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 semi-arid lowlands of sub Saharan Africa and Ethiopia in particular. Flood based irrigation is an inexpensive and rooted in tradition in many rural communities which contrasts 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 the Ethiopia for many decades, but it has gained attention by the government only recently. This study was conducted through 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. Both the traditional and modern schemes are not free of challenges. The traditional schemes suffer from floods that damage their diversion structures, while poor design and construction of diversion structures led to failure of new ones. A range of socio-technical issues to improve the planning, implementation and operation of schemes is proposed, ranging from- the design of headwork and canals consistent with the size and nature of expected flows; structures to
minimize sedimentation; building farmers and district officers’ capacity to operate; and monitoring and improving the management that is adversely impacting the performance of the schemes. Consulting farmers at every stage of the development, 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.

**Keywords:** traditional irrigation, community involvement, flood-water, modern, siltation

**INTRODUCTION**

Agriculture is the dominant factor in livelihoods and landscapes of the sub-Saharan Africa. Access to water is a major constraint on reducing poverty and increasing livelihoods for the majority of communities and countries in the region. Nowhere more so can this be shown than in Ethiopia, where agriculture accounts for 80% of the populations’ employment. Rainfed agriculture, where crops grow only once a year is vulnerable to inter-annual variations and longer terms changes in rainfall patterns. Frequent long dry spells lead to crop failure in such rainfed systems causing a chronic food shortage and poverty [1], the severity of which increases with altitude. In response, the Government of Ethiopia (GoE) has recently embarked on policies and implementations that encourage full or supplementary irrigation to minimize the risk [2] and to increase cropping intensity. However, the high investment cost of ‘conventional’ irrigation schemes and lack of reliable water sources in some areas compelled the use of flood based farming including spate irrigation (SI) across large areas of the country. They are seen as a viable option to buffer against extreme weather Events and changing climatic patterns

SI is a form of water resources management that is practiced in regions where runoff producing mountains border arid and semi-arid lowlands [3] [4]. It is an ancient form of water management involving the diversion of flash flood running off from the mountainous landscapes [5]. Oweis *et al.*, [6] distinguished two systems of spate irrigation: *Wadi-bed* and *Off-wadi* systems. In the former case, 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 later system, the flood is forced out of its natural course to the 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, different vernaculars such as ‘Gelcha’ or Lolaa Debesuu in southeast lowlands and ‘Telefa’ in the northern parts are used to describe the SI system, implying that it has been rooted in the water management culture of the communities [7]. Recently, the popularity of SI in the country is increasing, although there is no reliable record to show the rate of expansion. In 2008 about 140,000ha of land was estimated to be under SI schemes [7] while a number of schemes were either under construction or study and design. The expansion of SI in the country is attributed to both biophysical and socio-economic factors. The existence of extensive flat, fertile but moisture stressed lowlands circumscribed by mountainous highlands that receive high rainfall is a favorable condition for spate irrigation. A common feature for many of the upland areas of the country are the ever expansion of rainfed agriculture using the traditional land management practices that are suitable for the plains, with the attendant loss of forest cover and extensive land degradation. As a consequence of the land degradation, the water storage capacity of the uplands declined leading to increased flooding during the rainy seasons and water shortage during the dry seasons. At the same time, water demand for livestock and crop production has increased in the lowlands in response to population growth that is exacerbated by influx of people from highlands and increased drought frequency. Set against a background of increasing interest in the promotion of 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 in Ethiopia and lessons for other countries in the region.
METHODOLOGY OF THE STUDY

This study covered four regional states of Ethiopia (Amhara, Oromia, SNNP and Tigray, Figure 1) where both desk work and field assessments were carried out. The available published and grey literature, design documents and reports have been reviewed; and some unpublished data from the research team and the projects were used. Two schemes from Oromia (Boru Dodota and Awadi) and from Tigray (Maekhoni, Hara2, Fokisa) each 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). The field investigation 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 from each selected scheme 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 spate irrigation schemes expansion and the livelihood impact of its use, the latter to be recounted in a separate paper.

