WORKSHOP ON

The Experience of Water Harvesting in the Drylands of Ethiopia: Principles and practices

December 28-30, 2001 Mekelle, Ethiopia

Mitiku Hailu, Mekelle University
Sorssa Natea Merga, CARE Ethiopia

Report No. 19
February 2002

Drylands Coordination Group
The Drylands Coordination Group (DCG) is an NGO-driven forum for exchange of practical experiences and knowledge on food security and natural resource management in the drylands of Africa. DCG facilitates this exchange of experiences between NGOs and research- and policy-making institutions. The DCG activities, which are carried out by DCG members in Ethiopia, Eritrea, Mali and Sudan, aim to contribute to improved food security of vulnerable households and sustainable natural resource management in the drylands of Africa.

The founding DCG members consist of ADRA Norway, CARE Norway, Norwegian Church Aid, Norwegian People's Aid, The Stromme Foundation and The Development Fund. Noragric, the Centre for International Environment and Development Studies at the Agricultural University of Norway provides the secretariat as a facilitating and implementing body for the DCG. The DCG’s activities are funded by NORAD (the Norwegian Agency for Development Cooperation).

This Report was carried out on behalf of the DCG branch in Ethiopia, which includes the Norwegian Church Aid in Ethiopia, CARE Ethiopia, ADRA Ethiopia, ADRA Sudan, Relief Association of Tigray, Women Association of Tigray and Mekelle University.

Extracts from this publication may only be reproduced after prior consultation with the DCG secretariat. The findings, interpretations and conclusions expressed in this publication are entirely those of the author(s) and cannot be attributed directly to the Drylands Coordination Group.
TABLE OF CONTENTS

1. INTRODUCTION ........................................................................................................... 1
   1.1 Workshop objectives......................................................................................... 1
   1.2 Scope and methodology................................................................................... 1
   1.3 Workshop recommendations ......................................................................... 2
   1.4 Opening address.............................................................................................. 3
   1.5 Key-note speech............................................................................................... 4
   1.6 Self-introduction of participants.................................................................... 6

2. DEFINITIONS AND CLARIFICATIONS ................................................................ 7
   2.1 Definitions........................................................................................................ 7
   2.2 Classification of water harvesting systems.................................................... 8
   2.3 Application of rainwater harvesting............................................................... 8
   2.4 Rainwater harvesting (SWOT analysis).......................................................... 10
   2.5 Different water harvesting techniques............................................................ 11
   2.6 Discussions on the presentations made......................................................... 11
   2.7 Domestic water security through rainwater harvesting.............................. 12
   2.8 Design and construction of rainwater harvesting systems......................... 13
   2.9 Discussion on presentations made................................................................. 15

3. WATER QUALITY .................................................................................................. 16
   3.1 Basic principles............................................................................................... 16
   3.2 Water quality standards.................................................................................. 17

4. WATER HARVESTING .......................................................................................... 18
   4.1 Norwegian Church Aid/ Ethiopia assisted water development program........ 18
   4.2 Water harvesting in Sudan arid lands with special reference to the Northern Darfur, Western Sudan......................................................................................... 18
   4.3 The experience of CARE Ethiopia in rainwater harvesting systems for domestic consumption................................................................. 19
   4.4 Discussions on the presentations made......................................................... 19
   4.5 Field visit........................................................................................................ 20
   4.6 Water harvesting for crop production............................................................. 23
   4.7 Water storage techniques................................................................................. 24
   4.8 Application and limitation of water harvesting system.............................. 24
   4.9 Micro catchment water harvesting systems............................................... 25
   4.10 Macro catchment water harvesting systems.............................................. 26
   4.11 Flood water-farming systems...................................................................... 27
   4.12 Flood water diversion system/ spate irrigation........................................... 27
   4.13 Water-Harvesting in the Somali National Regional State of Ethiopia......... 28
   4.14 Water harvesting system planning and design considerations.................. 29
   4.15 CoSAERT’s experience on small-scale water harvesting techniques......... 31
   4.16 Water resource potential of Aba’ala area (Northern Afar), Ethiopia............ 31
   4.17 Discussion on the presentation made........................................................... 32
   4.18 Management and maintenance of water harvesting system....................... 32
C. Rainwater harvesting systems for domestic consumption

D. Water harvesting in the Somali National Regional State of Ethiopia

E. CoSAERT’s experience on small scale water harvesting techniques

F. Water harvesting, the key to successful crop production and resource management in Water stress environments: Eastern African experience

G. Water resource potential of Aba’ala area (Northern Afar), Ethiopia: A prefeasibility study

H. Water harvesting in micro dams: Its impact on the Socio-economic condition of the community and the salinity of the irrigated fields in Tigray

I. Water harvesting for crop production in semi-arid areas of North Eastern Ethiopia: A case study of floodwater diversion in Aba’ala agro-pastoral area

J. Water harvesting practices in Raya Valley integrated agricultural development programme observation areas

5.3 Terms of Reference
1. **INTRODUCTION**

The economy of Ethiopia is agrarian, and mainly relying on household labor. Agriculture production is aimed at self-subsistence and dependent on forces of nature. As such, success in production in the lowland agro-ecology is severely affected by climatic variability. The total annual rainfall is inadequate for crop production; since often the rainfall distribution is erratic. The most common shock to which mainly the lowland inhabitants are exposed is insufficient agricultural production resulting from moisture stress. Techniques to improve soil moisture retention or water harvesting is not known to most farmers or not commonly practiced.

The nutritional security of the country is affected not only by factors influencing household food security but also by access to clean water. Currently only about 25 percent of the population have access to potable water.

**Water harvesting systems** have been successfully utilized by people in some parts of the world where water shortage exists. The application of water harvesting techniques although potentially high is still actually low in practice in Ethiopia. In order to meet the water demand for various purposes, sustainable systems of water harvesting and managing should be developed. Local approaches and indigenous experiences have to be encouraged and be applied easily at both village and household levels.

1.1. **Workshop objectives**

The Drylands Coordination Group (DCG) arranged workshop where its members and partner organizations met to present and discuss their practice and experience with water harvesting projects. Such sharing of experiences and coordination is likely to enhance the quality of water-harvesting projects carried out. The workshop’s focus was on the presentation and discussion of local/indigenous practices for water harvesting and their possible consequences.

*The workshop’s specific objectives were*

- To create a forum for experience sharing
- To strengthen the technical capacity of field staff on basic principles and practical aspects of different types of water harvesting projects
- To discuss possible unintentional effects of such projects

1.2. **Scope and methodology**

Each participating organization presented their experience with different water harvesting methods. The presentations were discussed. The participants divided into small groups and worked on specific issues and presented for plenary discussion. To get practical experience the participants were also divided into two groups and visited different water harvesting projects around Mekelle, one group visited the lowland water harvesting projects and the other group visited the highland projects.

Groups presented their observations at plenary and discussions made. Before the end of the workshop the participants broke into groups and came up with the following sets of recommendations.
1.3. Workshop recommendations

1. Promote awareness on water harvesting to improve planning design and implementation methodologies. Carry out similar workshops frequently with different resources persons and diversified participants including main stakeholders. Promote traditional water harvesting and community management structures.

2. Establish and strengthen water extension system

3. Train and strengthen the capacity of local communities

4. Work towards improving the utilization of water harvested to bring impact on users livelihood

5. Continue the assessment of environmental impact of the water harvesting systems and recommend mitigation measures

6. Strengthen the Ethiopian Rainwater Harvesting Association

7. Strengthen data base management and information exchange among networks

8. The coordination, which is likely to deal with watershed management, should include different disciplines such as sociology, anthropology, etc

9. Improve the utilization of all harvested water and conduct more studies to improve efficiency of harvested water

10. Develop a guideline to monitor and evaluate the technical, economical, partnership and environmental issues on water harvesting

11. The stakeholders should have a forum on water harvesting issues and networking. There should be a coordinating body to over-see, facilitate and coordinate the stakeholders. There should be a clear-cut policy and guideline on water schemes operation, maintenance and cost-recovery

12. The stakeholders in water harvesting need to have clear responsibilities and accountabilities

13. Capacity of field staff has to be enhanced through short term and long-term trainings in irrigation management, water management, design, construction and operation of water schemes. Equipment and materials for study and design, field investigation, laboratory feasibility hydro meteorological stations should fulfill

14. Workshops, seminars and forum for discussing water-harvesting issues need to be organized including all stakeholders. Study tours and experience sharing visit be arranged

15. Research should be initiated on water management, environmental impact, hydro meteorology, erosion and sedimentation. Linkage between research and extension has to be also established.
The establishment and roles of DCG Ethiopia/Sudan by W/ro Tihut Yirgu, current DCG Chairperson

**Background**

The Dry land Coordination Group (DCG) is a forum for cooperation that promotes quality assurance of development projects dealing with food security and environmental rehabilitation in the dry lands of Africa. DCG was established by the Norwegian NGOs responsible for running the development projects funded under the then Sahel-Sudan-Ethiopia (SSE) Programme. The current DCG members are ADRA Norge, CARE Norge, Norwegian Church Aid, Norwegian People’s Aid, Strømme Foundation and the Development Fund. Noragric, the Centre for International Environmental and Development Studies at the Agricultural University of Norway, functions as a secretariat and technical advisor. NORAD funds the DCG activities through a renewable three-year frame agreement.

The overall objective of DCG is to improve the livelihood security of vulnerable households in drought-prone and marginal areas, especially in Africa. In order to achieve this, collaboration among partner organizations is essential. This collaboration creates the opportunity for joint actions that yield synergetic effects on agricultural development and natural resource management.

