Runoff Irrigation Systems in Western Lowlands of Eritrea:

Potentials & Constraints

Abraham Mehari (1) and Mehreteab Tesfai (2)

1) University of Asmara, College of Agriculture, Department of Agricultural Engineering, P.O. Box 1220, Asmara, Eritrea, e-mail: abrahamhaile2@yahoo.com

2) University of Asmara, College of Agriculture, Department of Land Resources & Environment P.O. Box 1220, Asmara, Eritrea, e-mail: mehreteabt@yahoo.com

Abstract

This paper describes the principles and practices of the runoff irrigation systems in the western lowlands of Eritrea, their potentials, constraints and possible improvement interventions. Runoff irrigation is a method of irrigation that directs surface runoff induced by rainfall from upland areas which is discharged through streams to irrigate nearby fields in the lowlands. Field surveys were conducted in selected runoff irrigation schemes such as in *Bultubyay, Areda, Falko* and *Mogoraib* , as a case study. At present, there are about 1,750 ha of land under runoff irrigation schemes in the western lowlands of Eritrea but the potential is estimated to be 50,000 ha. The main constraints observed (in those irrigation schemes) were poor design of diversion and canal structures because of little knowledge on rainfall volume of the catchments, stream flow discharge, sediment load, irrigation efficiency, soil properties and crop water requirements of the schemes. Furthermore, there are no interior basin bunds in the irrigated fields that could slow down the flow of runoff water and allow the sediments to settle. The lessons learned from this study revealed that the characteristics of catchment rainfall, stream flow, sediment concentration, irrigation efficiency, soil properties and socio-economic conditions should be studied in order to select suitable sites for runoff irrigation schemes and for proper design and construction of the irrigation structures. Apart from this, training and field visit to similar irrigation systems in the eastern lowlands of Eritrea will enhance the knowledge and skills of the western lowland farmers on runoff irrigation systems.

Keywords : Eritrea, irrigation design, runoff irrigation, schemes, systems, western lowlands.

1. Introduction

Irrigation is one of the methods used to increase food production mainly in arid and semi-arid regions. It can enhance food security, promote economic growth and sustainable development; create employment opportunities; increase the subsurface water storage and recharge ground water; improve living conditions of small-scale farmers and thus contribute to poverty reduction and protect the environment from pollution.

On the other hand, if irrigation is not properly managed, it can have adverse effects on the environment and the users. For example, the irrigation water in the channels could create a climate, conducive for mosquitoes to multiply, thus contributing to malaria spread out and other water borne diseases. Apart from this, irrigated agriculture, supplied with poor drainage infrastructure may lead to salt build-up in soils and groundwater.

It is estimated that 70-80% of the population of Eritrea makes a livelihood on the production of crops, livestock and fisheries. The population of Eritrea is expected to rise from 4.3 million in 2001 (CIA, 2001) to 5.4 million by 2010. On the basis of 0.160 ton of annual food requirement per person (World Bank, 1994), the total annual food requirement by the year 2010 would be 864,000 tons. According to CIA (2001), the total potential arable land in Eritrea is estimated 1.5 million ha, with nearly 50% being found in arid lowlands and semi-desert agro-ecological zones. These two zones receive on average 200-400 mm of rainfall, which is low for agricultural production unless otherwise supplemented by irrigation.

Using the average grain yield of 0.74 ton/ha (World Bank, 1994), about 1.2 million ha of land should be cultivated to satisfy the food requirement of the population by 2010. However, there exists only about 750,000 ha land suitable for rainfed agriculture (CIA, 2001). Therefore, increasing agricultural production could be realized only if intensification of agriculture is complemented to rainfed agriculture. Intensification of agriculture such as developing new irrigation systems (like drip irrigation) as well as improving the existing systems (like runoff irrigation system) in the potential irrigable areas of Eritrea would enhance food security and sustainable development.

2. Runoff irrigation systems

2.1. Principles and practices of runoff irrigation

Runoff irrigation is a method of irrigation that directs large quantities of surface runoff induced by rainfall in the upland areas which is emitted through normally dry streams to irrigate fields in the lowlands. The runoff water is diverted by means of simple earthen, brushwood, gabion or concrete structures to the fields. The fields are flooded at least twice to three times to a depth of a minimum of 50 cm. The purpose is to provide more water during the rainy season thereby reducing the risk of poor yields due to long, dry periods.

