Impacts of Small-Scale Irrigation Technology on the Nutritional Wellbeing of Children in the Amhara National Region of Ethiopia

Belainew Belete[1] and Surafel Melak[2]

Abstract

It is agreed that adopting irrigation technology improves production, productivity, income, and access to food for farm households. However, evidence on nutritional outcomes of small-scale irrigation technologies is quite scant. The existing studies focus on the productivity and poverty effect of irrigation. Thus, this study examines the impact of adoption of small-scale irrigation technologies on child nutritional wellbeing of farm households where nutritional wellbeing is measured through anthropometric indicators. Data were collected from 130 sample households drawn from Dangila and Bahir Dar Zuria wereda's[3]. The Propensity Score Matching (PSM) method was employed to identify comparable technology adopting and non-adopting sample households. The study found malnutrition to be severe in the study area. Both chronic and acute malnutrition problems were found to be wider for girls, for children aged below 2 years of age, and for non-adopters of the technology. Results of the average treatment effect on treated participants suggest that adoption of small-scale irrigation technologies has a positive impact on improving the adopters' short-term nutritional status but its impact on children being chronically malnourished and underweight is insignificant. This study concludes that children of small-scale irrigation technology adopting households have significantly lower acute malnutrition status than those of non-adopting households even after controlling for the potential heterogeneity. Targeting diffusion of small-scale irrigation technology with early nutrition-specific intervention for long-term nutritional improvement is vital to secure child nutritional wellbeing.

JEL Classification: Q16, I31, C21, D02, C91, I39

Keywords: Child Nutrition, Impact Analysis, Propensity Score Matching, Small-Scale Irrigation Technology.

---

[1] Lecturer of Economics at Debre Tabor University, Ethiopia. P.O.Box. 272, Debre Tabor (corresponding author, +251-9182-530-17; Email: belayecon@gmail.com).

[2] Assistant professor of Economics at Bahir Dar University, Ethiopia. P.O.Box. 79, Bahir Dar. Email: msur69@gmail.com

[3] *Woreda* is the lowest administrative organ of the regional state.

1. Introduction

Rain-fed agriculture is the mainstay of livelihood of households in Ethiopia though it is subject to erratic climate problems (Ayele, 2011; Hagos *et al.*, 2009; Yami & Snyder, 2012). Such climate variability is a threat to agricultural production and productivity which expose households to production risks, and lack of adequate and nutritious food (Domenech and Ringler, 2013; Foltz, Gars and Zaitchik, 2013). In areas where rainfall is limited and resources are underemployed, irrigation potentially reduces vulnerability to climatic variability and improves productivity and product diversity (Namara *et al.*, 2011; Getacher, Mesfin and Gebre-egziabher, 2013a). Hence, adoption of irrigation technology enables farmers to adapt and strengthen their resilience in climate vulnerable regions, diversify their diet, and increase the nutritional content of foods through bio and post-harvest fortification (Ayele, 2011; FAO, 2011; Hagos *et al*., 2009; Namara, Upadhyay, & Nagar, 2005).

According to Hagos *et al*. (2009) and Wehabrebi (2014), improving agricultural efficiency through adopting irrigation technology is a foundation for improving rural households' food security in Ethiopia. Besides, irrigation application with appropriate technology enables Indian farmers to produce diversified and high-value crops, which enable them to improve their nutritional and welfare status (Namara, Upadhyay and Nagar, 2005; Adeoti, 2008; Hagos *et al.*, 2009; Munongo and Shallone, 2010). However, irrigation technology adoption is challenged by technical, economic and institutional factors (Kulkarni, 2011; Getacher *et al*., 2013b).

Although irrigation plays an enormous role in alleviating poverty and food insecurity in developing countries like Ethiopia, it is still traditional, small scale and at subsistence level with limited access to technology and institutional services (Kulkarni, 2011; Namara *et al.*, 2011; Tekana and Oladele, 2011).

Agricultural intervention leads to a shift in food production, production variability, dietary diversity, labour productivity, and a change in the role of women (Hagos *et al*., 2009; Namara *et al*., 2005). The way these changes take place has impacts on the nutritional status of households (Domenech and Ringler, 2013). But the impact on different members of the households and community such as beneficiaries, non beneficiaries, children and women differs. Measuring and identifying the differences is critical for the redesign and implementation of effective irrigation interventions to optimize the nutritional wellbeing of the households and the community.

Policy makers, program managers and other stakeholders have mainly focused on inputs and immediate outcomes (distribution and use of resources) of the intervention by putting aside the anticipated goals of improving the well-being of households and society (Bhattarai & Hussain, 2002; Gertler *et al*., 2011; Lance *et al*., 2014). In developing countries, where resources are scarce and each dollar spent is aimed at maximizing its role in poverty reduction and improving wellbeing, impact evaluation is vital to identify what does and doesn't work to improve wellbeing and reduce poverty (Baker, 2000; Gertler *et al.*, 2011).

Nowadays, a few studies have investigated the impact of irrigation on nutrition, which is an engine for economic sustainability. A study by Domenech & Ringler (2013) in eastern Ghana and Namara *et al.* (2011) in the South of the Saharan Africa show that irrigation improves nutritional status of households. Likewise, the installation of micro irrigation technologies in India has helped farmers to produce more diverse and higher quality crops, which enable them to improve their nutritional status (Domènech, 2015a). However, Malapit *et al.* (2013) in Nepal found that irrigation has a dichotomous effect on nutrition outcome. Nutrition is improved as a result of food improvement but health impacts of chemical application (pesticides and insecticides) in irrigation agriculture reduces nutritional wellbeing. Moreover, irrigation technology improves the nutritional outcome of farm households through improving the quality and quantity of food, but sometimes it reduces the nutritional status of households because of mono-cropping and unsafe water.

Macharia & Muroki (2005), Peiris & Wijesinghe (2010),and Steiner-Asiedu *et al*. (2012) found that those children whose mothers actively participated in agricultural activities have low nutritional status, but women's involvement in income-generating irrigation activities and their control of income from irrigation has greater impact on increasing the child nutritional status of the households (Malapit *et al.*, 2013). Women's disempowerment in agricultural activities results in high malnutrition problems (being underweight, stunted and wasted) of their children (Domenech and Ringler, 2013; Malapit *et al.*, 2013). Thus, the impact of irrigation technology on nutritional status is not clear since its impact on nutrition is realised through product diversification and empowerment of women.

