0i}\right], I=1, X_i = x\right\}$ using $Y_{0i}, I=0, X_i$ close to x drown from the households who have no access to irrigation, i.e., I =0 to serve as a comparison group for each household $\left\{E\left[Y_{1i}\right], I=1, X_i = x\right\}$ in the treated, i.e., I =1, therefore, the missing data is now estimable through the counterfactual as follows.

$$\Delta_i = Y_{1i} - E\left[Y_{0i}\right] \qquad [8]$$

But, since Equation (8) estimates homogeneous impact, while the heterogeneous impact (ATT) is estimated as:

$$ATT = \left[E\left(\Delta_i \left| I=1\right.\right)\right] = \frac{1}{I}\sum\left(Y_{1i} - E\left[Y_{0i}\right]\right)I = \frac{1}{I}\sum \Delta_i I \qquad [9]$$

5.2. Selection procedure of participants

When we embark on impact evaluation, especially when non-parametric method is employed, it is important to have clear understanding about the selection processes of project site beneficiary placement, administrative and institutional details of the program (Ravallion, 2005), both at household and plot level.

Accordingly, in Tigray, irrigation project sites were selected based on environmental and geological futures of the area, which includes: availability enough catchments area, sufficient reservoir, presence of sufficient command area, geological feasibility, short crust length. In the regional state of Tigray, it is a tradition to consult the community and make sure that the project is accepted by the community before construction is started. Moreover, priority is given to drought prone areas. Accordingly, since the site selection criteria are related to topographical issues, whether a plot is irrigated (treated) or not depends on factors, such as rainfall agro-ecology; slope of land, susceptibility to erosion, soil type and soil quality. Commonly, irrigation projects found in lowland areas with upstream catchments, therefore, we assume that plots that become irrigated are steep sloped, and those which are susceptible to erosion. Furthermore, because of continuous soil erosion and/or sediment accumulation that take place prior to project inception, potentially irrigable plots can be peroxide by their soil chrematistics.

The issue of household's access to irrigation (i.e., whether a household is treated or not) is relevant after the project is constructed. According to criteria used in the region, priority is given to farm households who get land within the command area before the project was constructed. The standard irrigated plot size is one tsimidi (i. e., 0.25 ha, that represents an area a farmer can plough with a pair of oxen within a day), hence, who had more than one tsimidi were lowered to one tsimidi considering that one tsimidi of irrigable land is equivalent to 2 or 2.5 tsimidi of rainfed land (depending on the availability of land in each community), however, in most of the communities, the withdrawal was done without compensation because of scarcity of land. Farm households who lost land because of water in the reservoir are the next beneficiaries to get the standard size of irrigable land in the command area. Finally, given that the command area allows (i.e., there is unoccupied irrigable land), additional farm households become beneficiaries among which poor households (i.e., who lacks livestock and have more family size) and female headed households get priority. Although small in number (49 households), we found that households can access irrigable land through land rental market. Accordingly, we used household head's sex, family size, female and male adult members of the household, plot size, a dummy variable for type of land rented in (1=irrigated, 0=raiinfed), number of plots owned by the household and dummy variable for ownership of land (i.e., whether the household has rented in land or not) as matching variables to estimate the propensity score. Usually, households with more family size, especially with more dependent are considered as poor in the rural areas of Tigray as elsewhere in Ethiopia. Plot number was used as matching variable, because it proxies the probability of having land in the command area and the probability of being considered as a poor. If a household owned more plots, the probability of having land in the command area is high, while the probability of being considered as poor to get access to irrigation is low. Although, livestock ownership was used as a selection variable, it is also an outcome of access to irrigation; hence, we opt not to use it as selection criteria.

5.3. Why Propensity Score Matching (PSM) Method?

In practice, participation in anti-poverty program cannot be randomly; hence, matching method is among the appropriate evaluation tools to assess the impact of such social programs. To apply the matching method, it is necessary to identify households from the non-participant group that is similar in terms of observable characteristics. However, in practice, since exact matching is rarely possible, because the observable variables based on which the counterfactual is estimated and individuals are matched can be many and different in dimensions making matching difficult, options for closeness in matching must be considered (Rosenbaum and Rubin 1985), hence, the Propensity Score Matching (PSM) method, which is based on the assumptions of conditional independence and common support, has been used as one method to solve the problem of dimensionality. The idea of estimating propensity score is used to balance households who have access to the treatment (irrigation) by choosing control households from those who have no access to the treatment (irrigation), but look like the treated households based on observable characteristics (Ho et al., 2007), therefore, are comparable to estimate the impact of irrigation. "The use of PSM relaxes the assumption of exogenous placement of anti-poverty programs, and it attempts to balance the distribution of observables, i.e., the propensity score" (Ravallion, 2005), therefore, unlike the much theoretic randomization, PSM emphasizes on the matching variables and on the quality and quantity of data

