Spate Irrigation in Tigray: The Challenges and Suggested Ways to Overcome Them

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Abstract

The perception is that floods are natural but may lead to catastrophic outcomes. However, flooding contributes to livelihoods through spate irrigation, especially in East Africa and parts of Asia. Spate irrigation is a traditional practice of farmers, especially in the Raya Valley for supplementing rain-fed agriculture. Lowland areas are not only surrounded by mountains that are sources of flood and fertile sediments but characterized by deep and fertile soil suitable for agriculture as a result of ages old alluvial deposition. However, the diversion of floods has been a challenge to both farmers and engineers. This chapter addresses the bright spots and challenges of spate irrigation practices, and presents experiences in Tigray, where the regional governments, with support from donors such as IFAD, are supporting spate irrigation farmers. The chapter also notes the poor performance of schemes related to design, which have been directly adopted from the conventional irrigation schemes based on perennial river diversion design procedures without due considerations for the peculiar nature of spate flows, such as higher sediment concentration, and the uncertainties in estimating timing and frequency of the floods. The chapter makes recommendations to fill gaps, including on capacity building and training of experts.

Key words: *Spate irrigation, rain-fed agriculture*

1. Introduction

What is flooding? What is flood-based farming?

The perception of many people is that flooding is a natural process, which may lead to catastrophic results if it coincides with the presence of a vulnerable object. For example, a flood disaster may occur when human settlements coincide with excessive rainfall events, rise of water levels or dam breaks. This may occur once in a blue moon or frequently. The occurrence of flood disasters depends mainly on the topography, climate, rainfall distribution, watershed, economy, and land use of a certain region (Di Baldassarre and Uhlenbrook 2011). Historically, floods have been intertwined with the livelihood of human beings in at least two ways. First, they have cherished and have facilitated the emergence of early civilizations along riverbanks, as in Egypt and Mesopotamia. Second, they have been considered as evil acts or punishments from spiritual forces. Today however, flooding is a broad term that includes flash floods, river floods and coastal floods. Their negative effects are typically most severe in the poorest countries, where populations and governments are least able to deal with this scourge. In Ethiopia, chronic incipient environmental changes promoting flooding have been associated with lack of land use planning, poverty and non-sustainable land use (Moges et al. 2010).

In many ways the significance of floods is self-evident; it is reported that flood disasters account for about a third of all natural disasters in terms of their number and the economic losses. As explained above, flooding is a serious issue all over the world. The articles referred to above are in accord with one another to explain some adverse effects of flooding. However, this chapter aims to see the advantages of flooding. Furthermore, it will try to investigate the real challenges in utilizing floods to the optimum as much as possible as it is the only means of livelihood in some part of Tigray, especially in the Raya Valley. Therefore, spate irrigation in particular and flood-based farming in general constitute the process of utilizing excess runoff (floods) in areas where no other options are possible (Mehari et al. 2005a). In Tigray, particularly in the Raya Valley, there is a potential of 80,000 ha of land to be irrigated by flood-farming by the total runoff of about 170 Mm^3yr^{-1} generated from the highland catchments (Eyasu et al. 2012). This study shows how spate irrigation is vital for livelihoods and food security in the Tigray Region, and starts to create a center of attention for the government on flood-based farming.

2. Research Questions

General question: What were the most critical challenges of spate irrigation in Tigray?
Specific questions:

1. What were the bottlenecks in modernizing the infrastructure of spate schemes to improve the reliability and regularity of diverting large floods and distributing them to the downstream fields?
2. Do the design and layout of the modern spate headwork and infrastructure enable the allocation of water in proportion to the indigenous water rights and rules and guarantee fair water-sharing within and among the head- and tail-end farmers?
3. Do the intervention of modernization of the headwork and infrastructural design have an impact on reducing deforestation and do they ease the farmers from their indigenous, rigorous maintenance tasks?
4. Does modernizing spate irrigation contribute to improving the livelihood of the beneficiary farmers?

