Constraints to the Development, Operation and Maintenance of Spate Irrigation Schemes in Ethiopia

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Abstract

Flood-based farming is among the potential options in ensuring access to water for crop and livestock production for small-scale farmers in the arid and semiarid lowlands of sub-Saharan Africa, and Ethiopia in particular. Flood-based irrigation while inexpensive is rooted in tradition in many rural communities which is in contrast to many other irrigation types which are unavailable (in terms of water source, technology or capacity) or are costly to develop. Spate irrigation has been practiced in different parts of Ethiopia for many decades, but it was only recently that it gained the government's attention. This study was conducted through a review and informal discussion with the objectives of documenting the current status, trends and prospects of spate irrigation in the country and the associated challenges, taking cases of selected schemes in different regional states. The study revealed that spate irrigation is expanding either through improvement of traditional schemes or by developing new ones. Neither the traditional nor modern schemes are free of challenges. The traditional schemes suffer from floods that damage their diversion structures, while poor design and construction of diversion structures have led to the failure of new ones. A range of socio-technical improvements in the planning, implementation and operation of schemes is proposed, including the design of headworks and canals consistent with the size and nature of expected flows, structures to minimize sedimentation, building capacity of farmers and district officers, and monitoring and improving the management that currently adversely impacts the performance of the schemes. Consulting farmers at every stage of the development, and building the capacity of engineers to deal with the unique nature of spate flows are the most likely interventions to ensure successful agricultural production using spate irrigation.

Key words: *Arid, semiarid, traditional irrigation, community involvement, floodwater, modern, siltation*

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Introduction

Agriculture is the dominant factor in livelihoods and landscapes of sub-Saharan Africa. Inability to access water is a major constraint to reducing poverty and increasing livelihoods for the majority of communities and countries of the region. This is particularly true in Ethiopia where agriculture provides 80% of employment. In Ethiopia, most cultivated land is under the rain-fed system characterized by one growing season and high vulnerability to interannual variations and longer-term changes in rainfall patterns. Frequent long dry spells lead to crop failure and cause chronic food shortages and poverty (Awulachew et al. 2010), whose severity increases with decreasing elevation, in response to which the Government of Ethiopia (GoE) has recently introduced and begun implementation of policies to minimize risk through full or supplementary irrigation (MoFED 2010). Given the high initial investment required for development of 'conventional' irrigation schemes and the lack of permanent water sources in some areas, flood-based farming, including spate irrigation is considered an option applicable across large areas of the country.

Spate irrigation (SI) is an ancient form of water management involving the diversion of flash floods running off from mountainous landscapes (Lawrence and Steenbergen 2005). It is practiced in arid and semiarid lowlands that border mountains with substantial runoff (FAO 2010; Van Steenbergen et al. 2011). Oweis et al. (2005) distinguished two systems of spate irrigation: *wadi*-bed and off-wadi systems. In the former, the bed of the wadi is used to store water either on the surface by blocking its flow or in the soil profile by slowing the speed to allow water infiltration so that the crops grow on the wadi floor itself. In the latter, the flood is forced out of its natural course to nearby areas suitable for agriculture.

Globally, SI is predominantly practiced in the Middle East, North Africa, West Asia, East Africa and parts of Latin America. In Ethiopia, vernacular terms for SI imply that it has been long rooted in the water management culture of the communities; it is called *'Gelcha'* or *'Lolaa Debesuu'* in southeast lowlands and *'Telefa'* in the northern areas (Alemayehu 2008). Popularity of SI in the country is increasing, although there is no reliable record to show the rate of expansion. In 2008, an estimated 140,000 ha of land was under SI schemes (Alemayehu 2008) and more schemes were either under construction or at study and design phases. The expansion of SI in the country is attributed to both biophysical and socioeconomic factors. Ethiopia has favorable conditions for spate irrigation; flat, fertile and moisture-stressed lowlands bordered by mountainous highlands with high rainfall. In addition, continual expansion of rain-fed agriculture that uses traditional land management practices suitable for the plains in upland areas has led to loss of forest cover and extensive land degradation. This land degradation has decreased the water storage capacity of the uplands, which in turn increased flooding during the rainy season and water shortages during the dry seasons. This has occurred amidst rising water demand for livestock and crop production in the lowlands; lowland populations have grown from an influx of people from the highlands related to the increased frequency of droughts.

Against this background of increasing interest in promoting irrigation to improve livelihoods, the objective of this study was to document the driving forces behind the expansion of SI, the potentials and challenges related to the different typology of SI schemes and lessons to be learned by other countries in the region.

