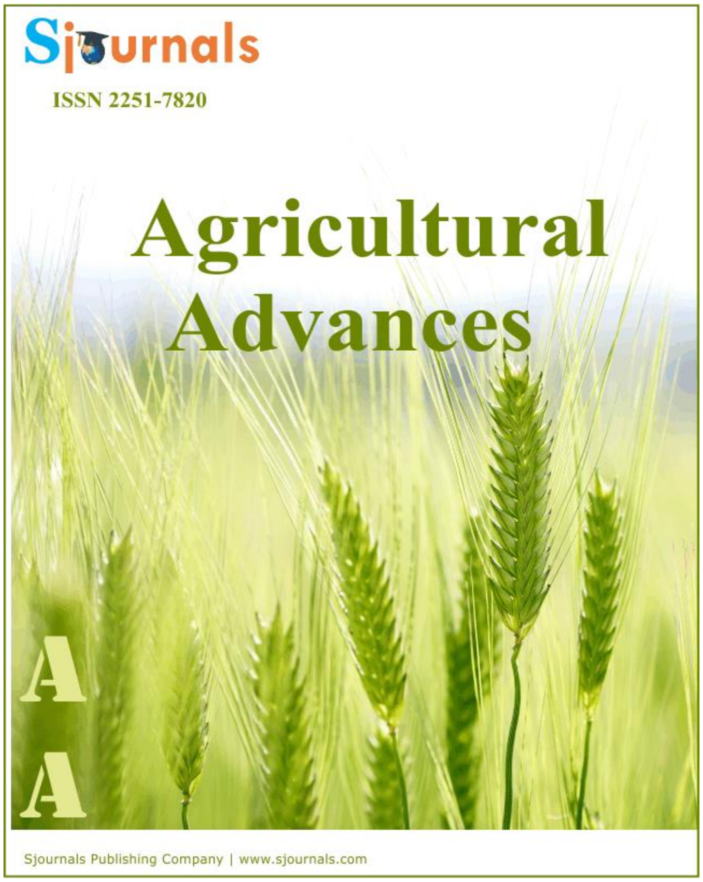
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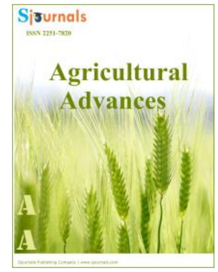

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Review article

Review of status and potential of spate irrigation in Ethiopia

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ABSTRACT

This article discusses spate irrigation in Ethiopia and aims to take stock of the current status of spate irrigation development. It summarizes experiences so far and formulates a number of recommendations on the development of this upcoming resource management system. It argues that raised weirs are useful mainly in areas where a large head for spate flow diversion is required, but that traditional earthen structures with conical stone/gabion reinforcements are cost-effective and technically adequate for floodwater distribution and management. It contends that the practical successes of sediment settling ponds (gravel traps) are at best mixed. The article further explains that water rights in spate are different from the sharing and allocation of perennial flows they are dynamic and respond to a situation that differs from year to year as well as within a year and that a certain degree of inequity among users is inevitable. Keeping the command area compact can ensure two or more irrigation turns and this can highly increase productivity as crops are no longer in the 'stress zone'. To transform spate irrigation in Ethiopia from subsistence to a business-oriented production system, the article proposes the promotion of cash crops including pulses and oil seeds as well as encouraging investors to go for bio-fuel development and agro-forestry in the lowland areas where huge potential exist.

1. Introduction

Ethiopia comprises 112 million hectares (Million ha) of land. Cultivable land area estimates vary between 30 to 70 million ha. Currently, high estimates show that only 15 Million ha of land is under cultivation. For the existing cultivated area, our estimate is that only about 4 to 5 percent is irrigated, with existing equipped irrigation schemes covering about 640,000 hectares. This means that a significant portion of cultivated land in Ethiopia is currently not irrigated. Well-managed irrigation development is key in helping Ethiopia overcome major challenges including population pressure; soil and land degradation; high climate variability, and low agricultural productivity. In addition, agricultural water development is crucial to improve smallholder livelihood and income in Ethiopia, since irrigation can help farmers increase their crop production, increase crop variety, and lengthen their agricultural seasons.