As compared to parametric models, PSM is preferred, because it relaxes randomization. Furthermore, its simplicity in relaxing the assumptions of functional forms that normally are imposed by parametric regression models, such as OLS is an advantage. "PSM allows the estimation of mean impacts without arbitrary assumptions about functional forms and error distributions. Furthermore, despite that regression models use full sample, PSM is confined to matched one (i.e., the region of common support), therefore, impact estimated with parametric models (i.e., based on full or unmatched samples) are more biased and less robust to miss-specification of regression functions than those based on matched samples."(Ravallion, 2005).

Finally, our study takes the advantage of having detailed survey data and full knowledge of the program. Our knowledge about the administrative and implementation procedure of irrigation schemes in the region helps us to identify proxy variables that determine program participation. We have collected a detailed data by administering the same questioner to both the participants and non-participants. The nearest neighbor and kernel matching methods were used to estimate the average treatment effect of irrigation on the treated (ATT). We have checked that the common support and balancing properties were satisfied in our data, hence, the remaining bias, if any, can be attributed to unobserved characteristics (Jalan and Ravallion, in press).

5.4. Limitations

There are three basic problems that confound impact evaluation in general, which includes: selection bias, spillover effect and data/measurement error (Ravallion, 2005) where our study is not exceptional. The main concern of non-parametric impact evaluation is whether the selection (placement) process to participate in the program is full captured by the control variables (Ravallion, 2005).

Since irrigation a policy induced program to reduce poverty, it is impractical to assume that participation could be random, hence, it should be emphasized that the concern about selection bias is that some of the variables that jointly influence income and access to irrigation are unobservable making it difficult to claim that the entire difference between the income of households with and without access to irrigation is attributed to irrigation (such a bias is specified in Equation 7c). This indicates that we can only minimize the level of bias. There are examples indicating that bias can be large in non-experimental impact evaluation among which (Lalonde, 1986; Glewwe et al., 2004; and Van de Walle, 2002) are few, but this does not mean that non-experimental impact evaluation methods can not be used(Ravallion, 2005).

The spillover effect is another methodological challenge of impact assessment, implying that eliminating selection bias by itself is not sufficient to identify the impact of treatment. The estimation method outlined in section 5.1 assumes that the presence of irrigation project in the community affects only those who have access to it (i.e., ATT), however, although they are not direct beneficiaries, those who get employment through the project implementation also benefits fro the project. For example, irrigation network construction and catchments treatment brought a huge employment opportunity for people inside and outside the command area. Furthermore, even after the project completion, more labour get recruited because of the labour intensive nature of irrigation. The benefits of lower food prices lead to improved nourishment of the whole community. On the other hand, irrigation brings negative externality, such as prevalence of malaria. In general, in the presence of positive spillover effect, estimated impact could be downward biased, while it could be upward biased if the negative affected is assumed in the estimation process.

6. Results and Discussion

6.1 Descriptive results

Household characteristics and resource endowments:

The descriptive results are presented in tables 2 and 3. There are no significant differences between irrigators and rain-fed farmers regarding household demographic characteristics and level of education. No significant difference is observed in farm size between the two groups. We noted that households who have access to irrigation hired more labor as compared to households who have no access to irrigation.

Both irrigating and rain-fed households have almost equal number of oxen, milk cows and labor although we observed slightly higher values in favor of irrigating households.

Comparison of level and sources of income, consumption and poverty:
Irrigators had, more diversified income sources. The irrigators had significantly higher non-crop farming income. The non-crop farming activities are mainly related to livestock rearing including dairying, poultry and bee keeping. There is no significant difference in the magnitude of income obtained from off-farm activities between the two groups, however, the contribution of off-farm income to non-irrigating households' total income is about 18 percent higher than that of irrigating households'. This might be due to the labor intensive nature of irrigation. The implication is that households who have access to irrigation are more occupied in their own farm and have less off-farm participation.