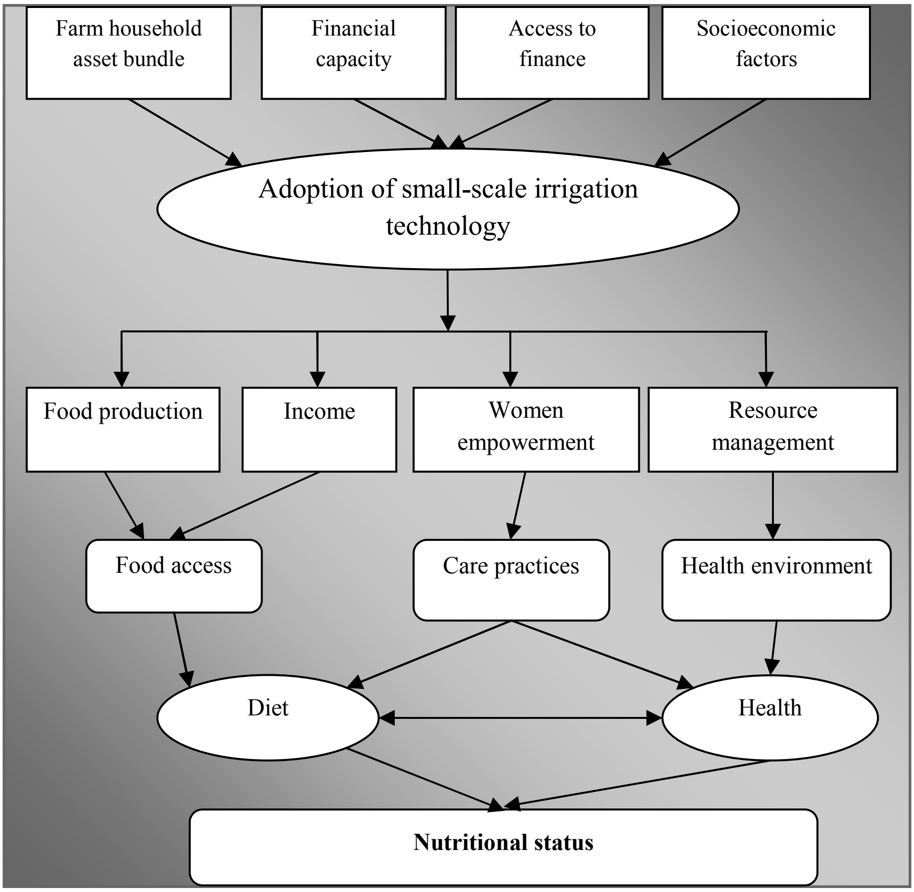
Small-scale irrigation is a policy priority in Ethiopia for poverty alleviation and addressing malnutrition to achieve sustainable development (World Bank, 2010; Haile, 2015; Solomon and Ketema, 2015). According to Hagos *et al.* (2009b), Ethiopia is said to have an estimated irrigation potential of 3.5 million hectares. From this total irrigation potential, only 5.2 percent is reported to be used during the 2015/16 production period (Central Statistical Agency (CSA), 2016). Irrigation practiced by smallholder farmers in Ethiopia is used only as supplementary to solve their livelihood challenges (Awulachew *et al.*, 2006; Hagos *et al.*, 2009; Kulkarni, 2011). Irrigated agriculture is becoming vital in meeting the growing demand for food security, poverty reduction and livelihood improvement in Ethiopia. A study by Asayehegn, Yirga, & Rajan (2012) in Laelay Maichew district of Tigray region using Hickman a two-stage model and Getacher *et al*. (2013) in Tigray region, Northern Ethiopia using ordinary least square show that small-scale irrigation has a positive and significant impact on improving the income of rural farm households. In Gubalafto district of North Wollo, Ethiopia, small-scale irrigation has helped to improve the livelihoods of farm households (Mengistie and Kidane, 2016). Studies on the impact of small-scale irrigation technologies in Ethiopia are biased towards the food security, income increment and poverty reduction outcome. A closer look at the literature on impacts of irrigation reveals a number of gaps and flaws. That is, evidence on nutritional outcome of irrigation is quite limited, highly inconsistent, and insufficient to draw strong inference. Some have applied a qualitative approach, which can't be tested empirically, and some others have failed to show the outcome is due to irrigation. Thus, further investigation in the study area is crucial to understand the nutritional outcome of small-scale irrigation technology more adequately.

Hence, this study attempts to provide empirical evidence on the impact of small-scale irrigation technology on farm household nutritional status of Dangila town and Bahir Dar Zuria district of the Amhara National Regional State, Ethiopia. Specifically, it attempts to investigate the nutritional status of farm households in the study areas. The rest of the paper is organized as follows. The second part of the paper describes the methodology used in this study, section three presents the results, and the last section provides conclusions and policy implications.

Conceptual framework

There are several potential pathways in which irrigation can influence nutrition outcomes including (1) production pathway, (2) income pathway (3) women's empowerment pathway, and (4) environmental pathway (Domènech, 2015b; Herforth and Ballard, 2016). The framework indicates that irrigation can influence the underlying and immediate determinants of nutrition such as food access, care practices, and health environments. Following the literature, the effect of small-scale irrigation technology on nutrition pathways is illustrated in Figure 1.

Figure 1: Conceptual frame work on impact of irrigations technology on nutrition status



Source: Author

2. Material and Methods

2.1 Data

In this study, we utilize data from a household survey collected from mid May to early June 2016 from two *woreda*s (Dengeshita and Robit *woreda*) of Amhara national region of Ethiopia (Figure 2). Primary data were collected from 135 randomly selected farm households, using a multi-stage stratified random sampling technique. In the first stage, Dengeshita and Robit *woreda*'s were selected purposely based on the existence of irrigation technology as pilot *wereda*'s (intervention sites) of the Innovative Lab for Small-Scale

Irrigation (ILSSI) project [4]. In the second stage, information from the agricultural offices of the selected *woreda*'s was used to select one *kebele* (the smallest unit of administration in the government structure under a *woreda*) in each *woreda* with a high concentration of smallholder technology such as pulley and rope-and-washer. In the third stage, the list of farm households in the selected communities was used to disaggregate them into adopter[5] and non-adopter[6] households. Finally, we used the proportional random sampling technique to select our sample farm households. Of the total sample households, 83 were classified as adopters of small-scale irrigation technology. Treated households (adopters) were selected by the ILSSI project at the time of intervention, which distributed either of the two irrigation technologies to the households (rope-and-washer and pulley) to produce the same crop (elephant grass and tomato in Robit, onion in Dengeshita, and pepper in all sites).

Data on anthropometric measure such as age, height and weight were administered by health extension workers from mid May to early June 2016. Mothers or closest caregivers from 13 to 49 years of age were interviewed to obtain information on the children's age and sex.