Methodology of the Study

This study covered four regional states of Ethiopia (Amhara, Oromia, SNNP [Southern Nations, Nationalities and Peoples] and Tigray, Figure 1.1). Both deskwork and field assessments were carried out. The available published and gray literature, design documents and reports were reviewed; some unpublished data from the research team and the projects were also used. Two schemes from Oromia (Boru Dodota and Awadi) and three from Tigray (Maekhoni, Hara 2, Fokisa) were selected for this review as representative of different geographic locations, typology (traditional, modern), scheme size (small, medium, large) and status (functioning or not functioning) (Table 1.1). The field investigation of each of these schemes involved a series of structured discussions with various stakeholders including experts who implemented or evaluated the projects, government officials and 15-20 farmers using a standard template, approach and checklist. This was followed up by a structured interview of 50 spate users (25 each from the traditional and modern schemes) and corresponding nonusers from Oromia and Tigray regions in order to understand the drivers of the expansion of spate irrigation schemes and the livelihood impact of SI use. The results of the latter provided the basis for a separate paper.

Figure 1.1. Distribution of the spate irrigation schemes and schemes visited for this study.

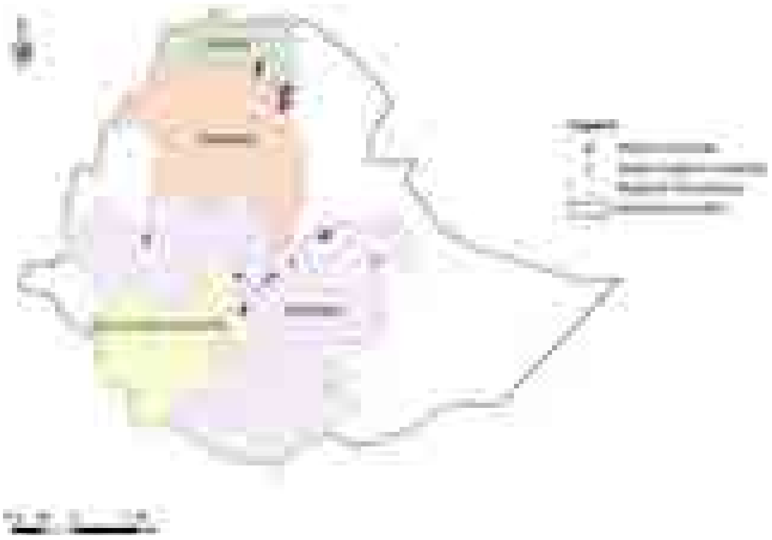


Table 1.1. Details of spate irrigation schemes reviewed in Oromia and Tigray regions.

Region	Scheme type	Name of scheme	Year of establishment	Command area (ha)	Status
Oromia	Traditional	Awadi		85	Functioning
	Modern	Boru Dodota	2007	5,000	Functioning below capacity
		Bura	2011	200	Functioning, new
Tigray	Improved-Traditional	Maekhoni		400	Functioning
	Modern	Hara 2	2010	200	Not functioning
		Fokisa		500	Functioning below capacity

Results and Discussion

Results

Spate irrigation systems have been used in different parts of Ethiopia since antiquity, and SI systems around Kobo in Amhara and Konso in SNNP administrative regions have been used for generations (Alemayehu 2008). However, over the last two to three decades, there has been a remarkable increase in development of SI schemes by farmers and development partners, although there is no comprehensive data to show the extent of the increase. In the four regions studied, both traditional and improved SI schemes are now prevalent although most of the modern schemes are not fully functional. The extent of commitment by the regional governments to the system varies, which may depend on the availability of other alternative water sources, awareness about SI and the potential area suitable for spate irrigation. Clearly, Oromia and Tigray regions have invested in large- and medium-scale schemes and upgraded the existing traditional schemes and constructed new ones.

Status and Potential of Spate Irrigation in Ethiopia

To aid the understanding of the current development and the future potential for spate irrigation, we reviewed the available literature on the subject, which is described below.

A. Incomplete inventory and supporting data: Despite the widespread use of SI in the country, information is inconsistent on the actual area under these systems and the estimate of the potential areas that can be developed. According to Alemehayu (2008), area under spate irrigation was estimated at 140,000 ha in 2008 (Figure 1.2), while the traditional schemes alone were estimated to exceed 100,000 ha as indicated in the National Investment Brief of Ethiopia. The potential for direct use of flood for irrigation or in conjunction with surface and subsurface storages is high since SI and flood recession cropping can be practiced in most of the wadis surrounded by hills receiving high rainfall; moisture-stressed lowlands cover approximately 60% of the country's total landmass (Alemayehu 2008). In an effort to utilize this potential, several regional states have embarked on development of new SI schemes or improvement of indigenous schemes so that their command area increases and the structures function permanently. For instance, Oromia regional state planned to develop spate irrigation with a command area of about 318,000 ha over 5 years (2005/06 to 2009/10) in different development corridors (Alemayehu 2008) out of which schemes irrigating over 7,000 ha were operational during the time of the study (Tables 1.2 and 1.3). In addition, final feasibility and design reports have been completed for 18 schemes with a command area of 34,000 ha (Table 1.4) while the remaining area was reported to be at different stages of study.