Figure 1: Distribution of the spate irrigation schemes and schemes visited for this study
Table 1: Some details of the spate irrigation schemes reviewed in Oromia and Tigray regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Scheme type</th>
<th>Scheme Name</th>
<th>Year of establishment</th>
<th>Command area (ha)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oromia</td>
<td>Traditional</td>
<td>Awadi</td>
<td></td>
<td>85</td>
<td>Functioning</td>
</tr>
<tr>
<td></td>
<td>Modern</td>
<td>Boru Dodota</td>
<td>2007</td>
<td>5000</td>
<td>Functioning below capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bura</td>
<td>2011</td>
<td>200</td>
<td>Functioning, new</td>
</tr>
<tr>
<td>Tigray</td>
<td>Improved-Traditional</td>
<td>Maekhoni</td>
<td></td>
<td>400</td>
<td>Functioning</td>
</tr>
<tr>
<td></td>
<td>Modern</td>
<td>Hara2</td>
<td>2010</td>
<td>200</td>
<td>Not functioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fokisa</td>
<td></td>
<td>500</td>
<td>Functioning below capacity</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

RESULTS
Spate irrigation systems have been used in different parts of Ethiopia since antiquity, although little attention was given to it in agricultural development policies. The SI systems around Kobo in Amhara and Konso in SNNP administrative regions have been used for generations [7]. However, over the last two to three decades, there was a remarkable increase in development of SI schemes by farmers and development partners, although a comprehensive data base showing the extent is lacking. In the four regions studied, both traditional and improved SI schemes are 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 system and the potential area suitable for spate irrigation. Clearly, Oromia and Tigray regions have invested on large and medium scale schemes development by upgrading the traditional schemes and construction of 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 revealed the following:

A. Incomplete inventory and supporting data: Despite a widespread use of spate irrigation in the country, information on the actual area under SI systems and the estimate of the potential areas that can be developed is inconsistent. According to Alemayehu [7], area under spate irrigation was estimated at 140,000 ha in 2008 (Figure 2), while the traditional schemes alone estimated to exceed 100,000ha 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, especially in the moisture stressed low lands that cover approximately 60% of the country’s total landmass [7]. 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 command area of about 318,000 ha over five years (2005/06 to 2009/10) in different development corridors [7] out of which schemes irrigating over 7000 ha were operational during the time of the study (Table 2-3). In addition, final feasibility and design has been completed for 18 schemes with a command area of 34,000 ha (Table 4) while the remaining was reported to
be at different stages of study. Evidently, the SI schemes in Oromia are concentrated in the south eastern parts of the region, areas which are characterized generally by low rainfall.

![Figure 2: Status of spate irrigation in Ethiopia as adapted from [7]](image)

**Table 2: Spate irrigation study and construction plan for development corridors in Oromia**

<table>
<thead>
<tr>
<th>Development Corridor</th>
<th>Planned area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005/06</td>
</tr>
<tr>
<td>Borana</td>
<td></td>
</tr>
<tr>
<td>South eastern Oromia</td>
<td>4,216</td>
</tr>
<tr>
<td>South Bale and Guji</td>
<td></td>
</tr>
<tr>
<td>North Shewa</td>
<td></td>
</tr>
<tr>
<td>Rift valley</td>
<td></td>
</tr>
<tr>
<td>Sub total</td>
<td>9,216</td>
</tr>
</tbody>
</table>

Source: A five years strategic plan for development corridors in Oromia

**Table 3: Area (ha) under spate irrigation in Oromia regional state in 2011**

<table>
<thead>
<tr>
<th>Name of Scheme</th>
<th>Traditional</th>
<th>Improved/modern</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boru Dodota</td>
<td>5,000</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Hargetti</td>
<td>500</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Bililo</td>
<td>500</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Ija Galma Waqo</td>
<td>350</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Ija Malabe</td>
<td>480</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>Awadi</td>
<td>85</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>Bura</td>
<td>200</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td></td>
<td>7,115</td>
</tr>
</tbody>
</table>

