Design and Performance of Community Based Irrigation in Tigray

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Abstract

The existing perennial streams in the Tekeze basin, is not dependable sources of irrigation water due to their limitations in their number and flow rate. Thus, harvesting of the seasonal surface runoff is the strategic option to promote irrigation in the Tekeze basin. In the absence of locally developed design guidelines and code of practice, the use of empirical equations, developed for other parts of the world, has been very helpful. Nevertheless, there has been a case of under and over estimation of design parameters as a result of which the performance of the irrigation schemes was adversely affected. This paper presents background information, challenges encountered and research needs in the design of community based irrigation schemes.

Introduction

Water has been recognized as the most important factor for the transformation of the agrarian system in Ethiopia (UNDP/ECA/FAO, 1994). This statement has been reinforced by the FDRE policy and strategy on rural development issued in 2002 (MoI, 2002). It is indicated that reliable water supply and efficient water management is a prerequisite action for fast and sustainable agricultural development in Ethiopia.

The existing perennial streams in the Tekeze basin, is not dependable sources of irrigation water due to their limitations in their number and flow rate. Thus, harvesting of the seasonal surface runoff is the strategic option to promote irrigation in the Tekeze basin (UNDP/ECA/FAO, 1994). In accordance with this COSAERT and Commission for Sustainable Agriculture and Environment Rehabilitation in Tigray (COSAERAR), in Tigray and Amhara, respectively, have been established in 1996 with the mandate of study, design and construction of irrigation schemes. The design procedure followed by these institutions was based on standard guidelines and empirical equations commonly found in textbooks. More over, multidisciplinary professionals are involved in the study and design of the irrigation schemes.

In the absence of locally developed guidelines and code of practice, the use of empirical equations, developed for other parts of the world, has been very helpful. Nevertheless, there has been a case of under and over estimation of design parameters as a result of which the performance of the irrigation schemes was adversely affected. Though limitations in technical capacity had a significant share in design problems, the issues that need research are listed below:

- Failure to harvest the design runoff by reservoirs,
- Early sedimentation of reservoirs,
- Under utilization of all of the harvested water in reservoirs due to under estimation of water use efficiency,
- Failure to prescribe economically important biological SWC measures at the catchments of reservoir dams,

This paper intends to present background information, challenges encountered and research needs in the design of community based irrigation schemes. Future strategy in the Tekeze basin is also discussed briefly.

Topography

The Tekeze river basin has a catchments area of about 68751km^2 with in Ethiopia as measured from a 1:1, 500,000 maps (MOWR/NEDECO 1996). Out of this, 35288 km^2 or 51% lies in Tigray and 27617 km^2 or 40% in Amhara. (Figure 1). The low land part of the Tekeze river basin consists of about 1500km^2 area, which is almost flat land (WOWR/NEDECO 1996). Observation of topographic map indicates that the above area has high irrigation potential in view of the water availability from Tekeze and its tributaries.

About 70% of the basin lies in the high lands at an altitude of over 1500m a.s.l. The area of land above 2000m-elevation a.s.l covers about 40% of the total basin. The arable land in the highland part of the basin is found in the plateaus and valleys. In those areas there is a significant elevation difference between the major riverbed level and the agricultural fields. Figure 2 and 3 show two cross sections of Suluh Valley to represent the relative position of the riverbed and plain land in the upstream part of the basin. The cross sections are typical of all rivers in the high land where the riverbed is very deep compared to the near by agricultural fields. At some potential dam sites, the riverbed is below 80m from the near by field (COSAERT / WAPCOS 2001).

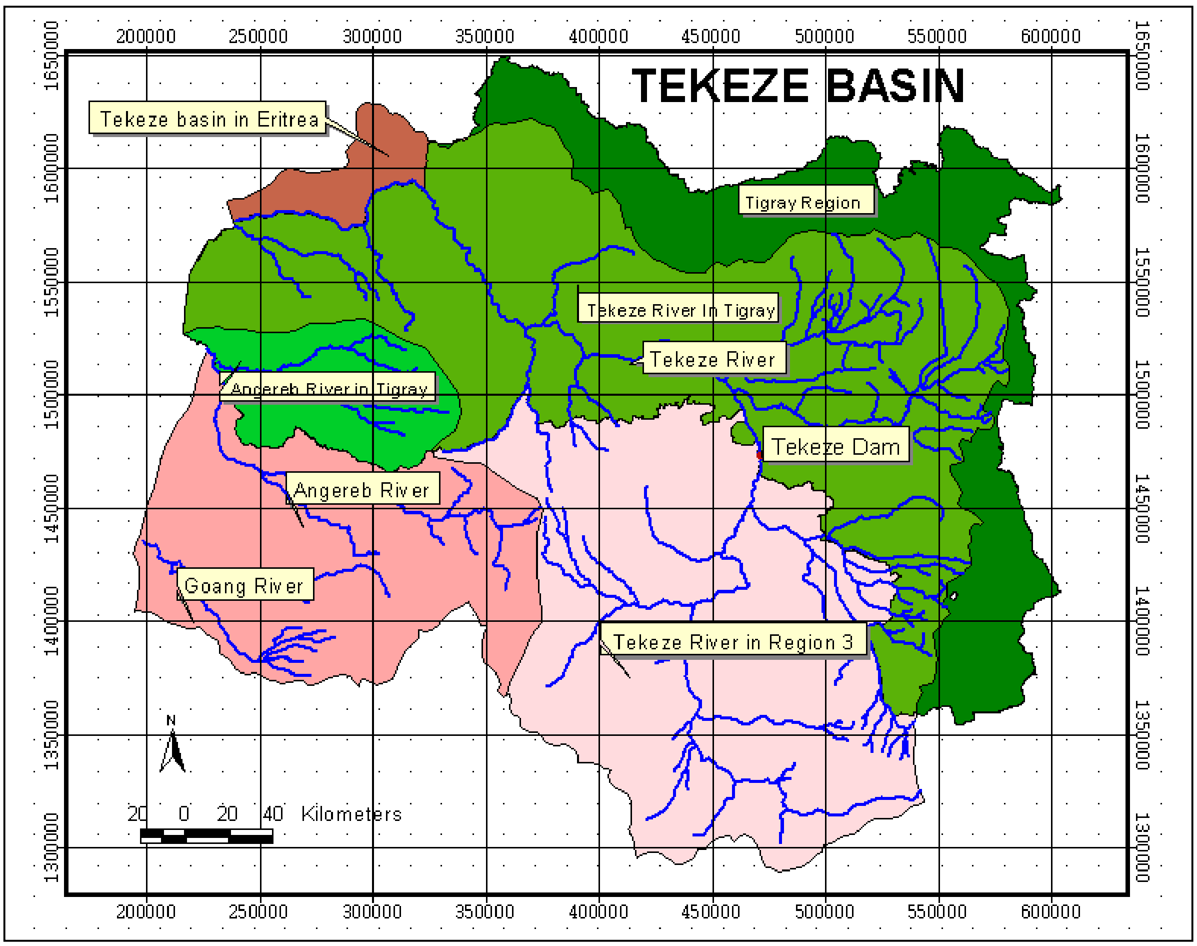


Figure 1 Tekeze River Basin.

