ECONOMICS OF SELECTED WATER CONTROL TECHNOLOGIES AND THEIR SUCCESSFUL USE: THE CASE OF ETHIOPIA

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Abstract

Using a production function, marginal productivity of farm inputs and benefit-cost analysis, we explore the economics of selected water storage technologies. From the production function, all farm inputs, including irrigation water is found to have a significant and positive effect on yield. Marginal value products of farm inputs are found to be positive but their magnitudes differ by type of storage structures, crop type, agro-ecology and regions. The financial returns of all water storage structures, measured in net present values, are feasible. There is a favorable precondition for sustainable adoption of these storages technologies. The level of education, the ratio of irrigated land allocated to irrigate annuals and perennials, access to markets and off-farm income are found to have significant effect on successful use of these storage structures.

Key word: NPV, production function, instrumental variables regression; Africa.

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1. Introduction

There is a growing interest on agricultural water management (AWM) technologies in Ethiopia. AWM generally refers to "the management of all the water put into agriculture in the continuum from rainfed systems to irrigated agriculture (Falkenmark and Rockström, 2004; IWMI, 2006). It includes irrigation and drainage, soil and water conservation, rainwater harvesting, agronomy, integrated watershed management, water for multiple use systems and all relevant aspects of management of water and land (IWMI, 2007). We focused, in this study, on rain water harvesting and exploitation of surface and groundwater using various storage technologies for supplementary and full irrigation.

AWM technologies are reported to offer considerable promise for increasing agricultural productivity and household income (IWMI, 2007; Hussain et al., 2007; Namara et al., 2007). It nonetheless remains unclear whether such technologies lend themselves easily to adoption by smallholder farmers (Marenya and Barrett, 2007). The typical analysis of technology adoption usually pertains to the choice of competing methods of accomplishing a production or marketing task. For example, crop choice, tillage practice, agro-forestry technologies, soil and water conservation technology and some aspects of natural resource management that are selected by individual farmers. AWM technologies are structurally complex having more suites that could be adopted separately on piece-meal basis. Marenya and Barrett (2007) dealt with adoption of technologies that require ongoing practice. More importantly, in our case, deep wells, small dams and river diversion are primarily unaffordable by individual farmers and they are provided by government or NGOs' investments.

While there are empirical evidences on factors influencing discrete process adoption or non-adoption (Feder et al., 1985; Rogers, 2003; Mercer, 2004; Doss, 2006). So instead of mere adoption what we tried to see the economics of these technologies, regardless of the fact that they are individually –on piece meal basis - adopted or introduced by external agents (Governments, NGOs, etc.). Many studies have analyzed the determinants of adoption without assessing the economic viability of the latter (Kassie et al., 2008). If technologies are not economically attractive from the outset, the probability of their uptake is very low and the outcome of adoption is not desirable. Understanding the profitability or the conditions under which improved technologies are profitable would add to our understanding of adoption decisions (Doss, 2006).

Economic viability is, therefore, an important requirement for successful adoption and ultimately poverty impact. As a report by AfDB, FAO, IFAD, IWMI, and the World Bank (2007) argued, without profitability the necessary income gains cannot be achieved and without profitability economic viability is unlikely.

Implementing programs of adoption at a large scale, in a sustainable manner, and that targets benefits to the poorest people, including women, remains a challenge (Upadhyay, 2004). As a result, many small-scale AWM programs implemented by NGOs have had limited impact (Moyo et. al., 2005; IWSD, 2006; Namara et al., 2005; Van Koppen et al., 2005; Shah and Keller, 2002). But equally relevant, if not more so, is also to explore why some households make profitable use of these technologies and why others fail to do so. There is hardly any evidence on how successfully such technologies are utilized by adopters once they decide to adopt them or are introduced to them. As far as our knowledge goes, there limited studies successful use AWM technologies (Namara et al., 2005; 2007). The main objective of this study is to understand economics of these technologies and factors that determine the successful use of these technologies once they are available to farmers. We saw the economics of AWM technologies by examining the contributions of farm inputs to yield, i.e. the marginal value product (MVP) of various inputs and the financial viability of water storage structures. Successful use was understood to be not only whether the household has introduced a given technology, which could be promoted through various external inducements but disadopted after experimentation (see Neill and Lee, 2001), but once it was introduced the extent to which farmers successfully used this technology. Hence, we measured successful use with level of values of output which could be a measure of translating the investment into a profitable investment given the constraints households face in a given bio-physical and socio-economic environment.