3. Research Methodologies

The methodologies used to address the above questions included:

1. Individual and group consultations and observations during a number of occasions when floods were disseminated, and structures were repaired and/or reconstructed.
2. Site visits during and after flood events to document the extent of fields irrigated and also to evaluate, if any, breaks caused to structures, canals and fields.
3. Field surveys with the help of farmers on spate irrigation scheme system layout before and after modernization.
4. Appraisal of design reports and other allied documents, and interviews with the engineers who were involved in the entire design and construction process to get background information on the initial phase of the modernization.
5. Exhaustive prearranged interviews with a representative of farmers, head of water user association, *water masters/"Abomai locally"* that represent the different community groups of floodwater users. Accordingly, a number of group discussions were also held. These activities gave insight into farmers' perceptions 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.

4. Results and Discussions

For expediency, this section is divided into three parts. The first part will briefly outline the order in which events happened in the past decades that led to the modernization of the spate irrigation system and assess the initial phase of the modernization. The second part will attempt to highlight the challenges during the modernization process. The major topics discussed here include the extent of the total actual irrigated areas and the uniformity of their distribution; the impact of the discrepancies between the design requirements and the practical functioning of some of the main components of the headwork, the under sluice (scour), the breaching bund, the weir, the siphons and others; the effect of the noncoherence between the design and layout of the system, and the indigenous or local water-sharing provisions, uniformity of floodwater distribution, and the investigation of the consequences of some of the measures taken by the farmers to acquire supplementary irrigation. The third element tries to put forward answers to the question: Does the modernized spate system in Tigray attain its targets? If so, it also addresses why and how. This is done on the basis of findings on efforts made in improving spate schemes in Tigray.

4.1. The process of modernization

The then Commission for Sustainable Agriculture and Environmental Rehabilitation in Tigray (CoSEART), now Tigray Water Resources Bureau (TWRB) has taken the leading role in modernizing spate systems in Tigray. The Hara Spate Irrigation Scheme (Figure 9.1) was the first of its kind to be modernized not only in Tigray but in Ethiopia. Figure 9.2 shows modern spate systems in Tigray. The design includes the provision of gated offtake at 90° to the river flow and gated sluice scours. Furthermore, the system design includes the provision of inverted siphons, chutes, drops and division structures.

But this scheme was only able to serve a few flooding events due to sedimentation of the offtakes and siphons. Furthermore, beneficiary farmers were also neglected during the design and construction phases. Two years later, the modernization was due to be expanded to the Tirke scheme. The only improvement included into the Tirke scheme is changing the gated offtake into an open pipe (orifice type) (Figure 9.3). Similarly, after a few flood events, Tirke failed.

Figure 9.1. The Hara Spate System offtake and siphon.

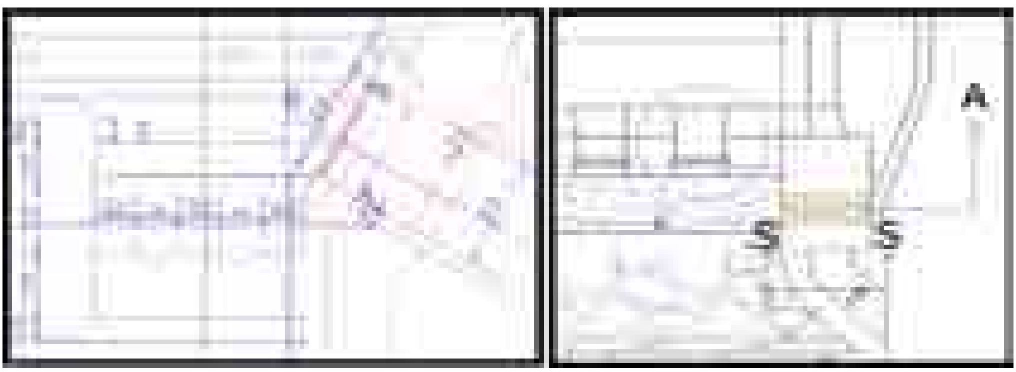
Later, the modernization was expanded to Fokisa, Beyru, Burka, Dayu, and Ula Ula with a major improvement to the offtake, i.e., widening the orifice and opening the canal, aligning it only at 120° and shifting the irrigation application time (in Cropwat) from 24 $hr.day^{-1}$ to 4 $hr.day^{-1}$. When we think of spate irrigation schemes, we should also consider a design which can supplement the total command area at least once at a time. Since the coming runoff is not reliable we should not think of a design which supplements the command area on a rotational basis, considering there is a big time gap between two runoff events. So it will be impractical to think of rotational irrigation on spate irrigation schemes, unlike river diversions which have water all the time.