Runoff irrigation is the oldest form of irrigation, which has been practiced in semi arid and arid areas for millenniums. The best known runoff irrigation systems are found in the Arabian Peninsula, notably in Yemen, where it dates back to 2000 years (UNDP/ FAO, 1987), and the Negev Desert region, which were built during the Israeli, Nabataean and Roman-Byzantian periods going back to 1,300 to 2,900 years (Evenari et al., 1971).

Runoff Irrigation System (RIS) has two main parts: the catchment area, where runoff is generated; and the field area, where runoff water is concentrated. According to Tauer and Humborg, (1992) to establish a runoff irrigation system, the following two basic requirements must be met:

- There should be a mountainous or hilly topography that generates run-off and adjacent low-lying fields on the same plain or at the foot of the slope to which the runoff water can be directed; and

- The fields should have deep soils that are capable of storing ample moisture to supply for the crops during periods having no precipitation. This is because (in runoff irrigation system) plants receive their supply of water during a dry period following a rainfall event exclusively from the moisture thus stored in the soils.

Two different types of runoff irrigation systems are employed, depending on the slope of the terrain. One is for locations where the catchment area and the fields lie adjacent to each other on the same plain called microcatchment system. The second is a catchment area located on a slope with the (usually) terraced fields at the foot of the slope, called macrocatchment system. The ratio of the catchment area to field area in microcatchment runoff system varies from 1:1 to 10:1 and from 10:1 and 100:1 for macrocathment systems. Some of the advantages and disadvantages of these two systems are explained in Table 1. In microcatchment, there is no loss of potential arable land caused by the presence of the catchments, because the catchment areas are sloppy and thus are unsuitable for agriculture. Whereas in microcatchment system, there is loss of arable land because the catchment basin and the fields lie on the same plain adjacent to each other.

Table 1. Some of the Advantages and disadvantages of microcathment versus macrocathment runoff irrigation systems.

Systems	Advantages	Disadvantages
Microcatchment	• Low investment	• Loss of potential arable land
	• Structures easily built & manageable	• Existences of homogenous relief
Macrocatchment	• No loss of potential arable land	• High investment
	• Possible expansion of fields	• High risk of runoff water

The microcatchment and the macrocathement runoff irrigation systems are both practiced in Eritrea (Figure 1). The Spate Irrigation System (SIS), which is believed to have been practiced in the eastern lowlands of Eritrea for over 100 years (Tesfai, 2001), is an example of a macrocatchment runoff irrigation. Most of the runoff irrigation systems practiced in the western lowlands of Eritrea, such as those found in Bultubyay, Areda and Falko are of a microcatchment type. Administratively, a large part of the western lowlands of Eritrea is found in zoba Gash Barka.

