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Developments in the Design and Construction of Modern Spate Systems in Tigray, Ethiopia

Hintsa Libsekal*[1] Tesfalem Gebre-egziabher[2] Atinkut Mezgebu[2] Eyasu Yazew[2]
1, Alamata Agricultural Research Center, Alamata, Ethiopia
2, Mekelle University, Mekelle, Ethiopia
* E-mail of the corresponding author: hintsaar@gmail.com

Abstract
Spate irrigation is an ancient irrigation practice that involves the diversion of flashy spate floods running off from mountainous catchments. Spate irrigation system in Ethiopia is common practice in arid areas in the past decades. Raya valley is one of the areas where spate irrigation is being practiced for long times and many schemes were modernizing since 1998. Individual and group discussion with experts and farmers were held and frequent field visit and observation to both traditional and modernized spate irrigation schemes were undertaken. Hara spate irrigation scheme was the first scheme for modernization and it was followed by Tirke spate scheme. In 2004, 2006 and 2011 many traditional spate schemes were modernizing by government and non-governmental organizations. The major improvement from the first schemes were changing of closed off take type in to open, enlargement of canal sizes, changing the diversion angle from 90^0 in to 120^0 and avoid crossing structures. The community participation was not strong during design and construction. As farmers had their own experience in construction of traditional spate schemes they were not happy for the modernized schemes and had less ownership. Sedimentation in both diversion scheme and canals are the major problem and root causes for failures of modernized schemes. Spate irrigation modernization intervention works should be accomplished through real participation of farmers and initiate them to practically influence the planning, designing and construction processes so that successful modernized projects could be accomplished. Spate irrigation has different characteristics from conventional irrigation system, therefore this needs special attention during design. Especial design criteria should set spate scheme construction.
Keywords: spate irrigation, design development, Raya valley, spate modernization

1. Introduction

According to FAO and UNDP, (1987) spate irrigation define as “an ancient irrigation practice that involves the diversion of flashy spate floods running off from mountainous catchments where flood flows, usually flowing for only a few hours with appreciable discharges and with recession flows lasting for only one to a few days, are channelled through short steep canals to bunded basins, which are flooded to a certain depth”. Mehari et al. (2007) also defines spate irrigation in the simple way as “a resource system, whereby flood water is emitted through normally dry wadi and conveyed to irrigable fields”. Moisture stress resistant crops, often sorghum and maize are grown in the spate irrigated agricultures and planted after the first flood irrigation water has occurred. In many areas crops can get matured and give reasonable yield using two or more floods depending on the water holding capacity of the soil.

Spate irrigation system in Ethiopia is increasing in arid areas particularly; south Tigray (Raya valley), Oromia (Bale, Arusi, West and east Hararghe), Dire Dawa Administrative Region, Southern Nations, Nationalities and Peoples Region (Konso), Afar and Amhara (Mehari et al., 2011)

Raya valley is one of the areas where spate irrigation is being practiced for long times. Farmers were diverting flood water to their farm land using traditional spate irrigation system. During the past decades many governmental and non-governmental organizations were trying to improve and modernize the traditional spate irrigation systems. Many traditional spate schemes were modernized while they did not perform as expected due to several problems. Among this problems are over sedimentation in diversion and canal, failure of structures, inappropriate design and poor participation of farmers during design and construction.

Hara spate scheme is the first scheme that has opened the closed eye in the design and construction of modern spate schemes in Tigray. The Hara spate system was first designed in 1998 by Concert Engineering PLC under the Raya Valley Agricultural Development Project (RVADP). But, this design was modified by the engineers at co-SEART (commission for sustainable agriculture and environmental rehabilitation in Tigray) which finally was constructed and handed over to the beneficiaries in 2000. This is mainly because the Co-SEART design team foreseen that the headwork was not economically designed but failed to identify that, the design methodology is adopted from the previous experience on conventional diversion irrigation.

Under this umbrella, the Tirke spate irrigation scheme was later designed in 2004 by the Tigray Water Resources Development Commission (which was formed by merging Co-SEART, RVADP and Tigray Bureau of Water Supply). The Tirke scheme was constructed in 2004 by Tigray Waterworks Construction Enterprise. Later on, 4 spates were designed and modernized in 2004 namely, the Fokisa, Burka, Beyru and Utu in which the

Fokisa, Burka and Beyru schemes were constructed in 2005. In 2005 other four schemes were designed in a modern way by TWRDC (Tigray Water Resources Development Commission) namely Ula-ula, Buffie, Tengago and Dayu spate schemes. These schemes were constructed in 2006 by TWWCE. In 2010, designers from Mekelle University were assigned to undertake the design of 40 spate schemes in which 13 of them were constructed the same year.

