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Irrigation technology and crop choices in Ethiopia: Spate vis-a-vis rainwater-harvesting irrigation technologies

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Moisture-stress weakens the use of modern inputs such as fertilizer, which could undermine yields. In a growing population, low yields cause food shortage. Investing in irrigation mitigates moisture-stress but expensive for smallholder farmers. Spate irrigation, a sudden flood run-off diverting, is cheaper to invest in than other irrigation technologies such as ponds and shallow-wells. This study investigated factors deriving the choice of spate irrigation in Ethiopia, and compared crop-choices and yields among irrigation technologies. To investigate the technology choice, logit model was estimated using data collected from Ethiopia in 2005. Secondary data was analyzed to examine crop-choice and yields. The findings show that: (1) farmers with higher irrigation capital, family-labour, lower operation and maintenance (O&M) costs and living in more arid and rainfall-shortage areas choose spate irrigation; (2) market access does not affect the choice; (3) spate users often grow cereals and pulses than other irrigation users, and this enhances food security; (4) spate irrigation increases grain supplies by increasing yields. These findings suggest that encouraging irrigation-capital creation, low-cost O&M, meteorological services, and considering regional diversities increased the probability of modernizing spate irrigation. The findings also inform the decision on crop choice in disadvantaged and remote areas to improve livelihood.

Key words: Irrigation technology, spate irrigation, rainwater harvesting, crop-choice, Ethiopia.

INTRODUCTION

Moisture stress constrains crop production in drought prone Ethiopia. It decreases the use of modern inputs such as fertilizer and improved seeds. The use of low modern input in turn limits yields. Consequently, food shortage happens. One way out is to invest in irrigation (Tilman et al., 2002). But, the question is which type of

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irrigation, large or small-scale? The efficiency of the large-scale irrigation is often low in Africa (Inocencio et al., 2005). Consequently, large-scale schemes in 1970s and 1980s in many African countries such as Ethiopia (e.g., Alwero and Gode dams) failed for low efficiency, high O&M costs and management limitations. During late 1990s, small-scale irrigations such as rainwater harvesting technologies (WHTs), in their broad definition ponds, shallow-wells and stream/flood diversions, were advocated as options mainly due to the relatively cheaper investment finance required to starting and maintaining them (Wakeyo, 2012: 1; World Bank, 1994).

Previous studies underlined that harvested rainwater reduces the negative effect of weather risk in crop production (Ngigi, 2016; Lasage and Verburg, 2015; Kato et al., 2011; Fox et al., 2005). These studies concluded that WHTs increase yields and sustain income by reducing production risk (Barron and Okwach, 2005). Because of this advantage, governments increasingly allocate public budgets (Lasage and Verburg, 2015) and start to stimulate smallholder farmers to invest in them (Wakeyo, 2012: 1-5). When rainwater harvesting program was stimulated in Ethiopia during early 2000s, the objective was to reduce the risk of rainfall shortage especially during the ripening phase of cereals (Gezahegn et al., 2006). However, because the quantity of water in ponds and shallow-wells is too small to water large parcels, farmers were using the water for high-value crops including fruits and vegetables on small plots (Wakeyo, 2012: 41), unlike in other countries such as Kenya for maize production (Barron and Okwach, 2005). This means that the risk reducing likelihood of harvested rainwater for production of cereal and pulses, which are the staple food crops in Ethiopia, could be low. However, to fill moisture stress gap in cereal and pulses production, spate irrigation could be better than ponds and shallow-wells.

Spate irrigation, 'sudden flood' in macro or micro catchment, and river run-offs (Ako et al., 2010), is interesting to study and understand its effectiveness in reducing moisture stress relative to WHTs. In spate irrigation, farmers wait until flood is drained and do not keep the water for future use unlike WHTs, though floods can also fill ponds (Pachpute et al., 2009). Often, spate irrigation is a traditional and incomparable to that of modern schemes (Al-Jayyousi, 1999). In Ethiopia, both spate irrigation and WHTs were promoted during early 2000s to supplement rain-fed and achieve food security. However, why farmers choose WHTs (ponds and shallow-wells) instead of spate irrigation is not well studied.

Studies also indicate that spate irrigation is used mainly for cereals, pulses, oilseeds (Mehari et al., 2008). The question is how it affects crop-choice. Often irrigation conditions rise in yields, but where irrigation is not available yields are almost stagnant in Ethiopia. For example, the FAOSTAT (2014) website indicates that wheat and maize yields in Ethiopia, are respectively 2.21 and 3.0 tonne per hectare in 2012, mainly due to risky rain-fed production. These yields are only one-fourth and one-eighth of the global highest yields respectively. Under risky weather condition, subsistent farmers do not easily change cropping patterns. They tend to grow traditional crops for food as a mechanism of avoiding risk (Wakeyo, 2012: 1; Rosenzweig and Binswanger, 1993). Under this relationship, one can ask research questions such as for which crops is spate-irrigation suitable and what their yield could look like.

This study contributes to understand spate irrigation better. Systematic studies on spate irrigation are lacking (IFAD, 2009; FAO, 2010) because spate irrigation has been carried out by subsistence-farmers often in remote, forgotten and disadvantaged areas that miss attention from researchers. The objective of this study is thus to: (1) identify factors that determine the choice of spate irrigation than other small-scale irrigation; and (2) compare the crop choice in spate irrigation with that of WHT; and study yields. The study could inform policy-makers about irrigation technology choice in disadvantaged areas.