Figure 9.2. Modern spate systems in Tigray (Embaye et al. 2012).

Recently, the operational design of Oda and Mersa schemes (which are in the design phase by Mekelle University, College of Dryland Agriculture and Natural Resources) considers practical irrigation intervals between floods and the diversion of floods using many small, open offtake structures. The developments on spate systems include but are not limited to:

1. Change the offtake type to open.
2. Avoid siphon/crossing structures that require pipes.
3. Change the layout of the diversion angle from 90° to 120°.
4. Enlarge the canal sizes.
5. Shift the irrigation application time from 24 $hr.day^{-1}$ into 4 $hr.day^{-1}$ and neglect the effective rainfall in crop water requirement calculations.
6. Limit the irrigation system design to the provision of only the main canal.
7. Maximum command area that can be irrigated by one headwork structure should not exceed 200 ha.

Figure 9.3. Open offtake design, closed and open types showing diversion angles as well.



Finally, it was learned that farmers' interests were limited to the construction of the headwork structure and provision of only the main canal. It was then followed by expanding the Tanqua Abergele wereda.

Table 9.1. Summary of the spate schemes in Tigray (Embaye et al. 2012).

S.No	Scheme Name	Location		Number Beneficiaries		Command Area		Project Cost		
		Northing	Easting	Male Headed HH	Female Headed HH	Designed	Actual	Headwork	Infra	Total
1	Hara	1374450	561400	726	558	400	0			
2	Tirke	1385928	564807			380	0			
3	Beyru	1390556	569354			500	50	187,837.09	975,647.47	1,163,484.56
4	Daya	1379013	565792	377	205	320	100-150	577,572.57	167,706.67	745,279.24
5	Buffie	1375094	576837			225	<50	186,984.08	407,654.60	594,638.68
6	Fokisa	1408091	561714			500	100-150	265,248.66	1,013,180.80	1,278,429.46
7	Tengago	1368040	558806	84	40	500	<50	218,302.06		218,302.10
8	Ula-Ula	1422402	572080			210	0	260,998.51	696,650.67	957,649.18
9	Burka	1422402	573967			280	100	249,805.36	339,624.61	589,429.97
10	Utu	1376027	559844					186,984.08	566,058.02	753,042.10
11	Durko	1463742	504797	60	4	400	new	1,222,802.02	2,341,648.98	3,564,451.00
12	Oda	1366964	558534	214	128	430	<50	1,349,744.25	3,066,299.23	4,416,043.47
13	Agbe	1493621	503579	100	8	400	new	3,048,386.31	994,633.69	4,043,020.00
14	Mersa	1355232	559734	114	100	350	new	1,330,170.69	1,870,655.70	3,200,826.39
15	Shiwata	1471522	495714	90	100	250	new	671,752.52	1,328,568.75	2,200,321.27

4.2. The challenges

The challenges of the modernizing of spate irrigation can be divided into three main categories. The first category is the institutional aspect. In this aspect, water user associations were simply formed for fulfilling donor's requirements. The establishment of these water user associations had disturbed the local rules and regulations, which had been effective in managing the flood distributions. During the first few floods, the modernization gave the immediate users an absolute right to use the diverted flood. However, this did not stay long. The canals and offtakes were filled in with sediments and shifted the power towards the downstream users.

Furthermore, the two initial schemes implemented were examples of limited involvement of beneficiaries. As reported by Haile (2009), spate irrigation modernization intervention works should be accomplished through the real participation of farmers and integrated to practically influence the planning, designing and construction processes so that successful modernized projects could be accomplished. Due to only partial community participation, the ownership was weak and not as strong as the traditional system.

The second challenge is related to design methodology and approaches. As there were no well-developed design guidelines and manuals specifically prepared for spate irrigation, the designers were forced to completely adopt from the conventional perennial flow diversion. Furthermore, little was known about spate irrigation, and spate characteristics were not considered during design. In this regard, the beneficiaries had a better understanding of the characteristics and complexities of the spate systems.