Source: Oromia Water Works Design and Supervision Enterprise (OWWDSE)
However, the new SI schemes in the region are not limited to the dry low land areas; apparently they are expanding also to the highland areas that receive relatively high annual rainfall. As shown in Table 4, the areas where these schemes are target receive 700-1000 mm rainfall per annum. This may be related to the increased variability in rainfall distribution including in the highlands that receive high rainfall, which is often followed by yield reduction or complete crop failure. The schemes are also distributed over ranges of altitude: from lowlands (1136 m asl) to the highlands (1914 masl). However, averaging around 2000 ha and ranging between 200 and 5000 ha, the command areas of the newly studied schemes are related neither to the amount of rainfall nor to the altitude.

Table 4 Planned modern spate irrigation schemes in Oromia for which study and design is completed

<table>
<thead>
<tr>
<th>Name of Scheme</th>
<th>Located in District</th>
<th>Command Area (ha)</th>
<th>Mean annual rainfall in the area (mm)</th>
<th>Average Altitude (m asl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agemsa</td>
<td>Mieso</td>
<td>1,000</td>
<td>700</td>
<td>1,455</td>
</tr>
<tr>
<td>Adami Hara</td>
<td>Mieso</td>
<td>760</td>
<td>750</td>
<td>1,303</td>
</tr>
<tr>
<td>Gagawisa</td>
<td>Mieso</td>
<td>1,000</td>
<td>900</td>
<td>1,468</td>
</tr>
<tr>
<td>Oda bela</td>
<td>Mieso</td>
<td>3,200</td>
<td>900</td>
<td>1,447</td>
</tr>
<tr>
<td>Chelechel</td>
<td>Raytu</td>
<td>5,000</td>
<td>1,000</td>
<td>1,136</td>
</tr>
<tr>
<td>Gungum/Egole</td>
<td>Dellomena</td>
<td>2,000</td>
<td>900</td>
<td>1,155</td>
</tr>
<tr>
<td>Dhadhaba gudda</td>
<td>Shashemene</td>
<td>4,000</td>
<td>900</td>
<td>1,852</td>
</tr>
<tr>
<td>Burraa</td>
<td>Shashemene</td>
<td>200</td>
<td>900</td>
<td>1,730</td>
</tr>
<tr>
<td>Hregolemeno</td>
<td>Shalla</td>
<td>1,000</td>
<td>950</td>
<td>1,835</td>
</tr>
<tr>
<td>Kobo borera</td>
<td>Ziway Dugda</td>
<td>4,000</td>
<td>725</td>
<td>1,914</td>
</tr>
<tr>
<td>Efadin</td>
<td>Fedis</td>
<td>1,000</td>
<td>190</td>
<td>1,381</td>
</tr>
<tr>
<td>Ija Guhe</td>
<td>Fedis</td>
<td>1,500</td>
<td>700</td>
<td>1,550</td>
</tr>
<tr>
<td>Arer</td>
<td>Babile</td>
<td>900</td>
<td>775</td>
<td>1,504</td>
</tr>
<tr>
<td>Efadin</td>
<td>Babile</td>
<td>1,000</td>
<td>700</td>
<td>1,381</td>
</tr>
<tr>
<td>Ija Denu</td>
<td>Meyu Muluke</td>
<td>105</td>
<td>750</td>
<td>1,337</td>
</tr>
<tr>
<td>Ija Medalu</td>
<td>Meyu Muluke</td>
<td>337</td>
<td>750</td>
<td>1,341</td>
</tr>
<tr>
<td>Tabo</td>
<td>Boset</td>
<td>5,000</td>
<td>700</td>
<td>1,200</td>
</tr>
<tr>
<td>Katar</td>
<td>Zwa-Dugda</td>
<td>2,000</td>
<td>800</td>
<td>1,699</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>34,002</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Oromia Water, Minerals and Energy Bureau, 2012; W., E., represent west, east, respectively

Another region where spate irrigation is a focus in agricultural development is Tigray. In this region also, in addition to upgrading the traditional SI schemes that were concentrated in the southern part of the region, the system was introduced to the drought-prone districts in the central zone such as Tanqua-Abergelle where it was not well known. In 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 districts’ office of agriculture and rural development in the two regions, about 42,000 ha and 427 ha are under SI schemes in Raya_Azebo (Tigray) and Kobo (Amhara) districts, respectively.

