Spate Irrigation Systems and Watershed Development in Eritrea:

-The Case of ‘Sheeb' watershed

Mehreteab Tesfai University of Asmara, College of Agriculture, Department of Land Resources and Environment, P.O.Box 1220, Telefax 291-1-162236, Asmara, Eritrea. E-mail: mehreteabt@yahoo.com

Abstract

This paper describes the interactions of the Spate Irrigation System (SIS) in Eritrea with their upper watersheds, as a case study in Sheeb watershed. The spate irrigation practices, among others, include techniques to harvest runoff water, sediments, and nutrients.

A strong relationship exists between the SIS in the lowlands of Eritrea and their upper watersheds. For example, the spate irrigation system in the lowlands of Sheeb area entirely depends for water, soils and nutrients on the resources of its upper watershed. Interventions of soil and water conservation practices in the upper watershed could reduce soil loss and sedimentation rates, in the long term. And, this in turn, lowers the quantity of sediments and nutrients harvested in spate irrigated fields of Sheeb. However, the runoff volumes may not be affected much (by such conservation measures) mainly because of the steep topography of the upper watershed with shallow soils, which induces more runoff than infiltration into the soils.

It can be concluded that the lessons learned from the Sheeb watershed will be very useful for planning watershed development projects in other spate irrigated areas of Eritrea and possibly in other parts of the world where similar systems are practiced.

Keywords: Spate irrigation system, watershed, lowlands, highlands, Sheeb area, Eritrea.

1. Introduction

Eritrea is located in north-eastern Africa between latitude 12 ° to 18 ° N and longitude 36 ° to 43 ° E. On the basis of climate, topography and soil conditions, Eritrea can be divided into six agroecological zones. These comprise: the moist highland zone, the arid highlands, the moist lowlands, the arid lowlands, the subhumid zone in the eastern escarpment and the semi-desert in the Red Sea coastal zones of Eritrea (FAO, 1997).

The low and erratic rainfall in the coastal zones of Eritrea makes agricultural production impossible without irrigation. Because, this zone receives abundant runoff water, sediments and nutrients from the adjacent highlands, the Government of Eritrea has identified it as an area for substantial agricultural development by spate irrigation (IFAD, 1995).

Spate irrigation can be defined as a preplanting system of irrigation where use is made of seasonal rivers (wadis) that produce flash floods, are diverted by structures to irrigate fields in the lowlands of Eritrea (Tesfai and Strossnoijder, 2001). In the lowlands, the floods are diverted to adjacent irrigable lands by means of temporary diversion structures called locally ‘agims' and, then conveyed by distribution canals called ‘misghas' to the series of fields that are surrounded by interior and exterior bunds, called ‘kifaf' and ‘tewali', respectively. In the fields, the water infiltrates into the deep soil profile while the sediments and nutrients are deposited on the soil. Seeds are sown in these fields and crops are produced using the residual soil moisture (Figure 1).

The study area is the Sheeb watershed (which encompasses a major portion of the eastern escarpments, and partly the central highland zones) and its spate irrigation area, which is, situated at piedmont plains in the Red Sea coastal zones of Eritrea. The spate irrigation area in Sheeb is located about 110 km north-east of Asmara (capital of Eritrea). Here the landscape is formed of flat to almost flat alluvial plains with an average elevation of 225 m above sea level.

The alluvial plains of the Sheeb area are part of the Red Sea basin drainage system. Numerous wadis (springing from the adjacent eastern escarpment and from the central highlands) flow through the area which eventually discharge into the Red Sea. The Sheeb watershed receives water mainly from two adjacent sub-watersheds i.e. wadi Laba and the smaller wadi Mai-ule. These watersheds cover a total area of approximately 800 km 2 (see Figure 2).