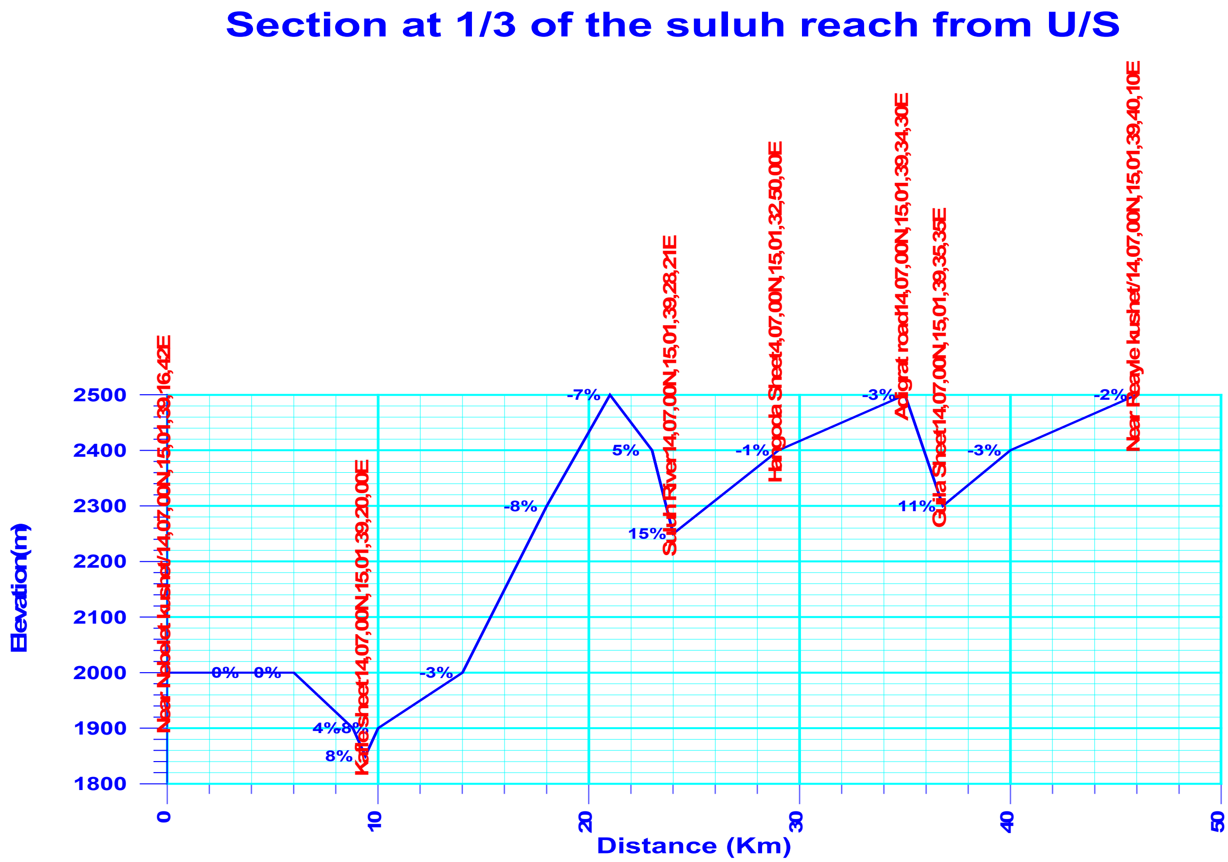


Figure 2. Cross-sections of Suluh Valley**.**

Irrigation Experience

The importance of irrigation in the Tekeze basin has been recognized many generations back according to members of the indigenous irrigation schemes. Field observations made in most part of the basin show that almost the entire available perennial surface water source is used for irrigation, except those found in deep gorges, as of many decades back. In Tigray alone, the total area irrigated by 2002 was 4773ha or 0.44% of the total arable land (BOANR, 2003). In some unpublished reports the total irrigated area is stated as 6500ha. The fluctuation in size of irrigable area from one year to the other could be due to the drying of the water source following drought or shortage of rainfall.

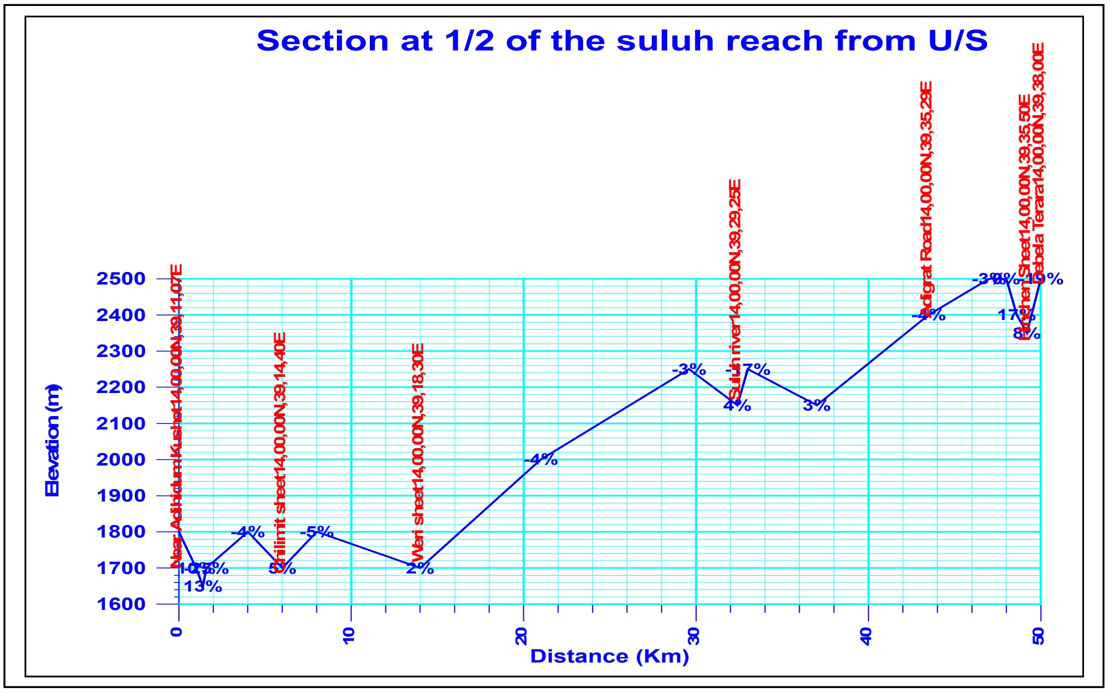


Figure 3. Cross-sections of Suluh Valley (Topographic Map 1:250,000).

Over the last decade government agencies and NGOs have intervened to develop new irrigation schemes and improve the indigenous irrigation schemes by constructing more stable hydraulic structures. As yet, a total of 56 irrigation schemes with a potential irrigable area of 3845 ha have been designed and constructed by COSAERT alone. But, very little has been done in improving the agronomic and water management practices. Thus, more work is still required to maximize benefit per unit volume of water.

Future Research Focus Area: Water Productivity Vs Water Harvesting

Although not without merit, efforts focusing on the improvement of the productivity of existing water source might not be adequate in ensuring food security in the Tekeze basin. Irrigation could play a significant role in enhancing agricultural production in the Tekeze basin only if water harvesting is considered as an integral part of the exercise.

The average yield of Wheat and Maize in the "high rainfall" areas is in the order of 20 - 25 and 50 - 55 qt/ha, respectively. In the "low rainfall" areas the average wheat and maize yield is 7 - 11 and 8 - 11 qt/ha, respectively, (BoANR, 1992 – 1998). This information could give a clue on the effect of moisture deficiency in the rain-fed agriculture.

The mean annual rainfall in the Tekeze basin ranges from 300 in the northeastern end to over 1200mm in the south western (Figure 4). The cumulative amount of rainfall could have been sufficient for crop production even in the "low" rainfall area. The problem is that there is large spatial and temporal rainfall variability to the extent of causing low agricultural production. The variability of annual rainfall ranges from 20% in the highlands of Western Tigray to 40% in Eastern Tigray (UNDP, ECA, FAO, 1994). As shown in figure 5, 70 - 96% of the rainfall during the growing season occurs in July and August. This fact explains that rain-fed agriculture suffers from moisture deficiency especially during the last two months (September and October) of the growing season. Therefore, supplementary irrigation would be of paramount importance to obtain at least one reliable harvest. The extent of the moisture deficiency during the growing season is depicted in figure 6, taking the 75% dependable rainfall and Maize in to consideration. For Quiha station, for instance, the moisture deficiency in September and October is 146 and 81 mm, respectively.