The activities of DCG are divided into the following categories:

1. Quality assurance and technical assistance to relevant and individual projects.
2. Topics of common interest for the DCG member and partner organizations that need to be explored through seminars and workshops.
3. Research and study assignments.
4. Information and networking.
DCG Ethiopia/Sudan
The Drylands Coordination Group for Ethiopia and the Sudan (DCG Ethiopia/Sudan) was established in April 2000 in Nazareth, Ethiopia. The overall objective of DCG Ethiopia/Sudan is not different from DCG Norway - that of improving the livelihood security of vulnerable households in drought prone and marginal drylands in Ethiopia and the Sudan. Currently DCG Ethiopia/Sudan has the following members: CARE Ethiopia, Norwegian Church Aid, ADRA Ethiopia, ADRA Sudan, Save the Children Norway, Relief Society of Tigray, Women's Association of Tigray, and Afar Integrated Pastoral Development Programme (based at Mekelle University).

To date DCG Ethiopia/Sudan members have organized different workshops dealing with a wide range of issues.

1. Conflict resolution (November 8-10, 2000) with emphasis on traditional conflict resolution mechanisms in the middle Awash and north Afar.
2. Revisiting the regulatory and supervision framework of the micro finance industry in Ethiopia (August 24, 2001)
3. Participation of civil society in formulation and implementation of UNCCD/NAP in Ethiopia (September 13-14, 2001)
4. Coping strategies of pastoralist communities in the drylands of Ethiopia (November 9, 2001), focusing on the Borona and north Afar pastoral communities.
5. Water harvesting

I wish you all to have a fruitful workshop.

Thank you!

1.5 A keynote speech:

Mintesinot Behailu, Vice President for Academics and Research Mekelle University

Dear Participants
Ladies and Gentlemen

It gives me great pleasure and indeed I am humbled to welcome you all to this eminent gathering to deliberate on the key issues in the 'Drylands' - 'Water harvesting'.

As presumably, well known to all of you, the Drylands occupy almost 40% of the Earth's total land surface, spreading over 110 nations. These areas are defined by their modest water supply; of course, less than that found in the forest regions, yet greater than that of the desert. Drylands are among the most productive ecosystems and their people stand among the most resilient on the planet.

Drylands are ecologically diverse and economically important. They serve as the world's breadbasket and are home to more than one billion people. The Earth's drylands have also been the stage for dramatic events in human development. A rich base of knowledge and skills have been refined through generations of living in the drylands, providing a hedge against a difficult climate and the ability to optimize the use of scarce resources.
Dear participants  
Ladies & gentlemen  

Agriculture remains the dominant activity of the drylands, though; the scope varies from capital-intensive agribusiness to nomadic pastoralism. Three quarters of the world's food supply consists of five crops; Potato, Wheat, Maize, Manioc and Rice, and all of these crops are grown in the drylands. Over the past twenty years, global agricultural production of major food crops has steadily increased from these environments. Global Cereal Production has nearly doubled in 20 years. During this same period, the proportion of undernourished people in the developing world decreased from 36 percent to 20 percent, evidencing the very fact that the productivity of the Earth's drylands is vital to world food security.

Although the productivity, beauty and heritage of the world's drylands are priceless, their use is not without cost. Nearly all drylands and their inhabitants are at constant risk from land degradation. The productivity of more than 70% of these areas is reduced through moderate and severe land degradation, causing Eco-migration. Millions of people have become eco-migrants, searching for better land and lives elsewhere.

Dear Participants  
Ladies and Gentlemen  

The challenge facing today's generations is to "meet needs without compromising the ability of future generations to meet their own needs". The only way to treat this challenge is through 'a blue revolution' (and not a green one this time!!), which emphasizes on increasing the productivity of water i.e. 'more crop per drop of water'. When elaborated it simply means [efficient water harvesting/water use for increased crop productivity!!]. I suggest this to be our slogan during the workshop and earnestly request you all to answer 'is it realistic to attain more crop per drop of water under the type of management practices we have?? If so, how what are the best practices??' and 'If not, what are its holistic consequences??!

I hope the workshop creates a very good ground to share multitudes of experiences of water harvesting technologies that maximize the productivity of water in the drylands. I would also hope that the direct and indirect impacts of such technologies should be treated.

If we are to make a sustainable socio-economic development and sound environmental management in these areas, this indeed is the only way- I really assure you that you are on the right track to take-up the challenge.

Wishing you a very fruitful deliberations and pleasant stay with us, I now declare the workshop officially open.

I thank you

1.6  Self-introduction of participants and expectations  

The workshop facilitators, Ato Sorssa and Dr. Mitiku requested the workshop participants to introduce themselves. Each participant introduced himself by telling his/her name, his/her professional background, where they work and their current position.
After the introductions, participants were asked to write their expectations on idea cards. The facilitators asked the participants to write one idea per card, making it legible and using key words or phrase. Participants’ expectations are summarized as follows.

Summarized expectations were:

- Get experience of others in water harvesting techniques (WHT)
- Learn techniques of water harvesting in the drylands
- Learn problems associated with WHT
- The use of water harvesting for crop and livestock production
- Socio economic issues of WHT
- Experience of others in the utilization of rainwater
- Get experience on how to maximize water use and improve water security in drylands
- Learn more about dry land problems and solutions
- Get experience to harvest rainwater
- Share experience of some areas about water harvesting which may be suitable to the dry land of south Omo
- Experience of drylands farming systems and method, the importance of water harvesting and dry land farming
- Love to hear also about water harvesting Institutions and how they are supported
- Share experience of success and limitation of rainwater harvesting techniques
- Learning collaboration between institutions in WH
- Experience sharing
- Learn about practice of WHT
- Community experience in WH and management
- To gain good ideas to solve water shortage problem in our area
- Transfer some techniques of water harvesting from Sudan to Ethiopia through discussion
- Learn best practices in water harvesting
- Want to hear about dissemination of water harvesting techniques
- Experience on problems encountered and their solutions, in dryland region of Ethiopia as a whole and Sudan
- Learn on success of water harvesting so far
- Learn challenges and success of water harvesting techniques and practice
- Share experience of organization working in drylands on water harvesting
- Learn about traditional (cultural) and research results on the issues
- To learn how others have solved similar problems in the water prevention technologies
- Get experience on water management at community level
- Establish relation with organizations involved in RWH activities
- Learn practical solutions for the problems in RWH efforts in dryland Ethiopia
- Learn on problems facing WHT
- Design and construction aspect of WHT
- Learn new WHT
- Learn new technology to harvest water before it run out of hand
- Learn irrigation technologies practiced in dryland
- Simple and cost effective WHT in the lowlands
2. DEFINITIONS AND CLARIFICATIONS

2.1. Definitions

Roof Catchment: Is a system of collecting rainfall water from a roof of a house or a building and store it in some storage facilities for future use when there is shortage of water.

In principle rainwater can be harvested from any roof. CIS roofs or tiled roofs are easiest to use and give the cleanest water. It is also possible to use roofs made from palm or grass thatch. Where a large volume of water is required than a single roof can supply a ground catchment or rock catchment is used to collect rainwater.

Ground Catchment: Is a system of collecting rainfall water from a defined ground surface and store it in some storage facilities for future use when there is shortage of water.

A selected area of ground surface can be fenced to prevent contamination by livestock and produce runoff, which will be stored in some storage facilities for domestic purposes. The ground surface has to be treated mechanically or by chemical to reduce infiltration and increase runoff. For better result if possible the ground surface can be covered with some conventional paving materials.

Rainwater Harvesting: Gathering and storing of water running from surfaces on which it has directly fallen.

Water Harvesting: The collection and storage of any form of water, either runoff or creek flow for different use.

2.2. Classification of water harvesting systems

The main components of all water harvesting system are harvesting area/ catchment and storage area. Harvesting area includes land, paved area and rooftop.

Four methods of rainwater storage are

- Tank above ground
- Excavated cisterns
- Small dams
- Soil moisture
The main categories of catchments or water sources are

- Roof top harvesting
- Runoff harvesting
- Flood water harvesting

Roof top harvesting and runoff harvesting can be also categorized as rainwater harvesting. Rainwater harvesting is a technique used to collect runoff from rooftop or ground surface whereas flood water harvesting is a system, which collects channel, flows.

2.3. Application of rainwater harvesting

Though the nature of limiting factor varies from place to place water resources are limited. In dry regions of the world sometimes only limited proportion of rainfall reaches the river system.

Ground water is not always available in arid part of the world or unfit for consumption. There are a number of factors, which limits other sources of water, and rainwater harvesting is the only choice.

Some of these factors are:

- Limited catchments from where river can flow or recharge ground water
- High cost of desalination plant for seawater
- High mineral content of ground water which makes it unfit for drinking
- Permeable limestone underlying rocks
- Shortage of rainfall, which limit availability of surface water (climatically dry area)

Overview of Roof water harvesting

Rainwater harvesting has been in use since the last thousand years in several pars of the world specially Asia and Africa. The collection of rainwater for domestic water supply has increased greatly in recent decades. The scale of application is still very low in Ethiopia. Nonetheless there is great potential for expanding the use of rainwater in the country. Rainwater can be harvested from many types of surfaces for different purposes.

a) Purposes of Rainwater Catchment includes

- Collect water for different uses
- Reduce flooding
- Replenish aquifers

b) Forms of water Harvesting

- Primary supply, usually in arid or semi-arid regions
- School supply, usually in rural areas
- Multi-household supplies – entailing the sharing of a tank
- Seasonal supply
c) Use Strategies

- Main supply when there are no any other sources
- Insurance/reserve for when other sources dry-up
- Second quality applications – such as laundry, toilets

d) Health

- Rainwater is often better quality than other sources (especially ground water)
- There is uncertainty about factors affecting water quality (storm, rats, gutters, tank, darkness)
- System design clearly affects water quality

e) Components of RWH System

- RWH system costs are usually dominated by tank costs
- Many types are known and documented
- Tanks can be above and below ground level
- Economic of scale (these pose cost problems for small systems)
- Income generating opportunities
- Inlet/outlets design is a challenge
2.4. Rainwater harvesting (SWOT analysis)