Figure 1.2. Status of spate irrigation in Ethiopia as adapted from Alemehayu T. (2008)

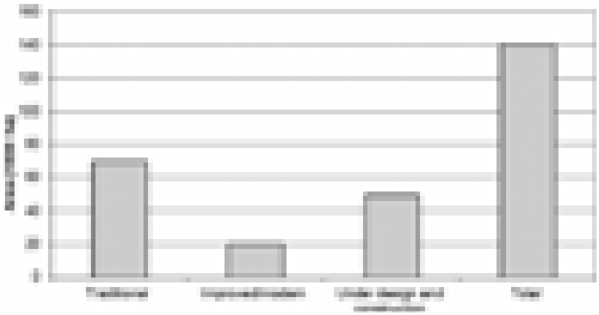


Table 1.2. Details of spate irrigation schemes reviewed in Oromia and Tigray regions.

Development corridor	Planned area (ha)					
	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Borana			650	1,200	1,600	3,450
Southeastern Oromia	4,216	27,550	74,264	49,509	41,258	196,797
South Bale and Guji		8,050	9,400	11,000	9,500	37,950
North Shewa		100	100	100	100	400
Rift Valley	5,000	24,000	19,000	19,500	11,500	79,000
Subtotal	9,216	59,700	103,414	81,309	63,958	317,597

Source: Five-year strategic plan for development corridors in Oromia.

Table 1.3. Area (ha) under spate irrigation in Oromia regional state in 2011.

Name of scheme	Traditional	Improved/modern	Total
Boru Dodota		5,000	5,000
Hargetti		500	500
Bililo		500	500
Ija Galma Waqo		350	350
Ija Malabe		480	480
Awadi	85		85
Bura		200	200
Total	85		7,115

Source: Oromia Water Works Design and Supervision Enterprise (OWWDSE).

It is notable that the command areas of the newly studied schemes are related neither to the amount of rainfall nor to the altitude. The new SI schemes in the region are not limited to the dry lowland areas, but appear to be expanding also to the highland areas that receive relatively high annual rainfall. As shown in Table 1.4, the target areas for these schemes receive a rainfall of 700-1,000 mmyear^{-1}. This may be related to the increased variability in rainfall distribution, including in the highlands that typically receive high rainfall; increased variability and periods of lower rainfall or drought have been accompanied by yield reduction or complete crop failure. The schemes are also distributed over ranges of altitude: from lowlands (1,136 masl) to the highlands (1,914 masl); they average around 2,000 ha and range between 200 and 5,000 ha.

Table 1.4. Planned modern spate irrigation schemes in Oromia for which study and design are completed.

Name of scheme	District	Command area (ha)	Mean annual rainfall in area (mm)	Average altitude (masl)
Agemsa	Mieso	1,000	700	1,455
Adami Hara	Mieso	760	750	1,303
Gagawisa	Mieso	1,000	900	1,468
Oda bela	Mieso	3,200	900	1,447
Chelchel	Raytu	5,000	1,000	1,136
Gungum/Egole	Dellomena	2,000	900	1,155
Dhadhaba gudda	Shashemene	4,000	900	1,852
Burraa	Shashemene	200	900	1,730
Hregolemeno	Shalla	1,000	950	1,835
Kobo borera	Ziway Dugda	4,000	725	1,914
Efadin	Fedis	1,000	190	1,381
Ija Guhe	Fedis	1,500	700	1,550
Arer	Babile	900	775	1,504
Efadin	Babile	1,000	700	1,381
Ija Denu	Meyu Muluke	105	750	1,337
Ija Medalu	Meyu Muluke	337	750	1,341
Tabo	Boset	5,000	700	1,200
Katar	Zwai-Dugda	2,000	800	1,699
Total		34,002		

Source: Oromia Water, Minerals and Energy Bureau (2012).

Tigray is another focus region for spate irrigation development. In addition to upgrading the traditional SI schemes that were concentrated in the southern part of the Tigray Region, the system has been introduced to the drought-prone districts in the central zone where it was not well known, such as Tanqua-Abergelle. In neighboring Amhara Regional State, traditional spate irrigation is practiced in Kobo District, which is adjacent to the Raya-Alamata in Tigray where spate is widely used. According to the district offices responsible for agriculture and rural development in the two regions, about 42,000 ha Raya-Azebo (Tigray) and 427 ha in Kobo (Amhara) districts are under SI schemes.

There is a general lack of comprehensive data on SI schemes in the SNNP Regional State. According to Van Steenbergen et al. (2011) the estimated command area of the traditional SI scheme at Yandefero was about 4,000 ha. Although not widespread as in Oromia and Tigray, local and international development actors have recently initiated new SI schemes in the region. According to the regional Irrigation Development and Scheme Administration Agency, a 300 ha scheme was under construction at Weyito in 2012 (Table 1.5). In addition, the Ethiopian Evangelical Church Mekaneyesus has constructed and handed over a modern SI scheme at Konso, but information on the command area is not available. Also, the International Fund for Agricultural Development (IFAD) is supporting the study of four new schemes in the region covering a command area of 1,250 ha.