Spate irrigation is a form of water management that is unique to semi-arid environments, particularly where mountain catchments border lowlands. As such, short duration floods are diverted from river beds and spread over land-to cultivate crops, feed drinking water ponds, or irrigate pasture areas or forest land. Some spate irrigation systems in Ethiopia have been in use for several generations, but in almost all areas spate irrigation has developed recently (van Steenbergen et al., 2011). Spate irrigation is on the increase in the arid parts of the country: in Tigray (Raja, Waja, Raya), Oromia (Bale, Arsi, West and East Haraghe), Dire Dawa Administrative Region, in SNNP, Southern Nations, Nationalities and Peoples Region (Konso), Afar and in Amhara (Kobe). Spate irrigation systems are practiced both in the midlands and lowlands in Ethiopia.

At present most spate systems are in the midlands and some in the lowlands. The area currently under spate irrigation in Ethiopia is estimated at 140,000 ha, but the potential particularly in the lowland plains is much higher (Alemehayu, 2008). This is important in Ethiopia to assure food security as sufficient food has to be produced to meet the requirements of a growing population that still substantially relies on food aid.

Spate irrigation is characterized by a great variation in the size and frequency of floods from year to year and season to season, which directly influence the availability of water for agriculture in a season. But spate irrigation is important for the livelihoods of a significant number of rural households, who often belong to the poorest section of the communities. According to Abraham (2007) spate irrigation is practiced in low land areas where there is surrounding mountainous with better rain fall pattern that can serve as source of flood and deep soils that are capable of storing ample water to support crops during period of low precipitation.

Wallingford et al. (2007) and Catterson et al. (1999) categorized spate irrigation in Ethiopia in to high land and low land systems. The high land spate system is usually referred as run-off system diverts flashy floods received from the same catchment to the relatively small irrigable land. The low land spate irrigation system is found in the foothills of mountainous water shades and has larger command area. The flood that comes from the neighboring mountains becomes steady and lasts for longer time. Spate irrigation in Ethiopia differ from those in the Middle East and South East Asia where farming is more unpredictable and entirely dependent on one or two flood events and rainfall events. In contrast farming in Ethiopia relies more on rainfall and spate irrigation usually serves as supplementary to rainfall. The objective of this article is to review and assess spate irrigation in Ethiopia and suggest practice and recommendation done so far.

2. Literature review

2.1. Water resources potentials of Ethiopia

The mean annual specific runoff varies from zero to 35 $ls^{-1}km^{-2}$. Minimum flows occur from December to March. Apart from the big rivers and their tributaries, there is hardly any perennial flow in areas below 1,500 m. In general, perennial streams and springs exist only in the vicinity of mountains with an annual rainfall of more than 1,000 mm. The country's annual renewable freshwater resources amount to some 122 billion m^3yr^{-1}(Bm^3yr^{-1}) contained in 12 river basins, which is only 1,525 $m^3yr^{-1}capita^{-1}$ share. However, only3% remains in the country. At this stage, the country withdraws less than 5% of its freshwater resources for consumptive uses.

The western portion of the country, with only 40% of the total land area, generates 83% of the surface water potential. It is estimated that 54.4 Bm^3yr^{-1} of surface runoff and 2.6 Bm^3yr^{-1} of groundwater could be technically developed for consumptive use. It is also estimated that in addition to clean water supply to its entire population, up to 3.7 M ha of land and 30,000 MW of power can be developed using the available water resources potential. However, only less than 300,000 ha of the irrigation and 854 MW hydropower potentials, respectively, have been developed so far. The current level of irrigation development is lower than 50% of the over 600,000 ha of irrigable land that should have been developed to meet the food demand of the present population in addition to what is being cultivated under rain-fed agriculture. The clean water supply coverage is only about 50% (DHV, 2002; UNESCO, 2004).

2.2. Development status

Some spate irrigation systems in Ethiopia have been in use for several generations, but in almost all areas spate irrigation has developed recently. Spate irrigation is on the increase in the arid parts of the country: in East Tigray (Raja, Waja), Oromia (Bale, Arsi, West and East Haraghe), Dire Dawa Administrative Region, in SNNP, Southern Nations, Nationalities and Peoples Region (Konso), Afar and in Amhara (Kobe) region. In southeast Ethiopia the word '*gelcha*' is used translating as channeling the flood to the farm. In the northern parts the word '*telefa*, meaning 'diversion', is common. Spate irrigation systems are practiced both in the midlands and lowlands in Ethiopia (Van Steenbergen et al., 2011).

Despite the burning need and the prevailing problem little is done in Ethiopia to use spate water for irrigation. The history of water harvesting in Ethiopia dates back to the pre-Axumit period (560 BC) (Getachew, 1999). It is a common and growing practice, particularly in arid parts of the country.