In this study, we focused only on shallow wells, deep wells, ponds, river diversions and small dams as these were assessed as promising technologies in the key informant interview. Water, be it surface or groundwater, is stored in a structure, conveyed and applied to the crop through different technologies. We only considered water storage structures without considering the different water conveyance and application technologies.

Empirical knowledge on the determinants of successful use of water system innovations is critical for designing relevant policies and institutions for effective scaling out of AWM technologies and best practices in the country. In the absence of such understanding, even well-intentioned interventions can have negative impacts on smallholders where they are not well suited to the needs and constraints of farmers (Pender et al., 2006). Furthermore, such analysis may also help to identify the policy interventions required to translate external introduction of technologies by governments into successful farm enterprises by farmers. As Wichelns (2003) argued, discussions involving water resources in developing countries can be enhanced by placing greater emphasis on the roles of non-water inputs and resource constraints in farm-level production and marketing decisions.

2. Literature Review

Smallholder farmers in developing countries are economic agents engaged simultaneously in the production and consumption of the same commodities and investments in improving productivity and sustainability of natural resources. This means that smallholder decisions for land and water management in agriculture are likely to be influenced by several inter-related factors both on the production and consumption side (Sidibe, 2005).

We briefly described the important determinants of successful use and systematically test it later.

In economies where capital markets are missing or not well functioning, households face credit constraints to finance new technologies that enhance the success of storage structures. In comparison to resource poor households, households with better resource endowments are in a better position to translate these technologies into successful ones (Holden and Shiferaw, 2002; Marenya and Barrett, 2007). Household endowments such as human capital (education, labor disaggregated by sex), financial capital proxied by credit access, oxen and other livestock holdings, land size and irrigated land size were included in the model to control for resource endowments. Credit access, the same with access to off-farm income, may relax cash constraint and thereby, facilitate successful use of these technologies. Adeoti et. al., (2007) indicated that the land area under irrigation affected the successful use of irrigation. We incorporated in the outcome equation the type of crops grown using irrigation. Crops can be categorized into high and low value ones. Growing high value crops is hypothesized as having positive effect on the success.

Access to services such as extension, training, etc., and access to input and output markets may play a critical role in successful use. Improved market access that raises the returns to land and labor is often the driving force for successful use of new practices in agriculture (Shiferaw et al., 2007). Successful use may be slower at far away locations because of low access to information and other complementary technologies, not to mention the higher cost of farm inputs. Investments in infrastructure and market institutions and a supportive policy environment are keys to success (Pender et al., 2006). Distance to major market, a proxy of market access, is included in the model. We also included the number of contacts with extension agents as network variables in our model. We hypothesized that households with better market access and social capital are more successful. Other variables such as region dummies (a proxy for moisture availability, population density, agricultural potential and other geographic determinants) may also have important bearing on successful use of these technologies (Ayele and Alemu, 2008).

We also incorporated age, sex and consumer-worker ratio in the model. Higher consumer-worker ratio leads to production of more food crops and less production for the market. Thus, we expect that higher consumer-worker ratio causes less success of use water control technologies. On the other hand, we could not attach any sign a priori to age and sex of the head.

3. Methodological Approaches

In showing the role of water storages, for supplementary and full irrigation and different inputs on crop production, we used a Cobb-Douglas (CD) production function and saw how different inputs influence production (Equation 1). A transcendental production function was found statistically significant, using individual t-test and general F-test F(14.26), but had serious problem of multicollinearity, a variance inflation factor (VIF) that exceeded 10 (Montgomery and Peck, 1992). The production function is given as follows:

$$\ln Y_j = \ln A_j + \sum_{ij} \alpha_{ij} \ln X_{ij} + \sum_{l} d_l D_{ij} + \varepsilon_{ij} \qquad \textbf{(1)}$$

Where $i = 1,2...k$ are inputs such as labor, oxen, fertilizer, pesticide/insecticide per plot area j , Y_j is output per field area owned by each household , α_{ij} measures elasticity, as a result of changes in the level of continuous variable X_{ij} , d_{ij} is a measure of the effect of different use of micro-irrigation technologies, and measures the mean effect of the dummy variable D_{ij} from the overall mean effect.