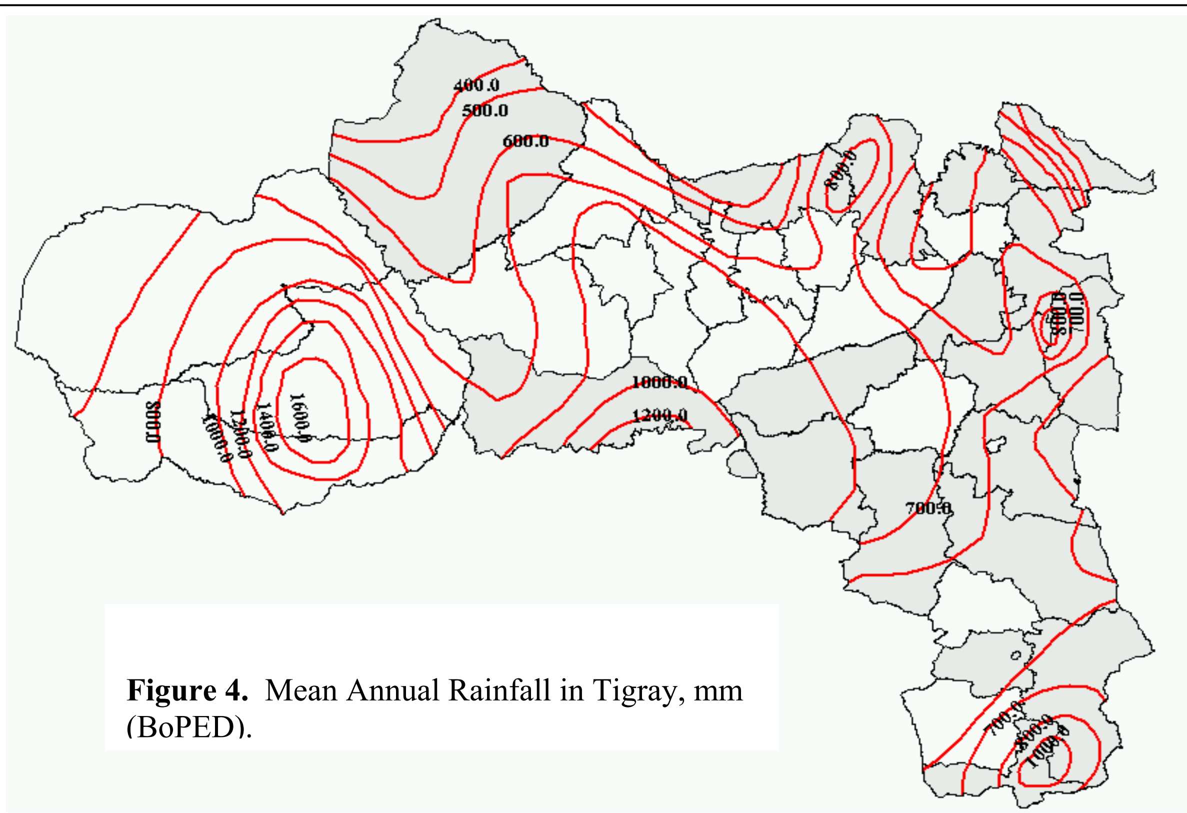


Figure 4. Mean Annual Rainfall in Tigray, mm (BoPED).

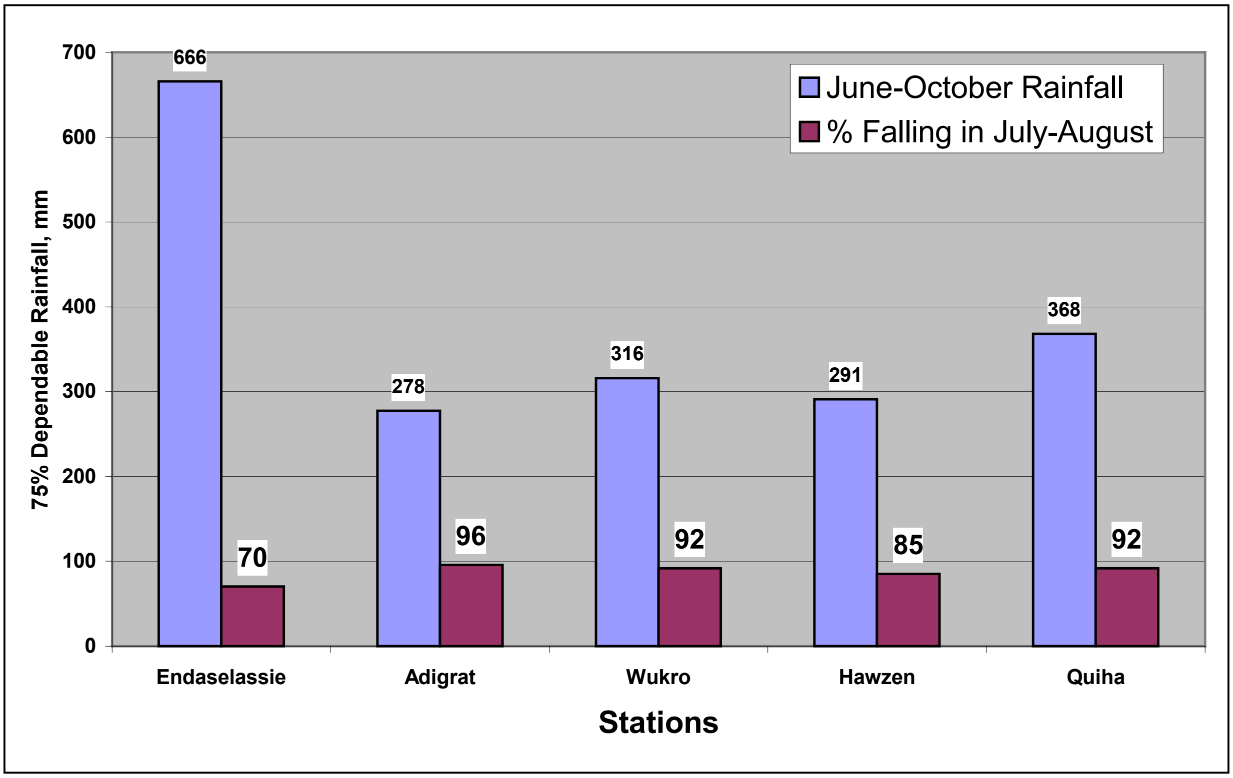


Figure 5. Seasonal Rainfall and Proportion Falling in July and August.

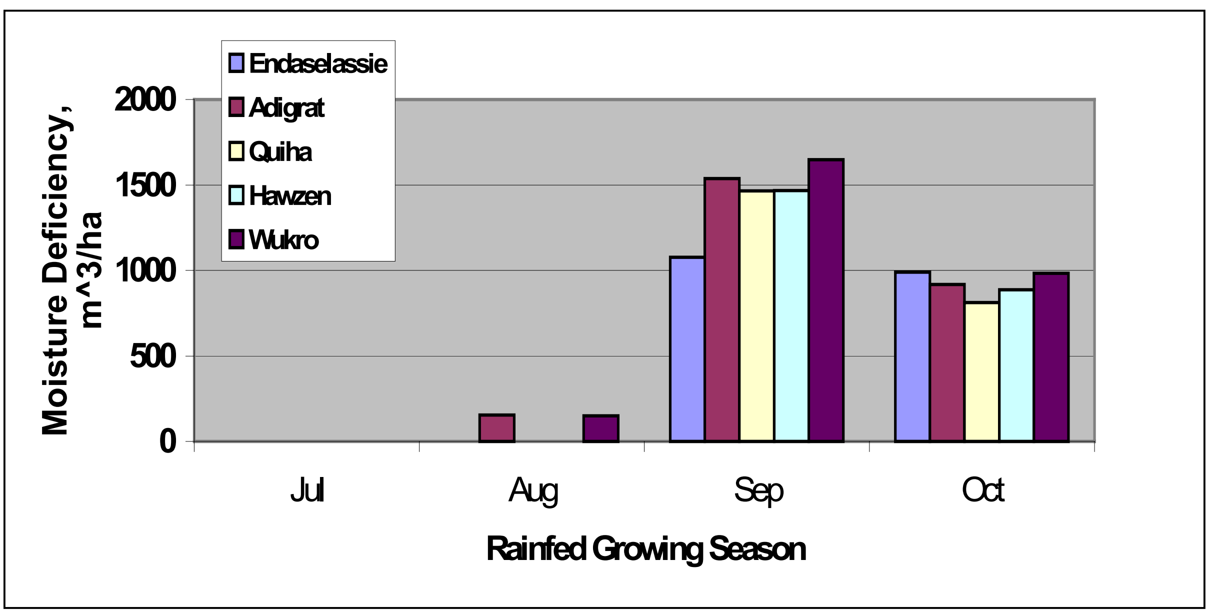


Figure 6. Moisture deficiency at three selected stations in Tekeze Basin.