In East Ethiopia farm runoff is collected in small embankment gullies, and the ponded water is used for irrigating valuable (perennial) crops, such as chat (Chat cadulis), coffee and fruit trees. Use of seasonal floods originating from eastern highlands and ending up in the lowlands has been practiced in Dire Dawa area since the 1980s. Many farmers along these riverbanks are practicing flash flood spreading for crop production. Farmers in these areas were able to establish simple diversion (using wooden trash and soil materials) canals to convey the floodwater into their farms.

Similar activities are found in the northern parts of the country, Tigray, Amhara and southern regions. Runoff irrigation is widely practiced in the Chercher Plains around Mahoni and Waja near Alamata in Tigray, the Gato Valley in North Omo, parts of eastern and western Hararghe, and many other places. The practice in the Gato Valley also includes the use of ridge ties to retain the moisture around the plants. Similarly, the people in Konso, Gidole and many other parts of the southern region have been exercising the art of conserving soil and water. These traditional rainwater harvesting techniques use the soils as a media, particularly using bench terraces and trash lines on their cultivated lands (Habtamu, 1999).

Fig. 1. Spate irrigation practicing on their cultivated.

According to various recent estimates, spate irrigation in the country varies from 100,000 to 200,000 ha. During the Expert Consultation Meeting in Cairo in 2008, the best estimate agreed upon was 140,000 ha (van Steenbergen et al., 2010). Areas under improved or modernized spate irrigation stand at 20,000 ha and considerable investment is lined up: spate projects under design and construction exceed 50,000 ha (Alemehayu, 2008). Most systems are relatively small with a few systems (Kobe, Yandefero, Dodota) touching the 4,000 ha mark. The traditional systems typically consist of free intakes incorporating a short diversion spur in many cases in a series. In Kobo in Amhara Region floods are diverted from a seasonal river (*Gobu*) and directed it to the cultivated fields.

Table 1
Spate irrigation systems characteristics in midland and lowland of Ethiopia (van Steenbergen et al., 2010).

Spate system	Midland (1000 to 1700 m)	Lowland (below 1000 m)
Rainfall	Supplementary	Less important
Catchment area	Limited	Large
River bed material	Coarse-cobbles, gravel and sand	Mostly sand
Gradient	Steep	Gentle
Flow	Flash floods and semi-perennials flows	Short-duration spate flows
Command area	Small	Can be large
Water diversion and distribution	Change of flood channel	Siltation or degrading of river, change of flood channels

Table 2
Spate irrigated areas in Ethiopia (van Steenbergen et al., 2010).

Total spate irrigated area	Traditional spate irrigated area that need improvement	Improved spate irrigated area	Spate irrigated area under design and construction
140,000 ha	70.000 ha	20,000 ha	50,000 ha

2.3. Potential and cultivated areas in spate irrigation

Ethiopia is known as a water tower of Africa for its peculiar geomorphologic and climatic setting. No drainage is coming in but flows out radiating in all directions. Arid and semiarid regions constitute 60% of the country's surface area with a rainfall variable coefficient of 50%. The remaining 40% is a recharge area with surplus rainfall with most of it flowing untouched through the surroundings.