From the CD production function the MVP of each requisite input was estimated. The MVP is calculated as follows $p.\left(\frac{\partial y}{\partial x_i}\right) = p.MPP = MVP_i$ where p is the market price and MPP is marginal physical product of each farm input i obtained as an output from the CD production function (For detail see Namara et al., (2007).

The financial feasibility of each of these technologies was determined using net present value (NPV) (Gittinger, 1982). The NPV is calculated as follows:
$\sum_{t=1}^{T} \frac{B_{t-}C_t}{(1+r)^t}$ where B_t is benefit stream, C_t is a cost stream discounted, the discount (r) rate is given by the denominator and $t,...,T$ is time horizon. The establishment costs of the different technologies are annualized since they have different useful lifetimes[2] (Anderson et al., 2008). A positive NPV implies positive financial return. We gauged the impact of the changes in discount rates on financial feasibility of these technologies.

The determinants of successful use can be estimated using instrumental variables regression model. Instrumental variables (also called two stage least square) regression yields coefficients that are consistent, asymptotically normal and efficient (Verbeek, 2000; Green, 2002; Wooldridge, 2002). Access to water storage technology is assumed to be endogenous and it can be instrumented using village level variables (like agro-ecology and district dummy). Assuming a single instrumental variable, the participation equation can be estimated by:

$$D_i^* = \sigma + \pi Z + \eta X_i + \upsilon \quad \textbf{(2)}$$

where Z is the instrument variable, X_i are the control variables, D^*_i is an estimated latent variable, and D_i is its observable counterpart. The outcome equation can be estimated as:

[2] The establishment cost is annualized using the establishment cost, discount rate and lifespan.

$$Y_i = \alpha + \beta D_i^* + \delta X_i + \varepsilon_i \qquad \textbf{(3)}$$

Note that the instrumental variable Z appears in the participation equation but not in the outcome equation. However, for Z to be used as an instrumental variable two conditions need to be satisfied:

(i) The instrumental variable should not be correlated with the error term; that is,

$$\text{Cov}(Z, \varepsilon_i) = \text{Cov}(Z, \upsilon) = 0 \qquad \textbf{(4)}$$

(ii) Z should be correlated with D; that is,

$$\text{Cov}(z, D_i) \neq 0 \qquad \textbf{(5)}$$

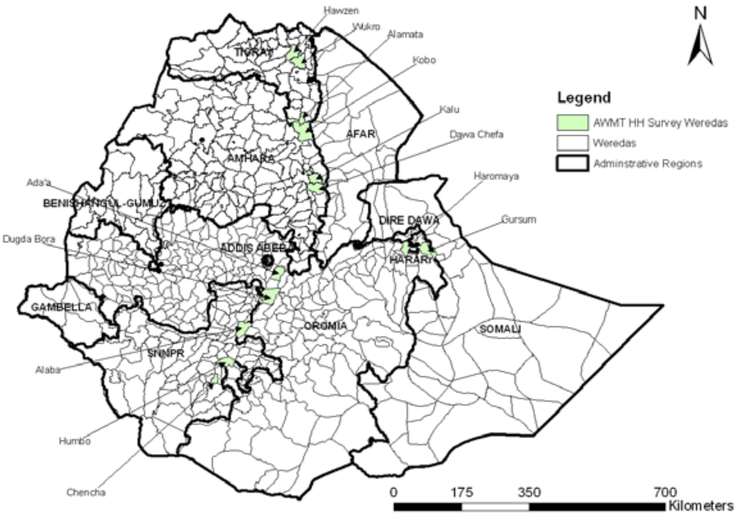
These conditions indicate that Z should have no partial effect on Y_i and that it should not be correlated with unobserved factors that affect Y_i. The second assumption that Cov(z, D_i) ≠ 0 can be tested by running Equation (3). If the coefficient of Z is significant, it shows that the two are indeed correlated. However, the first condition that Cov(Z, ε_i) = Cov(Z, υ) = 0 needs to be maintained by 'appeal to economic logic or introspection' (Wooldridge, 2006, p. 512).