**Successes**

- RWH is successful where other sources are not available or when full potential of other sources can not be achieved
- Considered as a superior quality in some areas
- Low O&M cost and easy to manage by users
- Can be used as a buffer security
- No conflict among users when system is owned individually
- RWH is a simple technology, which has the potential to dramatically, improve water security
- Many social benefits as well as improve water security

**Weaknesses**

- Flat test and easier contamination of open tank
- High dependency on rainfall
- Lack of knowledge on the technology and poor awareness
- High per capita cost and difficulties in replicating
- Insufficient catchment areas
- Low priority given to RWH by donors and governments
- Unacceptable to urban riches
- Not capable for providing water throughout the year as a single source
- Difficult for thatched roofs

**Opportunities**

- When problems like ground water depletions/salinity/high cost of water treatment is an issue
- User acceptance/participation/mobilization of rural communities
- When other water sources are at a distance
- Under bimodal high rainfall situations chance of success is very high
- Certainty of water supply (even duration may be short)
- Relatively easy to demonstrate the advantages to water vendors (water trading)
- Relief to women
- Increase awareness among stakeholders
- Help to reach communities on demand responsive approach

**Threats**

- Acid rains and corrosion of roofing material health risks due to prolog use
- Can fail at worst times (end of sever drought period)
- Lack of priority in funding
- Threats to sustainability due to poor O&M
- Cost effectiveness
- Climate change and geographic limitations
2.5. Different rainwater harvesting techniques

- Roof catchment
- Ground catchment
- Small earth dams
- Rock catchment dam
- Subsurface dam
- Pond

2.6. Discussions on the presentations made

Q1: What is the difference between rainwater and water harvesting?

Rainwater harvesting is gathering and storing of water running from surfaces on which it has directly fallen whereas Water Harvesting is the collection and storage of any form of water, either runoff or creek flow for different use.

Q2: What are the experiences of harvesting rainwater from thatched roof?

Grass thatched roof doesn’t produce good quality water. It discolors the water and makes it less palatable for domestic purpose. It should be used only when no other alternatives are available. In Ethiopia rainwater harvesting from thatched roof is not common.

Q3: What is your experience of water quality harvested from CIS roofs?

Generally the quality of water harvested from CIS is good. It should be noted that corrosion of roofing material is health risk.

Q4: According to your explanation the storage system of roof catchment needs to be cleaned with the first shower. The second shower may be little to fill the tank? Is this not a problem?

Depending on the local rainfall amount and pattern of course this can be a problem. From sanitation point of view it is important to use the first rain to flush/clean the system.

Q5: Why were some ponds abandoned in your project area?

Especially if ponds are located in catchment where there intensive cultivation and the catchment is not treated well the rate of siltation or sedimentation is very high. This siltation will decrease the storage capacity of pond tremendously soon. Labour requirement for desilting the ponds is high and is not attractive to the community.

Another potential problem with pond is that if located on sandy soils or soils with high infiltration rate the stored water will be lost through seepage within few weeks. It is due to these reasons that ponds were abandoned.

Q6: Is it acceptable to pastoral communities owning water privately and sealing water?
In Borena zone there are individual pastoralists who own cisterns privately. In some cases two to four individuals have their own cistern. However, they have the culture of sharing the water from their own cisterns with other community members.

**Q7: How is water distribution effected for rainwater harvesting system constructed at community level?**

Distribution of stored water from cisterns is the main duty of the WATSAN committees. The committee fix schedule for water distribution and assign two to three individuals from a community who are responsible for water distribution. According to the schedule set community members will go to the distribution point and collect their share.

**Q8: Is evaporation not a problem in open tanks?**

Evaporation is a function of temperature, humidity and wind. In open tank the water surface is exposed. Thus the evaporation from open tank is higher than closed tank.

### 2.7. Domestic water security through rainwater harvesting

- About 83% of the Ethiopian population live in rural areas and are dependent on livestock and agriculture for their livelihoods.

- Roughly 13% of the rural population of Ethiopia has access to safe water supply and 6% to adequate sanitation (UNICEF, 2001). Only Afghanistan ranks lower than Ethiopia in the percentage of rural population with access to safe water while in the area of sanitation, Ethiopia is the fifth lowest.

- Time spent in collecting water is also an issue as noted. Less time spent traveling to and collecting water from the source will result in an increase amount of time for other activities including school attendance.

- In areas where other sources of water are limited rainwater can be harvested and domestic water security can be addressed.

- Even in big cities where public water supply is available some community members collect water from rooftops covered by CIS.

- Rainwater harvesting is the immediate hope for thousands of scattered, small communities that cannot be served by centralized water supply schemes in the near future.

- Thus the development of this technique and its dissemination among the rural community is highly important.

- At present only 12% of rural households in Ethiopia own house with CIS. This can be a main limiting factor in water harvesting efforts especially in rural areas.

- Thatched roof is not investigated catchment for RWH. It is important to do some research on the possibilities of water harvesting from grass thatched roofs.
• Provided proper attention is paid to RWH by government, NGOs and other financial institutions RWH can contribute significantly to domestic water security

• In some rural areas this technology will be appropriate for many years to come

2.8. Design and construction of rainwater harvesting systems

Design work should take the following into consideration:

• Social Assessment
• Technical Assessment
• User Water need/demand

Social Assessment

Before commencing construction of rainwater harvesting facilities the following social data is necessary.

• Existing rainwater harvesting practice
• Opinion of local people about the usefulness and quality of water collected from roofs, ground surface and other harvesting areas
• Views of individuals on how much time and money they would wish to expend

To determine the volume of water to be stored or capacity of cistern to be constructed the following points have to be considered

• Amount of rainfall
• Available harvesting area
• Required quantity of water
• Tank size that is appropriate in terms of costs and construction methods

In practice costs and construction methods tend to limit tanks to smaller capacity than would otherwise be justified by harvesting area or quantities of water required.

The amount of rain that falls depends on the climate of the area. Rainfall amount vary between seasons and years and rainfall record will allow only approximate estimate to be made. Deciding the optimum size of tank is largely a matter of local judgment and experience.

Technical Assessment

The design of rainwater harvesting system for specific area requires detailed analysis. Information will be needed on rainfall, existing water sources, and availability of materials and harvesting surface or area. Professional personnel should not design the technical aspect of rainwater harvesting without reference to local views. One might make a precise technical calculation of optimum size of storage tank or area to make construction easier or to cut costs. If users draw water from the tank at different quantities or at different intervals from those assumed the constructed tank would not give service as expected.
It is not possible to design an appropriate rainwater harvesting system by simple process of data collection to come up with optimum design. System design should be based on information and opinion, which come from users and designers.

**Users Water Needs/Demand**

Studies have shown that people with water supply next to their houses will often use above 20 liters of water per person per day. If the water supply is located long distance from their house water consumption per person is less than 10 liters per person per day. For designing of water supply system in dry areas where rainfall harvesting is the only option assuming 10 liters per person per day appears to be reasonable.

Most arid and semi-arid regions in Ethiopia have one rainy season, which yields significant runoff that can be harvested. The rainy season is usually from June to September for about 90 days. To supply drinking water through out the dry period the tank volume should be large enough to supply a family or group of families for 270 days.

\[
\text{Demand} = \text{Number of dry days} \times \text{daily consumption} \times \text{Number of people}
\]

This is also the basis for calculating the volume the tank. The water system owners should clearly understand how much water the family can expect to receive each season and how that compare to their needs. If household use higher than estimated, the tank will run dry before the next rainy season.

In most cases the cost of constructing rainwater-harvesting system is beyond that a family or a group families can afford. Under such circumstances rainwater-harvesting facility can be constructed in stage until the demand is met. The harvested water can be used effectively during peak harvest period when the demand for labour is relatively high.

**Cost of Rainwater Harvesting System**

The success of rainwater harvesting systems in a given community depends on if it is technically effective and economically efficient. It should give sense in terms of productivity of resources used. It is difficult to judge if the resource is used efficiently in case where the water harvested is essential for survival. Efficient resource utilization can be judged very easily where water harvesting is a means of profit.

Carrying out cost benefit analysis is very difficult. Real benefits should include improved health and reduced time spent for collecting water. Saved time can be used for productive activities such as agriculture production. At least the economic issue that should be addressed is rainwater-harvesting system has to be affordable.

**Generally the cost of rainwater harvesting is high compared to other conventional water supply systems (springs, shallow well, deep well, etc.**

2.9. **Discussion on presentations made**

**Q1: Is it possible to achieve water security through rainwater harvesting given the magnitude of water shortage in pastoral area?**
As you may realize the unmet gap is high for Ethiopia. In some pastoral areas rainwater harvesting is the only options. If rainwater harvesting is promoted in the right way it will definitely assist in achieving water security. It should be noted that constructing efficient rainwater harvesting system would require trained manpower, other resources and time.

**Q2: Can the gap between water demand and supply be narrowed in pastoral area only through government efforts?**

Only government effort cannot alleviate this problem. Community awareness creation and mobilization is very crucial. Beside these the support of NGOs and other financial institution is also decisive.
3. WATER QUALITY

3.1 Basic principles

In any part of the world regardless of the economic status of a country, safe and adequate water should be considered a basic human right. Water supply service must meet certain qualitative and quantitative standards.

The quality of drinking water is important because it affects human health. The main water quality indicators of drinking water are characterized by their physical, chemical and biological parameters. These parameters are affected by the physical environment and human activities.

**Biological Contamination** is the contamination of water sources by water borne pathogens, such as bacteria, viruses and other free-living organisms that pose a hazard to human health. The most common causes of biological pollution of drinking water sources in the Ethiopian context are the presence of human and animal excreta in the water.

**Chemical Contamination** is the result of sources contamination by wastewaters, natural runoff or pollutant intrusions. The pollutants can be chemical fertilizer, pesticides, by-products of human and industrial wastes and naturally occurring minerals in ground waters.