To the best of our knowledge, no study used primary household data to look into spate irrigation. Most empirical studies focus on storage based WHTs instead of spate irrigation (He et al., 2007; Oweis and Hachum, 2006; Rockstrom et al., 2002). In addition, previous studies use qualitative analysis to investigate why farmers go for spate irrigation in a few Asian and North African countries (Mehari et al., 2007, 2008). Similar studies carried out in Ethiopia on spate irrigation are also qualitative and used qualitative methodologies (Kato et al., 2011; Van Steenbergen et al., 2011). Our study contributes to the knowledge of spate irrigation by using household survey data and econometric analysis.

STYLIZED FACTS ABOUT SPATE IRRIGATION

Investment and operating requirements

Investment finance requirement

Spate irrigation is easy to start than other types of irrigation because of several reasons. Mainly, it requires relatively low finance to invest (FAO, 2010). The traditional structures are less expensive because they use labour input and local material for diversion. In Ethiopia, on average it costs $170 to 220 per ha for non-permanent spate irrigation scheme and $450 for permanent scheme (Alemayehu, 2008). For instance, in Koloba spate irrigation, the estimated cost is $330 to 450 per ha for permanent scheme. These costs are not so high compared to the average cost of permanent WH schemes which is about $800 to 1000 per ha. This indicates the cost advantage of spate irrigation in areas where technologies such as WH are too expensive to invest in.

Skill requirement

In spate irrigation, the structures of the schemes are not sophisticated to demand advanced expert skills. Farmers can construct them from local materials using simple hand-tools. Just furrow can also be used and other conveyance equipment may not be critically important. In WHTs such as ponds, imported materials such as plastic geo-membrane and water lifting equipment are necessary. In addition, from their experience, farmers realized that plastic-sheet ponds do better than cement-ponds (Wakeyo and Gardebroek, 2015). The shortage of plastic sheets, however, forced farmers to disadopt the plastic ponds (Wakeyo and Gardebroek, 2015). This implies that constraints such as plastic sheet shortage for pond construction do not affect spate irrigation.

Labour

Labour seems to be relatively less constraining in spate irrigation than others because floods are occasional. However, during flood-diversion, labour demand is high and labour shortage could undermine the success in flood trapping for spate irrigation (Lawrence and Steenbergen, 2005). Labour shortage could also invite failures when demand overlaps with seasonal and high-paying activities.

Crop choice

Literatures indicate an integrated approach is used to study how farmers decide their crop choice (Benin et al., 2004; Evers et al., 1998). The investment decisions on reservoir or water source, method of irrigation and crop-choice are more integrated than separate. Therefore, crop-choice considers the length of growing-period, quantity of water, socio-economic condition and culture, including labour, market, and consumption pattern.

The crop-choice could affect the success in spate irrigation. Successful cash-crops that performed well in Yemen, Pakistan and Eritrea include pulses and oilseeds (van Steenburgen et al., 2011). In Ethiopia, successes are observed in cereals and pulses e.g., maize and chickpeas, and perennials. For example in central areas, farmers harvest chickpeas in February after the major growing season, using the spate moisture collected in October and November, at the end of the major rainy season.

Other socio-economic aspects

Income and uncertainties

The majority of farmers using spate irrigation in Pakistan, Yemen and Eritrea are resource poor, with per capita income of less than a USD a day (FAO, 2010). The weather uncertainties, lack of access to modern markets limit farmers to a subsistence level. In areas where spate irrigations are used, credit and information are missing; transport and communication are scant. In addition, education, potable water, and health facilities are inadequate. Malaria and water-borne diseases are prevalent. Also, locations in the command area affects income, that is, upstream farmers are richer than downstream spate-irrigation users, as usual in conventional irrigation (Lipton, 2007). Also, because of weather uncertainties, users of spate irrigation could often face low returns and crop failures. To escape those income uncertainties, farmers diversify their income (van den Ham, 2008) by keeping livestock, working off-farm and saving resources. In addition, to avoid risk, irrigators cultivate low-yield and drought-resistant traditional and relatively low water intensive crops such as sorghum, barley and wheat.

Land and tenure systems

The average farm-size in spate irrigation is generally small in many countries. It is less than 2.5 ha in Eritrea, Morocco and Tunisia; but it goes large in Balochistan (Pakistan) and selected areas in Yemen, with an average of 5.4 to 7.8 and 2.5 to 5.0 ha (FAO, 2010), receptively. The average irrigated landholding in Ethiopia is unknown, but estimated to be two hectares in Dodota-Sire spate irrigation (Aman, 2006).

In addition to farm-size, in several countries tenure-uncertainties are common. Often the tenure system varies from full ownership by landlords to several degree of ownership by tenants. In Sudan (FAO, 2010), where land is rotating between farmers annually, the tenure system allows the use of rotating spate irrigation among farmers on a fixed land, but prohibits permanent schemes including WHTs.

In Ethiopia, from land ownership perspective, farm land is public with land use right is certified. The land certification may encourage investment in private WHTs. The land certification is also complemented with share-cropping and contracting and this may allow farmers to access ‘spate land’. Spate-irrigation could also be communal under a regulation that allows cooperation. Therefore, in the empirical analysis, to test the influence of farm-size on irrigation technology choice is appropriate instead of the influence of land tenure.