Till the beginning of 2011 and end of 2010, modernization was limited to Raya Azebo and Alamata Weredas as these weredas are known for traditional spate irrigation practices. In 2010-11 however, attempts were made to expand spate systems in to Tanqua Abergele Wereda. As a result, the Shiwata, Agbe and Durko schemes were designed and are at their final stage of construction.

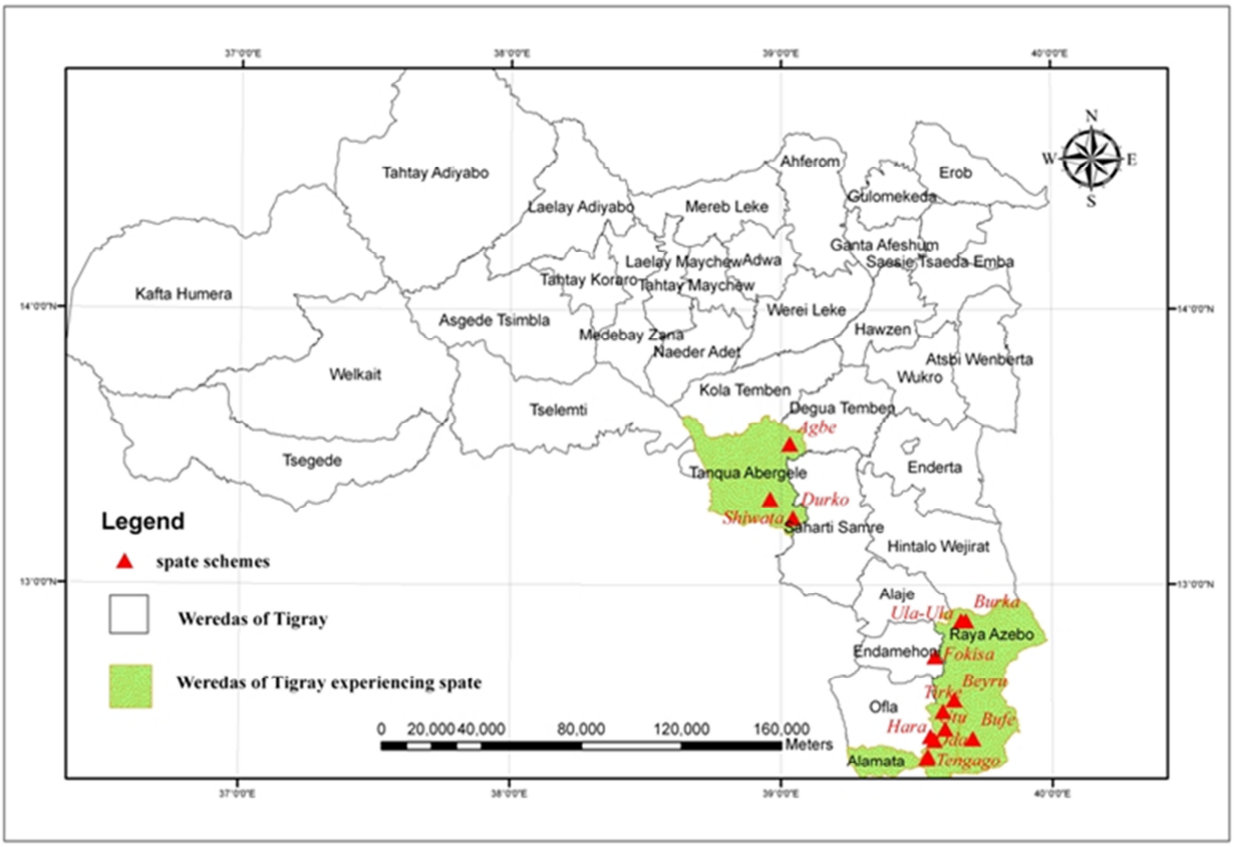

Figure 1. Location of spates schemes in Tigray

2. Research Methodologies

The methodologies used to assess the design development was

- Individual and group consultations and observations during a number of occasions when floods were disseminated, and structures were repaired and/or reconstructed;
- Site visit during and after flood events to make a documentation about the extent of fields irrigated and also to evaluate, if any, break caused to structures, canals and fields;
- Field surveys with the help of farmers that led to the research of a comprehensive first attempt of some spate irrigation scheme system's layout before and after modernization;
- Appraisal of design reports and other allied documents, and interviews with the engineers that were involved in the entire design and construction process to get hold of background information on the initial phase of the modernization;
- Exhaustive prearranged interviews with a representative of farmers, head of water users association, ***water masters/ "Abomai locally"*** that represent the different community group of flood water users. Accordingly, a number of group discussions were also held. These activities gave an imminent into the farmers' perception about the modernization, particularly with regard to the approach used, and the degree of effect of the inconsistency between the modern design, and the traditional water-sharing arrangements;