Although farming income constitutes, on average, about 72 percent of the total sample household's income, it contributes 76 percent of income of households who have access to irrigation, and only 66 percent of income of households without access to irrigation. Given the contribution of agriculture to the income of rural households, such differences in the proportion of farming income supports the argument about the role of investment in irrigation as a poverty reduction strategy. In general, the descriptive statistics makes clear that irrigators have less off-farm employment and more cropping income.

Overall, the total income of non-irrigators is only about 67% of that of irrigators. Thus the mean income for irrigators is significantly higher than that of non-irrigators. However, the difference in the total household consumption expenditure between the two groups is not that significant. The consumption expenditure is higher for irrigators only by 8.6%. The implication is that even though the observed income gap between irrigators and non-irrigators is huge, the non-irrigators where able to smooth their consumption level and bring it almost to the level of that of irrigators through various mechanisms. This confirms the usual claims made in the literature that consumption expenditure is the preferred measure of welfare to income[13]. Although the average per capita income of irrigators and rain-fed farmers are above the official poverty line that of irrigating households is almost double of that of the non-irrigating households. The difference between per capita consumption expenditure of irrigators and non-irrigators is statistically significant.

The observed income difference between the two groups is also reflected in the poverty incidence rate. The poverty incidence was calculated using a poverty line determined based on the estimated income required to access the minimum calorie required for subsistence (i.e., 2200 kcal) and other essential non-food goods and services. The official national poverty line is 1075 Birr in 1995/96 constant national average prices (Weldehanna 2004), however, the regional poverty line (for Tigray region) was estimated at Birr 1033.5 (Hagos 2003). Our study shows that poverty incidence (i.e., the proportion of poor households) among irrigators group is significantly lower than that of non-irrigators. The poverty incidence among non-irrigators is slightly higher than the regional average for Tigray and significantly higher than the national average (Table 2 and 3). In general Tigray, Amhara and SNNPR are the worst regions in terms of poverty incidence and depth.

6.2. Model results

The propensity score matching allows for the statistical comparison group to irrigation participants. Table 4 presents the logit regression used to estimate the propensity scores on the basis of which the matching was subsequently done. The logit regression suggests that the probability of access to irrigation increases as household's ownership of land (both in size and number of plots) increase.

[13] However, beware that the consumption smoothing is usually achieved through distress measures such as drawing down on the stock of assets owned such as livestock, borrowing, etc.

Table 5 gives our estimates of average income gains, off-farm labor allocation and magnitude of off-farm income difference based on Nearest Neighbor, Kernel and stratification matching methods.

The overall average income gain due to participation in irrigated agriculture ranges between 3600 to 4500 Birr based on the matching method adopted. The average income gain estimated stratified matching method is lower than that of the Kernel matching method and nearest neighbour methods. The nearest neighbour matching method is some what conservative since only 71 cases from the total of 282 rain-fed farming households were judged to be comparable to irrigators when using this method (Table 5). On the other hand, the stratification matching method is not restrictive. Although the Kernel matching method is marginally conservative as compared to stratification, but resulted in higher overall income gain. 236 rain-fed farmers where estimated to be comparable to the irrigators when using the Kernel matching method.

The mean overall income gain due to participation in irrigation calculated based on the whole irrigators and non-irrigators sample (i.e., without using PSM method) is 1413.07 (4278.445 minus 2865.377, see table 2). Thus the use of the whole rain-fed sample as a counterfactual would under estimate the impact of irrigation on income and poverty. The bias is about 2208.19 (3620.26[14] minus1413.07) Birr. Moreover, the irrigators had lower off-farm income than non-irrigators but the difference is not statistically significant.

6.3 Stochastic dominance analysis

Although randomization is considered as a powerful method of impact assessment, no single method is ideal implying that a combination of tools might be appropriate (Ravallion, 2005). Accordingly we have used a stochastic dominance analysis to check the robustness of our estimation of matching method. Such an assessment is based on set poverty lines, which ideally give the minimum income that is sufficient for an individual to fulfill a minimum level of consumption, therefore, the individual's standard of living is above the poverty line. The general principle of setting a poverty line is that the individual whose income is above the poverty line is being adequately nourished and can fulfill the basic needs. We used a poverty line equal to 1033.5 Birr (Hagos, 2003). We assessed the impact of access to irrigation on the cumulative distribution of income and then poverty reduction by simulating multiple poverty lines. We found that the stochastic dominance tests confirm the results of propensity score matching that investment in small-scale irrigation has significant impact on household income and poverty statues. Results of the stochastic dominance tests are reported in figures 3-5. Comparing the head count ratio (the first order stochastic dominance tests), we found that poverty incidence is significantly low for households with access to irrigation. Similarly, the second and third order stochastic dominance tests confirm that the depth and severity of poverty is lower for irrigating households.