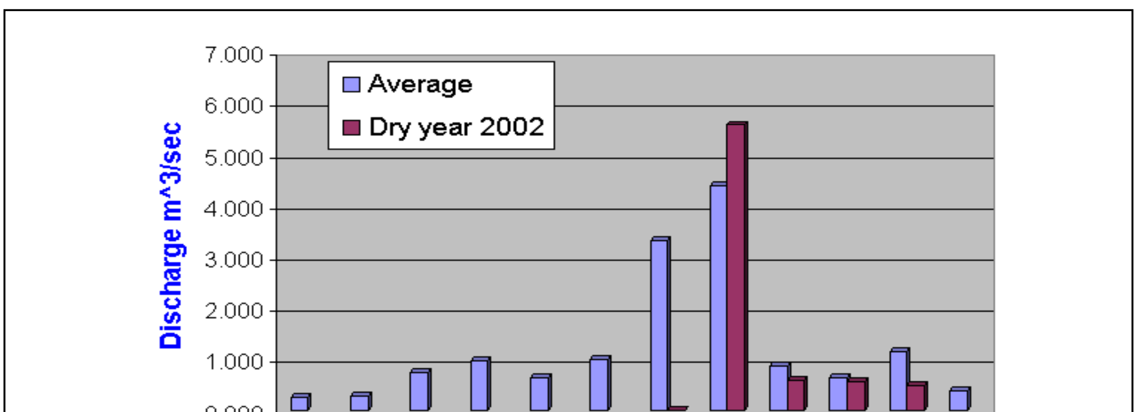
Materials and Methods

This paper is prepared in light of the efforts made to promote irrigated agriculture in Tigray during 1996 - 2003 as 51% of the basin falls in Tigray. The facts indicated in the paper are based on field observation as well as review of study and design document.

Challenges in the Promotion of Irrigation in the Tekeze Basin and Limitations With the Source of Irrigation Water

Perennial Streams

Tekeze River is perennial near the international border with a minimum flow of $2m^3/s$ (MOWR - NEDECO 1996). In the highland part of the basin only large rivers are perennial with some flows. The minimum dry season discharge of those streams ranges from 0.5 to over 70 L/s (Co-SAERT 2002) (Figures 7 and 8).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0.26	0.29	0.74	0.97	0.63	0.99	3.33	4.40	0.87	0.64	1.15	0.40
Dry year 2002							0.01	5.58	0.59	0.57	0.5	

Figure 7. Suluh River monthly discharge of 2002 compared to average of Previous years.

Most of these streams and some springs are already used for irrigation. A reconnaissance survey conducted in 2000 shows a total of 3492 ha has been irrigated in 466 indigenous schemes. With some investment in the 466 schemes, it was indicated that the irrigable area could be expanded by 5272 ha. However, as per an unpublished document from the Tigray Biro of Water Resources Development (TBoWRD), the above-mentioned size of potential irrigable area is highly exaggerated following a ground verification exercise. In most of the schemes, deficit irrigation is practiced due to the limitations in the stream flow rate and seepage along the canal.

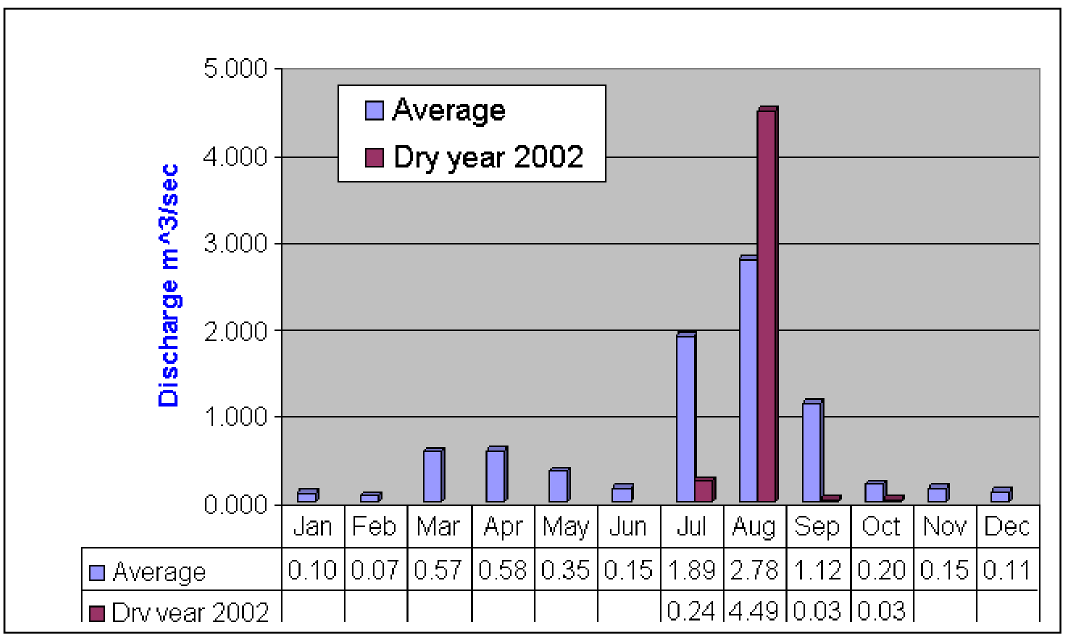


Figure 8. Ilaalla River monthly discharge of 2002 compared to average of previous years.

Limitations with Ground water

Geology

There is no detail hydro geological study made in the Tekeze basin. An important document that would give a clue about the ground water potential in the region is the 1:1,000,000 geological map prepared in 1996 by the Ethiopian institute of geological survey. About 25% Tigray is covered with sedimentary rock, which is believed to be relatively better water bearing formation. However, the ground water recharge rate in the indicated area is adversely affected by low and/or intensive rainfall condition (300 - 550mm), ruggedness of the topography and absence of surface vegetative cover.

Igneous rock covers about 54% of Tigray. This rock could be a source of ground water if it is weathered or have fractures in it. However, the igneous rock covering the area West of the Tekeze river, which is the major part, has little or no fractures and weathering. The third major rock category is basement and it covers about 21% of Tigray. This type of rock has no potential ground water source. Thus, about 75 of the region, covered by igneous and basement, has little or no ground water potential.

Mining Available Ground Water for Irrigation

In area where ground water is mined for domestic water supply, a continuous decline of the water table is being observed. According to unpublished document from the TBoWRD, a total of 350 (16.7%) hand pumps, 6 (4%) deep wells and 108 (21%) springs and very high number of shallow hand dug wells have been reported to be dry in connection with the 2002 drought. Monitoring of the Aynalem well field, (which is the source of water for Mekelle town) shows that the water table has been declining at a rate of 2 - 2.4m per year during 1998 - 2003 (Figure 9). Therefore, the possibility of utilizing ground water for irrigation is very remote.