3. Results

3.1. The Hara and Tirke spate systems

Via the modernization and adaptation processes, the headwork of these two spate systems is broad crested weir with gated off-take (closed off take) in which all the structures are made of masonry and concrete. Moreover, the irrigation system was designed and constructed using all farm structures such as the main, secondary, tertiary and field canals, settling basins, piped crossing structures (siphon), division structures (division box and turnouts) and drop structures (drops and chutes). These two schemes failed immediately after the first flood mainly due to two reasons. Firstly and largely, the design was completely adopted from the conventional perennial flow diversion without due considerations to the spate characteristics. Secondly, participating local farmers and utilizing their indigenous knowledge was hardly incorporated. Consequently, the off-takes and siphons of these two systems are filled with sediments immediately and were very difficult to dredge and clean the sediments. But, the key lesson taken from these two schemes was, to realize the sediment (bed) load was so high that it needed to change the off-take type and siphons in to open and avoiding piped crossing structures (siphons).

Figure 2. The Hara Spate scheme

3.2. Improvements in the design and construction of spate systems

The Fokisa, Beyru and Burka spate systems were designed and constructed after realizing that, open off-takes do not work properly in the spate system headwork. As a result, farmers were consulted and participated for their indigenous knowledge to some extent but it was only limited to the design of off-take and diversion angle. These schemes are therefore designed with some improvements both at the headwork and irrigation systems. The improvements made were:

1. To change the off take type in to open
2. To enlarge the canal sizes
3. Changing the diversion angle from 90^0 in to 120^0 and
4. To avoid crossing structures that require pipes

Figure 3 The Beyru abd Fokisa open off-takes and weir

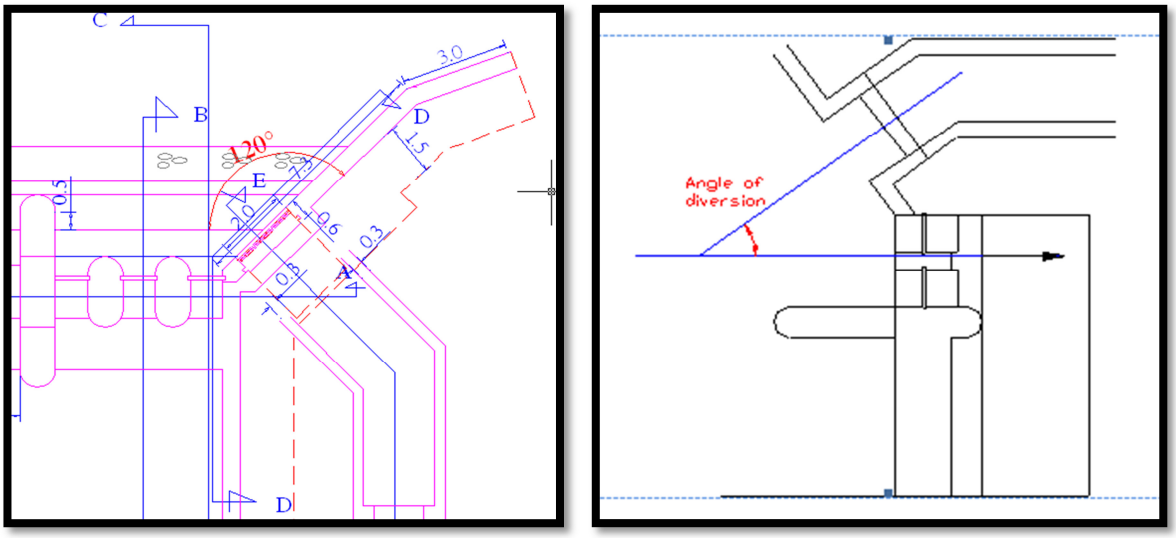

Figure 4 Open Off takes design showing diversion angles

Though there were some improvements, the main problems such as silting of off-takes and canals, reduction of the diverted discharge were not equivocated. Sedimentation affects the operation of schemes by reducing discharge capacities and raising water levels (Lawrence et. al. 1998). Consequently, these schemes were not able to irrigate their design capacity. Here what should be distinguished is that, even if the canal and off-takes were able to divert their design discharge capacity, the schemes cannot irrigate their design command area. This is mainly because, the crop water requirement estimation utilized, which is vital for determining the canal and off take capacities, is directly adopted from the perennial diversion system methodologies. Here what were missed are, the flood duration (including the recession flow) is mostly below two to four hours but the crop water requirement (duty) calculated was for 24 hours and effective rainfall was considered. Mehari et al., (2005) has proven that, impractical cropping pattern and effective rainfall assumptions result in underestimation of the net irrigation water requirement to be used for the design of the off take gates and canal systems.
During the Ula-ula, Buffie, Tengago and Dayu spate schemes design however, some improvements were made:-