Water management, water share and equity

The water management in spate irrigation varies between countries and communities. In some countries (e.g., Eritrea) communal irrigation rights and rules are available. Flood water sharing is based on water volume where distribution is proportional and rotational because estimating the flood volume is possible. Based on the measured volume in meter-cube per second a sharing rule is set in Eritrea[1]. The problem is that under rotational distribution, flood is not sufficient even for upstream farmers e.g., Tahima in Yemen (Mehari et al., 2007). In other countries, however, flood management depends on the construction around fields. For instance, in Pakistan, substantial structures of bund are constructed in farmer-managed schemes to guide and divert flood. In the *tokar* system in Sudan, diversion and guide bunds are supported by embankments to restrict outflows to the sea and retain flood flows (FAO, 2010). In Ethiopia, farmers whose plots are close to run-off areas are beneficiary, unless they contract it out for share-cropping.

Equity of access to run-off is often a challenge in spate irrigation. FAO (2010) remarked that in Pakistan and Eritrea, the mechanism of solving access to flood is by dispersing land-owners plot in several parts of a command area than in a single one (common in Pakistan and Tunisia) and ownership rotation of the irrigable land (e.g. Sudan and Eritrea). In the case of Ethiopia, land ownership is relatively fixed by land certification. This means that the certified land-use right seems to dictate the flood use right. However, because ownership is relatively fixed, flexibility is lacking unlike the case of Pakistan and Eritrea, and individual farmers could choose the fixed water storages such as ponds, shallow-wells instead of flood diversions. Nevertheless, to increase access to flood share cropping, renting in, contracting or exchanging land are common (Oka et al., 2013), as in Dodota-Sire spate-irrigation scheme.

Limiting factors

Climate uncertainty and sedimentation

Documents indicate that climate variability limits the use of spate irrigation (FAO, 2010). This is because flood availability depends on the rainfall, and its shortage hinders the use. The uncertainties are exacerbated by climate change, risk of damage and collapse of canals due to the flood that causes high cost of maintenance. These problems are also common in ponds, but not often in shallow-wells because of is reliable water source (Playan and Mateos, 2006). Sedimentation is also another difficulty common in spate irrigation. Water logging and erosion have a disastrous effect if flood-breaks are not constructed. Birhanu and Mengiste (2007) indicated that in Arsi-Dodta spate irrigation scheme in Ethiopia, the effect of water-logging is so serious that continuous irrigation water flow stunts the growth of cereals. In addition, technical faults could also exacerbate sedimentation. Faults cause course-change and flood loses, creates gullies, reduces soil moisture and increases maintenance burden (van Steenbergen et al., 2011). The success thus depends on technical effectiveness, flood management, maintenance capacity, soil type and geo-physical conditions similar to that of WHTs.

Conflicts

Diversion of run-off is carried out within a watershed where farmers' interests could overlap in collecting and diverting the water run-offs. Often unequal sharing of flood between upstream and the downstream users is the cause of conflict. Defining the water-right, water distribution and its enforcement, and paying proper attention to the traditional rules (Meinzen-Dick and Nkonya, 2007; Ostrom and Gardner, 1993) could be solutions to decrease conflicts. In individual storage facilities such as WHT, conflicts are relatively low because of individual scheme ownership in limited space.

Studies indicate that a defined water right is necessary to address the conflicts in spate irrigation. Coulter et al. (2010) studied low lands of Ethiopian Somale Region and the finding supports this claim. Mehari et al. (2007) also remarked that in Eritrea local rules or agreements for spate irrigation are more important than national or regional water use laws, and sometimes both local and national laws work complementarily.

EMPIRICAL METHOD AND HYPOTHESIS

Empirical method

Econometric analysis is used to test the determinants of technology choice between spate irrigation and WHTs, which is a binary choice. With the aim of identifying factors deriving the choice of two categories of irrigation, binary choice models such as probit and logit can be estimated (Verbeek, 2008). The question is how to choose between logit and probit models. The basic principle to choose between the two is the distribution of the error term in the latent variable equation. In case of probit model the distribution is normal with mean zero and constant variance, whereas in logit model the distribution is logistic (Cameron and Trivedi, 2009: 476-479). In addition to the distribution, empirical fit of the data is also essential for the choice. For example, econometric studies suggest looking at the sample size (Cakmakyapan and Goktas, 2013) as criteria to choose between them, suggesting that in large sample the estimation of logit fits to the data better than probit. Moreover, checking the correct classification of the estimate is also leading to choose between the two models. Finally, ease of interpretation of the coefficients is also another criterion for choosing. Studies indicate that logit model is preferred for interpretation. Therefore, because of its many advantage over probit, we chose the logit model for estimation. The cumulative distribution function of the logit model is:

$$\Pr(\mathrm{Y}=1|\mathrm{X})\mathrm{e}^{-X'\beta}]^{-1} \quad (1)$$

where Y is the dichotomous dependent variable that represents

[1]Flood volume (*fv*) is categorized as *fv< 25, 25 <fv< 50* and *fv>50-100* m^3/s. When *fv is* low, i.e. < 25 m^3/s, rotational distribution is not feasible (Mehari et al. 2007).

whether spate irrigation is chosen or not; $\Pr(Y=1|X)$ is the probability of choosing spate irrigation given the vector of explanatory variables X; and β is vector of coefficient of explanatory variables; and e is the base of natural logarithm.

Equation 1 can be rewritten in several ways. The most simplified form (Walsh, 1987) leads to the estimation of the probability of choosing spate irrigation of an individual variable keeping the influence of all other variables constant:

$$\Pr(Y=1|X) = \frac{e^{\beta_o + \Sigma_i^k \beta_i x_i}}{1 + e^{\beta_o + \Sigma_i^k \beta_i x_i}} \quad (2)$$

for k explanatory variables included in the estimation. For convenience in estimation, Equation 2 is equivalent to estimating the marginal effect of each exogenous variable (Cameron and Trivedi, 2009: 479).