The basic requirements for safe drinking water are that it should be:

- Free from disease-causing organisms
- Containing no compounds that have an adverse effect on human health
- Fairly clear (low turbidity and little colour)
- Has no offensive test or smell

The practical application of these requirements varies from place to place depending on the living standard of a community and type of water source. The World Health Organization (WHO) guidelines are basically a source of reference for accurate and reliable information.

Usually rainwater harvested is much cleaner than water from any other source. However some pollutions have to be expected which may be caused by birds, small animals and wind blown dirt.

Even though rainwater is cleaner than any other water sources it lacks mineral salts (including Fluorides and Calcium salts) whose presence is regarded as beneficial.

When rain falls after long dry period, water collected from roofs and ground catchment may carry debris arising from dust and leaves, which have accumulated on roofs or ground surfaces.

To maintain the water quality the gutters and roofs or harvesting area should be cleaned before the onset of the rainy season to prevent leaves, dust and dead animals and insects washing into the tank. If the tank is not empty at the end of dry season it should be emptied and any silt collected in the bottom should be removed. The interior of the tank should also be cleaned with a brush. Space between roofs and wall should be closed with stone and mortar to keep out wind blown materials, lizards, birds and insects.
It is also recommended that water running from roofs and ground surface be diverted away from storage tank during few minutes of the first rain.

3.2 Water quality standards

<table>
<thead>
<tr>
<th>Parameters</th>
<th>WHO Guideline Value</th>
<th>ESRDF Temporary Recommended value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min pH</td>
<td>6.5</td>
<td>5</td>
</tr>
<tr>
<td>Max pH</td>
<td>8.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Total solids</td>
<td>1000 mg/l</td>
<td>2000 mg/l</td>
</tr>
<tr>
<td>Total hardness</td>
<td>500 mg/l</td>
<td>600 mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/l</td>
<td>800 mg/l</td>
</tr>
<tr>
<td>Sulphate</td>
<td>400 mg/l</td>
<td>600 mg/l</td>
</tr>
<tr>
<td>Floride</td>
<td>1.5 mg/l</td>
<td>4 mg/l</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/l</td>
<td>3 mg/l</td>
</tr>
<tr>
<td>E.Coli</td>
<td>10 pper 100 ml</td>
<td>30 pper 100 ml</td>
</tr>
<tr>
<td>Nitrate</td>
<td>10 mg/l</td>
<td>40 mg/l</td>
</tr>
</tbody>
</table>
4. WATER HARVESTING

4.1. Norwegian Church Aid/ Ethiopia assisted water development program

By Seyoum W/Hana

Abstract

Norwegian Church Aid Ethiopia (NCA/E) has been assisting the Ethiopian government in the implementation of water development program since 1980.

NCA/E’s intervention in water development activities are well drilling, cisterns, ponds, roof catchments and diversion dam construction. The total estimated beneficiaries served by NCA constructed schemes are about 475,00. Almost all NCA/E assisted water development projects are community initiated.

The main challenges to the organization water development program are frequent drought, maintenance problem, high water demands by human and livestock, lack of responsible persons, dependency and low level of replication due to high cost.

4.2. Water harvesting in Sudan arid lands with special reference to the Northern Darfur, Western Sudan

By Gamal Mohammed Osman

Abstract

Rainfall patterns in Sudan arid lands have changed drastically in both intensity and distribution. This leads to low productivity and crop failure in some regions.

Water harvesting is found to be one of the coping mechanisms, to obtain sufficient water for farming. Both traditional and innovated techniques of different design are used. The idea of water harvesting and spreading encouraged many traditional farmers to adopt water-harvesting techniques on small scale for vegetable and millet production.

Generally in Northern Darfur, terracing can be used to control erosion that resulted from surface run off. It is therefore the primary function of terrace in Darfur is to meet both water conservation needs as well as erosion control.
4.3. The experience of CARE Ethiopia in Rainwater harvesting systems for domestic consumption:

By Sorssa Natea

Abstract

CARE International in Ethiopia has been involved with water development focusing on a community-based approach since 1989. The organization has been operating in Adama and Boset woredas of Eastern Shoa zone since 1987.

Community needs assessment in this project area ranked “inadequate access to water” as number one problem communities are facing in the project area.

The majority of the population spends more than six hours to collect water from rivers, lakes and other sources. To alleviate this problem the government had sunk deep well in few areas but success was very limited due to unfavourable geological conditions.

The development of ground water is not viable option. Thus, the project strategy to improve the quantity and quality of surface water is through water harvesting which includes roof catchment, ground catchment and pond excavation/rehabilitation. Generally, acceptance of the ground catchment has been extremely high; the level of community participation is very good. The technology has proved very appropriate for the project area.

WATSAN committees are set up at all water harvesting systems. This committee is responsible for construction and overall management of the system.

4.4. Discussions on presentations made

Q1: As compared to surface water what is the quality of ground water?

Contamination of either ground water or surface water depends on the existence of contaminating agents in a given location. Ground water is normally accessed through wells, protected springs and boreholes. Where groundwater is abundant, fresh, uncontaminated and close to the surface, it provides an excellent source of water supply.

Surface water source are more accessible than ground water. Surface water is, however, more susceptible to contamination.

Q2: What is the health implication of ESRDF standard?

It is expected to have certain impact. WHO standard is believed to be safe. ESRDF standard values in some cases are four folds of that of WHO. Thus, it should be having some negative health impact.

Q3: Has ESRDF mandate to develop its own standard?

May be they can develop their own standard for their own purpose. I think this will help them during project screening and approval.
Q4: Has CARE made assessment of effective water harvesting techniques that can be replicated and disseminated widely in the community?

Most water harvesting techniques that CARE is promoting can be replicated depending on the scale. If large water harvesting facility is required it may be beyond the financial and technical capacity of most communities. Small structures can be built and maintained at community and individual levels.

Q5: Virtually access to clean water is the right of individuals. To what extent is this reality in pastoral communities?

In reality as explained earlier the majority of the Ethiopian population has no access safe potable water. This doesn’t mean that they have no right.

Q6: According to your presentation constructing ponds is cheaper than ground and roof catchment. So, why are you constructing expensive structures?

It is true that ponds are much cheaper than roof catchments and ground catchments. However, generally ponds are not sustainable and don’t provide clean water relatively.

Q7: Cost per capita is the common parameters used in water supply project. In your presentation you used cost per liters of water. Is this not confusing?

Using cost per capita and cost per liter is possible as indicator for cost effectiveness. In dry part of the country it is not possible to supply 20 litres/day/person. In most rainwater harvesting system we are assuming 10 litres/day/person. Thus cost per litre of water is more explicit. In fact this can be converted to cost per capita if required.

4.5. Field visit

December 29, the second day of the workshop was assigned for fieldwork. Workshop participants were divided in two groups. Fieldwork report back guide questions were provided to each group and the facilitators gave explanations. It was explained that each group has to elect its chairperson and reporter.

Fieldwork (Report-back guide questions)

1. Is the scheme/water harvesting technique appropriate to the local situation?
2. Do you think this intervention can be sustainable? What is the likely chance of its replicability?
3. What improvements can be made (strong experience to build on and weakness to be improved)?
4. What are the likely negative environmental impacts of the scheme(s) you have visited?
5. What mitigation measures do you suggest?

Same day the groups returned from the field and convened to work on the outs to be presented the next day. Each group compiled its finding for next day presentation.
Groups Report

Group one

The group visited a total of seven schemes around Aba’ala and Gumselassa. The group has discussed on the different positive and negative aspects of the development schemes and has also forwarded some recommendations.

Area closure on the Aba’ala and Mayshguala River

1. The scheme is appropriate to the local situation from the perspective of both economic benefit and environmental conservation.
2. There is community participation in planning and decision-making. From this it appears that the scheme will be sustainable.
3. Improvement of management is required so that encroachment by peasant through fire wood charcoal production could be minimized.
4. May be there would be some harmful animals (hyenas, snakes).
5. These could be controlled through PAC.

Micro-dams

1. Dam is very appropriate to this locality to make water available to population in the area for different use.
2. If management practices are improved these schemes are sustainable and applicable to the local situation.
3. Soil salinity, standing water and poor water quality may be the parameters to be monitored seriously.
4. Need better management practices to ensure sustainability.
5. Apply appropriate mitigation method for the likely negative environmental implications.

Cisterns (ground catchment and roof catchment)

1. The scheme is very relevant to the local situation.
2. These have been constructed very recently. It is very early to judge on the sustainability of the system. The technology is simple and can be managed by the local population.
3. Improve the design (sizing storage tank should depend on the rainfall and catchment area, filtering system should be in the right order). For both structures drainage facilities are required. For roof catchment facility to flush the fist flood to exclude debris needs consideration.
4. The scheme is environmentally friendly.
5. The mitigation measures are necessary.

Ponds

1. Ponds for water harvesting is very appropriate to the local situation.
2. This intervention can be sustainable and replicable provided that the management system is reinforced.
3. Strengthening the responsible body/community group for proper operation and maintenance is required.
4. Not much
5. None

**Flood Diversion Dike**

1. This water harvesting system is very much relevant for crop production in the area
2. The replicability and sustainability of this structure is very much questionable. Because its operation and maintenance is not simple to be handled by the local people. Design of constructed structure has to be revised. Include proper silt regulating structure. Ensure that dam is properly keyed to the riverbanks and safe against erosion.
3. More comprehensive engineering investigation and follow up is required
4. Accumulation of gravel and bulder on farmland, losses of agriculture land. Not much
5. Revise and redesign the system.