The third challenge is the way sediment control and management are addressed, as floods in spate area wadis carry high sediment loads. The main problem with sedimentation of offtake and canals is that this reduces the diversion capacity of the canal system, thereby significantly reducing the irrigated area (Lawrence 2008). Figure 9.4 shows sedimentation at the Fokisa offtake and canal systems. Sediment movement along the wadi in the command area might lead to excessive erosion at the wadi and lowering of the wadi level, or excessive siltation by courser and finer sediment particles. Rivers in spate flood periods lift and deposit huge quantities of sediment; there is constant change in bed levels, both in the river system and in the distribution network which causes frequent changes and adjustments of the system (Mehari et al. 2010).

Figure 9.4. Sedimentation at the Fokisa offtake and canal systems

5. Comparisons

To evaluate whether modernization significantly improved the livelihood of the beneficiaries, it is worth making comparisons between the traditional and modern spate systems in terms of both investment and operational cost, structural flexibility and durability, sediment control and management, wadi stabilization and environmental considerations.

5.1 Structural flexibility

As reported by Anderson (2008), traditional spate irrigation structures seem rudimentary, but they have been sustained for many years using only simple local materials and indigenous skills. Their advantage is their flexibility. Spate floods lift and deposit large quantities of sediment resulting in active change of bed levels, both in the river system and in the distribution network; there are frequent changes and adjustments of the system (Mehari et al. 2010). Traditional headwork structures can easily deal with the wadi-level changes either by moving upwards and/or removing the headwork structures (Mehari et al. 2006). The modern ones however, lack this flexibility (Eyasu et al. 2012).

5.2 Irrigation/Diversion efficiency

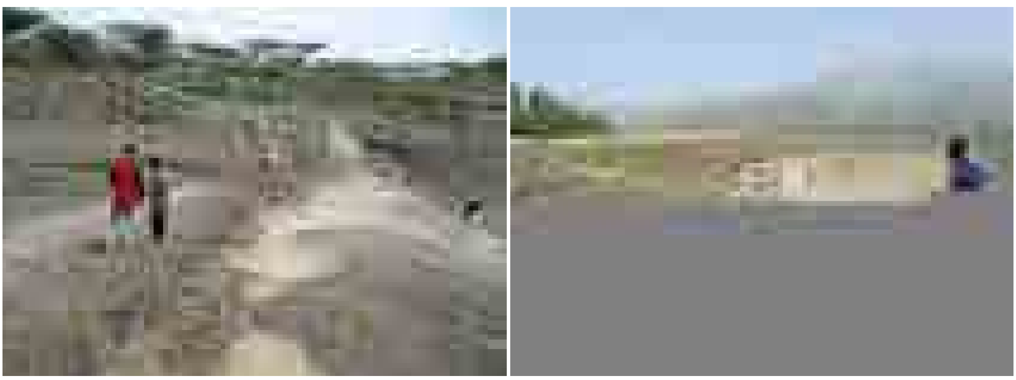
The diversion of the traditional systems is done using many, small offtake diversion structures; hence, they enable equitable sharing of water at many small diversion points and create fewer conflicts between most upstream and tail-end users (Eyasu et al. 2012). They are also relatively efficient in diverting the whole flood into the irrigated field using many small offtakes constructed along the wadi route. As far as the latter case is concerned, they are by far better than the modern ones. In the Raya Valley, the efficiency of the modern ones in terms of irrigation capacity has never exceeded 50% of the design capacity (Eyasu et al. 2012).

The services of the traditional systems are however, only limited to lower head diversions or shallow-depth wadis. As a result, it is almost impossible to construct them in deeper wadis (Zaqhloel 1988; Mu'Allem 1988). The modern ones enable easier diversion of floods in deeper rivers (Mehari et al. 2005a) like the Dayu Spate Irrigation System in Raya Valley. Though susceptible to sedimentation of the offtake and canal structures, if the offtake and canal routes are well dredged, the modern systems enable the diversion of higher discharges (very large floods). Very large floods, however, create considerable damage to the command area and canal structures.