The dependent variable of the econometric model is a dummy variable indicating whether the farmer chose spate or other small-scale irrigation. We assigned 1 to users of spate irrigation and 0 to non-users.[2]

Variables included in the estimation of the logit model

Based on the stylized facts, previous empirical studies and (van Steenbergen et al., 2011; FAO, 2010) theoretical literature in technology adoption, variables potentially affecting the choice of spate vis-à-vis other irrigation are identified and coefficient sign is hypothesized. For the sake of space, only the hypothesized sign of coefficients of estimation are indicated.

The variables responsible for technology choice in irrigation are household head's age (+), gender (±), education (±), livestock size (±), farm-size (+), market access (±) (Sadoulet and de Janvry, 2006), specialization in crop production (+), ease of selling output (+), rainfall-shortage months (±) (Wakeyo and Gardebroek, 2013), household size(±), family labour availability (+) (Moser and Barrett, 2006), training (±), irrigation capital (proxy: irrigation equipment-cost) (±), O&M cost (±), aridity (±), slope (+) (Bracken and Croke, 2007), agro-ecology (±), low, medium, and high altitude (Pachpute et al., 2009) (±), and regions (±).

STUDY AREA AND DATA

Ethiopia has 12.7 million farmer households and total land of 112.3 million ha. Of this total land, 16.4 million (15%) is suitable for crop production. In the country, smallholder farmers produce 95% of the agricultural output. About 90% of the 80 million lives in the highlands that covers 60% of the land area. High altitude, slope and dominance of plateau characterize the topography. The high altitude and slope cause fast flood to divert and use it for spate irrigation or trap it into ponds. About 200,000 ha is under spate irrigation and the amount of land under WHTs is unknown.

The study areas of the spate irrigation include 30 sample sub-districts selected from the four major regions of Ethiopia. A primary data was collected in 2005 from the four major regions and used for econometric analysis of cross-sectional data. To investigate the other objectives, secondary data are used in supplement of the available data. The study makes comparison of the yield effect of spate irrigation with rain-fed.

In 2005, a survey was conducted in the four regions and categorized farmers into ponds, shallow-wells and spate irrigation users. The selected households were stratified by their regional and sub-district distribution and the type of WHTs. Most sample farmers use ponds, followed by shallow-well and spate-irrigation users (9%). In terms of agro-ecology, nearly 80% of the sample farmers are from high- and midlands, and 15% are from lowlands. Among the spate irrigation users, 25% are from the lowlands and 75% are from the high and midlands.

RESULTS

Descriptive statistics

Among the explanatory variable, the average farm-size is 1.65 ha, which varies by district. In low-land districts, it is larger than that of the mid- and highlands because the later are densely populated and farm-land is fragmented (1.67 compared to 1.48 ha for other WHTs users). On average, larger farms could lead lowlanders to choose spate irrigation on their relatively larger farms compared to that of highlanders. The problem in the lowlands could be labour shortage, for example. The computed data (not depicted here) also indicates that farmers facing labour shortage in spate irrigation are higher (36%) than in other irrigation (27%).

Agro-ecologies condition farming systems. Accordingly, mid- and highlands of Ethiopia engage in mixed farming whereas lowlanders engage in livestock rearing. In the low lands, farmers access water from collected rainwater or rivers. The midlands also face water scarcity and they use spate irrigation to supplement their rain-fed cultivation.

The average number of rainfall shortage months is 3.5, about 3.7 for spate users, but 3.4 for other technology users. The data shows March, April, May, June, September and October are from the highest to lowest frequency. Farmers use spate for supplementary irrigation mainly during the minor growing season from March to May.

The data also shows that spate irrigation users are disadvantaged in marketing opportunities. The mean walking distance to market in hours is longer for users (1.5 h travel on foot), but shorter (1.4 h) for non-users. Similarly, the ease of selling output is lower for users than for non-users. The statistics is summarized in Figure 1. Higher mean age could show that more often older farmers tend to use spate irrigation than younger, unlike (Feder et al., 1985). It could mean that spate irrigation depends on experience.

Choosing between spate and other irrigation: Estimated econometric results

A logit model is estimated for spate irrigation choice (dummy) on data collected from 1705 Ethiopian farmers with robust variance estimation. Next marginal values are computed and indicated in Table 1. The marginal effect

[2] For the sake of space, the descriptive statistics is not depicted here. It can be provided on request.