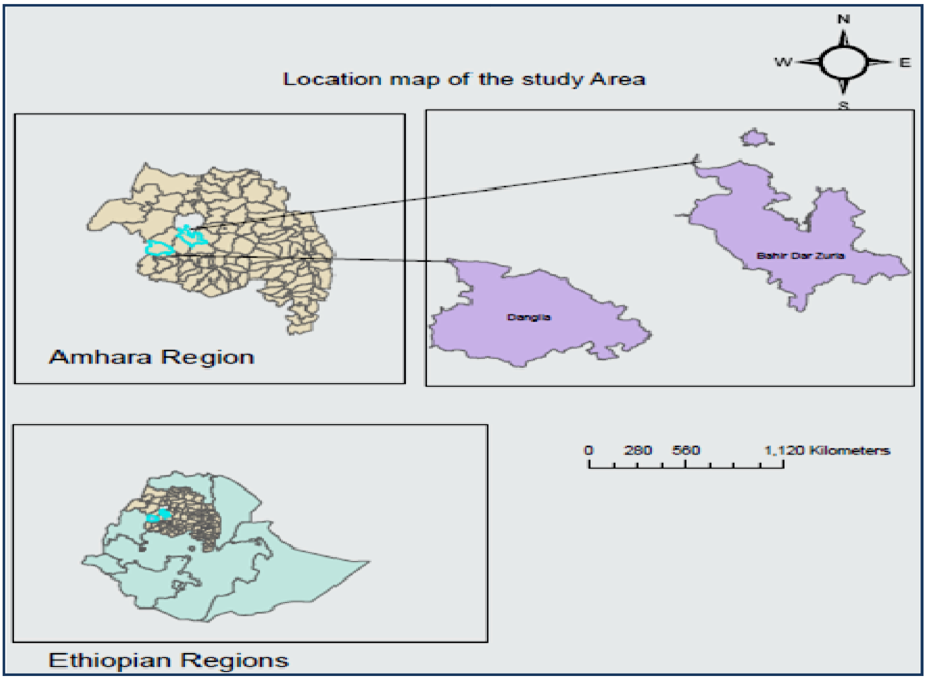
According to the protocol used by DHS, for children below 60 months of age, height is measured to the nearest 0.1 cm. The recumbent measure was used to measure the length of children younger than 24 months; standing height was measured for children aged 24 months and above. Weight was measured to the nearest 0.1 kg through beam balance scale (O'Donnell, Doorslaer, Wagstaff, & Lindelow, 2008).

[4] Feed the Future Innovative Lab for Small-Scale Irrigation (ILSSI) is a five-year project launched in 2013, aiming to increase food production; improve nutrition and livelihoods of farm household; accelerate economic development; and protect the environment through improved access to small-scale irrigation technologies. The technical intervention (irrigation technology provision) of the project is aimed at expanding irrigable land, using optimum irrigation techniques in order to battle poverty and malnutrition problems, and improve the livelihoods of farm households in Tanzania, Ethiopia and Ghana.

[5] Adopter (treated) households are farm households who adopt either of the two irrigation technologies, i.e., rope-and-washer or pulley.

[6] Non-adopter (control) households are farm households who rely on rain-fed agriculture.

Figure 2: Study Area Map



2.2 Analysis of Child Nutritional Status

In this study, the nutritional status of the child was compared with Z-scores[7] of the reference group. Computation of normalized anthropometric Z-score requires data on sex, height, weight of the children. Z-score of height for age (HAZ), weight for age (WAZ) and weight for height (WHZ) were calculated using the 2006 WHO growth standards with dedicated anthropometric software in STATA version 13. A sample of 130 children was used for the final analysis, and the remaining 5 samples that had missing anthropometric data were excluded. Based on the 2006 WHO recommended cut off points, children whose HAZ was below -6 and above +6, whose WAZ was below -6 or above +5, and whose WHZ was above +5 or below -5 were excluded, since these extreme values were probably a result of measurement or data entry error (Mei and Grummer-strawn, 2007).

[7] $\text{Z}-\text{score}=\frac{\text{observed value}-\text{median value of the reference population}}{\text{standard devation value of reference population}}$

2.3 The Analytical Model

In this study descriptive statistics and econometric analyses were employed to analyze the impact of the intervention on the nutritional wellbeing of treated groups. Nutritional impact evaluation was conducted by employing the Propensity Score Matching (PSM) method to answer the question: "What if a household had not adopted irrigation technology?" Anthropometric indicators of nutrition such as stunting, being underweight, and wasting of children under five years of age were used as they are more reliable and accurate indicators of the nutritional status of households (Amendola and Vecchi, 2008). To do so, propensity score P(x) is calculated on the basis of all observed covariates (X) that jointly affect participation in small-scale irrigation technology adoption and outcomes of interest (Khandker, Koolwal and Samad, 2010).

The adoption decision of small-scale irrigation technology is a discrete outcome with a value of 1 if the household adopts either or both of the technology and 0 otherwise. The probability of small-scale irrigation technology (pulley and rope-and-washer) adoption is estimated through binary logistic regression. The econometric estimation is specified as:

The latent (index) model:

$$y^* = X_i\beta' + u \qquad (1)$$

Where,

y^* *is latent variable*, $x\beta'$ *is index function and u is the errorterm*; $u \backsim l(0, \frac{\pi^2}{3})$.

If $y^* > 0, Y = 1$ *and* $y^* \leq 0, Y = 0$

$$pr(Yi = 1/x) = \frac{1}{1 + e^{x\beta}} = \frac{e^{x\beta}}{1 + e^{x\beta}} = \Lambda(x\beta') \qquad (2)$$

Where $pr(Yi = 1/x)$ is the probability of success and $x\beta'$ is the linear combination of covariates,

whereas the probability of failure is specified as:

$$1 - pr(Yi = 1) = \frac{1}{1 + e^{x\beta}} \qquad (3)$$

Odis ratio (L) is obtained by dividing (2) by (3)

$$L = \frac{pr(yi = 1/x)}{1 - pr(yi = 1/x)} = \frac{\frac{e^{x\beta}}{1+e^{x\beta}}}{\frac{1}{1+e^{x\beta}}}$$
$$= e^{x\beta} \qquad (4)$$

Finally,

$$ln(L) = ln\left(\frac{pr\left(yi=\frac{1}{x}\right)}{1-pr\left(yi=\frac{1}{x}\right)}\right) = \ln e^{x\beta} = \Lambda(x\beta) \qquad (5)$$

Where $ln(L)$ log of logit model odds ratio, $\Lambda(x\beta)$ *is cummulative distribution function*, $\beta's$ are coefficient of the regression estimated by maximum likelihood estimation technique and x'_i vector of covariates that determine the dependent variable (decision on irrigation technology adoption).

So, the logit (treated) model of estimating the propensity score is

$$ln(L) = x_i\beta'_j + U \qquad (6)$$

Where U is error term and other variables are as defined above.