Table 1.5. Spate irrigated areas (ha) in SSNP regional state.

Name of scheme	Traditional	Improved	Total	Under design and construction
Weiyto		300	300	
Konso/Yandefero	4,000		4,000	
Birbirsa				250
Galge				300
Mega				300
Mareqo				400
Total	4,000	300	4,300	1,250

Source: SNNP Irrigation Development and Scheme Administration Agency.

B. Drivers of expansion of spate irrigation: Expansion of spate irrigation in Ethiopia may be attributed to the increased demand from farmers for full or supplementary irrigation to overcome the increased climate-related crop failures and the shift in the policy of the government and other agencies from food aid which is believed to create a dependency syndrome (Lind and Jalleta 2005) to local food production and development to sustainably ensure food security in the drought-prone areas of the country.

Regardless of the location, farmers attributed the expansion of spate irrigation in their areas to climate-related factors such as reduced rainfall, increased dry spells and increased temperature, which reduced the length of the effective growing period and increased crop failures. About 63 and 85% of 191 farmers interviewed believed that the rainfall and the length of growing period (LGP) decreased during the last decades. Similarly, about 73 and 64% believed temperature and frequency of dry spells increased over the recent years. To overcome the shortage of water due to reduced rainfall and other factors, the farmers turned to spate flows that supplement the erratic rainfall. However, the majority (over 90%) of the farmers interviewed believe that the volume, frequency and duration of spate flows are also decreasing in response to the reduced rainfall.

On the other hand, the Government of Ethiopia has identified irrigation (especially small-scale) as an important component of adaptation to climate change (GoE 2007) and ensuring rural food security in its economic development programs (MoFED 2006). The current food security policy of the country aims at increasing production and farmers' income using locally available resources and affordable inputs, a policy supported by big donors like the World Bank (2011). In an attempt to translate the policy into action, both the federal and regional governments, supported by bilaterally and multilaterally funded projects are developing water resources for agriculture, and in areas where it is found feasible, spate irrigation is also considered as an option.

Typology and Management of Spate Irrigation Systems

Typology of spate irrigation systems: Traditional systems

The following examples and points about traditional schemes are based on our field observations. Traditional spate irrigation schemes refer to schemes that are planned, constructed and managed by farmers themselves with no or limited external interventions. The design and construction approach and size of the scheme vary depending on the amount of floodwater available to divert, experience of farmers and availability of materials for construction. The structures often have diversions and can sometimes have canal systems, such as primary, secondary and tertiary canals, as components (Van den and John 2008). Among the limitations of the traditional schemes is that the diversion structures are simple deflectors constructed using brushwood, stones and sand that can be easily washed away by heavy floods, which in turn necessitate frequent reconstruction (Daniel et al. 2005). In addition, as they can divert only a limited part of the flood, the command area per diversion is also limited, requiring a series of diversions over a wadi to irrigate large areas. However, the systems allow equitable distribution of water between upstream and downstream users (Daniel et al. 2005). As the number of users per diversion is limited, the management of water is simple. The canals are often very wide (up to 3 meters) and sometimes stabilize and become permanent when used over extended periods of time, as witnessed in Raya Valley.

Most traditional schemes in Ethiopia are small in size (less than 200 ha) and often constructed and managed by an individual or group of farmers. A wadi scheme that is located in Arsi Negele District, Oromia Region was constructed 20 years ago by an innovative farmer and it has been continuously improved by the community. In this scheme, the flood emerging from Aga Mountain is diverted from Awadi Ephemeral Riverbed by a stone bund (Figure 1.3) to irrigate 85 ha of land. Recently, the Japan International Cooperation Agency (JICA) assisted the community to replace a wooden flume constructed across a gully with steel believed to last longer (Figure 1.4). Similarly, the traditional diversion structures locally known as 'maegel' (in Raya Valley) (Kidane 2009) and 'melee' in Kobo Valley (Alamrew et al. [unpublished]) are used in Tigray and Amhara regions, respectively. Unlike many spate irrigation schemes in which cereals such as maize and sorghum are grown, onion and potato are crops commonly grown in the scheme.

Figure 1.3. Stone bund diversion in Awadi traditional SI scheme.

Figure 1.4. Improved metal flume in Awadi traditional SI scheme.

Typology of spate irrigation systems: Modern systems

Development of the modern schemes in Ethiopia is a recent phenomenon as part of the effort to enhance agricultural productivity to meet the increased demand for food and to spur overall economic growth. Efforts have been made to ‘modernize’ the traditional schemes or develop new ones during the last two decades. The modernization of the traditional SI schemes is often aimed at reducing the labor required to maintain diversions, improving the control of water within the distribution systems and increasing the capacity of structures to tolerate the damage due to large floods. In the modern SI systems, the structures are expected to guide and split floods while avoiding excessive sedimentation and promoting the deposition of suspended sediments in the cultivated lands instead of filling up the canals. Consequently, the design for improvement must ensure that the structures cope with frequent and sometimes large changes in wadi bed conditions (FAO 2010). In addition, FAO (2010) suggests that the design has to respect the established systems of water allocation arrangements, priorities and amounts in order to avoid conflicts. Several modern SI schemes in Raya Valley are the result of improvement of the traditional schemes through the Raya Valley Development Project (Michael 2000).