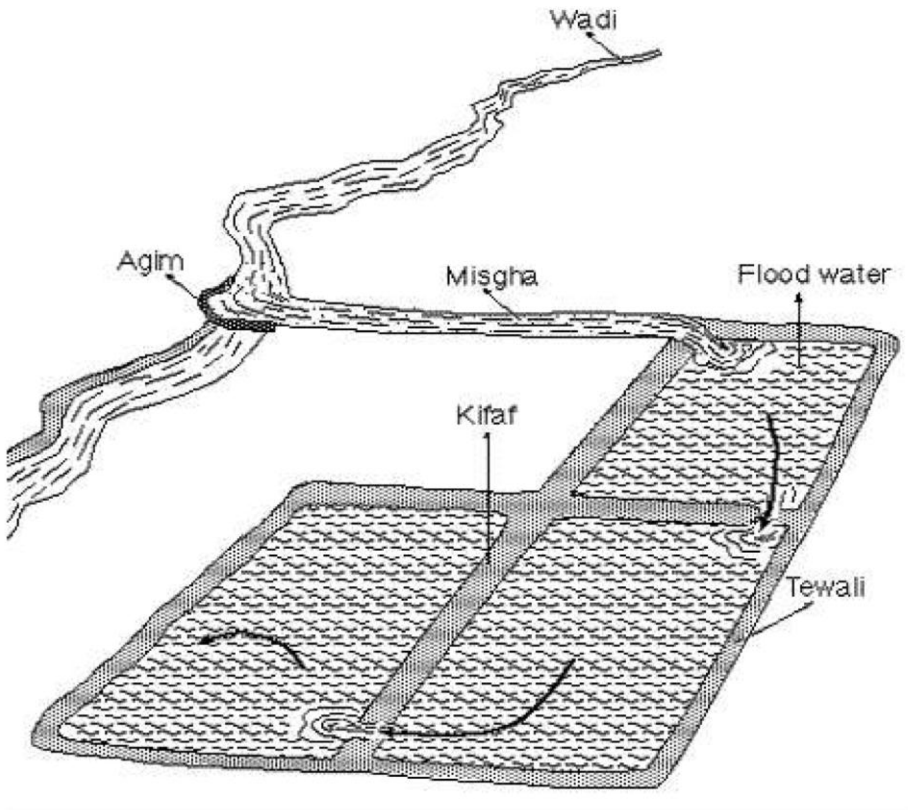

Figure 1. The spate irrigation system in Eritrea.

Table 1 shows the elements of the lowland system versus the highland system of Sheeb watershed. Except for tillage implements, all other elements are different between the lowlands of Sheeb and the highlands of Sheeb watershed. For example, the SIS is only practiced in the lowlands but not in the highlands because of the topography, climatic and soil conditions (in the highlands) are not conducive to establish the system.

However, it is important to stress the strong relationships that exist between the lowland and the upper watershed area of Sheeb. The lowland system of spate irrigation entirely depends on the resources of its upper watershed. Any change in the upper watershed (such as rainfall, erosion, and land-use) has a direct impact on the SIS in the lowlands of Sheeb area. For instance, if there are small rains in the upper watershed of Sheeb, less water will be available for spate irrigation in the lowlands of Sheeb area, resulting to lower yield and eventually decreasing the productivity of the SIS as a whole.

Table 1. The elements of highland system versus and lowland system in Sheeb watershed.

Elements	Highland system	Lowland system
Agroecological zone	Sub-humid & CHZ †	Semi-desert, coastal zones
Climate	Cool and sub humid	Hot and arid
Hydrology	Wadi Laba & Maiule basin	Flash floods (wadis Laba, Mai-ule)
Rainfall (annual)	550-800 mm	< 200 mm
Agriculture	Rainfed agriculture	Spate irrigation
Topography	Mountainous with steep slopes	Alluvial plains with flat slopes
Altitude, (a.s.l)	2000-2625 m	165-275 m
Geology	Precambrian basement complex	Alluvial sediments
Soils	Residual and weathered soils	Transported soils
Tillage	Oxen drawn implements	Oxen drawn implements ‡
Cereals (dominant)	Wheat, barely	Sorghum, maize, millets
Vegetables & fruits	Potatoes, citrus, some coffee	Watermelons, tomatoes
Livestock (dominant)	Equines, sheep	Camel, goats
Vegetation	Dispersed woody vegetation	Scattered bushes and scrubs
Household	Sedentary farmers	Agro-pastoralists, transhumance

† Includes only parts of the Central Highland Zone.

‡ Oxen drawn implements fitted with plough tip and its accessories.

In the past decades or so, the upper reaches of the Sheeb watershed were said to be covered with forests, shrubs and grasses (Mohammed, D. personal communication, 1999). However, with removal of trees for fuel-wood, for construction of traditional houses and for expansion of arable farming, runoff and erosion losses have increased in the Sheeb upper watershed. As a result, soil erosion became severe and tremendous amount of soils and nutrients have been eroded and transported to the lowlands of Sheeb area.

2. Impacts of watershed development on the spate irrigation system

2.1 Impacts of watershed development on Water Harvesting

Water harvesting can be defined (in this paper) as the collection of water by diverting the runoff (from the highlands) into the spate irrigated fields, mainly for crop production. The basic elements of water harvesting comprise a runoff producing area (in this case, Sheeb watershed) and a run off receiving area (i.e. spate irrigation area in Sheeb).