Hence, impact is measured by the difference in outcomes of control and treatment group by average treatment effect.

$$ATT = E(\tau_i/\varphi = 1) = E[(Y_1 - Y_0)/\varphi = 1] \qquad (7)$$

Where $E(Y_1/\varphi = 1)$ is an average outcome of households who are treated (used the technology);

$E[Y_0/\varphi = 1]$ is an average outcome of treated households if they did not use the technology. In this study the outcome variables are:

1. Stunting (HAZ): the measure of growth retardation (shortness) for the given age. It measures the prevalence of children in long-term growth problems as a result of poverty, chronic diseases and low socio-economic status. The prevalence of chronic malnutrition (stunting) is the percentage of children 0-59 months old who are below minus two (moderate) and below minus three (severe) standard deviation from the median height for the age of the WHO child Growth Standard.

2. Wasting (WHZ): the measure of thinness for the given height. Prevalence of acute malnutrition is the percentage of children 0-59 months old who are below minus two (moderate) and below minus three (severe) standard deviations from the median weight for the height of the WHO child Growth Standards.

3. Underweight (WAZ): the measure of underweight as a result of composite problems of chronic and acute malnutrition problems. Prevalence of underweight is the percentage of children 0-59 months old who are below minus two (moderate) and below three (severe) standard deviations from the median weight for the age of the WHO child Growth Standards.

Explanation of variables and hypothesis

Following the adoption literature of Adeoti (2008), Asante (2013), and Gebregziabher *et al*. (2014), the explanatory variables included in our model and their hypothesized effect on adoption decision of small-scale irrigation technology are discussed below.

Household head age: is the age of the household head in years to capture the working capacity of farm household heads. The effect of age on adoption is dichotomous. On the one hand, older farmers are experienced enough and they have accumulated physical and social capital, adaptive expectation which enables them to try the new technology. Therefore, they are highly likely to adopt new irrigation technologies. On the other hand, younger household heads are less likely to own productive resources and they are exposed to farm risks but they are more capable to work than older heads. Therefore, young households can cope with farm risks like drought by adopting technology. Thus, it was difficult to prioritize the effect of age on small-scale irrigation technology adoption before seeing the empirical result.

Dependency ratio: is the proportion of dependants who rely on economically active household members in the given household. This variable indicates the number of household members that can assist in operating the irrigation technology. Small-scale irrigation technologies are labour-intensive and require adult labour to operate them. Farm households with a lower dependency ratio offer extra labour to assist irrigation technology. Therefore, we hypostasized that households with low dependency ratios have higher probability to adopt small-scale irrigation technologies.

Household head education level: is the maximum schooling level (grade) that the household head completed. This indicates household capacity to adopt a technology. More education enables farm households to manage and operate the complex technology. In adoption studies by Adeoti (2008) and Getacher *et al*. (2013b), it was found that better educated households have a higher tendency to adopt irrigation technology. Thus, it was expected that better educated households would be more interested in adopting irrigation technologies.

Land holding size: is the land holding size of the households in hectares, which measures the wealth status of the households. In agricultural activity, land is the prime input for both dry and rain-fed production. In technology adoption research, large land holding encourages the adoption of irrigation technology (Adeoti, 2008; Bagheri and Ghorbani, 2011). Accordingly, we hypothesized that farmers with greater land holding have greater probability to adopt irrigation technologies.

Extension service: is the frequency of visits made by agricultural extension workers per year. Extension service enables farmers to identify problems related to farming activity, crops, and soil. Hence, access to this service is important to adopt technology. Therefore, we hypothesized that households who were frequently visited by extension workers have a higher tendency to adopt irrigation technology than less frequently visited farming households.

Market distance: is the distance in kilo-meters from a household's residence area to the nearest market. Living closer to a market centre helps farm households to have alternative income sources other than farming (irrigation) activities. On the other hand, farmers living farther away from markets have less opportunity to be engaged in off-farm activities like petty trades, which encourage irrigation in dry seasons and adoption of irrigation technologies. Therefore, we hypothesized that the effect of the distance of markets from farm households' villages on adoption of small-scale irrigation technology is difficult to predict.

Credit access: is the dummy variable with a value of 1 if the household has access to credit and 0 otherwise. Investments on farmers (credit provision) facilitate the diffusion of irrigation technology. Empirical evidence confirms that households with credit access are more likely to adopt irrigation technology than those without (Adeoti, 2008). Likewise, it is expected that access to credit positively affects the adoption of irrigation technologies.

3. Results and Discussion

3.1 Nutrition analysis

The survey results show that the mean Z-sore of height-for-age, weight-for-age, and weight-for-height are -1.78, -1.29, -0.32, respectively, which shows the entire distribution has shifted downward below the mean. As depicted in Table1, the standard deviations of height-for-age, weight-for-age, and weight-for height are 1.55, 1.06, and 1.44, respectively. The findings of this study show that the distribution of the sample was spread wider than the reference group, so there is no data inaccuracy as a result of measurement error (Mei and Grummer-strawn, 2007).

Table 1: Summary Statistics of Anthropometric Indices Z score in the Sight

Variable	Observation	Min	Max	Mean	S.D.
Haz	132	-5.37	4.03	-1.779	1.548
Waz	135	-5.19	2.51	-1.288	1.059
Whz	130	-4.23	4.98	-0.324	1.441

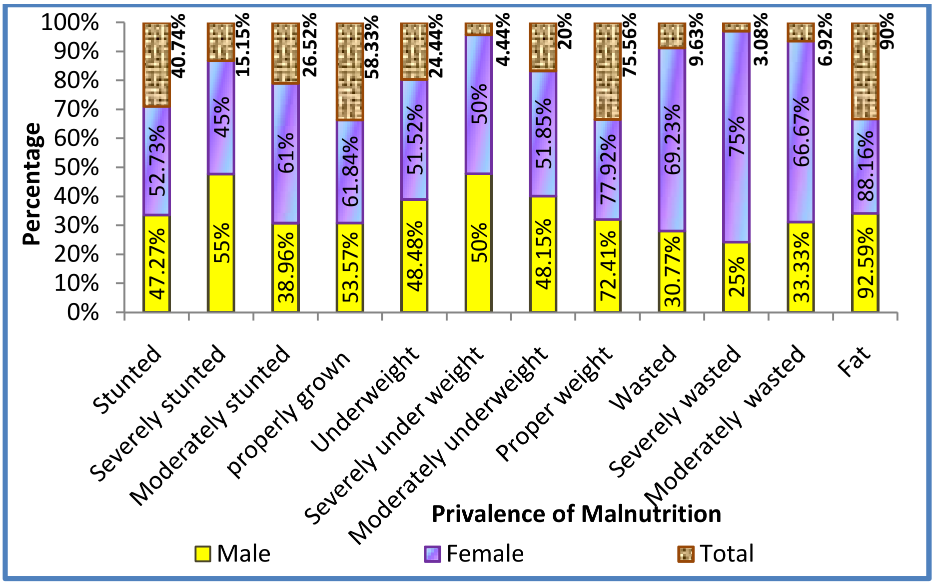
Source: Survey Result Estimation

The prevalence-based analysis of child nutritional status was reported based on common cut-off values, often considering whether or not the z-scores of the indices are below the median of the reference group by about twice of the standard deviations.