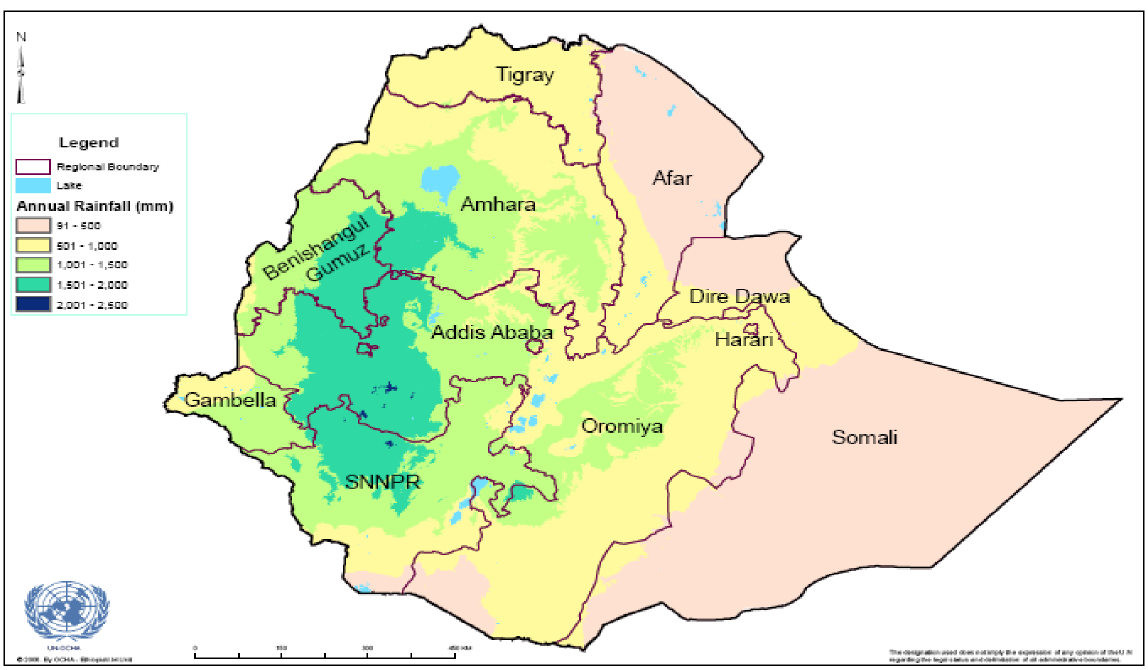

Fig. 2. Annual rainfall map of Ethiopia (OCHA, 2006).

Lowlands with thick and fertile alluvial covered plains and availability of runoff flowing across these plains of millions of hectares of land are suitable for spate irrigation in Ethiopia.

With increasing population and land degradation the food-insecurity problem is affecting even the highland areas. The main reason for the occurrence of drought is the erratic nature of rainfall and a moisture deficit for full crop growth. Various attempts have been made to harvest rainwater, floodwater, and groundwater to tackle the food security problem. Hundreds of thousands of ponds and hand-dug wells were constructed throughout the country in 2004/05 but the effort was not as successful as expected.

The radial flow from every side of the middle part of the country is considerable and can be captured before entering the deep-cut gorges. It is possible to cultivate the most food insecure arid parts of the country by making diversion canals of various scales (Taye, 2014).

2.4. Administration of spate irrigation

Administratively, farm structures and farms are mostly private. But irrigation schemes are mostly public. E&M of spate structures are administered by both public and private parties (Taye, 2014).

2.5. Size of spate irrigation systems

There are three scales of perennial irrigation systems in Ethiopia. Schemes larger than 3,000 ha of irrigable land are categorized as large scale, those from 200 to 3,000 ha as medium scale and any scheme below 200 ha as small scale. As improved spate irrigation is new and its coverage is limited to a few localities no agreed scale is assigned. Oromia is using its own range of <500 ha as small, 500 to 2,000 ha as medium and >2,000 ha as large comparing the level of complexity and manageability with perennial irrigation schemes (Taye, 2014).

2.6. Characteristics of spate irrigation systems

Almost all traditional systems are managed by farmers and are small scale in size. Infrastructural upgrading of traditional systems is done by local governments and in very limited cases by NGOs with labor and material contribution from the user community. E&M of these improved systems are totally handled by the community; local government and NGOs offer occasional support when costs and damages to the structures are beyond the capacity of the users. Construction of medium- and large-scale spate irrigation schemes is done mostly by government and seldom by NGOs. In one of the regional governments, Oromia, an enterprise has been given a mandate to own/administer large perennial and spate irrigation schemes. It covers all the investment costs and distributes water to the users on cost recovery principles.

It is planned that water use fees will compensate for E&M of main, secondary and tertiary canals and the weir site. Permanent staff and all necessary equipment for maintenance of the scheme will be assigned for each scheme (Taye, 2014).

2.7. Sources of water for spate irrigation

The main source of water for spate irrigation is seasonal flows in the dry streams. Using water harvesting and groundwater recharging techniques, farmers in some areas use water from ponds and shallow groundwater reserves to irrigate their farms. Such practice is growing fast, and the need for centrifugal pumps is increasing at higher rates (Taye, 2014).

Fig. 3. Pumping water for supplementary irrigation from remote ponds along traditional spate flow canals.