Set with its features such as a diversion headwork, rejection spillway, main canal, branch canals, secondary canals, tertiary canals, drop structures, division boxes, storage reservoirs and drainage culverts, and with a potential command area of 5,000 ha, Boru Dodota modern SI scheme was newly developed by the Oromia regional government. Apparently, the scheme was designed and constructed based on the experience from conventional river diversions with a narrow weir (Van den and John 2008) resulting in constrained flood flow leading to huge silt deposition. Due to the sedimentation problem, the scheme is running far below its design capacity. In addition, currently, a number of modern SI schemes are either under study and design or being constructed in different parts of the country.

Another example of a modern SI system is Bura Scheme, constructed in Arsi Negele District of Oromia Region by JICA, based on the lessons learnt from Boru Dodota. The scheme components include diversion headwork, rejection spillways, main, secondary and tertiary canals, drop structures, division boxes and drainage culverts designed and constructed to reduce the problems of headwork and main canal siltation. With an investment cost of about USD 1,268 ha^{-1}, the key improvement includes a wider diversion weir (10 m) that splits flood flows efficiently and avoids excessive sediment load, and a relatively higher weir crest so that silt-free water enters the main canal. In addition, it has two rejection spillways along the main canal as a consequence of which the lined main canal is almost free of silt. As this scheme was not fully functional during the time of the study, it is too early to assess its performance, but the improvements in the design and construction would be expected to curb the siltation of the structures, a main problem in spate irrigation systems. According to the development agents in the area, farmers have positive expectations expressed through allowing construction of canals through their fields and some have already started using the water.

Management of Spate Irrigation Schemes

According to FAO (2010), the life expectancy and sustainability of SI schemes is often dependent on the appropriateness of design and construction, but equally important is the effectiveness of operation and maintenance (O&M). This requires a well-tailored management plan. FAO (2010) has identified three types of management arrangements: 1) predominantly farmer-managed, 2) jointly managed by local government and farmers, and 3) jointly managed by a specialized agency and farmers. These systems of management are applied often to schemes based on command area size, being less than 1,000 ha, 1,000 ha to 5,000 ha, and more than 5,000 ha, respectively.

Management of Traditional schemes

The O&M of traditional schemes in Ethiopia are purely the responsibility of farmers. For example, the users of the Awadi traditional scheme in Oromia Region independently manage the scheme through their water user association (WUA) led by a committee. The committee organizes maintenance works such that whoever has a plot in the scheme should provide free labor on specified dates or pay a fine. The penalty due to failure to participate in maintenance work or other offences is determined by the water user committee. The committee is also responsible for water allocation and manages the financial resources of the association, including income from regular contributions from members and fines.

In the Raya Valley, farmers elect *Abo-gereb* (literally father of river) and *Abo-mai* (literally father of water). The *Abo-gereb* organizes the farmers to construct and maintain the diversion structure and main canal, and he allocates floodwater to the *Abo-mais*. The *Abo-mai* is responsible for construction and maintenance of the secondary canals and for regulating the distribution of floods to the farmers having plots within the secondary canal areas. Flood distribution is based on a predetermined sequence by casting lots (Kidane 2009). In case of any offense, the *Abo-mai* is responsible for reporting to the *Abo-gereb* who is authorized to institute penalties. According to Alamerew (unpublished), a similar system of management is applied in schemes located in Kobo Valley of the Amhara Regional State. In this case, a committee of three individuals elected by the users locally known as *Aba-haga* (literally father of water) is responsible for scheduling the construction and maintenance of structures, distribution of the flood among the users and fining offenders.

Management of Modern Schemes

There is no standard management system, but WUAs or committees were formed in all the modern SI schemes considered in this study. The difference between the modern and traditional schemes is that external agents, such as the district offices of agriculture, facilitate the formation of the WUAs on the modern schemes. In some of these schemes the government is directly involved in O&M of the schemes.

Apparently, management of the modern schemes is considered beyond the capacity of the farming communities, especially those over 5,000 ha. For example, Boru Dodota was intensively managed by the regional Water, Mineral and Energy (WME) and Agricultural and Rural Development (ARD) bureaus for the first 2 years after construction. Joint management by a specialized government agency from WME or ARD and farmers was supposed to take over. A WUA was established for the scheme. However, the WUA is not functioning properly, and the joint management arrangement was not implemented; the scheme has experienced difficulties in O&M. Scheme size, severity of the headwork, and design and construction shortcomings added up to problems with siltation. Farmers alone could handle the maintenance needs of the scheme with their hand tools. Therefore, the success of such schemes is contingent on the quality and sustainability of O&M support provided by qualified external agencies, including government and other development partners. It also implies the need for strengthening WUA capacity and legal recognition to discharge responsibilities, including facilitation of the regular O&M in conjunction with a responsible government agency.