We estimated robust standard errors to correct for heteroskedasticty (White, 1980). We tested also for possible multicollinearity; we had to eliminate highly collinear variables with a VIF that exceeded 10 from the regression.

4. Study Site and Data Sources

This study is part of a comprehensive study on AWM technologies in Ethiopia, which included inventory of technologies and practices in Ethiopia (see Loulseged et al., 2009a) and an assessment of the poverty impacts of most promising technologies (Hagos et al., 2011b). This study, which was conducted as part of the poverty impact study, was conducted during October-December 2007 and was implemented by the International Water Management Institute (IWMI) with support from United States Aid for International Development (USAID). The survey data, on which this study is based, was gathered from a total sample of 1517 households from 30 Peasant Associations (PAs) in four national regional states (see Figure 1) for the 2006/2007 cropping season.

Figure 1: Study weredas (districts)



The PAs were selected after the identification of the presence of one of the promising technologies, which was done through key informant interviews (Loulseged et al., 2009b). Then households from each PA were selected randomly, once the households were stratified into those with access and without access to the selected water storage technologies, following a non-proportional sampling approach. Details of the sample households by type of technologies from the four regions are given in Table 1.

Table 1: Sample households using different water storage technologies suites from the four regions

Region	Water storage management technologies						
	Purely rainfed	Pond	Shallow wells	Deep wells	River diversion	Micro dams	Others†
Amhara	118	8	49	67	27	1	0
Oromia	184	12	22	14	47	0	0
SNNPR	208	67	54	0	25	0	0
Tigray	129	48	90	5	39	33	24
Total		639				774*	

† Others include technologies such as spate irrigation, soil terraces and soil bunds.

* There are some missing observations. This does not add up to 1517.

The explanatory variables used in the regression were chosen based on the literature review presented in the preceding sections plus our expectations.

5. Results and Discussion

5.1 Summary Statistics

This section reports a summary statistics and the results of the mean separation tests of important variables for users and non-users. The statistical test result could serve as some indicative measure of the differences in important variables between users and non-users. However, a more systematic analysis of successful use will be required before drawing definite conclusions on the determinants of successful use. Accordingly, statistically significant difference was found in mean values of important variables as shown in Table 2.

Table 2: Mean separation tests of some important variables of households with and without access to water storages

Variable name	Nonuser (n= 641)	Users (n= 876)	p-value*
	Mean (SE)	Mean (SE)	
Value of fertilizer used	274.9 (27.0)	399.5 (32.7)	0.0053
Value of seed used	272.1 (31.1)	698.1 (204.1)	0.0762
Value of labor used	600.9 (34.7)	1114.3 (67.6)	0.0000
Value of insecticide used	19.6 (3.1)	75.4 (19.7)	0.0161
Loan size (cash)	1293.4 (108.0)	1688.9 (102.5)	0.0083
Crop income	302.3 (16.4)	682.5 (57.0)	0.0000
Livestock income	51.6 (5.37)	67.3 (4.25)	0.0201
Agricultural income	352.9 (7.2)	749.7 (57.2)	0.0000
Non-farm income	63.7 (4.36)	67.0 (4.95)	0.6276
Consumption expenditure per adult equivalent (monthly)	39.2 (4.46)	40.8 (3.71)	0.7739
Face food shortage	0.373 (0.019)	0.35 (0.016)	0.4475
Market share	0.07 (0.01)	0.15 (0 .012)	0.0000
Oxen units	1.18 (0.05)	1.71 (0.055)	0.0000
Livestock units (in TLU)	3.27 (0.11)	4.64 (0.15)	0.0000
Land holding (in *timad*±)	5.12 (0.16)	7.14 (0.19)	0.0000
Labor endowment (adult labor)	2.961 (0.06)	3.054 (0.05)	0.2340
Labor endowment (Adult male)	1.4456 (0.04)	1.568 (0.04)	0.0209
Labor endowment (Adult female)	1.496 (0.04)	1.47 (0.03)	0.6650

* Two-sided test of equality of means

± A *timad* is quarter of a hectare.