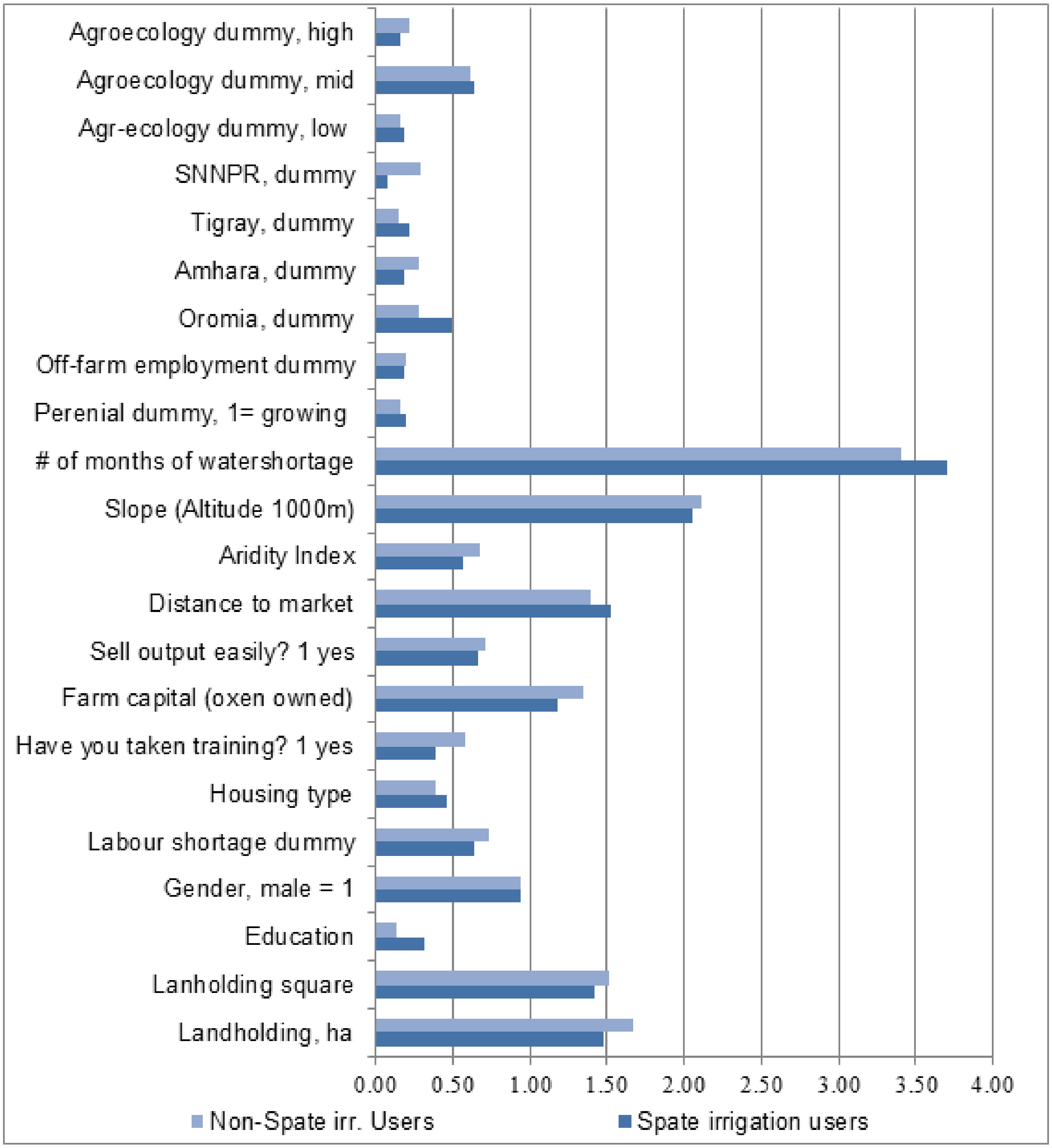

Figure 1. Statistical Summary of variables used in the estimation of technology choice.

indicated in Table 1 is used for interpretation (the parametric estimate can be provided on request)[3].

The estimated result indicates that farm-size, relatively lower age, lower aridity, O&M costs, training, being in Southern Nations and Nationalities and People's Region (SNNPR) and Amhara region decrease the probability to use spate irrigation, whereas owning more irrigation capital, family labour, literacy, relatively older age, living in lowlands and mid-highlands, the number rainfall-shortage months, slope and being in Oromia increase the probability of choosing spate irrigation than other WHTs. Many of the findings are in line with the stylized facts, e.g. spate irrigation is common in the lowlands (van Steenbergen et al., 2011; FAO, 2010; Pachpute et al.,

[3]The test results of the estimation that leads to the computation of marginal effect show robust estimate of logit model. Accordingly, the Wald test rejects the null hypothesis that all coefficients are zero at 1% level of significance. Moreover, the computed classification of the predicted values indicates that 91.85% of them are correctly classified, showing robustness and correct specification of the model.

Table 1. Estimated marginal values.

Variable	dy/dx[a]	Delta method (Standard errors)
Education (1 is literate, 0 otherwise)	0.042***	0.014
Age	-0.008***	0.003
Age square	0.092***	0.026
Gender, male=1	-0.010	0.027
Number of livestock	-0.001	0.001
Farm-size	-0.029*	0.016
Squared farm-size	0.001	0.003
Distance to market, '000km	0.0001	0.0001
Labour availability (no shortage = 1)	0.044***	0.014
Specialization, dummy (1= one crop)	0.017	0.017
Did you take training on irrigation? (Yes = 1)	-0.059***	0.013
Irrigation capital (in '000 ETB[b])	0.010*	0.007
Annual cost (in '000 ETB)	-0.098	0.069
Aridity index	-0.039*	0.024
Number of rainfall-shortage months	0.012**	0.005
Slope (proxy: altitude)	0.032**	0.015
Agro-ecology, low	0.043*	0.025
Agro-ecology, mid	0.031*	0.019
SNNPR, dummy	-0.107***	0.029
Amhara, dummy	-0.039*	0.025
Oromia, dummy	0.051**	0.023

***, ** and * respectively indicate 1, 5 and 10% significance levels([a]). [b]ETB is the Ethiopian Currency Birr. One ETB was 0.0741 US$ in June 2010.