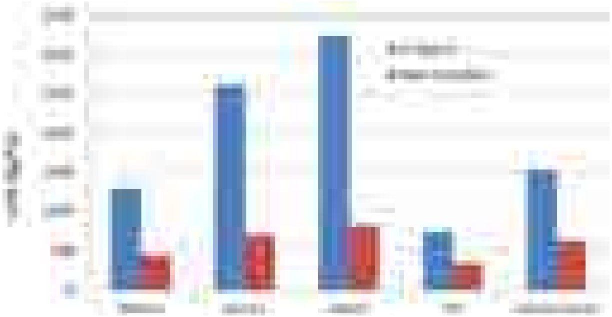
In Raya and Kobo valleys, similar to the case with the traditional schemes, farmers often elect a committee of five individuals after the construction. The committee is responsible for mobilizing farmers to carry out minor maintenance works, including desilting structures, while major maintenance is carried out by government. In addition, the committee distributes the floodwater among the Abo-mais. This is slightly different to Boru Dodota. There are two steps in the management system (the committee and the Abo-mais) and there is committed support from government for major maintenance works, which is currently lacking in the case of Boru Dodota.

Contribution of Spate Irrigation to Crop and Livestock Production

Contribution to crop production

Generally, spate irrigation supports low-input, risk-averse farming, but there are still uncertainties in the timing, frequency and size of floods. Floods can provide too little water that results in water shortages or too much water that results in damage to crops and irrigation infrastructure. Such uncertainties make cropping of high-value moisture-sensitive crops and use of inputs like fertilizers precarious. Consequently, drought-resistant crops such as sorghum *(Sorghum bicolor),* maize *(Zea mays),* millet *(Eleusinecoracana Gaertn),* cowpea *(Vigna unguiculata)* and horse bean *(Vicia faba)* are widely grown *(Michael 2000).* Most farmers in Boru Dodota scheme grow local varieties of wheat, barley, maize, tef and haricot bean that are not necessarily high yielders (Birhanu and Mengistu 2007). However, data from the year 2007 indicated that supplementary irrigation using spate increased yield of the crops as compared to both a good year (2006) and a normal year (2007) as seen in Figure 1.5. The yield increase over the good year's average for maize and haricot bean was 167 and 275%, respectively (Van Steenbergen et al. 2011). Similarly, due to uncertainties in water availability, farmers in Raya and Kobo valleys grow sorghum and tef with limited use of fertilizers similar to the case with rain-fed systems, instead of opting for crops of their choice and use of higher inputs. In good years, when rainfall and floods are sufficient, the sorghum yield can be as high as 7 tons ha^{-1}; in bad years it may completely fail. Therefore, ensuring water availability through spate or other means increases crop productivity in the areas, but the advantage can be augmented if other complementary technologies including improved varieties of high-value crops are used.

Figure 1.5. Effect of supplementary irrigation on crop yield in Boru Dodota scheme in 2007.



Source: Adapted from Birhanu and Mengistu (2007).

Contribution to livestock production

Livestock is an integral and important component of household livelihoods in most arid and semiarid lowlands where spate irrigation can be practiced (FAO 2010). Access to feed and drinking water is a crucial challenge to livestock production. Natural grazing, crop residues and crop aftermath grazing constitute the main source of feed in the mixed crop livestock systems. However, while livestock populations are increasing, feed availability and productivity of livestock are decreasing (Tolera and Abebe 2007). Natural grazing is shrinking due to increased area closure on slopes and expansion of agricultural practices in plains (Alamerew, unpublished). The importance of crop residues and aftermath grazing is increasing, but the availability of these resources depends on the productivity of the crops that are highly dependent on water availability. Spate irrigation can be beneficial for livestock. Increased crop yield (grain and straw) means increased availability of livestock feed. According to FAO (2010), spate irrigation has boosted the availability of animal feed by increasing the biomass production in Amhara Regional State of Ethiopia. In addition, the non-crop biomass (weeds) that grows within and outside the crop fields is often an important feed resource. According to development agents and farmers, spate irrigation has improved the availability of feed and, therefore, increased the household income from livestock products in Raya and Kobo valleys, which accommodate large populations of cattle, goat, sheep, etc. Floods are also an important source of drinking water, especially when stored for the dry seasons. The floods feed small ponds, known locally as “horeye” in Raya and “kure” around Kobo.