Stunting (chronic malnutrition)

As can be seen from Table 2 and Figure 3, 40.74% of the sampled children were suffering from growth retardation (too short for their age). This chronic malnutrition (stunting) is due to long-term factors such as poverty, inadequate dietary intake in their lives, and recurrent illness. The prevalence rate of stunting in the study area was higher than the prevalence rate of Ethiopia at national level (40%) but lower than the prevalence of stunting in the Amhara Regional State (42%) (CSA, 2014). The prevalence rate of stunting in the study area was very high, which results in poor mental and physical performance and poor school performance. It also reduces intellectual capacity and deters long-term economic progress.

Figure1: Prevalence of Malnutrition, by Gender



Source: Survey Result Estimation

Boys suffer from chronic malnutrition more than girls (47.3% vs 53%). From the total percentage of malnourished children (40.70%), 53% of the girls and 47.3% of the boys were dissatisfied with their basic needs during their first years of life (Figure 1). Besides, from the 15.2% stunted children, 11.84% of the girls, and 19.64% of the boys had severe chronic malnutrition. Of the 26.52% of the children, 38.96% of the boys and 61.04 % of the girls had moderate chronic malnutrition. But of the remaining 58.33% children, 61.84% of the girls and 53.57% of the boys were found to have grown well in terms of their long-term growth status (Figure 1**).**

Prevalence of chronic malnutrition is higher for children aged below two years than children above two years by about 10.67%. The proportion of children who have grown well aged above two years is also higher than the proportion of children aged below two years by 11.79%. Accordingly, children below two years of age suffer stiff chronic malnutrition whereas children above two years of age are characterized by a lower level of stunting (Table 2).

Children of both irrigation technology adopters and non-adopters are persistently short heterogeneously (Figure 2).

Table 2: Prevalence of Malnutrition in Children under 5 Years of Age, by Sex and Age

Anthropometric indices	Age group in months	
	0-24	**24.1-60**
Stunted	46.67	36
Severely stunted	22.48	9.46
Moderately stunted	25.86	27.03
Properly grown	51.72	63.51
Underweight	21.67	26.67
Severely underweight	1.67	6.67
Moderately underweight	20	20
Proper weight	78.33	26.67
Wasted	13.33	6.67
Severely wasted	3.57	2.7
Moderately wasted	10.71	4.05
Fat	85.71	93.24

Source: Survey Result Estimation

The prevalence of severe chronic malnutrition problem was more serious for technology adopters than for non-adopters (17.65% and 12.5%, respectively). But the problem of moderate stunting is more prevalent for technology non-adopters (28.75 %) than it is for technology adopters (23.53%). Finally, the result indicates that a larger proportion of children whose parents adopted irrigation technology was well-nourished than those whose parents did not adopt the technology. That is, 58.82% of the technology adopters and 57.75 % of the non-adopters were properly grown for their expected age.

Wasting (acute malnutrition) of children

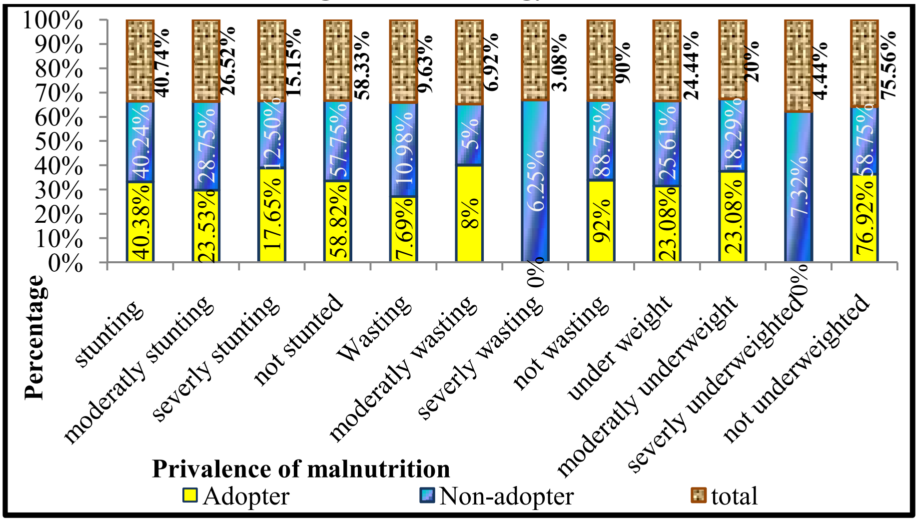
The result in Table 2 indicates that, on average, 9.6 percent of the children had acute malnutrition (low weight-for-height of the child for the given sex and age) as a result of recent malnutrition problems. The prevalence rate of acute malnutrition in the study area was medium**,** which is higher than the prevalent rate of children in Ethiopia in general and the Amhara region in particular (ICF International, 2011; Woldehanna, 2014). As presented in Figure1and Table 2 above, the prevalence rate of thinness (wasting problem) is higher for girls and children younger than 2 years of age. The result is consistent with previous studies (CSA, 2014; ICF International, 2011; Woldehanna, 2014).

The prevalence of wasting is higher among children of households that adopted technology than those that did not, accounting for 11% and 7.7%, respectively. Children of technology adopters were fat 92% compared with 88.75% of those children whose parents did not adopt the technology.

Being underweight

The survey result also shows that 24.44% of the children were found underweight (Figure 3**).** From two children at least one suffers health and general nutrition problems. This was higher as compared to the result obtained from 2011 DHS data of Ethiopia at national level and the regional level prevalence rate (CSA, 2014). Table 3 and Figure 1 jointly show that 20% of the children, 51.85% of the girls, and 48.15% of the boys were moderately underweight; 4.44% of the children, 50% of the girls and 50% of the boys were severely underweight. Moreover, the problem of being underweight was more prevalent on girls (51.52%) and children older than 2 years (26.67%).
Finally, children of households that did not adopt technology suffer from the problem of being underweight by about 2.5 percent more than those children whose parents adopted the technology.