2009); certain slope eases run-off diversion; more aridity increases the probability of using spate irrigation than WHTs. Low altitude areas have rainfall shortage and farmers use the opportunity of occasional run-off for irrigation. In Ethiopia, areas listed as users of spate irrigation are either in the relatively low-lands or mid altitudes. The mid-highlands have substantial share of crop production but, often weather shocks undermine yields. In fact the samples are from highlands and within the highlands the relatively low landers choose spate irrigation, in line with our expectation. Unlike low and midlands, in the highlands, population density, relatively small farm-size and precipitation invite WHTs than spate irrigation.

The estimated marginal effect indicates that a unit change in irrigation capital, proxied by the value of irrigation equipment, increases the probability to choose spate irrigation by 0.01, indicating that spate irrigation is more capital intensive compared to ponds and shallow-wells. Higher irrigation capital means that less expensive and simple hand-tool irrigation equipment such as water cans and buckets do not help much in spate irrigation, as they are in ponds and shallow-wells. Therefore, farmers with higher irrigation capital could trap sudden and powerful water run-off, manage and use it. This finding is in line with the descriptive statistics. Contrarily, higher annual-cost of O&M tends to discourage the probability to choose spate irrigation, indicating that farmers spend relatively less on O&M of ponds and shallow-wells than in spate irrigation which is likely, because after construction, the WH schemes are usually not susceptible to flooding.

The estimated marginal value also indicates a unit rise in aridity index decreases the probability of choosing spate irrigation by 0.044. In less arid areas, relatively better rainfall could discourage spate irrigation and farmers choose to use WHTs. The significance of aridity thus indicates that with the increasing drought effect of climate change, spate irrigation becomes more important. In the estimation, also the positive and significant coefficient of number of months of water shortage is consistent to our expectation, that is, when the number of water shortage months listed by farmers increases the probability to choose spate irrigation increases due to the problem of rainfall shortage for long time. FAO (2010) suggests that spate irrigation is common in long and dry-season areas of occasional rainfall. In WHTs irrigation, this variable is found to increase the likelihood of abandoning WHTs (Wakeyo and Gardebroek, 2015) because the precondition for collecting harvested water is the availability of run-off and the probability that run-off fills ponds declines with increasing number of dry months.

The estimates also show relatively small farm-size decreases the probability of using spate irrigation but very large farms (positive but insignificant coefficient) increase the probability of using it. The reason for choosing spate irrigation with small farm size could be that: (1) farmers with large landholding may have options to diversify crops to decrease risk than to use spate irrigation, this is a finding contrary to that of Marenya and Barrett (2007) with the adoption of improved natural resource management practices in Kenya; (2) small farm size may limit the space to trap flood; (3) but for small landholders it could be easy to construct ponds and shallow-wells.

The estimated result also showed that labour shortage decreases the probability to choose spate irrigation. Because irrigation activities are labour intensive (Wakeyo and Gardebroek, 2013; Moser and Barrett, 2006), farmers who face family labour shortage do not start spate irrigation. The estimated marginal value also indicates when a household escapes labour shortage, the probability to start spate irrigation increases by 0.044. On the other hand, relatively lower age carries a negative and significant coefficient whereas relatively older age carries a positive and significant coefficient. The former's negative sign indicates that younger farmers are more interested in ponds and shallow-wells whereas older farmers are interested in spate irrigation. The older farmers have accumulated experiences in using spate irrigation which is a traditional irrigation practice.

Education is found to positively affect the choice of spate irrigation, unlike the one suggested by the stylized facts. A move from illiterate to literate increases the probability of choosing spate irrigation by 0.043. A strange result is that training decreases the probability of using spate irrigation. This happens because farmers took training prior to choosing technologies and they may tend to choose WHTs afterwards instead of spate irrigation.

Similarly, being in Oromia regions is associated with increasing the probability of spate irrigation whereas being in SNNPR is associated with decreasing it. In Oromia, the regional government supports spate irrigation more than the case in other regions, in line with the finding of Alemayehu (2008).

In this study, there is no evidence that livestock asset, very large farm-size, household size, level of specialization in crop production, ease of selling output, distance to market, and gender affect the choice of spate irrigation. The fact that market variables are less important in spate irrigation could indicate that farmers are not using them to produce high-value crops, rather subsistence food crops (Moore and Fisher, 2012). Creating market access could lift spate-irrigation users in subsistence agriculture.

The estimated econometric model fulfils the necessary test criteria, that is, Wald test indicates that not all the coefficients are equal to zero.

Comparing crop choice in spate and other irrigation methods

In dealing with the crop choice, we hypothesized that spate irrigation tends to favour crops that grow on a relatively larger plot such as cereals, pulses and oil-seeds than smaller plots unlike WHTs (Wakeyo, 2012: 2-5). Those crops are important to increase food-crop supply for food security because of the cereal-biased consumption culture in Ethiopia. Ponds and shallow-wells favour vegetable and fruits, that is, cash-crops on small plots, because of the limited quantity of water.

The 2005 irrigation technology type and crop choice data is summarized in Table 2. The table indicates that the number of households that use irrigation for a category of crops, e.g., cereals and vegetables. Both ponds and shallow-well users favour vegetable and fruit growing, garlic, onion, cabbage, tomato, potato, papaya, avocado, etc., whereas spate irrigation grow cereals and pulses, such as maize, wheat, *teff (eragrostistef)* and sorghum.

Using the water from ponds, only in 2.5% of full irrigation users and 12.7% of supplementary irrigation users produce cereals and pulses, respectively. Similarly, using shallow-wells only 2.5 and 3.4% of the users produce cereals and pulses by using supplementary irrigation and full irrigation, respectively. On the other hand, households using spate irrigation tend to favour cereals and pulses. Table 2 indicates that 3 and 24.6% of the households use supplementary spate irrigation, respectively, to produce cereals and pulses than vegetables, fruits and other tree crops.