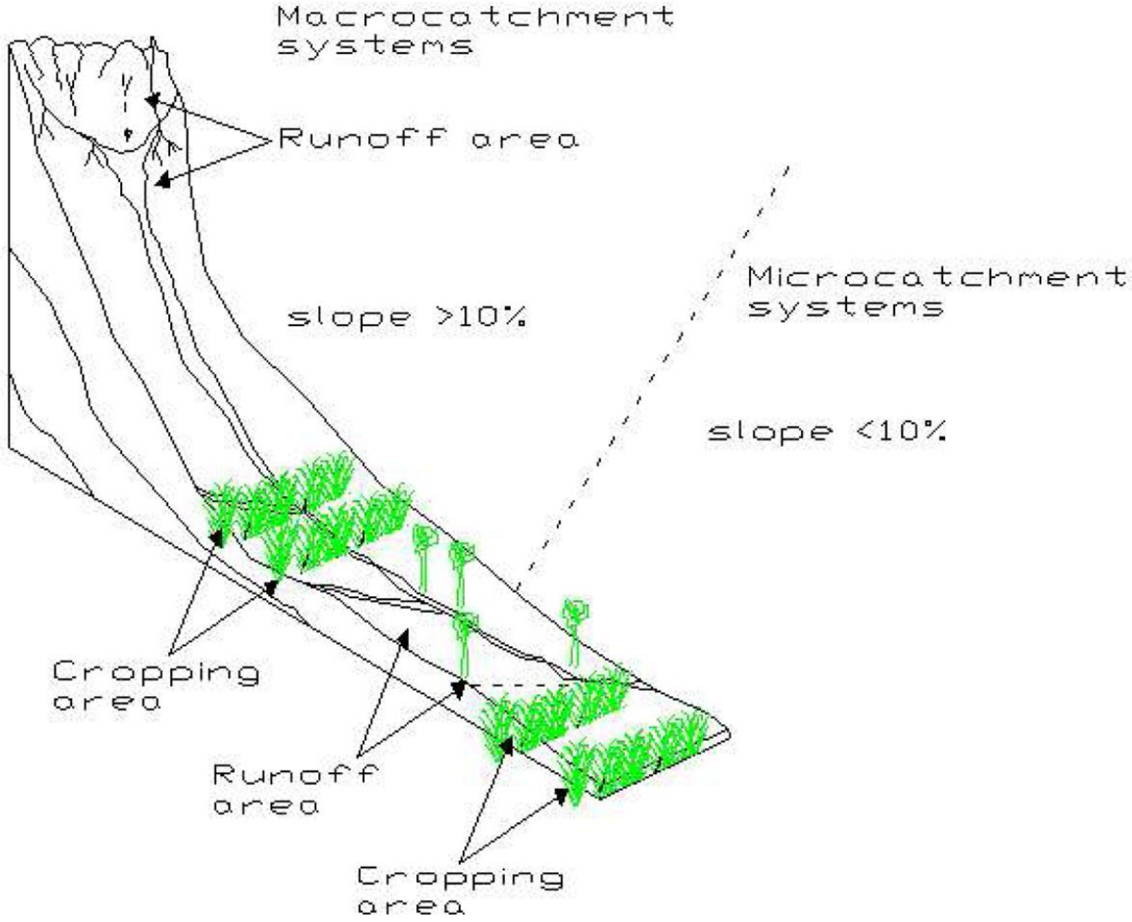

Figure 1. The runoff irrigation systems in Eritrea

3. Potentials of Runoff Irrigation Systems

In the following section, the land and water resources of the western lowlands and their potentials in relation to runoff irrigation system are described.

3.1. Water Resources

Unfortunately, Eritrea is not well endowed with fresh water resources owing to the arid climate prevailing in the country and due to shortage of rainfall. Eritrea has five main drainage basins, namely the Mereb-Gash, the Setit, the Barka-Anseba, the Red Sea and the enclosed Danakil basins (Table 2). All these rivers (except the Setit River) are ephemeral which flow during the rainy season from July to September. The Mereb-Gash, the Barka-Anseba and the Setit rivers all flow into the western lowlands, and discharge towards the eastern Sudanese plains. The Mereb-Gash is a narrow westward oriented basin covering the area from the southern part of the central highlands to the Sudanese border. The Setit River has perennial flows along the southwestern zone, which shares a common border with Ethiopia. The Barka and Anseba rivers originate from the northwestern slopes of the central highlands and flow northward to a confluence close to the Sudan border in the extreme northwest of Eritrea. Although the annual rainfall volume of the Barka Anseba basin is estimated at 14,815 million m^3, the annual flow volume is projected at only 41 million m^3.

This is probably because much of the flow is rapidly infiltrated into the sandy plains of the river valleys (FAO, 1994).

Table 2 : Estimated mean annual flow volume, catchment area and rainfall of the major drainage basins.

Drainage basin	Catchment area (1)	Mean annual rainfall (2)	Mean annual rainfall volume (3) = (1) ´ (2)	Annual flow volume (4)	Mean annual runoff coefficient (5) = (4) ¸ (3)
	km 2	mm	Mm 3	Mm 3	-
Red Sea	44,689	350	15,641.15	444	0.028
Barka-Anseba	39,506	375	14,814.75	41	0.003
Mereb-Gash	23,455	600	14,073	532	0.038
Denkil basin	10,532	200	2,106.4	135	0.064
Setit basin	7,517	650	4,886.05	49	0.010
Total	**125,699**	**-**	**-**	**1,201**	**-**

Source: WRD (2000)

3.2. Land and Soil Resources

The currently irrigated area in Eritrea is estimated at 28,000 ha (FAO, 1997), out of which spate irrigation covers about 50%. Table 3 shows the estimated potential irrigable command areas of the major river basins in Eritrea. Estimates on the total potential irrigable area of the river basins has been reported variously as 300,000 ha by EVDSA/WAPCOS in FAO (1994) and about 600,000 ha by the MoA report in FAO (1994). The former does not cover the eastern lowlands where a macrocatchment runoff irrigation system is practiced, and some minor potential areas in the highlands. The later estimate covers all land areas assumed to be suitable for irrigation without considering the availability and accessibility of water and the suitability of soils for irrigation. Therefore, both estimates can not be considered reliable and should be treated with caution.