Comprehensive data on SI schemes in the SNNP regional state is lacking. According to Van Steenbergen et al [4] the estimated command area of the traditional SI scheme at Yandefero was about 4,000 ha. Although not widespread like in the case with Oromia and Tigray, recently, local and international development actors initiated new SI schemes in the region. According to the regional Irrigation Development and Scheme Administration Agency, a scheme irrigating 300 ha was under construction at Weyito in 2012 (Table 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. Besides, 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 5).

<table>
<thead>
<tr>
<th>Name of Scheme</th>
<th>Traditional</th>
<th>Improved</th>
<th>Total</th>
<th>Under design and construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weiyto</td>
<td>300</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Konso/Yandefero</td>
<td>4,000</td>
<td>4,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birbirsa</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galge</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mega</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mareqo</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,000</td>
<td>300</td>
<td>4,300</td>
<td>1,250</td>
</tr>
</tbody>
</table>

Source: SNNP Irrigation Development and Scheme Administration Agency

B. Drivers of spate irrigation expansion: 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 government and other agencies policy from food aid which is believed to create dependency syndrome [8] 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 [9] and ensuring rural food security in its economic
development programs [10; 2]. 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 ([11]. In an attempt to translate the policy into action, both the federal and regional
governments, supported by bi-laterally and multi-laterally 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**

Based on our field observations the following examples and points about traditional schemes can be
made. Traditional spate irrigation schemes refer to schemes that are planned, constructed and managed
by farmers themselves with no or limited external interventions. Their design and construction
approach and size of the scheme varies depending on the amount of flood water available to divert,
experience of farmers and availability of materials for construction. The structures often have diversion
and sometimes can have canal systems such as the primary, secondary and tertiary canals as
components [12]. Among the limitations of the traditional schemes is that the diversion structures are
simple deflectors constructed using brushwood, stones and sand that can easily be washed away by
heavy floods necessitating frequent reconstruction [13]. In addition, as they can divert only a limited
part of the flood, the command area per diversion is limited requiring a series of diversions over a wadi
when there is a need for irrigating large areas. However, the systems allow equitable distribution of
water between upstream and downstream users [13]. 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) which sometimes
can stabilize and become permanent when used over extended period 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. Awadi scheme that is located in Arsi Negele district, Oromia Region was constructed twenty years ago by an innovative farmer and it was continuously improved by the community. In this scheme, the flood emerging from “Aga Mountain” is diverted from Awadi Ephemeral River bed by stone bund (Figure 3) to irrigate 85 ha of land. Recently, the Japan International Cooperation Agency (JICA) assisted the community replace a wooden flume constructed across a gully by steel which is believed to last longer (Figure 4). Similarly, the traditional diversion structures locally known as ‘maegel’ (in Raya valley) [15] 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.

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 feed due to population increase and to spur the 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 [3]. In addition, FAO [3] 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 the traditional schemes improvement through the Raya Valley Development Project [14].

Set with its features such as 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 5000 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 narrow weir [12] resulting in constrained flood flow leading to huge silt deposition (Figure 5). 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.