Surprisingly, users were also found to have significantly higher asset endowments such as male adult labor, oxen, livestock (in TLU) and land holding, which may imply that those with access to water storage have managed to build assets. On the other hand, it may also mean that households with better resource endowments may be targeted by the program (or due to self-selection), an issue that the study may not be able to establish in the absence of baseline data. However, the mean separation test indicated that there is no significant difference in mean consumption expenditure per adult equivalent, incidence of food shortage and size of non-farm income.

The problem with such mean separation tests is that they did not control for the effect of other covariates. In the following sections, we will systematically identify the determinants of successful use by controlling for relevant covariates.

5.2 Output and Factor Productivity

From the results of the CD production function, the quantity of seed, labor, oxen, land area, fertilizer and herbicides/pesticides used have significant positive effect on yield. The most limiting factors to increased yield, given current farming in Ethiopia, are labor and seed quantity. Thus, increasing those inputs may increase output but the non-linear effect of those inputs need to be explored (see Table 3). Other farm inputs such as chemicals (fertilizers, herbicide and pesticide), as can be seen from the empirical evidence, are also vital. Moreover, it can be seen that using water control technologies for full irrigation has significant positive impacts on yield per timad[3]. That implies that, full irrigation, obviously, (in contrast to rainfed) leads to a positive increase in yield. Likewise, the use of micro water harvesting technologies (to lift, convey and apply water) also has a significant positive effect on yield. This result shows that irrigation water as an input plays an important role to enhancing agricultural productivity.

From the production function, we estimated the MVPs (see section 3) of different farm inputs under different water storage structures, agro-ecology, region and crop categories. The results show that the marginal values of labor, land area, oxen used, seed quantity and fertilizer is significantly positive and higher under full irrigation compared to rainfed. For instance, a unit of labor used under supplementary and full irrigations, yielded close to two and three times respectively of the value generated under rainfed agriculture in a season. Likewise, a timad of land used under

[3] One timad is a quarter of a hectare.

supplementary and full irrigations yields close to 2.9 and 5.01 times respectively the value generated under rainfed agriculture in a season. The marginal values for seed quantity, oxen units and pesticides/insecticide also show the same pattern as labor. However, the marginal effect of fertilizers, although positive, is the same in supplementary irrigation as rainfed. But it increases close to three times under full irrigation (see Table 3). The MVPs of pesticides/insecticides are higher in supplementary irrigation than full irrigation, although it is higher in irrigation system than rainfed.

Table 3: CD production function

Dependent variable: log(output) per timad		
Variable	**Coefficient**	**Standard error**
Supplementary (dummy variable rainfed=1)	-0.019	0.062
Full irrigation (dummy variable rainfed=1)	0.539	0.052***
Micro irrigation (dummy variable yes=1)	0.360	0.080***
Log(seed per timad)	0.065	0.011***
Log(fertilizer per timad)	0.044	0.012***
Log(labor per timad)	0.554	0.018***
Log(land area in timad)	0.218	0.027***
Log(pesticide per timad)	0.133	0.033***
Log(oxen per timad)	0.238	0.026***
_cons |	5.13	0.055***
Number of obs = 7073		
Wald chi2(9) = 1943.38		
Prob > chi2 = 0.0000		
Log likelihood = -13599.443		

*, **, *** significant at 10, 5 and 1 percent level of significance

The marginal value for the different inputs under different water storage structures is also significant and positive. That means the MPVs of land, labor, seed, oxen, fertilizers and pesticide/insecticides are superior under almost all types of water storage structures compared to rainfed system. The MVPs of each farm input is higher for ponds compared to the various water harvesting regimes but it is statistically insignificant.