Table 3. Estimates of irrigation potential of the river basins in Eritrea†.

River basins	Potential irrigable land (ha)
Red Sea	137,000
Barka-Anseba	na
Mereb-Gash	67,560
Denkil depression	na
Setit	224,600
Total	**429,160**

†: Adapted from FAO (1994). na: not available

The total potential area to develop RIS in Eritrea is estimated to be 187,000 ha. Of which, nearly 50,000 ha are found along the major river basins in the western lowlands and the rest in the eastern lowlands along the coastal plains of Eritrea, where the SIS is predominately practiced.

The Ministry of Agriculture at Zoba Gash-Barka has been actively engaged in establishing microcatchment runoff irrigation systems, under both “controlled” and “uncontrolled” diversion systems. A controlled water distribution system refers to a system where the main diversion structure feeds water to a main canal, which in turn supplies water to a group of 4 to 5 fields with division boxes. In an uncontrolled system, runoff water is directly fed from the headwork to the irrigated fields without distribution canals. At present, there are about 16 run off irrigation sites that cover about 1,750 hectares runoff irrigated lands, benefiting about 1025 households (Table 4). Most of the households are returnees from Sudan who own 1-2 ha of irrigable land. The average family size of the households is about 5-6 persons.

Table 4 : Runoff irrigation types and their irrigated areas in Zoba Gash-Barka

Sub-zoba	No. of runoff sites	No. of Runoff irrigation types		Total irrigated land (ha)	No. of beneficiary households
		Controlled	Uncontrolled		
Dighe	4	2	2	350	175
Mensura	2	-	2	250	125
Mogolo	3	3	-	280	140
Gogne	1	1	-	150	75
Haykota	2	-	2	230	140
Forto	3	1	2	290	170
Tesseney	1	1	-	200	200
Total	**16**	**8**	**8**	**1,750**	**1,025**

Source: MoA, Zoba Gash-Barka (2003)

The majority of the soils in western lowlands of Eritrea are classified as Vertisols and Fluvisols according to FAO-Unesco (1988) soil classification system. The Vertsiols are predominantly found in southwestern lowlands in the extensive clay plains bordering the Sudan and the Fluvisols develop in the alluvial plains along the major riverbanks. Both types of soils are deep with good water holding capacity and consist of high to medium fertility.

4. Constraints to Runoff Irrigation Systems

The information on the constraints of RIS in the western lowlands is based on field observations and discussions held with the farmers and staff of the MoA in the Zoba Gash-Barka.

4.1 Structural irrigation design & construction

The problems with regard to design and construction of irrigation structures at diversion, canal and field sites in the runoff irrigation schemes could be described as follows:

Firstly, the designs of the main diversion structures in most of the runoff irrigation schemes are not based on long-term measured data of flood discharge. The lack of knowledge on flood discharge could have a two-fold problem. The estimated peak discharge could be unrealistically high resulting in an expensive design. Conversely, the estimated peak discharge could also be very low; resulting in weak structures that could not withstand the expected floods. This results in water loss through seepage and frequent breaching of the structures. For instance, in Bultubyay uncontrolled runoff irrigation system, the diversion gabion structure was unable to withstand the big flood that occurred in the year 2002. Subsequently, the water seeped below the structure and partially destroyed the gabion and more than 75% of the runoff water was lost out of the system.

Moreover, the diversion structures are built without the knowledge of rainfall volume of the catchments, stream flow discharge, sediment load, irrigation efficiency, soil properties and crop water requirements of the schemes. For instance, in the preparation of design, no consideration is given to sediment concentration of the river flow probably because no measured data exists. The diversion structures are not supplied with any sort of sediment ejectors or gravel/sediment traps. Accumulation of sediments at the upstream of the headwork and main canal intake could substantially reduce the amount of water being diverted to the fields. For example, in the Areda controlled runoff irrigation system, about 2 m sediment depth was deposited in two rainy seasons which blocked the gate openings of the main canal. The cost of excavation of the sediments was beyond the capacity of the local farmers and even for the Ministry of Agriculture at Zoba Gash-Barka.

Secondly, no measured data exists on the total water requirement of the irrigation command areas for e.g. in Bultubyay and Areda schemes. This implies that the quantity of water that should be conveyed by the canals to irrigate the fields is not well known. Furthermore, the width, depth and length of the canals and the gates of division boxes were not properly designed. Such poor design could lead to either excessive or insufficient water applications into the fields and loss of water in the canals and fields.