**DHP Demonstration site**

1. It is very appropriate to carry out the demonstration in that locality to come up with site-specific applicable crop production practices.
2. The replicability and sustainability depends on research output
3. None
4. None
5. None

**Group 2 (North Group)**

The group-visited schemes including Agula, Birki and Genfel river diversions

1. The water harvesting techniques are appropriate. Farmers have access to water for crop production throughout the year. Crop productivity has been increased
2. Yes, the water harvesting system can be sustainable and replicable. To ensure this strong extension system and responsible institution for operation are required
3. Water logging due to canal seepage were observed
4. Efficient water utilization

**Korir Earth Dam**

1. Yes, the infrastructure is appropriate
2. The system can be sustainable and replicable provided that responsible institution for operation and maintenance have done their part properly Strong extension work is also a requirement
3. Water loggings have been noted during the visit
4. Efficient water utilization should be practiced

**Recommendations**

1. Improve traditional river diversions
2. Carry out researches on efficient water utilization, soil loss, etc
3. The continuity of similar workshop is very important
4. Sub-catchment treatment (water and soil conservation works) need to be carried out
4.6. Water harvesting for crop production

Categories of WH systems for crop production

- Micro catchment water harvesting
- External catchment system

Micro Catchment

- Is usually referred to as ‘within field’ catchment system
- Is characterized by overland flow harvested from short catchment length of usually between 1 and 30 meters and stored in soil profile.
- Ratio of catchment to cultivated area is usually 1:1 to 3:1.
- Plant growth is as a result of nearly uniform distribution and uptake of run-off.

External Catchment system

- Sheet flow harvested from long catchments
- Characterized by catchment length of usually 30-200 meters
- Runoff stored in soil profile
- Ratio of catchment to cultivated area is usually 2:1 to 10:1
- Overflow of excess run-off is possible
- Uneven plant growth is observed unless there is land leveling

Typical examples

- Contour stone bunds
- Trapezoidal bunds

4.7. Water storage techniques

a) Tanks above ground

Usually meant for rooftop rainwater collection. Collecting water from roofs covered by corrugated iron sheet, thatch or tiles and requires storage facilities above ground like oil drums or tanks built from concrete

b) Excavated tanks dugouts or cisterns

Serve the purpose of storing surface runoff for longer time, which can be used for domestic, or livestock water supply

c) Small dams

Retain water behind them and stay longer for different purposes including small-scale irrigation

d) Soil at field capacity

The profile of soil under this condition can store soil moisture leaving ample empty pore spaces in the soil for aeration of crop’s root zone. The maximum amount of moisture, which can be held in soil under this condition, is referred to as field capacity of the soil profile.

e) Soil at saturation
Pore space in soil is filled with water. At this stage except rice, crops growing will suffer waterlogging problem. Under this situation aeration is difficult.

4.8. Application and limitation of water harvesting systems:

Theoretically, water-harvesting program is feasible at any place where water runs off a catchment and could be collected

The system is practicable mostly in the arid and semiarid regions where rainfall agriculture is limited by erratic rainfall

Limiting factors to water-harvesting techniques

- Rainfall
- Slope
- Soil type
- Cost
Slope

The ground slope is the main limiting factor for water harvesting. This technique is not recommended on steep slope areas greater than 5%, the main reason being large volume of earthwork and an uneven distribution of run-off.

Soils

The soil should be deep, fertile, and free from salinity problems, good water holding capacity and be with good infiltration rate that is preferably medium of fine soil texture.

Cost

The cost of the system selected can be affected by the quantity and type of structure/earth or stone work/ involved. Labor and its financial implication may be a limiting factor to implement the system especially on a self-help basis

4.9. Micro catchment water harvesting systems:

- Is known as within field catchment
- A series of units, each of which is separated from the surrounding operates independently
- It collects run-off within its own basin or catchment or field

Typical examples are

- Negarim Micro catchment
- Contour Bunds
- Semi Circular bunds
- Contour Ridges/contour furrows

Negarim Micro catchment

- Diamond shaped in layout plan
- Closed by small earthen bunds
- Infiltration pit in the lowest corner of each
- Runoff is collected within the basin and stored in infiltration pit

Contour Bunds

- Earthen bunds are constructed following contour line
- Bunds are spaced closer to each other
- Provision of perpendicular small earth ties divides the system into separate individual micro catchments
- Used to grow trees, fodder and crops like sorghum.

Semi Circular bunds

- Have semi circular basin
- Diameter and distance between bunds vary
- Catchment to cultivated area ratio 4:1
Contour Ridges/contour furrows

- Are suitable for crop production
- Ridges are spaced at 1 to 2 meters interval and follow contours
- Ridges are constructed from borrows of furrows on the up slope
- Runoff is collected from the uncultivated area and stored in the furrows

4.10. Macro catchment water harvesting systems:

- Stone contour Bunds
- Trapezoidal Bunds
- Flood Water Diversion System /Spate Irrigation
- Floodwater Farming System

a) Stone contour Bunds

- They are constructed on flatter slope up to 2 to 3% on field already cultivated or highly degraded.
- They receive runoff from the denuded catchment.
- The purpose of the system is to check of the run off to infiltrate.
- Easily replicable by farmers.
- Useful for soil and water conservation

b) Trapezoidal Bunds

- This technique is a long slope catchment system and enclose relatively large areas and impound large quantity of run off
- The tips of the trapezoidal bunds are built on the contour.
- The enclosed area is variable in size.
- The two wing walls of the system extending upslope, which form trapezoidal shape.
- Crops are planted in the enclosed area varying from 0.1 to 1 hectare.
- The bunds may be constructed as a single unit or in sets.
- In the later case the system is arranged in a staggered configuration.
- Units in lower lines intercept over flow from the bunds immediately above them.
- The usual distance set between the tips of adjacent bunds within one row is 20 meters. The spacing is not rigid can be adjusted according to the site conditions.
4.11. **Floodwater farming systems:**

- Farming is undertaken within the streambed by blocking the water flow and concentrating the run-off.
- More water is utilized on the spot as opposed to the diversion of floodwater of the main course.
- The streambed can be either the valley bottom or the entire flood plain.
- Area can be inundated during peak flood flow.
- The technique employed under the system is by building permeable long but low rock dams across valleys.
- The structures can be considered as a form of terraced wadi.
- Large amount of work is involved which makes labour intensive.
- Excess water over flows the stone dam and/or filter through the dam body.
- Gradually the sediment fills up the area behind the dam with fertile deposits, which creates favourable condition for crop cultivation.
- Provision of overflow is allowed with sort of spillway in case of building the dam with earth. However earth bund is usually damaged during peak flood flows.

4.12. **Flood water diversion system /spate irrigation:**

- The system forces the water to leave its natural course, which cannot be achieved without manipulation.
- Water is conveyed to the near by suitable land or crop production and applied by means of channels or bunds.
- It is a water spreading technique in which the water flow passes through or zigzags around structures.
- These structures are usually made of earth to slow down the flow and spread it over the land to be cultivated by allowing it to infiltrate.
- The land must be close to the floodwater diversion site, usually on a flood plain with alluvial soils and low slopes.

**Two major components of the system**

- Main structure, the diversion dam/weir/with an overflow spillway
- Water spreading bunds or channels used as water conveyance structures

**Modernization of spate irrigation system involves the design of**

- Permanent weirs
- Canal head regulator
- Sediment excluder
- Canal network
- Water distribution system

**Potential sites for spate irrigation**

- Lowlands with low and erratic rainfall
- Reasonable spate flow occurrence
- Suitable and deep soil
- Acceptable slope and an undulating topography
Labour for construction and maintenance

Sustainability of spate irrigation

Sustainability of a system is the degree to which it continuous to function throughout its life period. Spate irrigation should meet the following conditions to be sustainable.

- Scheme product should be what the local people want
- Technology has to match farmers’ knowledge of construction, operation, maintenance of the system
- Technology should match with farmers’ organizational capacity level
- Technology should correspond to the financial capacity level of the farmers
- Technology has to be easily replicable and adaptable
- Extra labour should be available during peak period
- To minimize risk development of conjunctive use of spate and ground water resource is important
- Diversification of means of income

4.12. Water harvesting in the Somali National Regional State of Ethiopia:

By Abdulkarim A. Guleid

Abstract

The Somali Region has been either in a state of drought, recovering from a drought or moving into a new drought since 1996. If this trend continues, as it is now, the future of the pastoralists in Ethiopia as a whole will be at risk.

Due to the lack of holistic planning both at the National and the Regional levels, little efforts have been done to rescue the pastoralists and their livelihoods or even to mitigate their sufferings.

Water resources in the Somali Region are always scarce and valuable. Traditionally, residents of the Region use both natural and man-made ponds and boreholes for both domestic consumption and for animals. The optimal output of this method is dependent upon the seasonal rains.

Rainwater harvesting is not only the appropriate technology in eastern part of the region it is also the only choice. Water harvesting is done through Birkas, earth dams and haffir dams. Dams and Birkas have become indigenous innovations for collecting rainwater in the region and require little maintenance. Their designs and constructions have been modified in recent years.

The water in the Birkas is properly managed and both the demand and the supply are well regulated by the families. Normally, the women manage the water in the Birkas, since they are mostly available at the sites. But the men do the maintenances. Women participate in the decision-making of water supply and demand for the families.