7. Conclusions

Poverty reduction in Tigray regional state is a core policy agenda of both regional government and the federal government of Ethiopia. Investment in small-scale irrigation was regarded as a key poverty reduction strategy and many governmental and non-governmental organizations have constructed different irrigation systems with a total irrigation capacity of 3700 hectares benefiting about 19000 farming households. However, limited efforts have been made so far to assess whether investments in small-scale irrigation in Tigray have attained the stated objectives of poverty reduction, food security and overall socioeconomic improvement in Tigray. In fact some of the limited efforts made to assess small-scale irrigation systems are quite pessimistic (see Pender et al. 2002). The main objective of this study was to robustly assess the link between public investment in irrigated agriculture and its

[14] This number shows the minimum gain based on the estimation of stratified matching method.

impacts on income and household poverty in Tigray.

To analyze the welfare impact of small-scale irrigation, Propensity Score Matching method has been applied to a data set generated from a random sample of 613 farming households (i.e., 331 irrigators and 282 rain-fed farmers) representing different agro-ecological zones of Tigray and irrigation system typologies. The main conclusions from the study are as follows:

- There is no significant differences in household demographic characteristics between the irrigators and non-irrigators sample households
- Irrigators hired more labor indicating the relative labor absorption potential of irrigated farming as compared to rain-fed farming
- Irrigators had more diversified income sources
- Households with access to irrigation had lower participation in off-farm activities again indicating the labor absorption or on-farm employment generation capacity of irrigated agriculture
- The mean income of irrigators is significantly higher than that of rain-fed farmers. There is also a difference (although not statistically significant) in total household consumption expenditure between the two groups.
- The over all average income gain due to participation in irrigated agriculture estimated using PSM method ranges between 3600 to 4500 Birr per household per annum, which is higher than the income gain estimated based on the whole sample (i.e., using the total rain-fed farmers sample as a counterfactual or comparison group). Hence, the use of PSM avoided the under estimation of the magnitude of irrigation impact on income.
- Finally, the significant income gain has significantly reduced poverty among farmers with access to irrigation.

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Table 1. Key to the acronyms used in Figure 1 or conceptual framework.

Accronym	Description
DAM	Source of water for irrigation is micro-dam
RDIV	Source of water for irrigation is river diversion
GWM	Source of water for irrigation is groundwater :modern communal
GWT	Source of water for irrigation is groundwater: private manual
IRRIG	Access to irrigation
LABOUR	Household's labor endowment
CREDIT	Access to credit
ASSET	Asset holding
LSIZE	Land holdings size
OXEN	Number of oxen owned
LIVESTOCK	Households livestock holding (TLU)
MARKET	Distance to nearest market
INPUT	Total expenditure o inputs used (Chemicals, fertilize, seed, etc)
LANDPR	Land productivity
LABPR	Labor productivity
HHSIZE	Household size in adult equivalent
AGE	Age of household head
SEX	Sex of household head
EDUC	Number of educated household members
COWORO	Consumer worker ratio
ALTITUDE	Altitude above sea level
AVRAFLL	Average rainfall
CV	Coefficient of variance of rainfall
SOILTYPE	Soil types
LANQUALI	Land quality
AGRINCOME	Income from agriculture (cropping income)
OTHINCOME	Income from other sources
HHINCOME	Total household income
POVREDU	Poverty statues based on income level

Table 2: Summary statistics of selected variables used in estimating the treatment effect