![Figure 5: Boru Dodota spate irrigation diversion headwork (a), silted up main canal (b) and canal blocked by sand minors (c)](image)

Another example of modern SI system is Bura scheme which was constructed in Arsi Negele district of Oromia region by JICA based on the lessons learnt from Boru Dodota. The scheme has components including 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 per hectare of about 1268 USD, the key improvement includes wider diversion weir (10m) that split 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 (Figure 6 a-d). As this scheme was not fully functional during the time of the study, it is too early to assess the performance, but the improvements in the design and construction certainly would curb the siltation of the structures which is the major predicament in spate irrigation systems. According to the development agents in the area, farmers have positive expectations which they have expressed by allowing construction of canals through their fields, while some have already started using the water.
Management of Spate Irrigation Schemes

According to FAO [3], the life expectancy and sustainability of SI schemes is often dependent on the appropriateness of their design and construction, but equally important is the effectiveness of their operation and maintenance which requires well-tailored management plan. FAO [3] identifies three types of management arrangements; namely i. predominantly farmer-managed; ii. Jointly managed by the local government and farmers; and iii. Jointly managed by a specialized agency and farmers. These systems of management are applied often to schemes developing command areas of less than 1000ha, 1000ha to 5000ha, and more than 5000ha, respectively.

Management of Traditional schemes

The operation and maintenance of traditional schemes in Ethiopia is purely the responsibility of farmers. For example, the users of Awadi traditional scheme in Oromia region independently manage the scheme through their water users’ association 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 fine. The penalty due to failure to participate in maintenance work or other offences is determined by the water users committee which is also responsible for water allocation. The committee also manages the financial resources of the association including income from regular contribution of the members and penalties.

In Raya valley, farmers elect Abo-gereb (literally means father of river) and Abo-mai (literally means father of water). The Abo-gereb organizes the farmers to construct and maintain the diversion structure and main canal, and he allocates flood to the Abo-mais. The Abo-mais are 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. Flood distribution is based on predetermined sequence by casting lots [15]. In case of any offense, the Abo-mai is responsible for reporting to the Abo-gereb who is authorized to penalize the culprit. According to Alamerew (unpublished), a similar system of management is applied in schemes located in Kobo valley of Amara regional state. In this case, a committee of three individuals elected by the users locally
known as *Aba-haga* (father of water) is responsible for scheduling the construction and maintenance of structures, distribution of the flood among the users, and fining the offenders.

**Management of Modern schemes**

There is no standard management system that is followed by all except that water users associations or committees are formed across all the modern SI schemes considered in this study. However, unlike the traditional schemes, external agents such as the district offices of agriculture facilitate the formation of water users associations. In some of the schemes the government is directly involved in the operation and maintenance of the schemes.

Apparently, management of the modern schemes, especially those which are too large (over 5000 ha) is beyond the capacity of the farming communities. For example, during the first two years after its construction, Boru Dodota was intensively managed by the regional Water, Mineral and Energy (WME) and Agricultural and Rural Development (ARD) bureaus. It was proposed that a joint management by a specialized government agency from WME or ARD and farmers would take over, which has never happened leading to difficulties in the operation and maintenance of the scheme. The water users association (WUA) was established, but it is not properly functioning implying the need for strengthening in terms of capacity and legal recognition to discharge its responsibilities including facilitation of the regular operation and maintenance in conjunction with a responsible government agency. Given the size of the scheme and the severity of the headwork siltation resulted from design and construction shortcomings; farmers alone cannot 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 operation and management support provided by qualified external agencies including government and other development partners.

In Raya and Kobo valleys, similar to the case with the traditional schemes, farmers often elect a committee of five individuals after the completion of the construction of the schemes. The committee is responsible for mobilizing the farmers to participate in minor maintenance works including removing silt from the structures while the major maintenance is carried out by the government. In addition, the committee distributes the flood among the Abo-mais. This is a slightly different approach when compared with the case at Boru Dodota in that there are two steps in the management system i.e. the committee and the Abo-mais and also that there is a committed support from the government with major maintenance works, which is currently lacking in the case of the former.
CONTRIBUTION OF SPATE IRRIGATION TO CROP AND LIVESTOCK PRODUCTION