2.8. Structures

Systems can be ordered according to the potential command area of schemes, the size can vary from a couple of hectares up to more than 30.000 hectares (Lawrence and van Steenbergen, 2005). The systems are categorized in small, medium and large scale systems. In Ethiopia the Regional State Oromia has its own division for spate irrigation, according to the complexity and manageability in comparison with perennial irrigation schemes. In this way schemes less than 500ha are considered small schemes. If the system is larger than 500ha and smaller than 2000ha it is called medium. Systems over 2000ha are large scale systems (Alemayehu, 2008). Besides distinction in sizes, the infrastructure of spate irrigation systems can be distinguished in three categories namely; traditional, improved and modernized systems. In most traditional schemes diversions like deflecting spurs can be found. Canals are usually very short and the bunds are mostly next to the flood channel. The improved systems include rejection spillways after the headwork, flow division structures like the flow throttling structure in main canals and drop structures.

Table 3
Different types of spate irrigation schemes and structures (Alemayehu, 2008).

Types of scheme	**Headwork**	**Canal structures**	**Field structures**
Traditional	-Deflecting spurs -Diversion bund intake	-Short canals -Flow division	Large bunds
Improved	-Deflecting spurs with rejection spillway -Weir with gabions and gated in take	-Control structures (Head regulators structures and orifice) -Division structure (Flow throttling structure) -Check/drops structure with of takes -Canal escapes	Large bunds
Modernize	Weirs with rejection spillway. Sluice gate (flush gate) and sand trap	-Main canal and secondary canals, -Division boxes -Check/drop structure with of takes -Canal escapes	-Tertiary canals -Lower bund

The traditional systems typically consist of free intakes incorporating a short diversion spur in many cases in a series. In Kobo in Amhara Region floods are diverted from a seasonal river (*Gobu*) and directed it to the cultivated fields tosupplement the rainfall. The main diversion canal is called '*enat mellée*' (i.e. mother *mellée*). The mother *mellée* starts as a small earthen embankment protruding into the flood course at an acute angle with a gradually curving and thickening build up that guides the flow to the cultivated fields. These main diversions are constructed at a convenient angle across the riverbed slope to divert the flood runoff and convey it to the command area. The longitudinal slope of the riverbed ranges from 1-3%. The system is further divided into '*awraj mellée* (secondary canals) and *'tinishua mellée'*(tertiary/field canals). Once the water reaches the field canals, it is spread with the help of bunds and *'shilshalo'* (contour/graded furrows). A special feature in Kobo is the excavated ponds that serve for livestock watering and are located downstream from the cultivated land. The ponds are fed from the main canal as well as the excess drainage from the cropped area (van Steenbergen et al., 2011).

Similarly in Aba'ala in Tigray there are many waterways that run into farms. In total there are 27 primary channels diverted from the three rivers. The diversion channels are made by digging an open channel both at the left and right banks of the rivers and strengthened by stone, boulders, shrubs and logs of trees. When there is flood almost all farms get water. Within the farms there are narrow furrows covering the entire field. These furrows distribute and can carry water for some time. The furrows are made in intimate succession to one another and slightly against the contour. Under a Norwegian Aid project some of these traditional intakes have been replaced with masonry walls.

Fig. 4. Traditional diversion structures in Hara, Tigray, Ethiopia (Haile, 2009).

Also, the Yandefero system in Konso (SNNPR) consists of a multitude of short flood intakes. At present there are 29 flood intakes made of soil and brush wood. The entire area that can in principle be irrigated is close to 4,000 ha. Eleven of the flood-intakes date back 30 years or more. Most of the remaining ones were developed in the last few years under various food-for-work arrangements. Recently, the Yanda River has started to degrade dramatically going down one to 2 m in large stretches. This degradation most likely was caused by the cutting of a stretch of downstream riverain forest which caused the Yanda River to shift its outlet to a lower section. The degrading of the river bed has forced farmers to extend the flood channels higher up in the river bed sometime curving around bends. This has left the intake structures more exposed to the force of floods, and several of them are no longer used. The remaining intakes sustain a mixed cropping system of small-holder maize, sorghum and cotton. Farmers do not reside in the lowland area for fear of malaria and tryposomasis. Instead they live in the midlands and travel 15-25 km and stay in Yandafero for a number of days and nights at a time (preferring to sleep in trees or on hill tops) to cultivate land.

Free intakes are the rule in the traditional systems, even in lowland areas. In West Harrarghe the lowland Weltane system is fed from the Koran Gogoga River through a short guide bund of stones and brushwood. In Hasaliso in Dire Dawa there are a series of free intakes taking some improved under relief projects and some entirely farmer-built, all located immediately downstream of the gorge. The river on this soft alluvial lowland plain is incised and the flood channels are relatively long. Some of the intakes have suffered from changes in the river morphology.