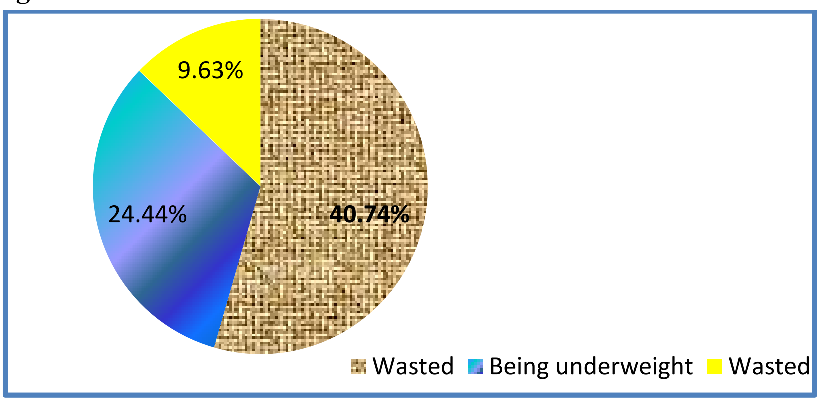
Figure 2: Anthropometric Measures of Adopters and Non Adopters of Small Scale Irrigation Technology



Source: Survey Result Estimation

Moreover, children whose parents adopted the technology have a higher probability of being moderately underweight and having the appropriate weight than those whose parents did not adopt the technology by about 4.79% and 18.17%, respectively, but none of the children of technology adopters was severely underweight (Figure 2**).** Therefore, the prevalence of being underweight is higher among children of farm households that did not adopt the technology.

Figure 3: Pie Chart of Child Malnutrition



Source: Survey Result Estimation

3.2 Econometric Analysis

3.2.1 Estimation of propensity scores

To match treated households with counter-factual households, propensity score matching was carried out by binary logistic regression. In this study, participation in adopting small-scale irrigation technology was the dependent variable with a dichotomous value of 1 for a technology adopter and 0 otherwise. The Wald test reveals that, jointly, all estimated coefficients are statistically significant at 1 percent (Table 3). The result revealed that additional years of schooling of the household heads increases the probability of adopting small-scale irrigation technology by 5.82 percent, citreous paribus. More educated farm households have better knowledge on the importance of technologies and are able to adopt them. The result is in line with the finding obtained in Kenya (Godfrey *et al*., 2014) and in Alamata District, Tigray, Ethiopia (Wehabrebi, 2014).

Dependency ratio of a household negatively affects the likelihoods of technology adoption because more adult members in the household imply cheap labour availability in the household, which can assist in the operation of the technology.

The result also shows that households with large land holdings have higher likelihoods of adopting technology, which is statistically significant at 5 percent. This might be due to the fact that irrigation is the activity in the dry season, and land for irrigation is prepared at the end of the Ethiopian summer season where rain-fed crops are not yet harvested. Thus, the household should leave the land waiting for irrigation. Therefore, having a large land size may permit households to allocate parts of their land for irrigation and adopt technology so as to lift water and irrigate in the appropriate season. This result is in line with the finding obtained in Ghana (Asante, 2013) .

Extension service has a positive significant impact on the probability of adopting irrigation technology. Receiving extension service for one more day augments the likelihood of adopting small-scale irrigation technology by 2.51

percent. The result is in line with the empirical finding of Gebregziabher *et al.* (2014) in Ethiopia.

Table 3: Logistic Regression Result for Propensity Score Estimation

Variables	Coefficients	MEF(dy/dx)	Z-value
Constant	-6.84 (1.678)		-4.08*
Age of the head	0.032 (0.006)	0.0077	0.222
Education of head	0.245 (0.0177)	0.0582	3.28*
Dependency ratio	0.599 (0.0775)	-0.143	-1.86**
Land size	0.796 (0.075)	0.189	2.52**
Extension service	0.106 (0.0091)	0.0251	2.76*
Market distance	0.165 (0.0195)	0.0392	2.01**
Credit access++	2.674 (0.084)	0.488	5.81*
Number of obs.	= 133		
LRchi^2 (7)	= 53.53		
Prob>chi^2	= 0.0000		
Pseudo R^2	= 0.3007		
Log likelihood	= -62.238351		

Remark: Figures in brackets are standard errors. ++ indicates dy/dx is for discrete change of dummy variable from 0 to 1; and * and ** indicate significance at 1% and 5% significance levels, respectively.

Source: Survey Result Estimation

Finally, investment in irrigation technology requires investment fund, which is the main constraint for most rural farm households (Godfrey *et al*., 2014). Thus, provision of either cash credit for technology or the technology in kind encourages farmers to adopt the technology. The econometric result of this study revealed that the probability of adopting irrigation technology for households with credit access is higher than households without credit access by 48.8%. The finding is in line with the finding obtained from Kenya (Godfrey *et al*., 2014).

3.2.2 Common support region

In this study, the common support region lies between 0.06 and 1 (Table 4). This means observations with the propensity score matching of below 0.06 and above 0.82 were discarded out of the matching sample. Based on the min-max criterion of determining the common support region, out of 130 households, 27 (15 control and 12 treated) lay out of the common region (support region) and were discarded from the analysis.

Table 4: Distribution of Estimated Propensity Scores

Groups	Obs.	Mean	Sta.Devia	Min	Max	Off support
All	133	0.39	0.29	0.003	1	27
Adoper	52	0.6	0 .263	0.061	1	12
Non- adopter	81	0.26	0. 216	0. 003	0. 817	15

Source: Survey Result Estimation.

In choosing the best matching algorism equal mean test, low pseudo-R^2 value and large matched sample were considered as the criteria. In line with this, kernel matching with band width 2 fits all the three criteria, and hence, the estimation result of this study is based on kernel matching algorism with 2 band widths.

Standardized bias, t-test, joint significance and Pseudo-R^2 are used to check the matching quality. Both partial and joint test of covariate and propensity score balance confirm that after matching, there is no significant mean difference between adopters and non-adopters. Therefore, it is trustworthy to estimate treatment effects based on kernel matching algorism with 2 band widths.

3.2.3 Impacts of small-scale irrigation technology on child nutritional status

The propensity score matching result (Table 5) shows there is a significant difference in acute malnutrition (wasting) status of children between households that adopted the technology and those that didn't. It is statistically significant at 10% level of significance. On average, Z-score of weight for a height of a technology adopter is 0.01 standard deviation above World Health Organization (WHO) child growth standard median of the reference group, whereas z-score of weight for a height of a technology non-adopter is 0.56 standard deviation below the median of the reference group. The result implies that children of households that did not adopt the technology are too thin for their height as a result of an acute food shortage, severe diseases or a combination of both, but children of technology adopting households are well nourished. The result is consistent with the descriptive statistics result prior to matching. From this result, it is possible to infer that adopting irrigation technology helps to improve the body weight for the given height of technology adopting households. The noteworthy impact of small-scale irrigation technology on immediate nutritional wellbeing of adopting households might have resulted from rapid change in food supply, rapid access and availability of nutritious food, improved maternal and child care, and health care service of technology adopting households.

Table 5: Impacts of Small-Scale Irrigation Technology Adoption on Household Nutrition

Outcome variables	Treated	Controls	Difference	S.E[B]	T-value
Whz	0.011	-0.551	0.561	0.399	1.81***
Haz	-2.069	-1.724	-0.345	0.426	-1.16
Waz	-1.199	-1.344	0.145	0.405	0.74

[B] Standards for bootstrapped error after 100 replications.