The surface runoff in the upper watershed of Sheeb is assumed to be higher than the infiltration rate of the soils. This assumption is based on the fact that, the steep topography of the highlands (with elevation varying from about 2600 m in the highlands to 200 m a.s.l in the lowlands), and shallow soils which induces more runoff than infiltration into the soils. Hence, soil and water conservation practices in the upper watershed may not affect much the amount of surface runoff reaching the spate irrigation area in the lowlands.

The amount of runoff depends very much on the rainfall intensity and duration of rainfall in the highlands. Dunne and Black (1970) reported that runoff develops when the rainfall intensity exceeds the infiltration rate of the soil or the water storage capacity of the soil. High-intensity rainfall coupled with short duration of rainfall, (a characteristic of semi-arid and arid climates of Eritrea) induces much runoff to flow towards the lowlands, so that more water could be harvested in the spate-irrigated fields of Sheeb area. But, this in turn depends on the efficiency of the flood diversion and canal structures and also on the water holding capacity of the spate soils in Sheeb area.

2.2 Impacts of watershed development on Sediment Harvesting

Soil erosion in Eritrea is severe, particularly during the rainy season when soils are tremendously eroded in the highlands zones (FAO, 1994). The onsite erosion effects in the upper watershed of Sheeb include detachment and transport of soil particles. While, the offsite erosion effects are sedimentation that occurs at the flood diversion and canal sites and subsequent deposition of fine sediments in the spate-irrigated fields.

Tesfai and Sterk (2001) have measured the thickness of sediment layers in the spate fields at Sheeb area using sediment pins. They have found the thickness of sediment layers in the fields to increase on average by 13 mm y^{-1} . The measure sediment layer is well below the long-term estimated sediment layer in the spate fields, that is, 30 mm y^{-1} by IFAD (1995). This maybe explained due to the excessive erosion in the upper watershed, where most of the soils in the hills and mountainous slopes are left now with shallow soils. FAO (1994) has reported the average soil depth in the agricultural fields in the highlands of Eritrea does not exceed 0.5 m due to sever erosion and deforestation.

The sedimentation (on the spate-irrigated fields) has build up soil depth and enhanced soil fertility. At present, most of the spate fields have developed very deep soils (on average 3 m) with good physical and chemical properties on originally dry infertile sandy soils.

On the other hand, the sedimentation at the diversion sites of the wadis, Laba and Maiule has negatively affected the SIS by depositing large quantities of bed load materials (about 0.9 million tons per year in wadi Laba only (Halcrow, 1997). These bed load materials block the passage of water in the canals and cause the irrigation structures to breach.

The soil and water resources in the upper watershed influence the SIS in the lowlands. When there are good rains and much runoff in the highlands, large amounts of sediments are harvested in the spate-irrigated fields. But, watershed development works in the highlands might negatively affect (in the long term) the amount of sediments that will be harvested in the spate-irrigated fields. For example, check dams construction (planted with live barriers) could trap some sediments. Likewise, construction of terraces along the hill slopes could reduce soil erosion. This implies that small amount of sediments are transported and deposited on the spate irrigated fields. Hence, expanding new spate irrigation schemes and/or reclaiming non-spate irrigated land in the Sheeb area might be hampered by watershed activities in the highlands.

Thus, interventions of integrated watershed activities (such as physical and biological soil and water conservation measures) should not be tailored only to restore the natural resource bases in the highlands but should also enable the existing SIS in the lowlands of Sheeb area to function in a sustainable way. This will be a considerable challenge for watershed development practitioners and farmers in the future.

2.3 Impacts of watershed development on Nutrient Harvesting

Apart from soil, the sediments from the highlands consists of debris of dead plant and animal materials and plant nutrients that enrich the fertility of spate irrigated soils. Spate irrigation has been practiced in the Sheeb area since the beginning of the 20 th century (Tesfai and de Graaff, 2000). Since then, the farmers in this area have harvested crops without applying organic and inorganic fertilizers, using only the nutrients deposited in their fields. During good flooding season, these farmers produce about 1,500 and 2,000 kg grain yield of maize and sorghum per ha, respectively.

The type of nutrients harvested in the spate-irrigated fields depends on the source of the runoff and the nature of soil chemical elements in the highlands. When the runoff is originating from the nearby hills and mountains, which are hardly vegetated, the sediments consist largely of coarse sand particles that are poor in nutrients. While, runoff from the agricultural fields in the highlands consists mainly of finer particles and relatively higher organic matter that enrich the spate-irrigated soils. Soil nutrients such as K^+, Ca^{2+}, Mg^{2+}, Na^+, containing compounds of chlorides, sulfates and carbonates salts are readily soluble and are easily transported (by the wadis) to the lowlands. Indeed, the spate irrigated soils are richer in soluble cations and anions than organic plant nutrients (Tesfai, 2001).