In Oromia Regional State One of the largest spate irrigation is Dodota, situated in a rain-shadow area in Arsi. Dodota takes its water from the semi perennial Boru River. The stream has no other off-takes upstream and is not used by other upstream or downstream users. The total net potential area for spate irrigation was estimated at 5,000 ha. The main objective of the design was to supplement the rainfall in the area. Based on the requirements, permanent structures made with concrete and masonry were constructed diversion weir to create head, flood channel with escape for high flows, and network of irrigation canal spanning the command area. 19 earthen small ponds with an average capacity of 60,000 m^3 were also introduced to temporary store flood water and distribute it during the dry spell periods in a regulated manner. A striking feature of the design process was "parallel implementation", as the design process was continuing parallel to the construction. A digital evaluation model was used and designs were prepared and adjusted as the project was implemented.

These modernization interventions have significantly contributed to improvement in crop yield, but the successes are being tempered by continuous sedimentation problems and lack of effective pond operational plan (Chukalla et al., 2010).

Fig. 5. Modern diversion weir in Boru Dodota, Oromia, Ethiopia (Chukalla et al., 2010).

Other states have also launched spate irrigation systems. In Tigray, the regional government in the last 10 years has made efforts to improve the traditional spate irrigation systems particularly in the Raya Valley. It has implemented more than 13 modern spate irrigation schemes sized between 250 and 500 ha, but sedimentation has been and is still a major problem. Similarly in Afar spate irrigation development is on-going. For instance the Tali and Alena irrigation projects were built in 2008/2009 to utilize the ephemeral flow from the Tali and Gulina respectively.

2.9. Cost of development of spate irrigation

Initially much of the investment in improved spate irrigation systems was done by non-government organization, but in recent years Water Resources Bureaus in several regions have taken over and sometimes invested substantially in spate irrigation development. The cost for development of spate irrigation projects obviously varies from place to place. In remote area labor cost are low and locally available material may be used, but the cost of mobilization and demobilization of machinery make the projects expensive. The scale of projects also affects the cost. In modernized structures with civil works the community maintenance input is very low at not more than 10% and as a result the project cost is high. On the other hand, the local contribution in improved traditional spate irrigation systems is very high and this reduces public investments. As estimated from ongoing spate projects, the current construction cost of spate irrigation systems ranges from USD 170 to 220 per ha for non-permanent headwork, including soil bunds, gabion structures and diversion canals and up to USD 450 for permanent headwork for small systems including diversion weirs and bunds. The costs of permanent headwork for large systems including diversion weirs, breaching bunds and siphons as estimated from one of the ongoing project (Koloba Spate Project) ranges from USD 330 to 450 per hectare (Alemehayu, 2008). These costs are very reasonable and at par with 'sensible' investments in spate irrigation elsewhere (Mehari et al., 2010).

2.10. Water distribution rules and rights

Water rights in spate irrigation are described as "reactive water rights" since they describe agreed claims and acceptable practices in a changing and variable environment (Lawrence and van Steenbergen, 2005).

There are several typical rules used in spate irrigation systems about the distribution of floodwater. Spate irrigation systems can differ in many ways but the essence of rights and rules can be very similar. The combination of the right and rules used in spate irrigation systems can be heterogeneous and inequitable or relatively homogenous and equitable (Steenbergen cited in Lackner and Vincent, 1998). In the guidelines of Community Spate Irrigation by Lawrence and van Steenbergen, (2005) the following repertoire of water distribution rules are used:

- ✓ Demarcation of land that is entitled to irrigation;
- ✓ Breaching of bunds;
- ✓ Proportion of the floodwater going to different canals and fields;
- ✓ Sequence in which the different canals and fields are irrigated;
- ✓ Depth of irrigation that each field is entitled to receive;
- ✓ Access to second (and third) water turns;
- ✓ Distribution of large and small floods.

2.11. Risks of spate irrigation and adaptation of cropping strategies

In areas of longer flood flows the major risk that farmers face is the flood itself, which frequently washes away farms and breaks structures. In areas of low spate flows there is a risk of crop failure as a result of interrupted flow. Among the various cropping strategies that are practiced by farmers, growing local varieties adapted to local agro-climatic conditions is the main one followed by using improved drought-resistant seeds. Intercropping and adopting short-seasoned crop types (after confirming the failure of the first one) is also common. Even without anticipating risk, farmers in eastern Ethiopia practice intercropping to satisfy their various requirements and to enrich the soil nutrients. Haricot bean, rape seed and chat (Catha Endulis) are main secondary crops to be cultivated during the main rainy season (Taye, 2014).