Perched Aquifer

In some valley plains, composed of either heavy clay soil or loose sandy /gravely soil, water table is found at a depth of 1 - 9 meter. Such source of water is being used for domestic water supply and irrigation. For instance, by 2003 the number of hand dug shallow wells and the cumulative irrigated area in Tahitay Koraro Wereda was 700 and 20 ha, respectively. The water lifting mechanism being used includes buckets, shadoof, treadle pump. In some cases where motorized pumps were introduced, the yield of the wells decreases mainly after January or about 5 month of the end of the rain season.

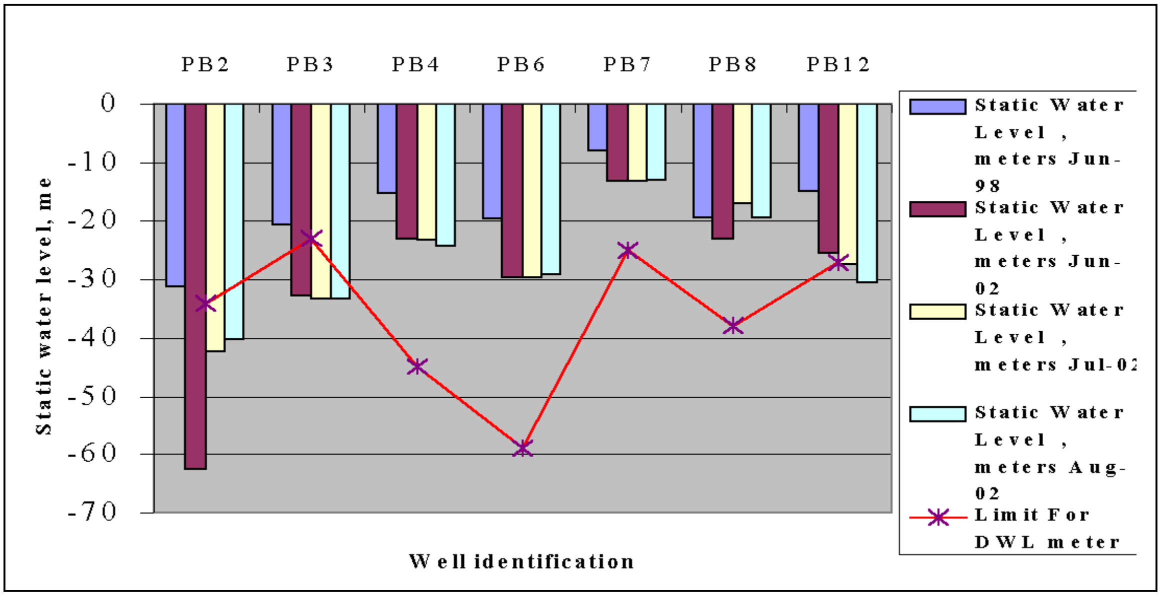


Figure 9. Trend of falling ground water level at Ayanlem well field.

Limitations with Rain Water Harvesting

Ponds

As of January 2003 mobilizing people is excavating small ponds with a capacity of 150 - 185m3. Each pond is expected to provide water for a supplementary irrigation of a plot size of 500-1000 m^2. The positive part of these ponds is that a household, which makes the operation and maintenance simple and smooth, owns them. The major challenge in this case is the possibility of water loss due to seepage. The other point is that due to the smallness of the plot size, the increment in production might not satisfy the annual food requirement of a family. Assuming an average wheat yield of 20 - 30 qt/ha, the total production from a 0.1ha plot would be 2 - 3qt. A family of five may need over 10qt of food per year. Therefore, either the pond size has to be increased or the family has to look for other source of income.

Limitations with Reservoir Dams

In the period between 1996 and 2001, 46 reservoir dams with a cumulative storage capacity and irrigable area of 49.91 million m^3 and 3115 ha, respectively, have been constructed (COSAERT 2001). However, the performance of the reservoirs was diminished due to seepage and failure to harvest the designed runoff.

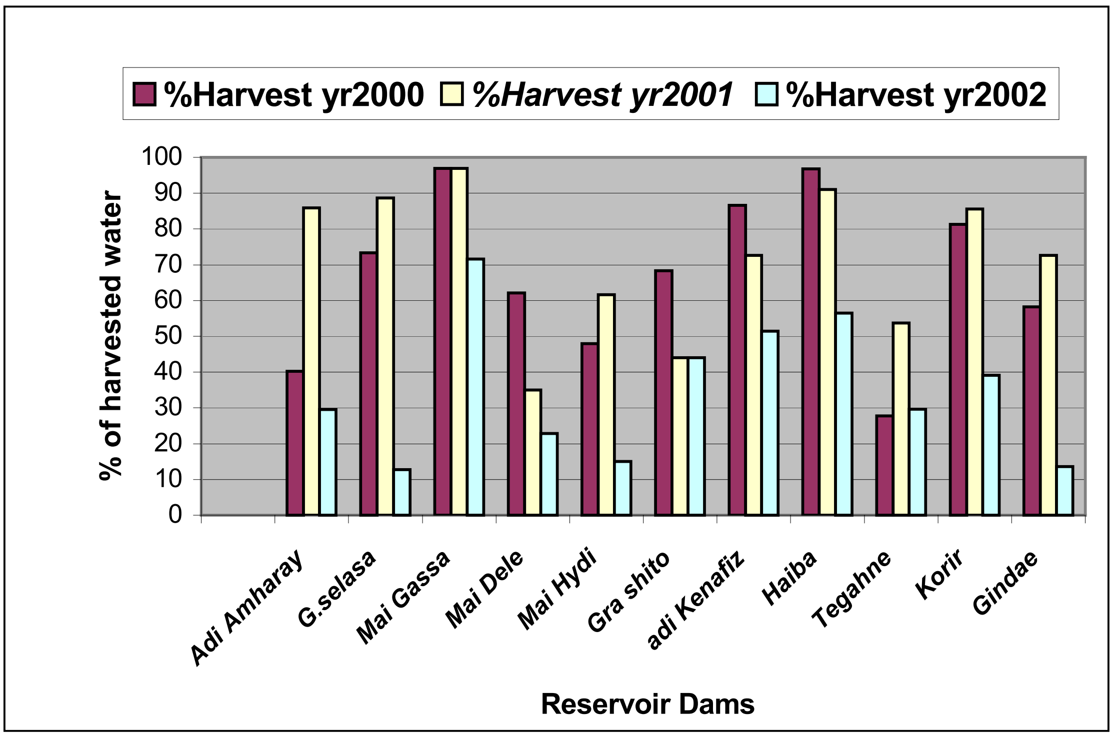


Figure 10. Percentage of harvested water by reservoirs as compared to their design capacity.

As shown in Figure 10 the proportion of runoff harvested by some of the reservoirs was 10 - 96% of the design capacity in 2000 through 2002. The pronounced harvest failure in 2002 is attributed mainly to drought. An unpublished study document made in 1998 by COSAERT shows that, even under normal rainfall conditions, the failure to harvest the designed runoff was attributed, among other things, to the following: Rain shadow effect created by the escarpment along the Tigray - Afar border, and over estimation of the runoff coefficient, **C** in the equation $Q = CPA$, where Q is runoff volume, P is precipitation depth and A is the catchments area.

Irrigation Performance

Cropping Pattern and Crop Productivity

According to a survey made by Co-SAERT in six irrigation schemes in 1999 and nine schemes in 2001, the dominant irrigated crop is maize. As shown in Table 1, the proportion of area covered with maize had increased from 49.1% to 89.5%. With random interviews, the farmers' reason for growing more of maize is that firstly it can be consumed directly and the stalk can be source of feed and fuel. Secondly, it is less laborious and not perishable. Thirdly, the seed and pesticides required for growing horticulture are expensive and not available easily. Thus, the irrigation schemes are not yet developed up to their capacity where benefit is the highest per unit of water. Under such conditions, it would be difficult for the irrigators to cover the O&M costs let alone to recover the investment fully or partially.