4.14. Water harvesting system planning and design considerations:
• Socio-Economic Aspect
• Agronomic Aspect
• Environmental Aspect
• Institutional/legal Aspect

a) Socio-Economic Aspects

• Community acceptance and participation
• Understanding of needs and aspiration of the community
• Prioritization of community needs
  - Drinking water
  - Livestock
  - Crop production

• Appropriate technology
  - To skill of people
  - To the environment

• Proper planning and studies
  - Construction materials
  - Construction skill
  - Construction method
  - Operation and maintenance
  - Low cost but long lasting/durability

• Pilot scheme approach
  - To check effectiveness
  - Cost and benefit
  - Skill
  - Data collection
  - Adaptive field research
• Technical services
  - Engineering
  - Extension
  - Training
  - Credit

• Economic aspects
  - Cost of investment and operation
  - Without and with benefits
  - Direct and indirect benefits

• Application
  - Pastoralist system
  - Sedentary agriculture
  - Communal vs. individual aspects
  - Tree planting vs. crop production

b) Agronomic Aspects

• Appropriate Agro-climatic zones
  - Less than 1500m altitudes
  - Rainfall less than 600 mm generally
  - Growing period less than 90 days

• Crop selection
  - Yield response to moisture (maize high)
  - Food crops, cash crops, tree crops

• Soil condition
  - Catchment should produce adequate runoff
  - Cultivated soil should be deep and of good moisture holding capacity
  - Structure of the soil should be good for bund construction
  - Soil should be fertile

• Crop management
  - Soil should be fertile
  - Time of planting is critical
  - Planting after early shower or after flooding
  - Appropriate spacing and plant population
  - Planting on ridges to avoid water logging
  - Follow crop rotation
  - Inter cropping may be advantageous
  - Weeding and cultivation

c) Environmental Aspect

• Ecological impact
• Down stream effect
• Introduction of disease
d) Institutional/legal Aspect

- Land and water use right
- Management and organization
- Services

4.15. CoSAERT’s experience on small scale water harvesting techniques:

By G/Medhin Tesfaye and Hadera Haile

Abstract

CoSAERT (Commission for Sustainable Agriculture and Environmental Rehabilitation for Tigray) promotes irrigated agriculture in the arid areas of Tigray region. The water harvesting techniques SEART promotes are micro dams, river diversions, in-stream and/or off stream ponds. Micro dams constructed are mainly used for supplementary irrigation. Water is crucial and first limiting factor for crop production in the region. Further study of water harvesting techniques is required to expand irrigated agriculture in the region.

4.16. Water resource potential of Aba’ala area (Northern Afar), Ethiopia:

A Pre-Feasibility Study
By Kifle Woldearegay

Abstract

A pre-feasibility study was conducted to assess the water resource potential of the Aba’ala area. The study reveals that rocks and soils of variable aquifer characteristics underlie the study area. The major rocks are Glacial Tillite, Adigrat Sandstone, Antalo Limestone, and Agula Shale. The major soil types in the study area are Alluvial Soils. The pre-feasibility study shows that the Aba’ala plain has annual surface water and groundwater recharge potential of about 110.3Mm$^3$ and 42.9 Mm$^3$ respectively. The study area is found to posses good water recharge potential, which could be developed by using surface water harvesting structures and/or groundwater wells.
4.17. Discussion on the presentations made:

Q1: You have mentioned absence of clear roles and responsibilities between different Bureaus, What effort did CoSAERT made to alleviate the problems?

The commission has expressed its concern several times. Most schemes completed are not meeting their planned potential. This policy issues. We believe the decision makers are considering it.

Q2: Do you think that Bureau of Agriculture (BoA) can manage such huge structure that CoSAERT has constructed?

The major maintenance work is the responsibility of CoSAERT. The extension component is what the BoA has to carryout. To do this they have the capacity.

4.18. Management and maintenance of water harvesting systems:

Management, operation and maintenance are critical measures to be considered for sustainability of WH system

The management skills involves
- Organizing farmers for maintenance
- Resolving conflicts
- Distribution of water to the beneficiaries

Operation is ensuring the function of the system as per the plan.
Maintenance includes works necessary to keep the WH system operating. Operation and maintenance is a routine work.

Common maintenance works are
- Repairing embankment
- Removal of silt from canals and drains
- Cleaning of vegetation from canals and drains

Main consequences of poor operation and maintenance are
- No water diverted to the field
- Poor water distribution
- Decreased canal capacity
- Seepage in the system
- Siltation of the supply system
Scheme Organization and Management

The overall scheme management task is the responsibility of beneficiary farmers. It is essential that certain rules of organization be established to carry out operation and maintenance.

Beneficiaries in the scheme should form Water Users Association (WUA). Beneficiaries should have water right and maintenance obligation.

Management Tasks

For a proper operation and maintenance of a scheme the WUA has to carry out the following management tasks:

- Maintains the water right of the project
- Ensures the distribution of water
- Organizes the maintenance works
- Acquires the required materials
- Fix the annual contribution
- Establish frequencies of maintenance
- Concludes contracts with local skilled and unskilled labor
5. ANNEXES

5.1 List of workshop participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>P.O. Box</th>
<th>Telephone</th>
<th>Fax</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdulkirim A.Gulieid</td>
<td>HFH</td>
<td>26060,</td>
<td>513631</td>
<td>516203</td>
<td><a href="mailto:HFH2000@hotmail.com">HFH2000@hotmail.com</a></td>
</tr>
<tr>
<td>Ali Belay</td>
<td>BoAAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assefa Fitta</td>
<td>ENCCD</td>
<td>8838</td>
<td>61-4370</td>
<td></td>
<td><a href="mailto:Kengo@tel.netef">Kengo@tel.netef</a></td>
</tr>
<tr>
<td>Aychachew Chegem</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dawed Deressa</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dawit Kebede</td>
<td>NCA/E</td>
<td>1248</td>
<td>512922</td>
<td>518167</td>
<td><a href="mailto:Dawitk@nca.ethiopia.org">Dawitk@nca.ethiopia.org</a></td>
</tr>
<tr>
<td>Debebe Gashawbeza</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dereje Assefa</td>
<td>MU</td>
<td>231</td>
<td>409015</td>
<td>400793</td>
<td><a href="mailto:Derejeaaa@yahoo.com">Derejeaaa@yahoo.com</a></td>
</tr>
<tr>
<td>Dirress Tesfaye</td>
<td>DHM/MU</td>
<td>231</td>
<td>0407500</td>
<td>04-400793</td>
<td><a href="mailto:Dinesst@yahoo.com">Dinesst@yahoo.com</a></td>
</tr>
<tr>
<td>G/Bishawkeza</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G/Medhin Tiku</td>
<td>RVIAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G/Tesadik Mariam</td>
<td>REST</td>
<td>20</td>
<td>402244</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadera Haile</td>
<td>“</td>
<td>520</td>
<td>406677/78/79</td>
<td>“</td>
<td><a href="mailto:Cosaert@telecom.net.et">Cosaert@telecom.net.et</a></td>
</tr>
<tr>
<td>Jamal W/Giorgis (Dr)</td>
<td>EARIO</td>
<td>2003</td>
<td>454438</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kifle W/Argay</td>
<td>MU</td>
<td>231</td>
<td>04-402270</td>
<td>400793</td>
<td><a href="mailto:Kiflewold@yahoo.com">Kiflewold@yahoo.com</a></td>
</tr>
<tr>
<td>Mamusha Lemma</td>
<td>MU</td>
<td>231</td>
<td>04-407500</td>
<td>400793</td>
<td><a href="mailto:Mamsuhalemma@hotmail.com">Mamsuhalemma@hotmail.com</a></td>
</tr>
<tr>
<td>Mintesenot Beihatu</td>
<td>MU</td>
<td>231</td>
<td>04-408627</td>
<td>400793</td>
<td><a href="mailto:Mue.tug@telecom.net.et">Mue.tug@telecom.net.et</a></td>
</tr>
<tr>
<td>Mitiku Haile (Dr)</td>
<td>MU</td>
<td>231</td>
<td>04-407500</td>
<td>400793</td>
<td><a href="mailto:Gualmitiku@yahoo.com">Gualmitiku@yahoo.com</a></td>
</tr>
<tr>
<td>Molla Demlie</td>
<td>MU</td>
<td>231</td>
<td>04-402270</td>
<td>400793</td>
<td><a href="mailto:Mold777@yahoo.com">Mold777@yahoo.com</a>,</td>
</tr>
<tr>
<td>Mohammed Abdulkadi</td>
<td>CoSAERT</td>
<td>520</td>
<td>406930</td>
<td>401064</td>
<td><a href="mailto:Coaer@telecom.net.et">Coaer@telecom.net.et</a></td>
</tr>
<tr>
<td>Mulu Muruste (Dr)</td>
<td>MU</td>
<td>231</td>
<td>04-407500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigussie Haregewein</td>
<td>MU</td>
<td>231</td>
<td>04-407500/409018</td>
<td>400793</td>
<td><a href="mailto:Niguha@yahoo.com">Niguha@yahoo.com</a></td>
</tr>
<tr>
<td>Shemelis Beyene (Dr)</td>
<td>CARE</td>
<td>4710</td>
<td>01-463422</td>
<td></td>
<td><a href="mailto:Care.eth@telecom.net.et">Care.eth@telecom.net.et</a></td>
</tr>
<tr>
<td>Seyoum Tamere</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seyoum W/Hana</td>
<td>NCAE</td>
<td>1248</td>
<td>01-512922</td>
<td>518165</td>
<td><a href="mailto:Seyoumwh@nca.ethiopia.org">Seyoumwh@nca.ethiopia.org</a></td>
</tr>
<tr>
<td>Sisay Mulatu</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorssa Natae</td>
<td>CARE</td>
<td>4710</td>
<td>01-463422</td>
<td></td>
<td><a href="mailto:Care.eth@telecom.net.et">Care.eth@telecom.net.et</a></td>
</tr>
<tr>
<td>Tafesse Mesfin (Dr)</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tegegne Alemayhu</td>
<td>SNNPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tihut Virgu</td>
<td>CARE</td>
<td>4710</td>
<td>01-463422</td>
<td></td>
<td><a href="mailto:Care.eth@telecom.net.et">Care.eth@telecom.net.et</a></td>
</tr>
<tr>
<td>Yonis Berkele</td>
<td>ENCCD</td>
<td>30357</td>
<td>01-611405</td>
<td></td>
<td><a href="mailto:Sso@telecom.net.et">Sso@telecom.net.et</a></td>
</tr>
</tbody>
</table>

5.2 Full text presentations:

A. Norwegian Church Aid/ Ethiopia Assisted Water Development Program
Norwegian Church Aid/ Ethiopia (NCA/E) has been assisting the Ethiopian government in the implementation of Water Development Program (WDP) since 1980.