Welfare indicators	Irrigators (N=330)		Non-irrigators (N=282)		*t*-test (Significance test of difference)
	Mean	SE	Mean	SE	
Household characteristics and resource endowments					
Family size (number)	5.066	.120	4.681	.127	-2.206**
Family size (adult equivalence)	4.495	.126	4.154	.129	1.884*
Female adult members of the household (number)	2.650	.078	2.482	.076	-1.5302
Male adult members of the household (number)	2.417	.082	2.199	.087	-1.817*
Number of plots the household cultivated in 2005/06	4.574	.109	3.351	.114	-7.736***
Number of oxen the household own	1.260	.056	1.121	.066	-1.625
Number of milk cows the household own	.656	.057	.660	.075	0.043
Farm size in hectare	5.018	.160	5.038	.203	0.082
Household members who can read and write (number)	1.426	.084	1.259	.081	-1.418
Income and consumption					
Total Household income in 2005/06 (Birr)	4278	364	2865	224	-3.178***
Total Household consumption expenditure in 2005/06 (Birr)	3058.839	111	2817.016	106.248	-1.555
Proportion of farming income (%)	.76	.011	.66	.016	-5.234***
Per capita income (Birr)	1230.097	169	799.304	63.477	-2.248**
Per capita expenditure(Birr)	803.190	34	785.259	30	0.393
Poverty incidence (%)	.44	.027	.56	.030	3.111***

Table 3. Poverty by region using poverty line based on Basket of Kcal

Region	Per capita consumption expenditure (Birr) (1999)	Poverty Index (%)		Poverty Gap (2002)
		1999	2002	
Tigray	903.60	0.58	0.56	0.17
Afar	1105.6	0.52	0.33	0.10
Amhara	917.2	0.57	0.54	0.16
Oromia	1184.0	0.35	0.34	0.08
Somali	1166.4	0.35	0.31	0.07
Benshangul-Gumuz	1026.8	0.48	0.47	0.13
SNNPR	945.5	0.57	0.56	0.18
Gambela	1223.5	0.42	0.34	0.09
Harari	1459.7	0.29	0.22	0.05
Addis-Ababa	1569.0	0.30	0.30	0.09
Dire Dawa	1397.1	0.25	0.29	0.07
National	**1087.8**	**0.46**	**0.45**	**0.13**

Source: FDRE (1999, 2002)

Table 4: Estimation of the propensity score to estimate the impact of irrigation on household's income, off-farm labor participation, and off-farm income

Variable	Variable Description	Coef.	z
accirri	Access to Irrigation (1=yes, 0=no)		
plotsize	Plot size in hectare	-2049959(.0378145)	-5.42
typland	Type of rented in land (1=irrigated, 0=rainfed)	-.4637671(.4452168)	-1.04
hheadsex	Household head sex(1=male, 0=female)	.0742088(.2271787)	0.33
familysize	Family size in number of people	.0532757(.0483211)	1.10
femwl	Adult female working labour	.0183509(.1003034)	0.18
mamwl	Adult male working labour	-.0856737(.0919116)	-0.93
plotnumber	Number of plots operated by the household in 2005/06 production year	.5404309(.0649462)	8.32
ownrship	Whether a household rented in land (1=yes, 0=no)	-.1359277(.183545)	-0.74
_cons	Constant	-1.079743(.4993401)	-2.16

Notes: () = Std. Err.; *, **, *** Significant at 10%, 5% and 1%, respectively;
Treatment is Access to Irrigation

Table 5: Impact of irrigation on household income, household labor allocation and off-farm income (Bootstrapped standard errors): Estimation results of matching method

Impact on	Matching Method	Number of Treated	Number of Control	Average Treatment effect on the Treated (ATT)	*t-statistic*
Income	Nearest neighbour (Equal version)	331	71	3940.604 (1348.995)	2.921**
	Nearest neighbour (random version)	331	71	3940.604(1677.466)	2.349**
	Kernel Matching Metod	331	236	4405.777 (1382.702)	3.186**
	Stratification	331	259	3620.260 (1516.378)	2.387**
Off-farm labour allocation	Nearest neighbour (Equal version)	331	71	14.171 (20.037)	0.707
	Nearest neighbour (random version)	331	71	14.171 (23.227)	0.610
	Kernel Matching Metod	331	236	8.808 (14.145)	0.623
	Stratification	331	259	9.605 (9.958)	0.965
Off-farm Income	Nearest neighbour (Equal version)	331	71	77.023(233.666)	0.330
	Nearest neighbour (random version)	331	71	77.023(446.155)	0.173
	Kernel Matching Metod	331	236	-256.966(288.294)	-0.891
	Stratification	331	259	-103.900(97.895)	-1.061

Note: numbers in parenthesis are bootstrapped standard errors, ** significant at 5% level of significance, $df = 8$