The Challenges of Spate Irrigation Systems

Spate irrigation systems are risk-prone and categorically different from perennial systems. The floods may be abundant or minimal, and production responds to the change in the frequency and amount of floods. The fluctuation of flood volume may be a source of inequity since some lands get better access to water than others (Van Steenberger et al. 2005). On the other hand, occasional high floods can cause damage to wadi beds and command areas unless design, construction, and O&M are tuned to deal with them. The high sediment load of the water, especially of the coarse materials can shorten the life span of the spate irrigation structures that are not designed to handle the sediment gush. Fine sediments can improve the fertility and physical conditions of the soil if delivered to the field, but care must be taken to avoid the rise of the command area against furrows and canals. Sedimentation of the canals can be detrimental to the functioning of the system regardless of the size of the materials deposited. New weed and soil-borne plant disease agents can be delivered to the field with floodwater and sediment, a risk not be easily managed (Ibrahim 2010; Ogba-Michael n.d.) (www.eritrean-embassy.se/.../AgronomyinSpateIrrigatedAreasofEritrea.pd) (accessed December 2013). Farmers in Boru Dodota blame the spate water for the invasion of new weed species, but they consider the problem tolerable in view of the benefits of increased crop and livestock productivity and enhanced soil health.

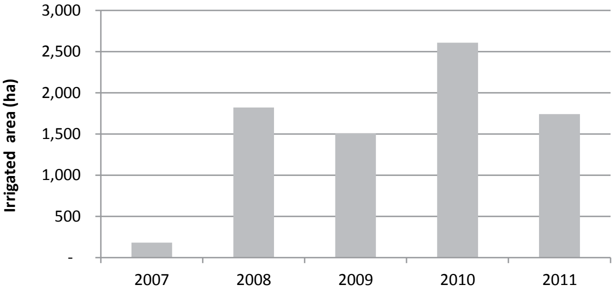
The predicaments of spate scheme modernization

Improvement efforts and construction of new spate schemes have often had depressing results, probably the result of deficient information for design and poor understanding of the flow regimes. The predicament of modernizing spate irrigation in Oromia and Tigray regions of Ethiopia, either upgrading traditional systems or developing new ones, are illustrated here.

The Boru Dodota scheme was newly constructed (started in 2007) by Oromia Water Works Construction Enterprise (OWWCE) to irrigate about 5,000 ha in the great East African Rift Valley. According to Dodota District WME Office, this was one of the cheapest spate schemes in the region, with investment costs of about USD 450 ha^{-1}. Apparently, the headwork design and construction followed conventional river diversion approaches without taking the heavy silt load of the flood into account. The narrow weir (5 m crest width) constrained the flow and led to huge silt deposition; the capacity of the system to divert the flood has been reduced (Van den and John 2008). In addition, the upper part of its lined main canal is filled with sediment up to the crest level of the first rejection spillway. In addition to the structural defects, sand miners built a silt barrier across the main canal and aggravated the siltation problem.

Stimulated by improved crop yield under spate irrigation, the demand for SI has increased over time (from 182 ha in 2007 to 2,607 ha in 2010). But in 2009, a bad year meant inadequate water to meet the demand (Figure 1.6). According to the district office of agriculture more land had been prepared in 2011 than that irrigated in 2010, but the flood that reached the area was too little due to the sediment deposited at the diversion headwork. Therefore, maintaining the conveyance system to ensure water delivery, storing water during the good years either on the surface as ponds or recharging the groundwater can help in narrowing the demand and supply gap.

Figure 1.6. Trend of irrigated land area in Boru Dodota spate irrigation scheme.



Although nine reservoirs have been built within the scheme to harvest the peak flow, they were empty because the gates do not close properly. On the other hand, several farmers have built ponds in their own fields. JICA supported some of the farmers' efforts and provided geo-membrane to line ponds. One farmer explained his life has changed for good because of the three interconnected ponds around his house (Figure 1.7). Stimulated by the improved livelihood of those using the flood, many farmers are constructing their own ponds, even without external support. Therefore, although not functioning as planned, the introduction of the modern SI in the area has stimulated floodwater harvesting initiatives by farmers, which may have a lasting effect.

Figure 1.7. Interconnected ponds developed by a farmer.

Upgrading or development of modern schemes has been underway in both Tigray and Amhara regions. In Tigray, while many traditional schemes were improved, more than 20 modern schemes were newly constructed in Raya Valley and another four in Tanqua-Abergelle *(Afera, shiwata, Durko and Agbe).* Two schemes from the region are briefly presented below as examples of the issues faced.

Fokisa: This is a modern scheme that operates far lower than the designed capacity because of siltation. Siltation of the diversion weir and canal is related to a design problem aggravated by the dominantly degrading and steep topographic feature of the catchment. The major part of the catchment area is steeper than 50% and is devoid of vegetation cover or soil and water conservation practices. According to Raya Valley Agricultural Development (RVDP 1997), the sediment yield in the catchment ranges from 1,550 to 1,740 $m^3km^{-2}year^{-1}$. The success of the modernization effort would be enhanced by revisiting the design and construction approaches, as well as understanding the status of the water source (catchment) areas and incorporating complementary watershed management activities in the plan.