Cereals, pulses and oilseeds production increase food supply. In spate irrigation, crops including *teff*, barely, wheat, maize, sorghum, chickpeas, field peas and vetch are produced (Figure 2), and most farmers use spate irrigation to produce maize, *teff* and barely.

Yield differences

Spate irrigation not only favours the production of cereals, pulses and oilseeds, but also increases their productivity (Van den Ham, 2008). Figure 3 indicates the change in yield (increasing yield) after starting to use spate irrigation in Dodota plains of Arsi in Ethiopia. The finding is similar to the one discussed by Postel (1999: 225) for Nabataea, Israel.

DISCUSSION

The study investigated the factors behind the choice of small-scale irrigation technologies by individual farmers and compares their crop choices and yield effects. The finding mainly shows labour-shortage and illiteracy could undermine the use of spate irrigation. Different from what it seems, spate irrigation is a labour intensive activity. Unlike other irrigation technologies, the use of treadle and motor pumps, which could ease labour shortage, is uncommon in spate irrigation in Ethiopia. Because of this, it requires to learn the use of the equipment from the experiences of other countries that predominantly use

Table 2. Irrigation technologies and crop choices in Ethiopia (2005).

Technology/Irrigation		Crop choice					
		Cereal (a)	Pulses and oilseed (b)	Vegetables and fruits (c)	Others (d)	Total (e)	Percent [(a+b)/e×100] (f)
Pond	Full	34	12	1302	39	1387	2.5
	Supplementary	206	53	1730	303	2145	12.7
Shallow-well	Full	3	-	120	3	126	2.5
	Supplementary	5	5	266	16	292	3.4
Spate irrigation	Full	4	-	128	3		3.0
	Supplementary	42	-	111	15	167	24.6

Computed from EDRI's data. Note that the table is adopted from Fujimoto et al. (2012).

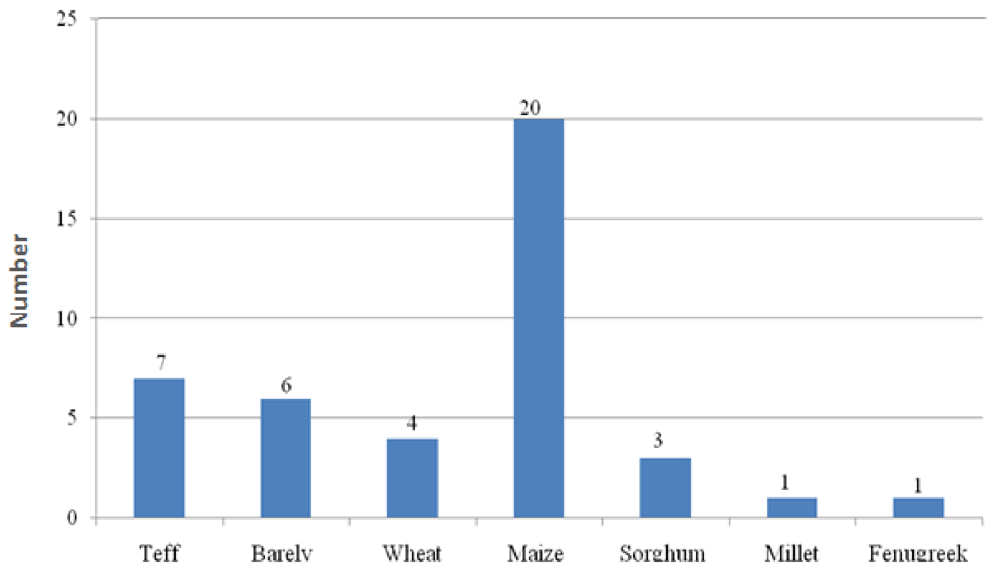

Figure 2. Sample households growing crops by supplementary irrigation in 2005.

spate irrigation (e.g., Pakistan). Examining the experience of other countries helps to avoid the risk of under-capacity uses of pumps for occasional flood.

The number of months of water shortage, and geographical factors influence technology choice. Information from meteorological service could decrease uncertainty and enables farmers to avoid risk in their crop choice and input uses. Moreover, irrigation capital also plays a positive role in spate irrigation. The need for farm equipment, flood breaks, maintenance of schemes damaged by flood, requires access to financial resource.

Literate farmers use spate irrigation more often than illiterate farmers indicating the importance of education in the seemingly low-skill irrigation compared to what is discussed in the stylized facts. On the other hand, it should not be surprising that training decreases the probability of using spate irrigation because the trained farmers could choose other irrigation methods.

Farm-size significantly decreases the probability of choosing spate irrigation. However, size is a relative variable and if the sample was also taken from the lowlands in the peripheral regions, the outcome could be different because the average farm-size in the lowlands of the four regions is often less than that of the lowlands in the peripheral regions. Therefore, rather than concluding about the role of farm-size, re-examining the finding in a further study could be essential.