5.3 Sediment control and management

According to IFAD (2005), not all modern spate schemes are an improvement over indigenous systems. Especially when farmers' views are not fully considered, the construction of modern engineered systems can worsen the operations for farmers. The modern systems divert all ranges of floods, including larger ones, which carry very high sediment loads (Mehreteab Tesfai 2002) that create considerable damage to the command area and canal structures. Lawrence (2008) has indicated that sediment concentrations rising to and exceeding 100,000 ppm or 10% by weight occur in floods in some wadis, and sediment concentration up to 5% by weight are common. The diversion of these higher sediment loads makes the life of the farmers difficult; farmers have to dredge higher sediment volumes both at the offtake and canal systems after every flood. As a result of failing to dredge before the floods, the systems will not irrigate the intended irrigation capacity. Studies undertaken by Embaye (2009, 2010) indicate that a volume of 8,350 m^3 sediment and 350 man-labor per season are required to dredge sediment from the Fokisa canal system. Figure 9.5 shows sedimentation at the Fokisa and Hara spate schemes. Traditional systems however, are helpful in avoiding sedimentation in cases of large floods (Anderson 2008) as the headwork structure is breached during higher floods.

Figure 9.5. Sedimentation at the Fokisa and Hara spate schemes.



5.4 Cost and durability

Traditional structures require low initial investment costs and are easy to construct. They however, utilize intensive labor for their O&M. As these structures are easily damaged by flood, a standby and enormous labor force is needed to maintain and reconstruct the structures almost after every flood. The modern schemes however, are designed and constructed to serve for about 25 years, though they are not yet all serving that long. As the modern structures avoid the periodic and yearly maintenance cost of the headwork and canal structures they have lower operational cost compared to the traditional ones. However, the other drawbacks of the modern spate systems are that their sediment dredging costs are high and they require high initial investment and highly skilled manpower for their design and construction (Steenbergen 2010).

5.5 Wadi stabilization

Even if the modern schemes are not effective in irrigating to intended capacity, they are very helpful in stabilizing the wadi level, which sustains the life of traditional systems upstream of the modern spate structures. These traditional schemes serve best when they are placed along bridge or culvert structures as these structures help in stabilizing the wadi bed (Mehretab Tesfai and de Graaff 2000; Eyasu et al. 2012). An example is the Harosha traditional spate system in the Raya Valley which is located immediately downstream of a bridge (Figure 9.6).

Figure 9.6. The Harosha traditional spate system having many diversion points along the wadi immediately downstream of a bridge (Eyasu et al. 2012).

5.6 Environmental considerations

Traditional spate systems have some drawbacks. They have a negative environmental impact in aggravating land degradation, as their construction requires the cutting of woods, bushes and shrubs. Big floods in these traditional systems destroy flood diversion channels and cause rivers to shift their course (Embaye 2009).

6. Conclusions

The existence of spate irrigation systems as a major source of food production in the Tigray Region, in particular in the Raya Valley, to a large extent, depends on whether current modernization activities transform them into competitive and credible sources of livelihood so that future generations will be encouraged to practice spate irrigation and invest in their development. In this regard, the overall objective set by the regional government is to understand the root cause of poor performance on spate systems and floods, indigenous water rights and agronomic practices, which among others, contributed to the impractical cropping patterns and rainfall assumptions, resulting in the underestimation of the net irrigation water requirement used for the design of the main canal head regulator gates; and the incorporation of inefficient weirs and siphons, which denied the farmers their upstream water right status and hence their ability to directly divert water from the wadi. These structures (weirs and siphons) also experienced sedimentation problems that further undermined the capability to sufficiently irrigate the irrigable area. The modern design layout did not provide the possibility to directly divert (from the wadi) the large floods.

Furthermore, as in the world's largest spate irrigation area in Pakstan, spate is seen as a nuisance (flood damage) rathern than as a potential benefit. The moderenized schemes have a failure rate of up to 65% (Khan 1988). Experience from Yemen also shows some drawbacks in floodwater management, which gives upstream users (farmers) absolute priority right (Girgirah et al. 1988). In Tigray, the tail-end farmers get the least amount of water due to lack of water management and knowledge barriers.

7. Recommendations

To fill the gaps identified in this article, capacity-building should be done focusing on three main aspects, as follows:

1. Development and dissemination of design guidelines and a manual that considers the special properties of the spate flows are mandatory to improve the efficiency of the modern diversion systems and increase the level of trust of the beneficiary farmers in the designs.
2. Flood-based farming should be mainstreamed in curriculums of universities that provide courses in water management so that researches can solve outstanding issues.
3. Short-term training should be given to engineers and water management experts currently working on spate irrigation.

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