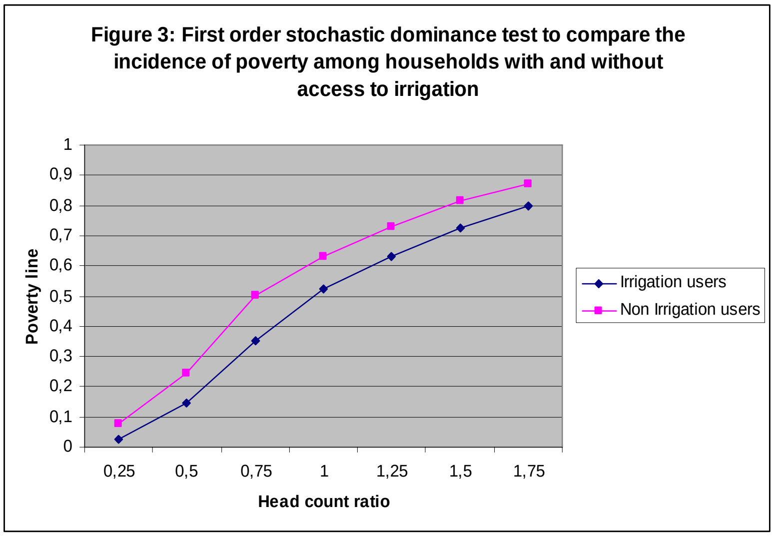


Figure 3: First order stochastic dominance test to compare the incidence of poverty among households with and without access to irrigation
Poverty line
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0,25
0,5
0,75
1
1,25
1,5
1,75
Head count ratio
Irrigation users
Non Irrigation users

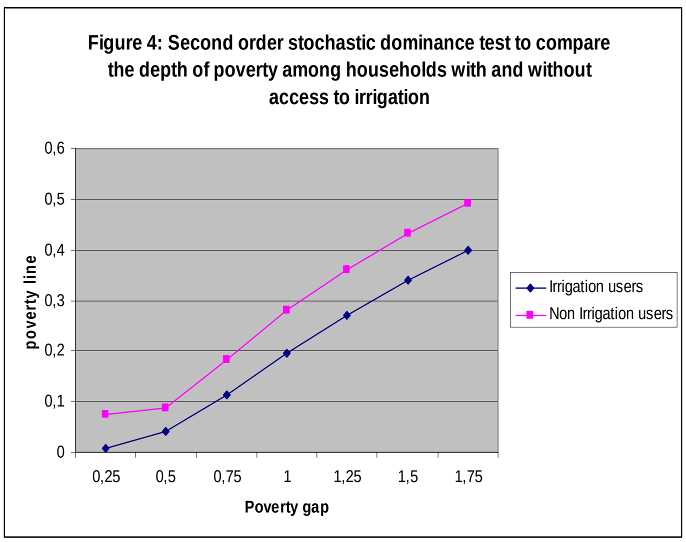
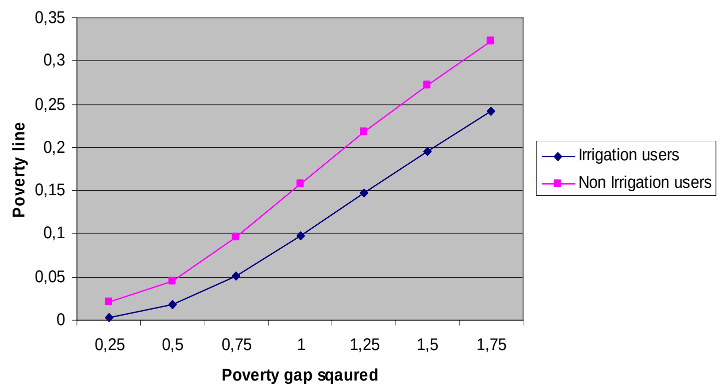


Figure 4: Second order stochastic dominance test to compare the depth of poverty among households with and without access to irrigation
poverty line
0,6
0,5
0,4
0,3
0,2
0,1
0
0,25
0,5
0,75
1
1,25
1,5
1,75
Poverty gap
Irrigation users
Non Irrigation users

Figure 5: Third order stochastic dominance test to compare the severity of poverty among households with and without access to irrigation