Some of NCA’s interventions in water development activities are

- Cisterns construction in Bale and Borena
- Ponds construction in Somalia and Bale
- Roof catchment practices in Rama and Armacho
- Diversion dam in Rama
- Well drilling

Initially the beneficiaries of the WDP were people who were moved to Bale Zone from agriculturally over utilized areas of Wollo as government resettlement program, Somalia War victims and displaced people from Ogaden.

Later the WDP has assisted other communities in Bale (Oromya Regional State), Sidamo North Omo and South Omo Zones in SNNPRS. All areas are located in the southern part of Ethiopia.

**Areas of Focus**

Drilling of new schemes in Bale

Development of alternative water schemes.
Community participation efforts

1994-1996  1. O&M in Bale and South Omo
           2. Revenue collection in Bale
           3. Strengthening local community and government structures
           4. Training of CP workers
           5. Construction of new schemes: a) Alternative schemes, b) Drilling

1997-2000  1. Operation and maintenance, on community, Wereda/WSU and zonal levels both in Bale and South Omo zones.
           2. Drilling only in South Omo and alternative construction of water supply schemes both in Bale and South Omo zones.

2001-2003  1. Capacity building at Regional, Zonal and Woreda levels
           2. Drilling in South Omo Zone and Konso Special Woreda
Total Estimated Beneficiaries Served by NCA Constructed Schemes

<table>
<thead>
<tr>
<th>Type of Scheme</th>
<th>Period</th>
<th>Number of Schemes</th>
<th>Initial beneficiaries per Scheme</th>
<th>Total initial beneficiaries</th>
<th>Total est. beneficiaries year 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilled</td>
<td>80-00</td>
<td>300</td>
<td>500</td>
<td>150,000</td>
<td>217,000</td>
</tr>
<tr>
<td>Rehabilitated</td>
<td>94-00</td>
<td>85</td>
<td>500</td>
<td>43,000</td>
<td>47,000</td>
</tr>
<tr>
<td>Hand-dug wells</td>
<td>91-00</td>
<td>111</td>
<td>350</td>
<td>39,000</td>
<td>46,000</td>
</tr>
<tr>
<td>Spring dev./ sub surface dam</td>
<td>93-00</td>
<td>47</td>
<td>1,500</td>
<td>71,000</td>
<td>83,000</td>
</tr>
<tr>
<td>Sub-total</td>
<td>80-00</td>
<td>543</td>
<td>-</td>
<td>303,00</td>
<td>393,000</td>
</tr>
<tr>
<td>Motor. sch.</td>
<td>94-97</td>
<td>12</td>
<td>3,000</td>
<td>36,000</td>
<td>42,000</td>
</tr>
<tr>
<td>Town supply</td>
<td>80-92</td>
<td>3</td>
<td>10,000</td>
<td>30,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Total</td>
<td>80-00</td>
<td>-</td>
<td>-</td>
<td>369,000</td>
<td>475,000</td>
</tr>
</tbody>
</table>

Community Participation

NCA/E assisted water development program has Strong wing of community participation section. Almost all projects are community initiated.

The following step plans are used for community participation and implementation of NCA/E assisted WDP:

Step 1-Project preparation and Coordination Meeting

Step 2-Visit to the Scheme Village

Step 3-Village Information Meeting

Step 4-Village mass meeting without outside representation

Step 5-Officials meetings with village leaders

Step 6-Location of Well Sites

Step 7-Drilling and Construction.
Step 8-Health Education Program

Step 9-Operation and maintenance period

Step 10-Handing-over of schemes to the community

Sanitation Around Water Points
People and animals are inseparable. The People give priority to their cattle. They use the same containers for fetching water for domestic use and watering their cattle. They also make trench cattle troughs around water points that may contaminate the source.

Cost Recovery

The pastorals communities in South Omo are not able to contribute cash for O&M on regular bases.

Challenges/Constraints

- Frequent drought
- Management/maintenance problem
- High need of water by human and livestock
- Lack of responsible person/s
- Dependency
- Low level of replication due to high cost

B. Water Harvesting In the Sudan Arid Lands With Special Reference to the Northern Darfur Western Sudan

By Gamal Mohammed Osman

Introduction

Sudan is the largest country in Africa extending from latitudes 3° 30’ N to 23° N., and from Longitudes 22° 42’ E. to 28° 30’ E. with an Area of about one million square miles (2.5 Million sq. km.). It includes the largest and most important portion of the Nile Basin, which is shared by Ethiopia, Uganda, and Egypt.

Perennial rivers provide water for irrigation throughout the year where such rivers exist.

The country has distinct tropical continental types of climate, and so it is divided into six climatic zones, namely the desert, semi-desert, arid, semi-arid, savanna, and the humid tropical. This tropical continental type of climate prevails over most of the country with four distinct seasons (Winter, Hot season, Rainy season, and Late summer or Darate). About more than ten states depends mostly on rainfall, these are namely Darfur (North-west-south states), Kordofan (north-west- south. states), Red sea, Kassala, Gdarif, and some parts of southern states.

Rainfall pattern in Sudan arid lands has changed drastically in both intensity and distribution, and this leads to low productivity and crop failure in such regions like Northern, Kordofan, and Darfur Regions.

Therefore other sources of water for Agricultural production are required to meet the increasing demands of the growing population.

Water harvesting is found to be one of the coping mechanisms to obtain sufficient water for farming. It is one of the techniques used in Run-off farming, mostly practiced along the Wadi-
beds of Sudan arid lands. Historically water harvesting is traced back to Sultanate time in Darfur. Now both traditional and innovated techniques of different designs are used, because of great potentialities of these arid lands (vast clay plains and numerous seasonal streams).

People in Darfur realized the magnitude of water harvesting, also it can be a means of water conservation, that can play a significant role, and makes the arid lands of Darfur, and other dry land areas self-sufficient in agricultural products, combat problems of environmental deterioration and provide base of sustainable Agriculture. Agriculture in Darfur, Kordofan and eastern states of Sudan depends mainly on rainfall. These arid land areas are the main providers of the total stable food crops in the country, i.e. Millet and sorghum.

As Rainfall is the main source of water for agriculture in the Sudan arid lands, it is always unpredictable, unreliable, it some times lead to crop failure resulting in food deficits. So other sources of water, and innovated techniques for water conservation are therefore needed, to meet the increasing demand of the growing population. The trials of the regional ministry in Darfur for using ground water pumps shows failure in Darfur region due to high cost of water production using turbine pumps.

On the other hand water harvesting and spreading proved to be one of the possible solutions. This idea encourage many traditional farmers to adopt water harvesting techniques on small scales for Vegetable and Millet production in Qoz lands of Northern Darfur rather than in Alluvial deposits, due to the fact that.

- Qoz land could easily be cultivated by farmers using hand implements.
- Cultivating the alluvial deposits with traditional hand implements is a difficult job.
- Rainfall received annually is not enough to support cropping on comparatively heavy alluvial deposits.
Evolution of water harvesting in Western Sudan

In western Sudan water harvesting is traced back to Sultanate time, where terracing was the most common technique for water conservation in very limited scale just enough for production of Mellons, okra, wild tobacco and other vegetable crops.

Terraces are small hand-made dykes along the contour lines for sheet flow or run-off collection, the area between the two terraces get moistened, and conserve water to be used for cropping, it is also can be a method or a technique for erosion control.

Following the periods of Drought, Famines, land degradation in late Sixties, Water conservation came to ground as an attempt to increase food and fodder production rates in arid lands areas.

Another reason is that both human and animal population has shown remarkable increase accompanied by increase in demand for food and fodder.

With the aid of government sector (soil conservation, Range & pasture Administration), Earth embankments were introduced, (Locally known as hafirs), in both eastern and western Sudan, these type of rain-water harvesting in western Sudan encourage some farmers to adopt this improved technique in farming. However most farmers till now are trying to find out the cheapest design for water harvesting.

Malam el widian project was the first place in western Sudan as anew practice of water harvesting. Other projects like El koma project, and El rakaz irrigation projects, are examples of a water harvesting techniques in northern Darfur.

Water Harvesting Techniques

A. Traditional Technique

Traditionally rainwater in the wadi beds is harvested by means of small earth embankments (Terrace), locally called Terus, these teruses constructed against the flow direction of water in the wadi beds, and they are normally not more than 30 – 50 cm height (Fig2). They are constructed manually by farmers using hand implements like shovels, hoes, ect., because they are hand made, they can not resist heavy loads of run-off water, even they might be completely washed out in heavy rains.

B. Innovation Techniques

B-1 Terraces

As mentioned before traditional techniques are not efficient for large scale farming systems. Therefore amofication of such terraces (or terraces) to larger U-shaped structures for she flow collection with diversion dykes to spread harvested water over the field (Fig.3).

B-2 Hafiers
Large earth embankments with the aid of heavy machines is another technique of water harvesting in Darfur area, (Figure no. 4 & 5) illustrate El koma and Elrakaz projects mentioned above this practice most commonly practiced by rich farmers in the area.

B-3 Modified Hafiers (Dams)

A third technique is almost similar to the second one, however both areas behind the earth embankment as well as the down stream could be cultivated. Here a large earth embankment act as a large (Dam) of 4 – 5 meters height constructed across a seasonal stream with a well-lined spill-way for water discharge into the farms. Example of that is the government project of Malam Elwidian. In north Darfur Arid land areas. (Fig. # 6)

The advantages of this techniques over the previous ones is in the following:-

- Summer cropping as well as winter season cropping is available (by using reservoir water stored).
- Irrigation of crops can be supplemented during years of bad, or low rainfall.
- Any additional water flow during rainy seasons will compensate for water loss from the reservoir irrigation.
- Plant water requirements could be fully secured down the stream.