Geographical location, agro-ecology, aridity and length of months of water shortage determine the use of spate irrigation. This shows that not all locations are suitable for spate irrigation. In line with this conclusion spate irrigation is a choice in the mid-highlands and the low-lands

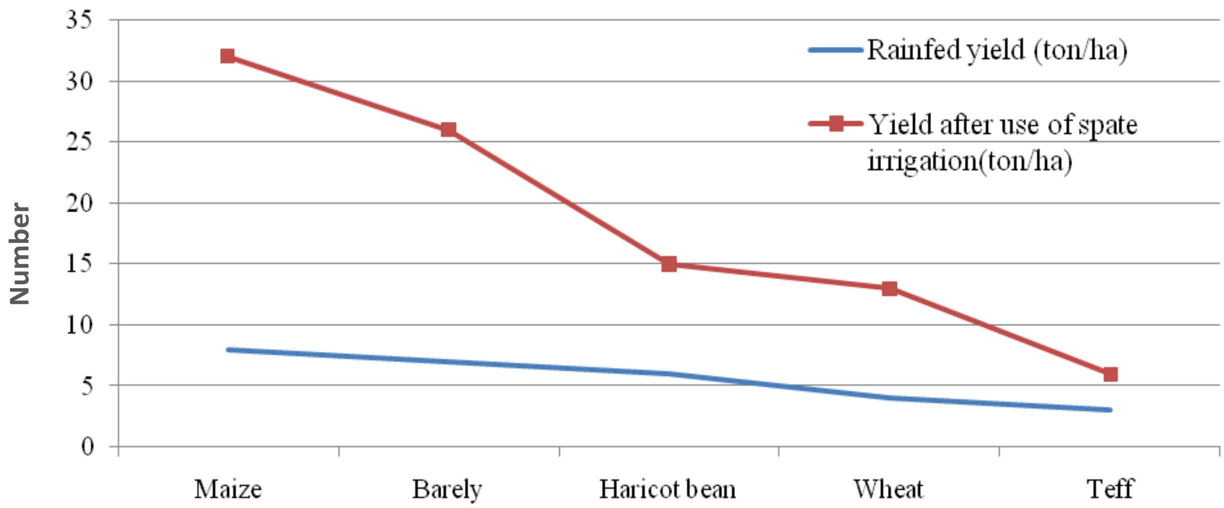

Figure 3. Change in yields after the use of spate irrigation in Dodota, Arsi 2007 (van den Ham, 2008).

compared to the highlands. The mid-highlands are the sources of a substantial share of crop production in Ethiopia, but yield is undermined by weather shocks. The use of spate irrigation in the mid-highlands means that crop production can be protected from such risks. So, to encourage spate irrigation in the midlands could enhance the source of food supply.

Diversity among administrative regions in institutional support makes difference in irrigation technology choice. Regional support to spate irrigation users through providing extension services, stimulating financial resource, orienting farmers, providing information to farmers have positive effects on the returns. These measures could decrease the number of subsistent poor households, who lose their asset and fall into poverty probability due to drought shocks (Nega et al., 2010; Barrett and Ikegami, 2008) lifts out of poverty in the disadvantaged low lands. If spate irrigation is used instead of the sophisticated and expensive irrigation schemes, Ethiopian farmers could increase food supply at low cost by decreasing the rainfall risk and by increasing yields.

Overall, three advantages of spate irrigation can be listed: (1) very large farm-size is positive but insignificant, which could indicate that spate irrigation is advantageous compared to other WHTs to develop larger farms than the case of WHTs (Wakeyo and Gardebroek, 2015); (2) because spate irrigation is a sudden flood overflowing wide areas where evaporation is high storage is costly, growing cereals and pulses more than high-value crops attracts farmers to address their staple food demand (food security); (3) spate irrigation is advantageous to grow crops of short growing period such pulses. This could open a specialization opportunity for relatively large farm-holder subsistence farmers in low lands, given that they are connected to markets by road infrastructure.

Spate irrigation increases food-supply at a relatively low cost by decreasing weather risk and increasing yields. It increases the yields and improves food-security because these crops are often staple-food crops. In fact the analysis is a simple comparison and does not try to measure precisely the crop choice and yield effects. In other words, several other factors could play role in choosing spate irrigation and the issue requires further studies. In addition, in the data used for the study the lowlands outside the four regions are not included in the survey. Had they been included, interesting insights would have been possible.

Conclusions

Some smallholder farmers in Ethiopia choose spate irrigation, that is, diverting a sudden flood-water which could otherwise be useless, instead of storing it into ponds, for several choice driving factors identified in this study. Spate irrigation enhances the production of cereals and pulses, which are often sources of staple food in Ethiopia. Evidences also show its significant impact on cereal yields. This implies that spate irrigation could improve food security in low-yield and drought prone country. Its lower investment cost compared to other irrigation methods makes it attractive in areas where other types of irrigation such as ponds and shallow-wells are not economically feasible, especially in remote and disadvantaged areas.

The findings lead to suggest scenarios under which spate irrigation is practiced. Smallholder farmers in arid and semi-arid areas, which are getting short period of rain and flood opportunity use to irrigate their relatively large farms for cereals, pulses and oilseeds. In arid and semi-arid areas, storage of flood water into WHTs is limited by high evaporation and insufficient water to irrigate large farms. This means that with the expanding aridity due to climate change and expected flooding, the importance of spate irrigation could grow. However, irrigation capital to divert and protect damaging flood is required. In addition, not all places are feasible for spate irrigation. Mid-and low agro-ecologies of the four major regions in Ethiopia are suitable. Moreover, like other irrigation methods spate irrigation is labor intensive. Therefore midlands and lowlands in relatively remote areas of intensive short period rainfall traditionally use spate irrigation. To modernize them, encouraging infrastructure to divert and protect irrigation schemes from damaging floods, investment in road to create market access, and promoting labor-saving technologies to ease labor scarcity are essential.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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