2.12. Crops and productivity of spate farming

Types of cultivated crops depend on preference of the community. Although sorghum is the main crop to be cultivated in spate irrigation areas some communities do not like sorghum as a food crop. In such areas, maize replaces sorghum. Cereals, mainly wheat, are also cultivated as a food crop. Productivity of spate irrigated farms has recorded a tenfold increase with the same farm management and input at a recently completed spate scheme.

Data on crop yields and other benefits are still sporadic in Ethiopia, but the modest evidence that exists suggests that yields are a big leap up from rainfed farming. The most comprehensive assessment was done in Dodota, comparing yield in the irrigated and non-irrigated area. This shows that for all major crops the increase in yields was substantial. Wheat yield went up from 4 to 13 ton/ha; barley from 7 to 12 ton/ha; teff from 3 to 6 ton/ha and haricot bean from 6 to 15 ton/ha and maize from 3 to 10 ton/ha (van den Ham, 2008).

In 1998, one farmer on a spate irrigation farm in Lage Oda Merga PA in eastern Ethiopia was able to raise his sorghum yield from 3 to 8 quintal (1 quintal=100 kg) in 1.2 ha of land. Another farmer raised his farm productivity from 8 quintals to 20 of sorghum, again from the same size of land. The low yield of the farmers was due to the use of local variety, red sorghum, Jildi (Getachew, 1999).

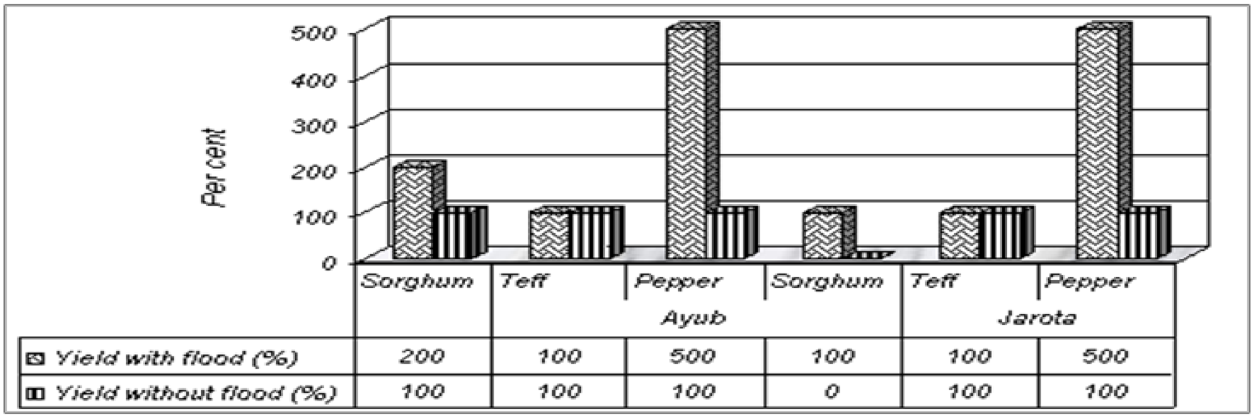

Fig. 6. Yield differences due to flood diversion (Source: PRA report, December 2001).

2.13. Gender and spate irrigation

Spate irrigation is a labor-intensive task and involves almost all segments of the community, except small children. Involvement of men, women and children depends on the degree of complexity of the task and cultural issues. The main responsibilities of men and women in spate are summarized below (Taye, 2014).

Table 4
Roles in spate irrigation schemes by gender.

Activity	Men	Women
Infrastructure-related	√	
Operation (water distribution)	√	
Maintenance	√	
Agricultural practices	√	√
Harvesting	√	√
Marketing	√	√√

2.14. Operational problem with spate irrigation

Many of the modernized system use designs that are akin to perennial irrigation systems diversion weir, under-sluice and gated intake. While many systems still need to come on-stream many of the problems with such conventional approach in other countries are also prevalent in Ethiopia (Lawrence and van Steenbergen, 2004). In a review of the spate irrigation systems in Aba'ala in Tigray, Haile and Diress (2002) list the following problems: Upstream and downstream users do not share the flood flowing through the river equitably,Technical faults in developing local diversion canals trigger changes in the river course, Improper secondary and tertiary canals leading to in-field scour and creation of gullies, Large amount of sand deposition in the canals and even in the cropped fields, The large maintenance burden of traditional spate irrigation systems.