CONTRIBUTION TO CROP PRODUCTION

Generally, spate irrigation supports a low-input, risk-averse farming owing to the uncertainties in the timing, frequency and size of floods which can be too little that crops may suffer of water shortage or too much that may damage crops and irrigation infrastructure. Such uncertainties make cropping of high value moisture sensitive crops and use of inputs like fertilizers precarious. Consequently, drought-resistant crop such as sorghum (*Sorghum bicolor*), maize (*Zea mays*), millet (*Eleusine coracana Gaertn*), cowpea (*Vigna unguiculata*) and horse bean (*Vicia faba*) are widely grown [14]. Most farmers in Boru Dodota scheme grow local varieties of wheat, barley, maize, tef and haricot bean that are not necessarily high yielders [16]. 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 (Figure 7). For maize and haricot bean the yield increase over the good year’s average was 167 and 275%, respectively [12]. 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 rainfed system, instead of opting for crops of their choices and use of higher inputs. In good years, when rainfall and flood are sufficient, the sorghum yield can be as high as 7 tons ha⁻¹ while it may completely fail in bad years. 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 7: Effect of supplementary irrigation on crop yield in Boru Dodota scheme in year 2007](image)

Source: Adapted from Birhanu and Mengistu [16]

CONTRIBUTION TO LIVESTOCK PRODUCTION

Livestock is an integral and important component of the livelihoods for households in most arid and semi-arid lowlands where spate-irrigated can be practiced [3]. Access to feed and drinking water is a crucial...
challenge to livestock production. Natural grazing, crop residues and crop aftermath grazing are the main source of feed in the mixed crop livestock systems. However, the contribution of natural grazing is shrinking due to increased area closure on slopes and expansion of agricultural practices in plains (Alamerew, unpublished) as a result of which feed availability and productivity of the livestock is decreasing ([17]), despite the increasing livestock population. Consequently, 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. The increased crop yield (grain and straw) due to the use of spate irrigation means also increased availability of livestock feed. According to FAO [3], 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 grow within and outside the crop fields are often important feed resources. According to the development agents and farmers, the improved availability of feed due to spate irrigation has increased household income from livestock products in Raya and Kobo valleys where large populations of cattle, goat, sheep, etc., are accommodated. Flood is also an important source of drinking water, especially when stored for the dry seasons. The floods feed the small ponds locally known as “bonye” in Raya and “kure” around Kobo (Figure 12).

Figure 8: Pond from spate for livestock watering in Raya valley

FARMERS OPINION AND PARTICIPATION
Since the traditional flood diversion structures get easily washed away by heavy floods, farmers are often tied up in reconstructing them. This has become increasingly difficult as the availability of brushwood materials is challenging owing to the widespread protection of forested areas. Therefore, farmers are in favor permanent structures that can divert maximum flood. A farmer in Raya valley for example praises the permanent structures (Box 1). However, diverting all the floods using the permanent structures is contrary to the traditional systems which allow flood to pass through for downstream users. Consequently, modernization may create upstream- downstream conflict [13].
When they saw the construction of irrigation schemes in their area, farmers at Boru Dodota expected a permanent irrigation water supply for use as full irrigation during the dry season. When they realized that the system supplies flood water only during the rainy season, they have shown their disappointment by refusing to use it. Consequently, at first, although ample water was delivered to the area, both the number of beneficiaries and the area irrigated was low. This shows that community participation at the initial stage was inadequate, similar to the case in Tigray where participation was often limited to providing labor and consultation which was limited to the beneficiary of the schemes, excluding the downstream users. The situation gradually changed as they observed the yield increase from the early adopters who used the floods to supplement the rainfall. Eventually, all the farmers having plots in the scheme have shown interest which culminated in severe competition for water. The family of Mrs Asnaku is one of the early adopters in the scheme, although initially they were not convinced of using flood water. However, they started to use it after observing the improved crop performance in parts of their field which was flooded in the night against their will as admitted by Mrs Asnaku (Box 2). Currently, the family is a surplus producer because of sustained use of the spate water. While the demand for spate irrigation is continuously increasing, some farmers still opt for a sustainable supply of water especially during the dry season as they did not like the randomness of the flood flow, which they call ‘liishaan kashalabbee’ literally means ‘mischievous water’ as one cannot be sure if and when it is available for use.
**The Challenges of Spate Irrigation Systems**