Table 4: Estimated marginal value product (in Birr) under different technologies

Factor inputs	Water input				Under different water storage structures					
	Rainfed	Irrigated		ANOVA F-test	Pond	Shallow wells	Deep well	River diversion	Small dams	ANOVA F-test
		S	F							
Labor (LMD)	386	759	1146	5.14***	3612	458	264	265	225	0.60
Land (Timad)	2235	6447	11209	69.6***	5501	5392	3830	3519	900	0.95
Oxen (pair)	779	1333	1603	6.54***	3460	998	1092	1257	812	0.36
Seed (kg)	68	155	367	70.7***	123	90	86	142	29	0.19
Fertilizer (kg)	21	23	64	12.14***	230	25	9	15	4	0.93
Pesticides/ Herbicides (ltr)	1683	3719	2218	3.59***	976	735	1116	1450	319	0.30

S= supplementary; F= full irrigation

*, **, *** significant at 10, 5 and 1 percent level of significance

The performance of water storage technologies are determined by diverse bio-physical and socio-economic conditions. By considering only bio-physical conditions, , the MVPs of some of the factor inputs is found to vary by agro-ecology. The MVPs of labor, oxen, seed and pesticides/insecticides were found to be higher in the upper highland than the midland and lowland. The difference of MVPs for fertilizers and land was insignificant in all agro-ecologies. Land is considered to be relatively more abundant in the lowlands than in the highlands; the MVP of land in the highland is expected to be higher than the lowland. But the result here is inconclusive. When these are disaggregated by regions, households in Oromia have higher factor MVPs of labor, oxen, seed, fertilizer and pesticides/insecticides (together with Amhara) followed by households in the other regions. Households in Tigray and Oromia have higher land productivity than SNNPR and Amhara.

Table 5: Estimated marginal value product (in Birr) by region and agro-ecology

Factor inputs	Agro-ecology				Region				
	Low land	Mid highland	Highland	ANOVA F-test	Amhara	Oromia	SNNPR	Tigray	ANOVA F-test
Labor (LMD)	331	497	1049	4.49***	278	897	663	237	4.43***
Land (timad)	4532	4522	3721	0.74	365	5348	3390	5574	6.60***
Oxen (pair)	946	914	2046	5.17***	801	2303	925	486	20.16***
Seed (kg)	141	81	113	3.11**	195	195	49	74	17.64***
Fertilizer (kg)	17	32	18	0.37	7	45	20	17	1.56
Pesticides/Herbicides (ltr)	2794	1602	5402	13.7***	837	1965	2125	992	3.70***

*, **, *** significant at 10, 5 and 1 percent level of significance

We categorized crops into high- and low-value ones and further disaggregated in to annuals and perennials; namely, low value annuals (LVA), low value perennial (LVP), high value annual (HVA) and high Value perennial (HVP) and attempted to see if MVPs differ by crop categories. LVA are mainly cereals and LVP are drought-tolerant perennial trees (like local Hops). HVA are mainly vegetables while HVP are fruit trees. As indicated in Table 6, factor MVPs are highly influenced by the type of crop category. Compared to LVA and LVP, households growing HVA and HVP have significantly higher MVPs. This implies that if households grow high value crops in combination with irrigation they generate higher marginal productivities. But they keep on growing low value crops, mainly cereals, as a matter of household food security.

Table 6: Estimated marginal value product (in Birr) by crop category

Factor inputs	Crop category				
	LVA	LVP	HVA	HVP	ANOVA F-test
Labor (LMD)	172	1511	576	1543	18.10***
Land (timad)	1219	6341	7876	10016	94.04***
Oxen (pair)	614	1049	1086	2156	17.09***
Seed (kg)	27	37	453	37	214.7***
Fertilizer (kg)	23	5	14	136	9.59***
Pesticides/ Herbicides (ltr)	1376	376	639	9718	202.94***

LVA=Low value annual; LVP= Low value perennial; HVA= High value annual;
HVP= High value perennial
*, **, *** significant at 10, 5 and 1 percent level of significance

When we disaggregate the MVPs of farm inputs by the type of micro-irrigation technologies, the marginal productivities of the different inputs are higher when households use motor pumps or water saving technologies such as family drip kits, but statistically insignificant (the results are not reported here).

Generally, the MVPs of different inputs are found positive when different water control technology is used and this is a favorable precondition for adoption and perhaps for successful use of these technologies.

5.3 Net Present Value

To simplify the analysis we made the following assumptions: In comparing water storage structures, current production patterns and input and output market conditions will remain the same throughout the project's life time. This is justified since the purpose was to compare amongst technologies currently rather than to make a prediction about what happens in the future if these factors change. We assumed that whatever happens will have the same effect on all these storage structures.

Based on experience in Ethiopia, different lifespans for the five water control structures are considered (see Table 7).