Water Use Efficiency

No data has been collected in the area of water use efficiency. However, signs of excessive seepage are observed along canal routes of many irrigation schemes. In some indigenous irrigation schemes, where water is delivered on rotation, moisture deficiency is noticeable. That is no attempt was made to match the stream size and the size of the irrigable area

Key Research Issues

At the Source of Water

1. Determination of rainfall-runoff relationship;
2. Determination of reservoir sedimentation rate and its mitigation measures;

3. Supplementary irrigation as the center of maximizing water productivity in semi arid areas;
4. Effect of excessive dewatering of shallow wells on productivity of grass land; and
5. Effect of reservoir dams in restoring downstream stream flow

Table 1. Irrigation Cropping Pattern as Collected in 1999 and 2001

Crop type	**Year of Data Collection**	
	1999 average of six Dams	**2001 Average of Nine Dams**
Maize	49.2	89.5
Onion	21.9	5.7
Teff	9.6	
Pepper	5.1	0.7
Barley	4.3	
Chick Pea	3.1	0.6
Tomato	2.8	2.7
Wheat	1.7	
Millet	0.7	
Fenugreek	0.6	
Field Peas	0.3	
Faba	0.3	
Bean	0.3	
Lettuce		0.6
Potato		0.2
Beet Root		

In the Conveyance System

1. Topographic advantage for using piped flow for conveyance and distribution of irrigation water.
2. Low cost options for mitigating conveyance losses

In the Irrigation field (Water use System)

1. Water use efficiency in a field with 5 - 15m furrow length
2. Irrigation under a condition of water scarcity

3. Matching cropping calendar with the period having the least irrigation water requirement.

Issues for Sustainability

1. Biological soil conservation measures with high economic return to the upland farmer
2. Nutrient content of sediment deposited in reservoir
3. Reclamation of degraded land for agriculture using sediment from reservoirs
4. Interfacing scientific and indigenous climate forecasting techniques to enhance agricultural production.
5. Sharing benefits obtained from irrigation between irrigators and upland farmers
6. Marketing of agricultural produce
7. Proportion of cost recovery/sharing required from the direct beneficiaries

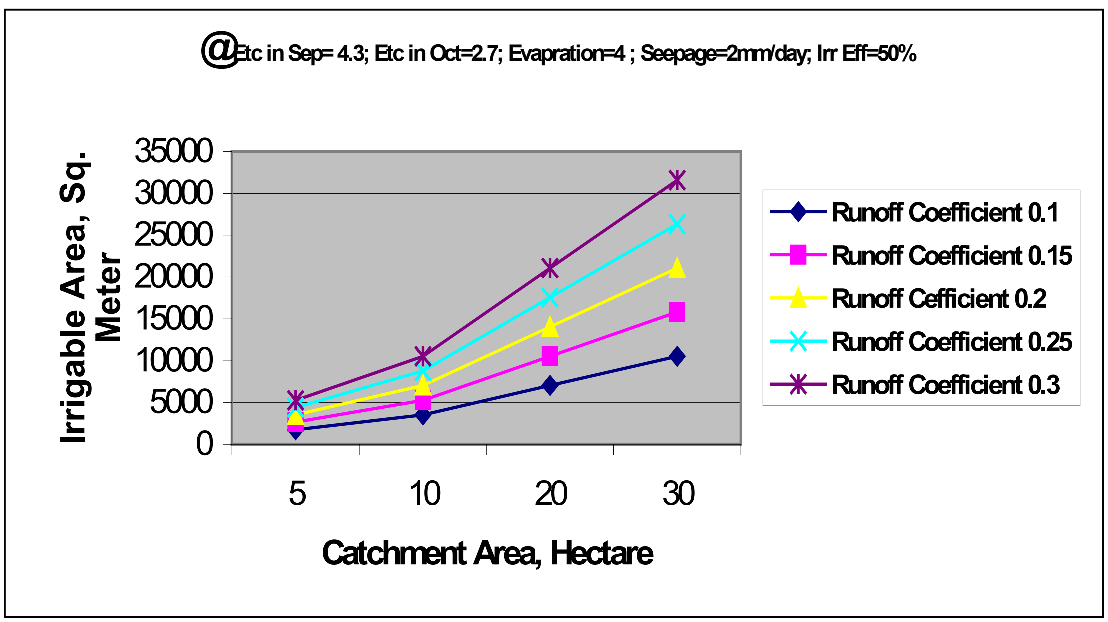


Figure 11. Area under supplementary irrigation with runoff harvested from 400 mm rain.

Details of the Research Issues at the source of water

Determination of rainfall runoff relationship

In the process of designing water-harvesting structures, the value of the runoff coefficient C, which is developed as a function of catchments characteristics, is obtained from textbooks. The attempt to directly adopt design parameters developed for other geographical location involves serious errors. An over estimation of the runoff coefficient results in expending unnecessary cost. Similarly, under estimation of the coefficient results in reduced irrigable size, (Figure 11).

Determination of reservoir sedimentation rate and its mitigation measures

Sedimentation rate

Table 2 shows reservoir dams whose dead storage level has been filled with sediment deposition earlier than anticipated. The design sedimentation rate indicated in Table 2 is obtained from literature, which was based on a sediment sampling conducted on streams around Mekelle in 1974 - 1976 (COSAERT 1997/1998). The limitation in such approach is that, firstly the data needs to be updated in view of the changes in land use. Secondly, the data could not be taken, as representative to all areas of interest for there is substantial temporal and spatial variability in factors causing sedimentation. An underestimated sedimentation rate gives wrong conclusion with regard to the feasibility of the reservoir. In addition, it could mislead the pace of the implementation of soil and water conservation on the catchment's area.

Mitigating Sedimentation through Integrated Watershed-Management Technologies

It has been long said that the introduction of integrated watershed-management practices in the catchment's areas of reservoir dams would retard rate of sedimentation. Often, the proposed SWC measures are physical structures, biological measures and closure of a portion of the catchments from human and livestock interference. These activities are implemented with the objective of improving the livelihood of the upland and down stream people. In some instances the SWC effort has yielded some benefit in rehabilitating the physical environment. This can be explained in terms of re-growth of indigenous shrubs and grass, reappearance of springs after being dry for long time, stabilization of gullies and the like. In most cases, however, the technologies introduced as part of the SWC measure were not observed in bringing a significant economic benefit to the people whose livelihood is connected directly with the catchment's areas of reservoir dams.

The expected yield from biological SWC measures, as outlined in the Awash basin master plan, is as follows:

a. Fuel wood
   - from hill side closure : 10 m^3/ha after 20 years;
   - from conservation forestry : 75 m^3/ha after 20 years;
   - from community woodlot : 100 m^3/ha after 8 years.

b. Fodder production
   - from conservation forestry and woodlot 0.2 ton/ha fro initial 2 years;
   - from hillside closure 0.5 ton/ha for entire period

The problem with the expected benefit from the existing biological SWC measures, as outlined above, is that 1) the farmers have to wait for a long period before the first harvest and 2) the yield is too low. Under such conditions, the upland farmers would consider the issue of SWC as the interest of outsiders who think that the resultant benefit would be obtained over the long term. Therefore, it is high time to revise the prevailing watershed management technologies such that the community would get direct benefit in the short term as well. In light of the above-mentioned problem, the following research questions are posed for consideration.

- Could there be a fast growing, high yielding and nutritious fodder grass or shrub that can grow under harsh environment. The harsh environment could be explained in terms of little rainfall and long dry period, poor soil fertility and shallow depth, etc.

- What kind of fast growing flowering shrubs can be introduced to enhance apiculture? Shrub varieties with different period and length of flowering can be considered.
- Could there be a benefit sharing mechanism between down stream water users and care takers of the watershed.