An evaluation of a number of other improved systems in Tigray came with comparable points (Teka et al., 2004). The Tirke irrigation system for instance suffered from the blockage of under sluices/off-takes by boulders, sediments and trash and erosion of downstream protection works as inequities in water delivery between land owners in the command area. In the Fokissa system similarly sedimentation was an important issue manifest in the silting up and blockage of pipe inlets and sluice piers, which catch trash and boulders during floods. In the Tali system in Afar sedimentation was also main problem as well as the lack of preparation of field plots. Sedimentation problems were also abundant in some of the East Harrarghe system, such as Belilo. The trash accumulation problem was at its most spectacular in Ondoloko in SSNPR. At this site, a substantial gabion weir and gated off take channel have been constructed on a small steep sand bed river. The diversion is badly sited on a very sharp river bend, so virtually all the river flow is directed towards the canal intake. The structure collected an enormous amount of flotsam and is not operational.

Fig. 7. Sedimentation problem in Fokisa, Tigray, Ethiopia (Gebreegziabher Embaye et al., 2008).

There are a number of common issues related to these operational problems. First is that spate irrigation is categorically different from conventional irrigation. To start with the high sediment and trash loads of the rivers in floods, experiences all around the world is that the successes of conventionally designed gravel traps and sediment sluices is at best mixed. Gravel traps, particularly when flushed, and scour sluices can be designed to work well in spate systems. For example in the large spate systems the scour sluice at Wadi Laba (Mehari, 2007) works very well in excluding boulders and cobbles from the main canal, as does the flushed gravel trap in Wadi Rima (Lawrence, 2009). However, the enormous amount of sediment to be removed from gravel traps requires sophisticated sediment management options involving frequent gate operations. These are only feasible in schemes that are large enough to justify the large investment required and require that appropriate levels of technical expertise are available to design the infrastructure to function in spate flow conditions, and the level of management and maintenance expertise is sufficient to enable the systems to be operated and maintained as intended. The resources and organization to effectively carryout such a sophisticated management task are generally absent in small scale farmer managed spate irrigation schemes flushing excess sediment from sedimentation ponds is in many cases not feasible as no water is dedicated for it. For these reasons, intakes incorporating gravel traps and scour sluices at the mostly small low cost farmer managed spate schemes in Ethiopia will often not be appropriate.

Also Taye (2014) reported that Constraint of spate irrigation in Ethiopia are multidimensional. The limited experience combined with the lack of due attention by researchers, government, NGOs and donors makes it more difficult to overcome the problems. The following are the major constraints out by this and other authors and clearly seen in the field (Taye, 2014); Rapid Deterioration of the physical condition, Rainfall variability, Equity, Lack of government financial support and extension services and Lack of market opportunities.

3. Summery and conclusion

Spate irrigation is a form of water management that is unique to semi-arid environments particularly where mountain catchments border lowlands. Some spate irrigation systems in Ethiopia have been in use for several generations, but in almost all areas spate irrigation has developed recently. Spate irrigation is on the increase in the arid parts of the country and practiced both in the midlands and lowlands in Ethiopia. Besides distinction in sizes, the infrastructure of spate irrigation systems can be distinguished in three categories namely; traditional, improved and modernized systems. In most traditional schemes diversions like deflecting spurs can be found. Canals are usually very short and the bunds are mostly next to the flood channel. The improved systems include rejection spillways after the headwork, flow division structures like the flow throttling structure in main canals and drop structures.

The cost for development of spate irrigation projects obviously varies from place to place. In remote area labor cost are low and locally available material may be used, but the cost of mobilization and demobilization of machinery make the projects expensive. To manage the unpredictable nature of floodwater and reduce the risk of conflicts, several categories of water rights and rules are in place in different spate irrigation systems. There are a number of common issues related to operational problems. First is a high sediment and trash load of the rivers in floods. The second problem is organizational. Spate irrigation being new in many areas the same applies to perennial irrigation; conflicts are bound to arise in the absence of agreement on water rights.

Therefore, systematic assessment of spate potential in the lowlands of Ethiopia and implementing feasible spate irrigation projects are essential to change the existing food insecurity scenario in the lowlands of Ethiopia. Conjunctive use of spate systems as a means of soil and water conservation adds more value to spate irrigation practices. The agronomy of spate irrigation systems should be given greater attention. Parallel with this the market conditions must also be improved. Donors, NGOs and all stakeholders should learn from existing successful spate practices and assist farmers to combat poverty.

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