- The crop water requirement calculations were calculated for 4 hours and neglecting the effective rainfall
- Irrigation system design was limited to the provision of only main canal

In these schemes also, even though there were some improvements, problems such as silting of off-takes and canals, reduction of the diverted discharge were not solved. But, the good lesson learnt was, the maximum command area that can be irrigated by one headwork structure should not exceed 200 ha. This is mainly because; the irrigation capacity of all the schemes modernized using similar way never exceeded 200 ha. But after these, there were no developments to the design and construction of spate systems till 2010-11.

In 2011 however, the design of Durko, Agbe and Shiwata schemes was made by interviewing the beneficiary farmers for the flood duration and frequency. As a result, command area was determined by irrigation capacity of a single flood. Even with these all improvements, the complication remains not solved and some schemes, such as the Hara, worsen the life of the farmers. In this scheme after modernization, the headwork structure hindered them to divert even a single flood.

Rivers in spate lift and deposit huge quantities of sediment as a result there is constant change in bed levels, both in the river system and in the distribution network which results in frequent changes and adjustments of the system (Mehari et.al 2010). In 2011, the importance of building weirs in these spate systems was in question. The Oda spate system, was designed with some improvement to the traditional system, as a simple off-take using gabion and only cut offs built to reduce the risk of bed level lowering around the river bed and off-take. This scheme is under construction and there is no chance to evaluate how it performs with respect to sedimentation and diversion efficiency.

3.3. Community participation and ownership

At the beginning of the modernization, especially in Hara and Tirke, community participation was limited only to know if they have an interest in the construction of the schemes. During construction farmers knew that, the off-take type is closed and they strongly opposed but they were ignored by the construction team resulting in to their failure. But, later, the design and construction teams tried to entertain some, but not all, of the requests of the farmers such as changing the off-take type, widening the bottom width of the off-take and main canal,

changing the orientation of the diversion angle. Though, there are improvements in participating farmers, it took around ten years to identify that, the indigenous knowledge and skills of the farmers are far better than that of the design and construction engineers.

Through such complex processes, it is obvious that, the sense of ownership in modern spate systems is weak and that is why most of the modern schemes cannot easily be maintained. With respect to community participation, sense of ownership, level of cooperation and institutional set up the traditional systems are very strong. These traditional systems have stronger rules and regulations which has created a perception of fairness of water distribution among the farmers and strengthened the degree of cooperation between them (Mehari *et al.*, 2007).

3.4. Sedimentation

Sedimentation is the main problem of the modern spate systems in Raya valley. Majority of the schemes failed because of sedimentation. In the modern schemes, settling basins were provided to avoid the entrance of sediments in to the main canal. But, these settling basins are not effective in spate systems (Embaye et.al 2011) as settling basins are designed to operate in a specific design velocity and in spate systems floods having wider range of velocities are diverted. Furthermore, Practical assessment of the sand trap basin at the May Ule and Wadi Laba basins in Eritrea indicates that the basins are subjected to rapid filling with sediments alongside the impracticality of sediment removal (Mehari et al., 2010). The other option to combat sedimentation of the modern system, used by the farmers, is to construct gabions over the weirs. An example is the Fokisa scheme, which operates with gabion reinforced headwork structure built over the weir to overcome the level rise in the river and command area, (Embaye T.G 2009).

Figure 5. Sedimentation at the Fokisa and Dayu main canals

4. Conclusion

The key to the failure of the process of modernization was that, it should have followed a real participatory approach. Haile K. 2009, has shown that, spate irrigation modernization intervention works should be accomplished through real participation of farmers and initiate them to practically influence the planning, designing and construction processes so that successful modernized projects could be accomplished. As a result of limited community participation, the sense of ownership is weak and not as strong as the traditional one's. Therefore, the main lesson learnt is, there should be real participation of farmers in all the processes and consequently the sense of ownership will then be strong.

The other cause of the failure is that, designs were completely adopted from the conventional perennial flow diversion without due considerations to the spate characteristics. The main problem with sustaining the traditional systems is that, they failed to build headwork structures that are capable of resisting larger floods. Apart from this, the beneficiaries had better understanding to the complexities in spate systems, especially sedimentation problems. The second lesson learnt is therefore, the designers must develop design procedures that suits to spate systems. As modernization is a process, the designers in particular and the stake holders in general should not be discouraged with what they have achieved so far.

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