Supplementary Irrigation as the Center of Maximizing Water Productivity

As shown in Figure 6, rain fed agriculture in most parts of the Tekeze basin is subjected to moisture deficiency. In addition to the dry spells in July and August, the amount of rainfall in September and October is insignificant under normal conditions. The effect of such moisture deficiency on crop yield has to be researched. A preliminary exercise using the Doorenbos and Kassam (1979) model shows that, towards the eastern end of the basin there would be 41% yield reduction due to moisture deficiency keeping other agricultural inputs constant. This result more or less coincides with the actual crop yield of the rain fed agriculture.

In light of the above facts, supplementary irrigation is being considered as the key input to obtain one reliable harvest in the basin. Water harvesting is the major means to undertake supplementary irrigation as indicated above. Therefore, many questions need to be answered in connection with water harvesting structures to be used for supplementary irrigation:

- What should be the minimum size of a water harvesting structure that would ensure food security at household level?
- What should be the least allowable ratio of irrigable area to inundated area?
- What should be the least allowable ratio of storage capacity to earth fill volume in embankment ponds?
- What kind of low cost seepage control technologies can be applied in the ponds?
- Would it be more beneficial to use the harvested water for double cropping than supplementary irrigation only?

- **The last question can be assessed in terms of the following:**
- Maximizing water productivity by reducing the proportion of evaporation and seepage losses, and
- Maximizing water productivity by growing high value crops in the dry season

Minimum Size of Water Harvesting Ponds For House Hold Food Security

According to unpublished information from the DPPB of Tigray a large number of population depends on food aid. The number of food insecure people in a given year positively correlates with the rainfall shortages. Stemming from this, every household should be encouraged and assisted to practice supplementary irrigation using a water harvesting structure. Therefore, it would be of utmost importance to identify the minimum size of a water-harvesting pond that would enable a family produce at least the annual food requirement from a certain plot.

A family of five may need about 10 qt food grains per year. Assuming a wheat yield of 30qt/ha and with manipulation of climatic information, a plot of 0.4ha can produce 10.1qt of wheat grain if supported with 4 irrigations beginning September 1st. A 0.5ha plot may produce 10.4qt with two supplementary irrigations (Table 3). This has to be verified through detailed fieldwork, the objective being to identify the minimum size of a water-harvesting pond that would enable to produce enough food for a family. Concurrently, appropriate agronomic and water management practices should have to be designed and introduced to the farmer.

What should be the Least Allowable Ratio of Irrigable Area to Inundated Area?

As explained above, irrigation water is a critical variable in obtaining at least one reliable harvest in the Tekeze basin. Only in rare cases, the topography lends itself conveniently for the construction of a reservoir. In such cases, substantial amount of water can be stored per unit area of land or per unit volume of earth fill. However, the ratio of irrigable area to inundated area in most of the reservoir dams, built by

COSAERT, is in the range of 2 - 3.5. This indicates that it would be difficult to construct a water harvesting structure unless a sizeable area is sacrificed.

Thus, a family or a community has to spare a portion of its land for a reservoir to impound water. If the land to be spared is an agricultural land, then the benefit attributed to the intervention has to overweigh. The analysis to be made in this aspect should include the social and political dimension of the problem by asking the following question: **What will happen if food deficiency persists and food aid is stopped?**

Maximizing Water Productivity by Reducing the Proportion of Evaporation and Seepage Losses

Under the culture of supplementary irrigation, harvested water is utilized within two months from the end of the rain season. Where as, with double cropping, the water has to be utilized in about eight months from the end of the rain season. Figure 12 shows, for a given volume of water harvested from a certain catchments area, more land can be irrigated under supplementary irrigation than double cropping. Such increment in irrigated land is mainly due to the possibility of utilizing the water that could have been lost as evaporation and seepage during November through April. As the catchments area, from which runoff is generated, increases the water use efficiency increases with supplementary irrigation (Figure 13). With small ponds the proportion of evaporation loss is very high. Thus, water productivity would be increased if the harvested water were utilized only for supplementary irrigation.

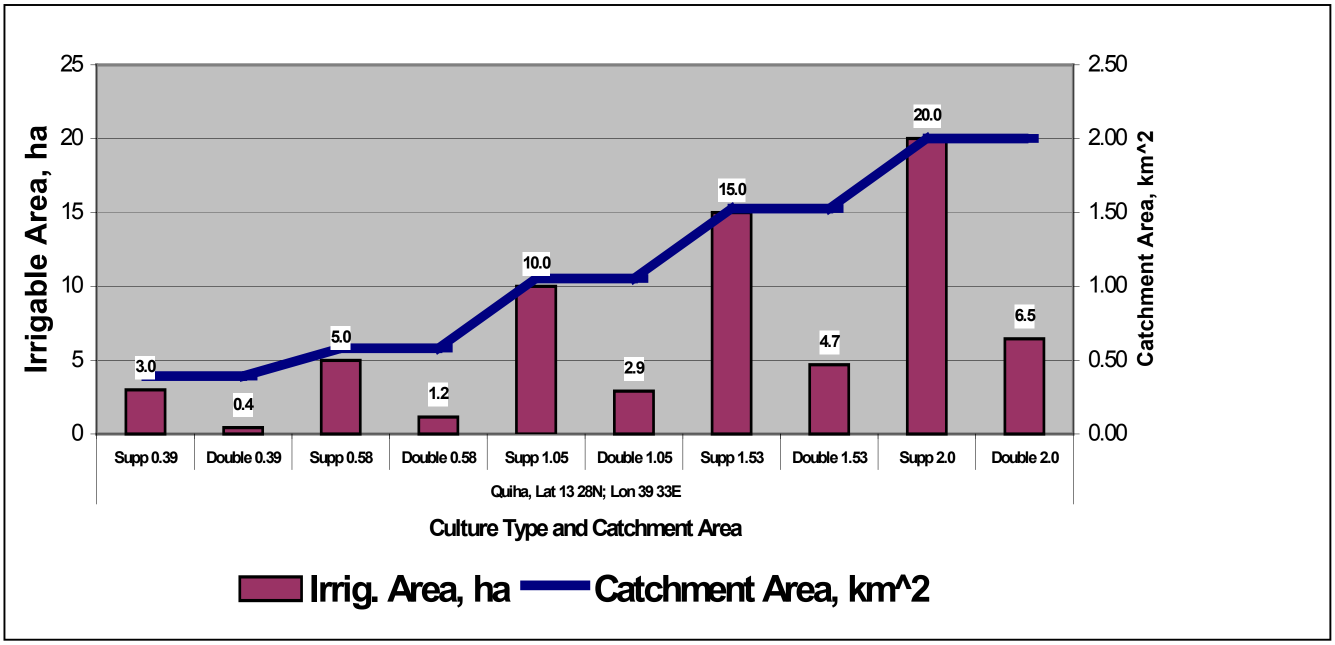


Figure 12. Irrigable area under double cropping and supplementary irrigation using water harvested from various catchments.