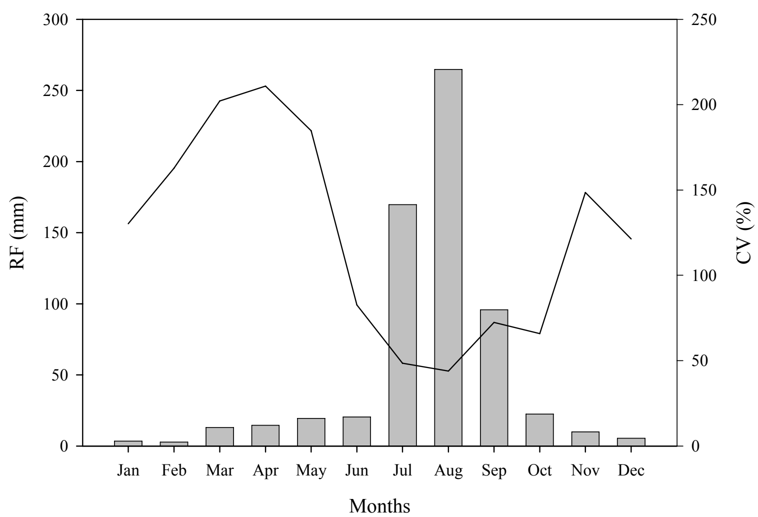


Figure 6: Average monthly rainfall distribution (RF) and Coefficient of Variance of rainfall CV) of Tigray (1956-2006)
Source: Ethiopian Metrology Agency, Tigray branch office

Appendix 1: Logit model Estimates of Propensity Score Matching

****
Algorithm to estimate the propensity score
****
The treatment is access to irrigation (accirri)

access to irrigation 1=yes, 0=no	Freq.	Percent	Cum.
0	282	46.00	46.00
1	331	54.00	100.00
Total	613	100.00	

Estimation of the propensity score

Iteration 0: log likelihood = -422.93873
Iteration 1: log likelihood = -377.59997
Iteration 2: log likelihood = -376.19771
Iteration 3: log likelihood = -376.18939
Iteration 4: log likelihood = -376.18939

Logistic regression Number of obs = 613
LR chi2(8) = 93.50
Prob > chi2 = 0.0000
Log likelihood = -376.18939 Pseudo R2 = 0.1105

accirri	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
plotsize	-.2049959	.0378145	-5.42	0.000	-.279111	-.1308809
typland	-.4637671	.4452168	-1.04	0.298	-1.336376	.4088418
hheadsex	.0742088	.2271787	0.33	0.744	-.3710532	.5194707
familysize	.0532757	.0483211	1.10	0.270	-.0414319	.1479834
femwl	.0183509	.1003034	0.18	0.855	-.1782401	.2149419
mamwl	-.0856737	.0919116	-0.93	0.351	-.2658171	.0944697
plotnumber	.5404309	.0649462	8.32	0.000	.4131387	.6677231
ownrship	-.1359277	.183545	-0.74	0.459	-.4956693	.2238138
_cons	-1.079743	.4993401	-2.16	0.031	-2.058432	-.1010546

Note: the common support option has been selected
The region of common support is [.24230422, .98838866]

Description of the estimated propensity score in region of common support

Estimated propensity score

	Percentiles	Smallest		
1%	.2458666	.2423042		
5%	.2771301	.2439084		
10%	.3179111	.2447952	Obs	590
25%	.4128555	.2452673	Sum of Wgt.	590
50%	.5375359		Mean	.5527539
		Largest	Std. Dev.	.1792381
75%	.6757212	.9483694		
90%	.8177568	.9499213	Variance	.0321263
95%	.8822696	.952905	Skewness	.3062784
99%	.9415825	.9883887	Kurtosis	2.282861

****

Step 1: Identification of the optimal number of blocks

Use option detail if you want more detailed output

****

The final number of blocks is 8.This number of blocks ensures that the mean propensity score is not different for treated and controls in each blocks

****

Step 2: Test of balancing property of the propensity score

Use option detail if you want more detailed output

****

The balancing property is satisfied

This table shows the inferior bound, the number of treated and the number of controls for each block

Inferior of block of pscore	access to irrigation 1=yes, 0=no 0	1	Total
.1428571	36	2	38
.2857143	46	6	52
.3571429	38	39	77
.4285714	60	107	167
.5714286	49	93	142
.7142857	21	54	75
.8571429	9	30	39
Total	259	331	590

Note: the common support option has been selected

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End of the algorithm to estimate the pscore

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end of do-file