Only crop values are considered in calculating returns from these investments. Other benefits such as fodder value and other environmental and ecological benefits were not accounted for because of lack of data in the calculation although AWM technologies, such as rainwater harvesting, have also been shown to have ecological and environmental conservation benefits (UNEP, 2005).

Farmers are expected to cover all annualized investment, operation and maintenance costs besides production costs. A 10 percent operation and maintenance (O & M) costs for all the technologies are assumed. 8, 10 and 15 percent discount rate was used to gauge the sensitivity of the outcomes.

Table 7: Cost-benefit estimates of selected water storage structures (in Birr/ha or unit)

Type of technologies	Establishment costs per structure	Operating cost	Life span (# years)	annuity factor (at 8 %)	Annualized establishment cost*(i n Birr)	O & M cost per structure 10%	Production cost Birr/h a	Crop value Birr/ ha	NPV (discount rate 8 %) Birr /ha	NPV (discount rate 10 %) Birr /ha	NPV (discount rate 15 %) Birr /ha
Pond	5,980	-	10	6.247	957..2	388.8	5901	7861	13,491	12,348	11,595
Shallow wells	9,343	-	12	7.536	1239.8	584.2	3531.2	4467	8,727	7,467	7,000
Deep well/ha	94,292	2500	25	10.675	8832.9	2841.8	2616.2	9843.4	21,366	13,466	12,691
Small dam/ha	50,000	-	25	10.675	4683.8	5000	2919.4	12,070.80	21,981	17,525	16,489
River diversion/ha	50,000	-	25	10.675	4683.8	5000	1629.3	2867.5	12,354	8,093	7,511
Rainfed (reference)							1804	2894.4			

Source: Tesfay (2008) and own calculation

± Includes costs of pond construction, geo-membrane plus treadle pump per pond.

+ Includes costs of well construction and for purchase of generator pump.

♣ The cost stream include system installation cost (Birr 53,253.75 per hectare), electricity installation (Birr 2,543 per hectare), construction of generator house (Birr 356 p hectare), and electro mechanical works (Birr 9,722 per hectare).

* Assuming a discount factor of 8 %.

Source: Authors

We used investment (establishment costs) data obtained from secondary sources and data on production costs and crop value from primary sources. Assuming that farmers cover all investment, operation, maintenance and production costs, the corresponding NPV of all water control structures is positive at 8% discount rate (see NPV1 in Table 6). 8 % is the current bank lending rate for long–term investment loans in Ethiopia (Tesfay, 2008). Even at 10 and 15 percent of social discount rates the financial feasibility all control structures remains positive (see NPV2 and NPV3). This shows that these technologies are financially viable from private financial cost-benefit analyses perspective.

Currently, the government, with donor and NGO involvement, is responsible for promoting most of these technologies. In areas where the groundwater potential is high, the government is promoting deep wells by covering the total establishment costs while farmers are expected only to cover the operation (e.g. electricity) and maintenance costs. River diversions and small dams are also usually provided by the government and farmers are expected to cover only O & M costs. However, in the case of ponds and shallow wells, after initial introduction with strong government support, farmers are now expected to cover the full cost of establishment. The government provides only technical support to farmers who would like to introduce these technologies besides providing, at cost, valuable water withdrawal and application inputs and tools. This implies that the private cost of accessing deep wells, small dams and river diversions, and to some extent ponds and wells, is very low although provided at high social costs. Nevertheless, the benefit-cost analyses and estimated MVPs above indicate that all water storage technologies are financially viable; farmers can sustainably adopt these technologies. The determinants of successful use are presented below.

5.4 Determinants of Successful Use

The result of instrumental variable model (IV reg) is reported in Table 8 below. Accordingly, the ratio of land allocated to irrigate annuals and perennials determine the successful utilization of water storage technologies. But farmers that have higher ratio of land allocated to irrigated annuals seemed to be more successful than farmers growing on irrigated perennials. Households located far from all weather roads were less successful than households that are close to the markets. Better market access will enable farmers to grow high value crops and are more likely to be market-oriented (Hagos et al., 2011a).