Hara 2: This scheme was constructed in 2010, only to fail in the same year before it was handed over to the users. The weir was toppled over and washed away, perhaps because the runoff was underestimated in the design. According to development workers in the area, at least three other schemes constructed in the same year failed in the same manner. Although there is no definite explanation for the failures, design problems may be related to the paucity of reliable data and lack of qualified engineers. Construction problems may also be a factor, as poor workmanship and lack of effective supervision were suggested to be possible reasons. Such information gaps may be partially bridged through effective participation of the local community.

Tigray is similar to the case in Oromia. After assessing the performance of the schemes developed earlier, modifications were made on the design of those constructed more recently. Improvements included changing the orientation of the offtake, omission of the under-sluice and limiting the command area under one scheme to 200 ha as with the traditional schemes. The advantage of keeping the size of the schemes smaller is threefold: it reduces the technical predicaments related to siltation and failure of the structures; it eases O&M challenges for the users; and it reduces upstream-downstream conflicts.

Discussion

To overcome the recurring chronic food insecurity that affects large parts of the population and to feed an increasing population, Ethiopia needs to significantly increase agricultural production (FAO 2006). According to Awulachew et al. (2010), agriculture in Ethiopia is largely rain-fed with only 4-5% of cultivated land estimated to be under irrigation. Even export crops, such as coffee, oilseed and pulses that contribute the major share of foreign currency are grown largely under rain-fed systems. Rain-fed systems however are increasingly vulnerable to weather-related crop failure. At the same time, deforestation and inappropriate land management practices are widespread, particularly given the expansion of farmlands into marginal areas such as steep slopes and in the highlands (Lemma et al. 2011). Land degradation has led to reduced storage capacity of the catchments and has increased peak flow during the rainy seasons and diminished baseflows during the dry seasons. In the meantime, reduced agricultural productivity and shortage of land in the highlands have accelerated migration of people to lowlands. Agriculture became more important in the traditionally agro-pastoral areas. These factors have raised the demand for irrigation as rainfall in the lowlands is hardly adequate for crop production. However, conventional irrigation development is limited by the availability of perennial water resources and is also costly.

Traditionally, some farmers in the mid-altitude and lowland areas have been using spate irrigation to supplement the unreliable rainfall, both for crops and growth of pasture. However, the structures used are often primitive and can easily get washed away. The government and other development partners seem to be convinced that spate irrigation systems hold potential at least in the short term to overcome the problem of crop failure. In different parts of the country, modern spate irrigation systems are expanding through the upgrading of the traditional schemes or development of new ones. As demonstrated in this study, the results of the modernization effort are often not satisfactory because of technical, socioeconomic and institutional shortcomings.

The design of improved water diversion structures, canals in spate schemes and estimation of the area that can be potentially developed using the spate water require data on hydrology and sediment transport (FAO 2010). Since such information is limited in the least settled parts of developing countries that are often targeted for spate irrigation, empirical models need to be used in conjunction with local knowledge that can be extracted from the local community. This requires development of local capacity in design and construction of spate systems combined with research to refine the socio-technical approaches in design, construction, and O&M of spate irrigation systems.

Conclusions

Traditional small-scale spate irrigation has existed in Ethiopia perhaps for millennia, but it is only recently that it has attracted the attention of government and other stakeholders. It is increasingly recognized as an essential input, especially in the lowlands, to increase crop and livestock productivity and enhance food security. This study revealed that the traditional spate irrigation systems are suitable for farmers to manage independently because of their size and limited number of users that can be easily mobilized due to the proximity of their settlements. However, the frequent failure of the structures necessitates frequent reconstruction, which challenges labor productivity. Currently, efforts to improve the schemes to overcome the problems and to maximize the quantity of flood diverted as well as the development of new schemes are widespread in the country. In these efforts, conventional approaches of river diversion design are often used without attention to the unique nature of the spate flows and farmers' opinion. Consequently, most modern spate irrigation schemes are not optimally operating, particularly due to siltation. Unlike the traditional schemes, because of the expansiveness in size and immensity in their silt deposit, management of modern spate schemes is beyond the capacity of the farmers and development agents at district offices.

Recommendations

Improvements of traditional schemes should reduce the labor required for maintenance and minimize damage to canals and fields by floods. However, modernization of traditional schemes should be preceded by understanding of the system when consulting with farmers. Reduction of siltation at the headwork and canals should be a major design criterion in large and modern schemes. Farmers need external support including provision of earth-moving machines in managing large-scale spate irrigation schemes that do not desilt automatically. Small-scale schemes that are easier for farmers to manage with minimum support from local experts may be more sustainable than the large schemes. Introduction of spate irrigation to new areas requires sufficient awareness creation and demonstration through piloting and performance evaluation. Integrating spate irrigation with watershed management may ensure sustainable water supply while reducing siltation of structures.

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