Spate irrigation systems are risk prone and are 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 source of inequity since some lands often get better access to water than others [4]. On the other hand, occasional high floods can cause damage to wadi beds and command areas unless design, construction, operation maintenance is tuned to deal with them. The high sediment load of the water, especially of the coarse materials can shorten the lifespan of the spate irrigation structures that are not designed to handle the sediment gush. The 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 born plant disease causing agents can be delivered to the field together with the flood water and sediment, a risk that cannot be easily managed ([18];[19](www.eritrean-embassy.se/.../AgronomyinSpateIrrigatedAreasofEritrea.pdf)). 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 they attained from the spate water through increased crop and livestock productivity and enhanced soil health.

**Box 2:** In the year 2008 flood time we resisted the entry of spate water in to our farmland as we thought it would not help but rather harm our crops. We managed to protect only some parts of our field since controlling the flood was beyond our capacity that it broke into the other parts. To our surprise, the part of the field which was flooded yielded much higher than the part we managed to ‘protect’. Finally, we understood that we made a mistake and in the subsequent years we became among the first to divert the spate water to our farmland. Today, we are worried if the flood continues to come or not since the structure is blocked by sediment.

Mrs Asnaku
THE PREDICAMENTS OF SPATE SCHEMES MODERNIZATION

Probably due to the deficiency of information required for design and poor understanding of the flows regimes, especially in estimating the design flow and the nature and quantity of sediment load coupled with scarcity of trained personnel, the improvement efforts and construction of new spate schemes have often ended with depressing results. Few of the schemes recently upgraded from traditional or newly developed in Oromia and Tigray regions and presented here illustrate the predicament of modernizing spate irrigation in Ethiopia.

Boru Dodota scheme was newly constructed (started in 2007) by Oromia water Works Construction Enterprise (OWWCE) to irrigate about 5000 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 its investment cost per hectare of about 450 USD. Apparently, the headwork design and construction followed conventional river diversion approaches without taking the heavy silt load of the flood into account. Due to its narrow weir (5m crest width) that constrained the flow leading to huge silt deposition the capacity of the system to divert the flood is reduced [12]. In addition, the upper part of its lined main canal is filled up with sediment up to the crest level of the first rejection spillway. In addition to the structural defects, sand minors that build a silt barrier across the main canal aggravated the siltation problem.

Stimulated by the improved crop yield due to spate irrigation, the demand for spate flood increased over time (from 182 ha in 2007 to 2607 ha 2010) but in 2009 which was bad year, the flood water was not enough to meet the demand (Figure 9). According to the district office of agriculture more land had been prepared in 2011 than that was 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 9: Trend of irrigated land area in Boru Dodota spate irrigation scheme
Although there are nine reservoirs that have been built within the scheme to harvest the peak flow, they were empty because the gates do not close properly (Figure 10). On the other hand, several farmers have built ponds in their fields. Some of the farmers’ effort was supported by NGOs like Japan International Cooperation Agency (JICA) which provided them with geo-membrane to line the ponds. One farmer explained his life has changed for good because of his three interconnected ponds around his house (Figure 11). Stimulated by the improved livelihood of those using the flood, many farmers are constructing their own ponds, even without external support. Therefore, although it is not functioning as planned, the introduction of the modern SI in the area stimulated flood water harvesting initiatives by farmers, which may have a lasting effect.

Figure 10: One of the storage reservoirs in Boru Dodota spate irrigation system

Figure 11: Interconnected ponds developed by a farmer
Upgrading or development of modern schemes has been underway in Tigray and Amhara regions as well. In Tigray, while many traditional schemes were improved, more than 20 modern schemes in Raya valley and another four (Afera, ibiwata, Durko and Agbe) in Tanqua-Abergelle were newly constructed. Two schemes from the region are briefly presented below as examples of the issues faced.