The level of education achieved by a member is positively related to the successful use of water control structures. That implies that educational enrollment positively affects the success of water control technologies. Educated household members are keener to try new and optimally use new technologies. Participation in off-farm employment has a positive effect on successful use of water storage technologies perhaps because such households have cash income to purchase necessary inputs such as fertilizer and seeds.

Table 8: Determinant of successful use

Coefficients	Description	IV regression	
		Coefficient	Robust St. Errors
Sex of the household head	Dummy (reference male head)	-5732.73	3085.76**
Age of the household head	Continuous variable	9.15	58.33
Education of the household head	Dummy (reference illiterate)	-1331.56	3022.69
Education attained by a member	Continuous	2324.76	1417.70*
Off-farm income	Dummy (yes= 1)	12423.75	7614.93*
Access to credit	Dummy (yes= 1)	-7004.87	4489.86
Land holding	Continuous	-24.92	949.40
Oxen holding	Continuous	-349.04	406.94
Livestock holding less oxen	Continuous	-1628.11	1530.68
Male adult labor	Continuous	-1863.04	1467.29
Female adult labor	Continuous	11130.14	7402.53
Consumer-worker ratio	Continuous	-3251.22	1701.78**
Ration of land allotted to low value perennials	Dummy (reference = rainfed annual)	7670.34	5503.53
Ratio of land allotted to high value annuals	Dummy (reference = rainfed annual)	3830.14	1474.61***
Ratio of land allotted to high value perennials	Dummy (reference = rainfed annual)	44114.2	23256.39**
Extension contact	Continuous	-12.96	22.48
All weather road	Continuous	-92.91	54.30**
Water availability	Continuous	476.90	303.39
Amhara region	Dummy (reference = Tigray region)	16785.7	10158.74*
Oromia region	Dummy (reference = Tigray region)	24313.7	13129.0*
SNNPR	Dummy (reference = Tigray region)	4728.28	4004.85
_cons	Intercept	-24908.14	17863.0
n= 891			
R^2= 0.121			

*, **, *** significant at 10, 5 and 1 percent level of significance.

Some household characteristics were found to have a significant effect on success. Consumer-worker ratio has a negative effect on successful use of water storage technologies. Households with more dependents may produce staple crops, mainly cereals, which do have lower market value. Female-headed households use water storage technologies less successfully than male-headed households. Finally, regional dummies, which may capture agricultural potential of the geographical area and population density, turn out to be significant. Accordingly households in Amhara region and Oromia region are more successful in utilizing water storage technologies compared to households in Tigray region. But the coefficient for households in SPNNR was insignificant, although the sign was positive.

6. Conclusions and Recommendation

There is increased interest to promote irrigation, through household-based or community investment, in Ethiopia to foster economic growth and to increase food security in the face of the recurrent droughts. Lately there is growing interest for household-based water control technologies by viewing the benefit of these technologies for supplementary and full irrigation use by farmers. Farmers are growing high-value crops and, thereby, improving their livelihood by drawing income from these technologies. Nonetheless, there is growing policy concern whether there will be sustainable adoption of these technologies by individual farmers, with limited external support, and whether investment cost recovery schemes can be introduced with little farmers' resistance. This requires knowing the financial feasibility and the economic return of these selected technologies on farm income.

Water control technologies, the result shows, have a positive economic return on yield and are financially viable. These are important preconditions for sustainable adoption and successful use of water storage technologies. The financial analysis also shows that if the government is to institutionalize investment cost recovery schemes, farmers operating these technologies are be able to pay. Government need to institutionalize active participation of farmers in promoting irrigation and cost recovery. This will have serious implications for poverty reduction and growth.

Water storage technologies can play a great role in improving people's livelihood and transforming agriculture but its effect could be higher in the face of a better supply of improved seeds, micro-irrigation technologies and farm inputs.

Households that have higher ratio of irrigated land allocated to annuals and perennials are more successful than those growing low value crops. This calls for increasing the land allotted to irrigated annuals and perennials which requires increased supply of seeds and/or improved market conditions for these products, which was not the main thrust of this paper.

Promoting education can enhance the successful use of these technologies because educated households may be able to increase the return of farm inputs and water control technologies. Moreover, improved market access conditions such as improved access roads, information, transportation and storage facilities can increase the profitability of irrigation.

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