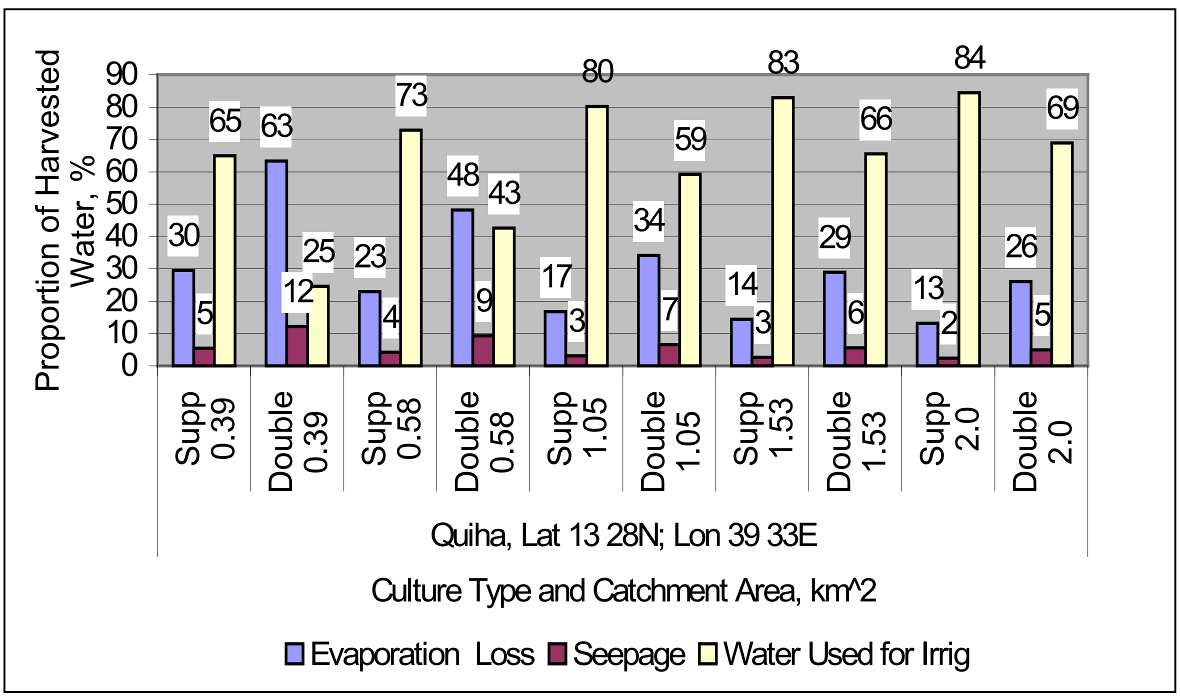


Figure 13. Proportion of utilized and lost water under double cropping and supplementary irrigation.

Most of the shallow wells dug, for domestic water supply and irrigation, are along the periphery of grasslands where thousands of livestock depend for their grazing. As yet, the grass in the indicated area is perennial mainly due to the capillary fringe from the shallow water table. However, the unplanned digging of the shallow wells might disrupt this natural irrigation process. Thus, unless, a mechanism is introduced to balance the mining and the rate of ground water recharge, the productivity and survival of thousands of livestock is in jeopardy.

In the Conveyance System

Topographic Advantage for Using Piped Flow for Conveyance and Distribution

Examination of 11 irrigation projects designed by COSAERT reveals that the average elevation difference between the reservoir outlet and the end of the supply canal is 1.15m per 100m. The slope of the field, perpendicular to the supply canal, is often more than 1%. In addition to the indicated elevation difference, the head above the outlet pipe, often up to 10m, could be sufficient to drive the flow of water through pipes. Thus, gravity being the source of energy to drive the flow, there could be a good demand for pipes and drip laterals if the price is attractive to the small scale subsistence farmer.

In the Irrigation Field

Water Use Efficiency in a Field with 5-15m Furrow Lengths

Use of short furrow length has significant contribution in minimizing the difference in infiltrated volume between the head and tail of the furrow. One disadvantage of short furrow length is that labor requirement is higher compared to longer furrows. However, this is not the case in the Tekeze basin as in almost all of the irrigation schemes the furrow length being considered is in the range of 5 - 15m. Farmers prefer short furrow length because it allows uniform water distribution in the field. On the other hand, short furrow length requires longer distribution system and hence more conveyance losses.

Therefore, the merit and demerit of the irrigation practice with short furrow length has to be examined.

Irrigation under a condition of water scarcity

The total annual volume of water draining from the Tekeze basin is 7.36 million m^3 with peak flow rate in July and August (MoWR 2001). However, due to topographic limitations it would be difficult to use a significant portion of the indicated volume of water except in the low land bordering the Sudan. Likewise, the tributaries of Tekeze River have their peak flow rate in July and August and minimal flow rate during the remaining period of the year. For instance, under average conditions, Suluh River is a perennial river with discharge varying from 0.26 to 4.4m^3/sec in January and August, respectively. In drought years, like that of 2002, the flow rate of Suluh River becomes nil as of the fourth month from the end of the rain season (figure 7).

On the other hand, observation of the cross section of the catchments of the tributaries of Tekeze river shows that the streambed is 20 - 100m below the potential arable land. That is, the water is inaccessible unless expensive water lifting mechanism is introduced. Thus, the possible source of irrigation water for the arable land located in the highland part of the Tekeze basin is seasonal runoff water to be harvested from the small catchments. Therefore, with the objective of benefiting more people it is becoming necessary to maximize the productivity of the harvested water. Ghinassi, Giacomin and Neri (2002) reported that seasonal water supplies ranging from 20 to 60% full irrigation yielded from 70% to about 90% marketable yield of Tomato.

Future Strategy in the Tekeze Basin

The Tekeze basin master plan specifies a large-scale irrigation in the low land part of the basin. Such irrigation scheme would get its water from reservoir dams to be built for hydropower generation.

Beside this, there is a possibility of constructing medium-scale reservoir-based irrigations schemes in the highland (COSAERT. 1996). Small-scale reservoirs and ponds which could be constructed by mobilizing people shall be given due consideration for their big role in ensuring food security. Attempts have been made at Suluh Valley to conduct an integrated water resource development study taking the whole 960km^2 wide valley as a unit. The aim was to study the possibility of using both ground water and surface water for irrigation.

Conclusion

Irrigation development in the Tekeze basin is possible mainly through water harvesting which in turn requires the design and construction of various hydraulic structures. The design is expected to yield stable and less expensive structure that would enable to obtain maximum benefit per unit volume of water. To this effect, design work needs to be based on locally tested procedures wherever applicable.

Table 2 Actual and Designed Sedimentation Rate in some Reservoir Dams

Name of Dam	Location Lat/con	Year		Catchment's area km^2	Total capacity 10^6M^3	Dead storage volume 10^6m^3	Designed sedimentation rate m^3/km^3,yr	Actual sedimentation rate m^3/km^3,yr
		Constructed	Field Up Storage					
Gereb Mihize	$13^{0}14^{1}16^{11}$ $39^{0}27^{1}00^{11}$	1998	2002	17.2	1.2	0.325	950	4724
Adi Kenafiz	$13^{0}14^{1}40^{11}$ $39^{0}22^{1}30^{11}$	1998	2001	13	0.67	0.067	1200	1719
Mai Gassa	$13^{0}14^{1}16^{11}$ $39^{0}27^{1}01^{11}$	1997	2001	9	1.3	0.153	970	4270
Gra Shetu	$13^{0}12^{1}10^{11}$ $39^{0}30^{1}20^{11}$	1998	2001	2.88	1.42	0.028	1000	3291

Table 3. Expected yield increment attributed to supplementary irrigation using ponds at Adigudom.

	Data : Average Wheat Yield at Adigudom (1995---2000) =				2	to	16	qt/ha	
	Potential Wheat Yield				30		60	qt/ha	
Area	Current Production			No. of Supplementary Irrigations & % of Associated Yield Increment					
				1	2	3	4	5	6
Ha	Minimur	Maximum		64.14	69.32	75.84	84.28	87.19	89.28
	qt	qt							
				Production in quintals @ 30 qt/ha as the Potential Yield					
0.05	0.1	0.8		0.96	1.04	1.14	1.26	1.31	1.34
0.1	0.2	1.6		1.9	2.1	2.3	2.5	2.6	2.7
0.2	0.4	3.2		3.8	4.2	4.6	5.1	5.2	5.4
0.4	0.8	6.4		7.7	8.3	9.1	10.1	10.5	10.7
0.5	1	8		9.6	10.4	11.4	12.6	13.1	13.4
0.6	1.2	9.6		11.5	12.5	13.7	15.2	15.7	16.1
0.8	1.6	12.8		15.4	16.6	18.2	20.2	20.9	21.4
1	2	16		19.2	20.8	22.8	25.3	26.2	26.8
2	4	32		38.5	41.6	45.5	50.6	52.3	53.6
3	6	48		57.7	62.4	68.3	75.9	78.5	80.3
4	8	64		77.0	83.2	91.0	101.1	104.6	107.1
5	10	80		96.2	104.0	113.8	126.4	130.8	133.9

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