**Fokisa** - is a modern scheme operating at much lower than the designed capacity due to siltation of the diversion weir and canal which is related to the 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 devoid of vegetation cover and soil and water conservation practices. According to RVDP [20], the sediment yield in the catchment ranges from 1550 to 1740 m$^3$ km$^{-2}$ year$^{-1}$. Therefore, besides revisiting the design and construction approaches, understanding the status of the water source (catchment) areas and incorporating complementary watershed management activities in the plan enhances the success of the modernization effort.

**Hara 2** - This scheme was constructed in 2010, only to fail in the same year before it was handed over to the users as the weir was toppled over and washed away, may be because the design runoff was underestimated. According to the development workers in the area, at least 3 other schemes constructed in the same year failed in the same manner. Although there is no definite explanation for the failures, design problem due to paucity of reliable data and lack of qualified engineers as well as construction problem due to poor workmanship and lack of effective supervision were suggested to be among the possible reasons. Such information gap may be partially bridged through effective participation the local community.

Similar to the case in Oromia, after assessing the performance of the schemes developed earlier, in Tigray also, modifications were made on the design of those constructed lately. Among the improvements were changing the orientation of the off-take, omission of the under sluice and limiting the command area under one scheme to 200 ha, which is similar to that of the traditional schemes. The advantage of keeping the size of the schemes smaller is triple fold: it reduces the technical predicaments related to siltation and failure of the structures; it eases operation and maintenance 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 the ever increasing population, Ethiopia needs to significantly increase agricultural production [21]. According to Awulachew et al., [22], agriculture in Ethiopia is largely rainfed with only 4-5 percent 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 rainfed system, which is increasingly vulnerable to weather related crop failure, underlining the need for significantly enhancing the role of irrigated agriculture. However, bringing sufficient land under conventional irrigation is limited by availability of perennial water resources and is costly to develop. On the other hand due to population pressure, deforestation and expansion of farmlands including to the agriculturally marginal areas such as steep slopes with inappropriate land management practices is widespread, especially in the highlands ([23]. The consequent land degradation led to reduced storage capacity of the catchments and increased peak flow during the rainy seasons and diminished or defunct base flows during the dry seasons. In the meantime, reduced agricultural productivity and shortage of land in the highlands accelerated migration of people to lowlands which increased the importance of agriculture in the traditionally agro-pastoral areas. This raised the demand for irrigation as rainfall in the lowlands is hardly adequate for crop production.

Traditionally, some farmers in the mid-altitude and lowland areas have been using spate irrigation to supplement the unreliable rainfall, both for agriculture and to improve the growth of pasture. However, the structures used are often primitive and can easily get washed away that maintenance needs are arduous. The government and other development partners seem to be convinced that spate irrigation systems are potential options; at least in the short term to overcome the problem of crop failure due to extended dry spells with limited investment. 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 and socio-economic shortcomings.

The design of improved water diversion structures and canals in spate schemes and estimation of the area that can potentially be developed using the spate water requires data on hydrology and sediment transport [3]. Since such information is limited in the least settled parts of developing countries which are the common targets of spate irrigation schemes; 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, operation and maintenance of spate irrigation systems.
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS
Traditional small scale spate irrigation has existed in Ethiopia may be over millennia, but it is only recently that it has attracted the attention of both the 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 easily be mobilized because of the proximity of their settlement. 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, often conventional approaches of river diversion design are used without attention to the unique nature of the spate flows and farmers’ opinion. Consequently, most modern spate irrigation schemes are not optimally operating mainly due to siltation of the structures. 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 while giving attention to farmers’ opinion. Reduction of headwork and canals siltation should be a major design criterion in large and modern schemes or farmers need external support including provision of earth moving machines in management of large scale spate irrigation schemes that do not de-silt themselves. Small scale schemes which are easier to manage by farmers 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 work 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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