Thirdly, the irrigated fields are not well levelled and graded to a uniform slope. In runoff irrigation system, levelling and grading of fields are very important to maintain uniformity of water distribution within the perimeters of the fields (FAO, 1985). Otherwise, lower spot of the fields could get excessive water and the higher spots could receive low amount of water. Furthermore, the water collection systems in the fields are poorly designed. There are no interior bunds within the fields that could slow down the speed of runoff water to infiltrate deep into the soil and to settle the sediments that contains soils and plant nutrients. In SIS, interior and exterior bunds are constructed in the irrigated fields to retain runoff water, soil and nutrients. Without such field bunds, runoff irrigation, as currently applied in Bultubyay, Areda, Falko and other areas, could create surface runoff, and erosion in the irrigated fields.

4.2 Operation & Maintenance

Most of the farmers in the runoff irrigation schemes are returnees from Sudan. These farmers lack the technical know how and skills of constructing and maintaining irrigation and soil and water conservation structures. Furthermore, these farmers were not involved during the preparation of design, construction and implementation of the runoff irrigation structures. This has probably misled the farmers to assume that the operation and maintenance of the irrigation system is the responsibility of the Ministry of Agriculture at Zoba Gash-Barka. Hence, most of the farmers are often reluctant to participate in maintenance of the irrigation structures.

4.3 Absence of Farmers' Organization

The farmers in the runoff irrigation schemes in the western lowlands are not organised in the form of committees such as irrigation committees and the likes. For example, there are no water users associations established in the irrigation schemes of Bultbyay, Areda, Falko and Mograib schemes. Therefore, these farmers could not mobilise their resources whenever operation and maintenance works are needed. Indeed, such types of activities require collective work as it is practised in SIS in eastern lowlands of Eritrea.

5. Concluding Remarks

By and large, the western lowlands of Eritrea have potential for the development and expansion of runoff irrigation systems. However, the RIS are functioning under several constraints among others, poor design of irrigation structures, lack of technical know how, absence of farmer's organization, etc. Therefore, to improve the existing RIS so that they become more productive (and hence contribute to food security) and also to develop new runoff irrigation sites in the western lowlands of Eritrea, the following intervention measures are suggested:

• Feasibility studies and primary data collection mainly on runoff discharges, sediment concentrations (using velocity-area method) and soil characteristics through systematic soil survey;

• Construction of field bunds (at least 50 cm height) and proper levelling and grading of the irrigated fields;

• Capacity building of farmers and extension agents through training and field visit to runoff irrigation system in the eastern lowlands of Eritrea; and last but not the least

• Establishment of Water User's Associations and strengthen institutional and organisational structures of the schemes through training, incentives and others.

6. References

Central Intelligence Agency, 2002. World Fact Book. Internet home page: **http://www.cia.gov/cia/publications/factbook**, 2/08/2002.

Evenari, M., Shanan, L., Tadmor,N., 1971. The Negev-the Challenge of a Desert. Cambridge Massachusetts.

FAO, 1985. Water quality for agriculture. FAO, Irrigation and drainage paper no. 33, Rome, Italy, 193 pp.

FAO-Unesco, 1988. Soil Map of the World, revised legend with correction. World soil resources report 60. FAO, Rome, Italy, 140pp.

FAO, 1994. Eritrea Agricultural Sector Review and Project Identification, Annex 5, Rome, Italy, pp 19-21.

FAO, 1997. Production Yearbook. Volume 51, FAO Statistics Series No. 142, FAO, Rome, Italy, 239pp.

MoA, 2003. Ministry of Agriculture, zoba Gash Barka, Annual report, Asmara, Eritrea.

Tauer, W. and G. Humborg, 1992. Runoff Irrigation in the Sahel Zone, CTA, Wageningen, The Netherlands.

Tesfai, 2001. Soil and water Management in spate irrigation systems in Eritrea, PhD thesis, Wageningen, the Netherlands, 211pp.

UNDP/FAO, 1987. Spate Irrigation: Proceedings of the sub regional expert's consultation on wadi development for agriculture in the Natural Yemen, Aden, 180pp.

World Bank, 1994. Eritrea. Options and strategies for growth, Vol. II report no. 12930 ER. Eritrea, W.DC. USA. pp 59-89.

WRD, 2000. Water Resources Department, Annual report, Asmara, Eritrea.