Source: Survey Result Estimation.

In contrast, chronic malnutrition (growth retardation) is more severe for children of technology adopting households than for non-adopting households. On average, the prevalence of stunting (too short for their given age) is more severe for the children of technology adopting households than it is to those of technology non-adopting households with a z-score of -2.07 and a 1.74 standard deviation below the median of the reference group, respectively. The severe problem of growth retardation from their long-term growth performance is due to recurrent infection resulting from the environmental cost of irrigation and the loss of care from their mothers because of work load of women brought about by irrigation activities. But the result is statistically insignificant.

The result also shows that the prevalence of being underweight for non-adopting households is higher than it is for adopting households. A glimpse into the nutritional status indicator of being underweight shows that, on average, the weight-for-age z-score indicator of technology adopting households is higher than it is for non-adopting household by 0.15 standard deviations. This means children of technology non-adopting households are both thinner for their height and shorter for their given age than children of technology adopting households as a result of a combination of both wasting and stunting problems. The reason might be due to the fact that technology adopting households have produced more both in rainy and dry seasons; this may in turn have which might have reduced both acute and chronic malnutrition of their children. But the result is statistically insignificant.

3.2.4 Sensitivity analysis

Sensitivity analysis was employed to check the problem of hidden bias as a result of unobserved confounder (Caliendo and Kopeinig, 2005). The estimation result of this study shows that the upper bound significance level (p-value) is significant ($p < 0.05$) at different sensitivity parameter up to $\Gamma=6$. This lower significant level shows the estimated result is insensitive to hidden biases. Hence, the inferences on the impacts of small-scale irrigation technology adoption on household child nutritional status (stunting, wasting and underweight) results are insensitive to unobservable characters.

4. Conclusion and Policy Implication

The ultimate motive of this study was to evaluate the impact of small-scale irrigation technology on farm household nutritional status in the study area. To do so, impact evaluation was undertaken on 130 households in Dengeshita and Robit towns of the Amhara region, Ethiopia. To analyze the impact of technology adoption on the intended treatment outcome, both descriptive and econometric analyses were employed.

Nutritional analysis through anthropometric measures indicated that malnutrition problems were found severe. More specifically, 40.7% of the sampled children were found suffering from the problem of growth retardation (stunting), 9.6% of the children were victims of wasting (thinness), and 24.44% of the sampled children suffered from a combination of both chronic and acute malnutrition problems. The problems of stunting, wasting and being underweight were harsh for girls and children aged below 24 months. Such a high prevalence of malnutrition severely affects future human capital formation and long-term economic performance. The prevalence of being underweight was serious for children of non technology adopting households, particularly girls and children aged above 2 years.

The average treatment effect shows that adoption of small-scale irrigation technology helps to solve acute malnutrition problems of children. Therefore, children of non-adopting households were found much thinner for their age than those of adopting households, but adoption of small-scale irrigation technology has no significant impact on stunting and being underweight in the study area.

Chronic malnutrition problem was more severe for technology adopters but a combination of acute and chronic malnutrition problem of technology adopter household was found better than their counter parts, the effect is statistically insignificant. Hence, the treatment effect estimation result shows small-scale irrigation technology adoption has a significant impact on improving short-term nutritional status of farm households.

The result of the sensitivity analysis test shows that the treatment effects were insensitive to the hidden biases. This means that the estimated impacts of small-scale irrigation technology on nutritional status were based on observed covariates.

Based on the empirical findings, the following policy implications are suggested. Policies and interventions of development agencies should incorporate strategies of expanding small-scale irrigation technology adoption focusing on the production of highly nutritious food, nutrition-sensitive agriculture, wiping out food insecurity, and environmental protection. We suggest nutrition-specific intervention, particularly during the child's first two years including pregnancy, is required for long-term nutritional improvement with short-term impacts on nutrition. Lastly, we recommend further research concerning the cost-effectiveness of the impact.

This study provides a set of lessons for policy makers and other development agencies for future project design in agricultural interventions in developing countries.

References

Adeoti, A. I. (2008). 'Factors influencing irrigation technology adoption and its impact on household poverty in Ghana', *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 109(1), pp. 51–63.

Amendola, N., & and Vecchi, G. (2008). 'Constructing a welfare indicator for poverty analysis in Iraq', pp. 134–157.

Asante, A. V. (2013). Smallholder irrigation technology in Ghana: Adoption and profitability analysis. Kwame Nkrumah University of Science and Technology.

Asayehegn, K., Yirga, C. and S. Rajan. (2012). 'Effect of small-scale irrigation on the income of rural farm households: The case of Laelay Maichew District, Central Tigray, Ethiopia', *The Journal of Agricultural Sciences*, 7(1).

Awulachew, S. B., Menker, M., Abesha, D., Atnafe, T., & Wondimkun, Y. (2006). Best practices and technologies for small-scale agricultural water management in Ethiopia. Addis Abeba, Ethiopia, Iinternational Water Manegment Institute .

Ayele, G. K. (2011). 'The impact of selected small-scale irrigation schemes on household income and the likelihood of poverty in the Lake Tana Basin of Ethiopia'.

Bagheri, A. and A. Ghorbani. (2011). 'Adoption and non-adoption of sprinkler irrigation technology in Ardabil Province of Iran', *African Journal of Agricultural Research*, 6(5), pp. 1085–1089. doi: 10.5897/AJAR09.380.

Baker, J. L. (2000). *Evaluating the impact of development projects on poverty: A handbook for practitioners*. Washington, D.C.: The World Bank.

Bhattarai, M. R. S., and I. Hussain. (2002). Irrigation impacts on income inequality and poverty alleviation: Policy issues and options for improved management of irrigation systems. 39. Colombo, Sri Lanka.

Caliendo, M. and S. Kopeinig. (2005). 'Some practical guidance for the implementation of Propensity Score Matching', (1588).

CSA (Central Statistical Agency). (2014). Ethiopia mini demographic and health survey 2014.

________. (2016). Agricultural sample survey 2015/16 (2008 E.C.) report on farm management practices (private peasant holdings, Meher season) (September – December, 2015). Addis Abeba.

Domènech, L. (2015a). 'Improving irrigation access to combat food insecurity and undernutrition : A review', *Global Food Security*. Elsevier, 6, pp. 24–33. doi: 10.1016/j.gfs.2015.09.001.

Domènech, L. (2015b). Is reliable water access the solution to undernutrition ? A review of the potential of irrigation to solve rutrition and gender gaps in Africa south of the Sahara. 01428. Washington, D.C.

Domenech, L. and C. Ringler. (2013). The impact of irrigation on nutrition, health , and gender: A review paper with insights for Africa south of the Sahara. IFPRI Discussion Paper 01259.

FAO (Food and Agriculture Organization of the United Nations). (2011). The state of food insecurity in the world 2011: How does international price volatility affect domestic economies and food security? ROME.