Establishment of enclosures in the degraded areas of Sheeb watershed and soil conservation practices along the hillsides could mitigate the severity of erosion and regenerate the natural vegetation in the watershed area. As a consequence, in the long term, the quantity of eroded sediments would decrease, which in turn, reduces the amount of plant nutrients deposited in the spate-irrigated fields. However, through adoption of nutrient adding and/or nutrient saving techniques (such as application of organic and/or inorganic fertilizers; growing leguminous crops; and restitution of crop residues) the fertility of the spate irrigated soils and crop yields could be maintained and enhanced.

3. Livelihood strategy of the Sheeb community

The average population of Sheeb community is estimated to be 18,800 during the cropping season and lowers in the rest of the year (Daniel, 1997). In Sheeb area, drinking water and animal feed (such as grasses) are only available during the cropping season and are scarce in the rest of the year (Tesfai and de Graaff, 2000). The Sheeb community has developed a specific livelihood strategy to combat these shortages of resources. During the summer, most of the people (85%) migrate with their livestock to the upper watershed (a kind of transhumance system) in search of drinking water and grass and to escape from the harsh climate of the year. They get drinking water, food (such as cactus fruits) and grasses for their animals because of the rainy season in the highlands. Some farmers also cultivate small plots of land that have inherited from their forefathers.

On the other hand, the transhumance system has affected the life of the Sheeb community in negative ways. For example, the strong windstorms and intense sun heat (in the summer) easily destroys the temporary houses locally called ‘agnet'. So, there is a need to rebuild the ‘agnet' year after year. And this drains the labour and capital resources of the household. Moreover, the migration (sometimes) hinders agricultural activities (such as repairing of irrigation structures, flooding of fields, sowing of seeds) are not performed at the right time and also the development of infrastructures (roads, buildings, etc.) in the Sheeb community is impeded by the migration of the people.

4. Sustainability of the spate irrigation system

‘Sustainability' is defined here as the ability of a system to maintain its productivity in spite of major disturbance such as stress and catastrophe conditions in the environment (Conway et al, 1987). The productivity of the SIS is entirely dependent on the frequency and size of floods diverted to the fields, which in turn depends on the occurrence of rains in the upper watershed and also on the efficiency of the diversion and canal structures in the lowlands. Since the rainfall pattern in the highlands is unpredictable and often is highly variable both spatially and temporally, the number and size of floods occurring in the Sheeb area are also variable in space and time, which results in good and bad seasons. Hence, cropped areas and crop production in SIS vary from year to year and also from field to field mainly due to variations in water supply.

Other problems that constantly threats the sustainability of the SIS are the repetitive construction and maintenance of the diversion and canal structures which are often breached by destructive big floods and high sediment loads. To construct and maintain these structures, a large number of trees, huge human and animal labour, and a considerable time are needed. For instance, annually tens of thousands of dry acacia trees are deforested from the upper watershed of Sheeb to construct flood diversion structures (at wadis, Laba and Maiule) in the Sheeb area. As a consequence, the vegetation resources of the Sheeb watershed have been severely degraded. Since replanting of trees have not (yet) been well performed, the Sheeb watershed has reached an alarming stage of vegetation catastrophe.

5. Concluding remarks

In general, the sustainability of the SIS in the lowlands of Sheeb area and its upper watershed is under considerable threat by the various factors mentioned above. However, there are several opportunities available to improve the traditional SIS and its upper watershed in Sheeb i.e. to make the system more productive, equitable and sustainable as well. These include: integration of indigenous technical knowledge of SIS with scientific know-how; construction of permanent flood diversion structures at the wadis Laba and Mai-ule; possibility of using of manure and crop residues in the spate irrigated fields; the development of infrastructure (like roads, schools, clinics, etc.) and interventions of integrated watershed management in the Sheeb watershed.

The spate irrigation system in the lowlands of Sheeb area has been developed at the expense of erosion and runoff from its upper watershed. Therefore, to reverse this watershed degradation and to make the SIS and its watershed more sustainable, integrated watershed development works has to be initiated in the area. However, before implementing watershed development projects, a detailed environmental impact assessment that considers not only the technical dimensions of the watershed but also the social, economic, political and cultural aspects of the entire Sheeb watershed should be carried out.

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