Foltz, J., J. Gars, and B. Zaitchik. (2013). 'Weather and welfare in Ethiopia'.

Gebregziabher, G., Giordano, M. A., J, S. L., & Namara, R. E.. (2014) 'Economic analysis of factors influencing adoption of motor pumps in Ethiopia', *Journal of Development and Agricultural Economics*, 6(90), pp. 490–500. doi: 10.5897/JDAE2014.

Gertler, P. J., Martinez, S., Premand, P., Rawlings, L. B., & Vermeersch, C. M. J.. (2011) *Impact Evaluation in Practice*. Washngton Dc, World Bank. Doi: 10.1596/978-0-8213-8541-8

Getacher, T., Mesfin, A. and Gebre-egziabher, G. (2013). 'Adoption and impacts of an irrigation technology : Evidence from household level data in Tigray , northern Ethiopia', *African Journal of Agricultural Research*, 8(38). doi: 10.5897/AJAR2013.7014.

Godfrey O., N. Millycent, O. Evans, N. Lucas, & M. Leonard. (2014). 'Factors influencing adoption of money marker pump technology and its impacts on household food security status in Bondo-Sub County-Kenya', *Asian Journal of Science and Technology*, 5(6), pp. 326–331.

Hagos, F., Makombe, G., Namara, R. E., & Awulachew, S. B. (2009). The importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. 128 Colombia, Srilanka: International Water Management Institute. .

Haile, G. G. (2015). 'Irrigation in Ethiopia, a review', *Journal of Environment and Earth Science*, 5(15), pp. 141–148. doi: 10.15413/ajar.2015.0141.

Herforth, A., and T. J. Ballard. (2016). 'Nutrition indicators in agriculture projects: Current measurement, priorities, and gaps', *Global Food Security*. Elsevier, 10, pp. 1–10. doi: 10.1016/j.gfs.2016.07.004.

ICF International. (2012). *Children's health and nutritional status*: Data from the 2011 Ethiopia Demographic and Health Survey. Calverton, Maryland, USA: ICF International.

Khandker, S. R., G. B. Koolwal, and H. A. Samad. (2010). *Handbook on Impact Evaluation: Quantitative Methods and Practices*. Washington, DC 20433, USA: World Bank. doi: 10.1596/978-0-8213-8028-4.

Kulkarni, S. A. (2011a) 'Innovative technologies for water saving in irrigated agriculture', *International Journal of Water Resource and Arid Environment*, 1(3) : 226-231.

Lance, P. M.,Guilkey, D. K., Hattori, A., & Gustavo, A. (2014). *How do we know if a program made a difference ? A guide to statistical methods for program impact evaluation..* Chapel Hill, North Carolina: Measure Evaluation.

Macharia, C. W., W, K.ogi.-Makau. and N. M. Muroki. (2005). 'A comparative study on the nutritional status of children (6-59 months) in a World Vision project area and a non-project area in Kathonzweni Division Makueni District, Kenya', *African Journal of Food Agriculture and Nutritional Development (AJFAND)*, 5(1).

Malapit, H. J., Kadiyala, S., Quisumbing, A. R., Cunningham, K., & Tyagi, P. (2013). 'Women's empowerment in agriculture, production diversity, and nutrition: Evidence from Nepal', *SSRN Electronic Journal*, (December). doi: 10.2139/ssrn.2405710.

Mei, Z., and L. M. Grummer-strawn. (2007). 'Standard deviation of anthropometric Z-scores as a data quality assessment tool using the 2006 WHO growth standards: A cross-country analysis', *Bulletin of the World Health Organization*, June. doi: 10.2471/BLT.06.034421.

Mengistie, D. and Kidane, D. (2016). 'Assessment of the impact of small-scale irrigation on household livelihood improvement at Gubalafto District, North Wollo, Ethiopia', 6(27). doi: 10.3390/agriculture6030027.

Munongo, S., and C. K. Shallone. (2010). 'Estimating the role of agricultural technologies in improving rural household welfare: A case of Masvingo', *Russian Journal of Agricultural and Socio-Economic Sciences*, 2(14), pp. 67–73.

Namara, R. E., Awuni, J. A., Barry, B., Giordano, M., Hope, L., Owusu, E. S., & Forkuor, G. (2011). *Smallholder shallow groundwater irrigation development in the Upper East Region of Ghana*. IWMI Research Report 143. Colombo, Sri Lanka, International Water Manegment Institute.93).

Namara, R. E., B. Upadhyay, and R. K. Nagar. (2005). *Empirical results from selected localities of Maharashtra and Gujarat states of India*. IWMI Research Report 93. Colombo, Sri Lanka, International Water Manegment Institute.

O'Donnell, O., Doorslaer, E. van, Wagstaff, A., & Lindelow, M. (2008) Analyzing health equity using household survey data: A guide to techniques and their implementation. Washington, D. C: World Bank. doi: 10.1596/978-0-8213-6933-3 Library.

Pandve, H. T. and Singru, S. A. (2012) 'Various Anthropometric Methods of Assessment of Nutritional Status in Under Five Children', pp. 349–352.

Peiris, T. D. R., and D. G. N. G. Wijesinghe. (2010). 'Nutritional status of under 5-year-old children and its relationship with maternal nutrition knowledge in Weeraketiya DS division of Sri Lanka', *Tropical Agricultural Research*, 21(4), pp. 330–339.

Solomon, S., and Ketema, M. (2015). 'The impact of irrigation technologies on rural households' poverty status: The case of Fogera District, north-western Ethiopia', *Agris On-line Papers in Economics and Informatics*, 7(1), pp. 59–67.

Steiner-Asiedu, M., Abu, B. A. Z., Setorglo, J., Asiedu, D. K., & Anderson, A. K. (2012). 'The impact of irrigation on the nutritional status of children in the Sissala West District of Ghana', *Current Research Journal of Social Sciences*, 4(2), pp. 86–92.

Tekana, S. S., and O. I. Oladele. (2011). 'Impact analysis of Taung Irrigation Scheme on Household Welfare among farmers in North-west Province, South Africa', 36(1), pp. 69–77.

Wehabrebi, A. A. (2014). Impact of small-scale irrigation on household welfare. Collage of Business and Economics, Mekelle University.

Woldehanna, T. (2014). The policy environment for linking agriculture and nutrition in Ethiopia. Agridiet research report 2.Cork, ireland, Agri diet

World Bank. (2010). *Small-scale irrigation in the Ethiopian highlands: What potential for poverty reduction and climate adaptation?* 3. Retrived from http://go.worldbank.org/2DNNMCBGI0

Yami, M., and K. Snyder. (2012). Improving sustainability of impacts of agricultural water management interventions in challenging contexts. Project report, International Water management Institute, Addis Ababa , Ethiopia .