Conclusion

Generally in Northern Darfur, terracing can be used to control erosion that resulted from surface run off. It is therefore the primary function of terrace in Darfur is to meat both water conservation needs as well as erosion control.

C. Rainwater Harvesting Systems for Domestic Consumption

By Sorssa Natea

Introduction

CARE International in Ethiopia has been working in Ethiopia since 1984. In response to the famine of 1984, CARE implemented a massive relief operation that lasted for almost a decade. Over the years, CARE Ethiopia has shifted its main focus from relief aid into more development-focused areas such as food security, reproductive health, and water and sanitation.

Since 1989, CARE has been involved with water development focusing on a community-based approach for over 100,000 participants. CARE has developed considerable expertise in the technical and social aspects of water and sanitation programming in all of its working areas and has incorporated a community-based approach that reinforces community ownership. Currently CARE implements 15 projects/programs with a total average annual budget of US$8.2 million. The projects are clustered geographically in seven zones and 14 woredas of east and West Hararghe, East Shoa, Borena, South Gonder, Zeghie and the Awash national park.
The water and sanitation activities of CARE Ethiopia Country Office include bore hole, spring development, shallow well, pond, and roof catchment and ground catchment construction.

This paper gives a highlight of water and sanitation program of CARE shoa, a project operating in semi arid part of the country in the refit valley where availability of surface water is limited due to geological and climatologically reasons.

**Background**

CARE International in Ethiopia has been working in Adama and Boset Woredas of Eastern Shoa zone. Agriculture is the principal activity employing more than 90% of the population in the area. Economic activities outside the agriculture sector are very limited. The economy of the area is classified as cereal-major and livestock minor. The production methods used are very traditional. Production is aimed at self-provision and is dependent on forces of nature. As such, success in production in this lowland agro-ecology is severely affected by climatic irregularities. The total rainfall, approximately 700 mm in normal years, is adequate for the major crops of teff, maize and haricot beans but rainfall distribution is often erratic. The most common shock to which the population is exposed is insufficient agricultural production resulting from moisture stress.

According to baseline survey results, inadequate soil moisture is number one problem. Periods of low or poorly distributed rainfall are not new to the area. Community describes mini-droughts occurring every four to five years.

An estimated 35 percent of the total populations in the project area are land less and this number is also increasing. In 1992 the estimated land less population was only 10 percent. The primary cause for this is increasing population pressure.

The nutritional security of the project area is affected not only by the factors influencing household food security but also by access to clean water and health facilities. The Community Needs Identification ranked “inadequate access to water” as the number one problem communities face in the project area. Currently only 25 percent of households in the area have access to potable water. This is a result of geological (Rift Valley volcanic) formations in the area, which severely limit groundwater. A Hydro geological study of the project area conducted in February 1996 documents the possibilities of groundwater development as follows:

- **Shallow wells** (10-25 meters) are feasible only in Adama Woreda close to Koka Dam on the Awash River;

- **Boreholes** (80-120 meters) are feasible in both Woredas only along the Awash River. As distance from the river is increased, depth to water increases as does water temperature and fluoride concentration, which makes it unsafe for human consumption based on WHO standards.

As a result, even successful past attempts on the part of the GoE to provide potable water through sealed wells have done little to address the issue of water access; the majority of the population must still travel to the river. Over 60 percent of the population currently spends 4 to 10 hours per day collecting water from this unprotected source. The amount of time and
resources used by households to obtain water has significant negative impacts on any efforts to promote better access to food.

As mentioned earlier, the development of groundwater is not a viable option in this project area because of the costs associated with tapping deep aquifers and the potential toxic levels of fluoride that might occur. Experiences of GoE and some neighboring NGO’s have shown that borehole drilling along the Awash River is as costly as approximately US$ 80,000 per borehole, which is prohibitive when the success rate is very disappointing.

The only viable alternative for water provision in the area is rainwater and runoff harvesting systems. Thus, the project's strategy is to improve the quality and quantity of surface water through roof catchment, ground catchment, pond construction/rehabilitation and formation and education of water sanitation committees.

**Ground catchments and cisterns**

Stone and cement mortar provides the paved surface for these ground catchments. Rain that runs off this pavement falls into a covered rock and mortar cistern and is held until needed. The quality of water collected is dependant on the level of sanitation practiced by participants but is likely to be much better than a community's conventional sources of water, usually ponds, puddles, and streams.

The project's focus on constructing water-harvesting ground catchments and cisterns are clearly appreciated by participants and highly regarded by the development community and GOE representatives. They are considered an important innovation for this region and CARE is considered the technical leader in their design and construction. They reduce the incidence of diarrhea, number of deaths caused by water-borne disease, and the time required for collecting water, usually by women. Each ground catchment costs around 25,000 to 30,000 Birr to construct (100m$^3$ capacity can supply approximately 140 people) compared to borehole wells that cost 500,000 to 900,000 Birr each plus pumping cost. To fill 100-m$^3$ capacity of storage tank, the paved ground surface area with stone masonry varies between 350 to 450 m$^2$ depending on the local rainfall amount.

The storage tank is mostly circular in shape and is partially below ground and partially above ground level, which is dictated by the site topography. Water is accessed from the storage tank by a pipe. The gate valve used to control the outflow is locked with pad lock to avoid unauthorized use.

Stone and cement mortar provides the paved surface for these ground catchments. Rain that runs off this pavement falls into a covered rock and mortar cistern and is held until needed. The quality of water collected is dependant on the level of sanitation practiced by participants but is likely to be much better than a community's conventional sources of water, usually ponds, puddles, and streams.

The design and construction techniques for water-harvesting catchments and cisterns have evolved and improved during project implementation to better serve participant needs and the rainfall conditions of the target areas. For example, in the beginning catchment areas were designed too small relative to the sized of the cistern so they don’t completely fill during years of rainfall below average.
The criteria used for site selection is distance to present water source, safety of present water source and level of community participation.

According to the recent survey made, from these ground catchments six of them have minor problems. The remaining fifty-three are in good condition and functioning well.

It should be noted that a secondary benefit of these systems is that water tanker in the event of emergency may easily fill them when water shortage becomes critical.

Generally, acceptance of this system has been extremely high, the level of voluntary community participation is very good and the demand presently exceeds the capacity of CARE to construct them. At present there are over forty requests or application from different communities, which CARE has not addressed yet due to budget and time constraints.

This technology has proved to be very appropriate for areas where other water sources, ground water and surface water sources, are absent or limited. Currently CARE Ethiopia is promoting this technology in different parts of the country.

**Roof catchments and cisterns**

Due to the prevalence of thatch-roofed housing, roof catchment systems are limited to community structures. Most of these community structures like schools, churches and mosques are poorly constructed which made fixing of gutters and down pipes on these structures very difficult. The expected life of the whole system is also short which doesn’t warrant high investment on water collecting and storage system.

CARE constructed roof catchments and cisterns on buildings that it can assure proper maintenance. Adoption of this technology has been supported through technical assistance to individuals with roofs in good condition or for participants that plan to construct new corrugated roofs for their houses. This activity will target people who can afford metal roofs and cisterns; these participants are more likely to be food-secure than those without metal roofs. However, water collected from these roofs will reduce the over all demand on other sources of drinking water, which may provide significant benefit to everyone, especially in communities with very limited supplies of drinking water.
Pond Excavation

The construction of open ponds provides a viable option for providing three to six months of water to most of the population and their animals. Before five years, several ponds were constructed in the area but their water holding capacity was very low due to the nature of soils in the area. Also, little community involvement resulted in low levels of pond protection and subsequent contamination.

This activity was phased out early in the project as planned. Ponds provide important sources of water for livestock, washing, bathing, and for drinking when better water is not available. If the pond and its watershed are protected from human and livestock contamination these sources can provide relatively safe water, especially for washing and bathing. When they are not protected from contamination, they can be a source of disease. Ponds also provide habitat for mosquitoes, especially Anopheles species that are vectors for malaria.

CARE's constructed/renovated ponds are appreciated and are needed to supplement water that is supplied by ground catchments and cisterns. However drinking this water is causing health problems and reducing the beneficial impact of this activity. Education in water sanitation and management is needed along with pond renovation and excavation activities but the wise use and management of pond water cannot be assured. Government line officials want higher quality water sources developed than ponds but providing sufficient quantities of drinking-quality water for all uses may not be practical in some communities.

Water sanitation and hygiene education

CARE extension agents helped communities form Water and Sanitation (WATSAN) committees in association with the improved water structures that CARE and the communities constructed. WATSAN committees are set up at all ground catchments constructed to mange the water supply system. Representation of women is ensured in the committees. Still the participation of the women is low because of cultural or social conditions, which prevent them from speaking in public.

The committees are responsible for mobilizing resources during construction, distribution of harvested water, maintenance of the structures, keeping the water free of contamination, and educating others in their community on improved sanitation and hygiene. Committee members may also disseminate information about other project activities, such as agriculture and nutrition messages. It is required that the committee comprises 50% women.

The project developed its water sanitation and hygiene messages. The home environment of participants’ present conditions can easily compromise the practices that are extending by the project.
Gender Impact

Constructing improved domestic water sources and health education have especially improved the lives of women who collect the water and care for sick children. CARE's activities have significantly reduced the time that women spend collecting water. The improved health of children also gives women more options on how they spend their time.

Counterpart Coordination and Sustainability

Collaboration with the government is excellent. Training of field level and higher government counterparts is highly appreciated and provide them with important skills.

Phase out plan

The phase out plan was that "communities will have the capacity to construct any additional catchment system and ponds with minimal technical support from the GOE." The cost and technical requirements of the systems used by the project prevent communities from achieving this goal.

D. Water-Harvesting in the Somali National Regional State of Ethiopia

By Abdulkerim A.Guleid

Background of SNRS

Water is not only one of the world’s most important resources, but also a scarce resource in many parts of the world. For the pastoralists in the Somali National Regional State (SNRS), water has always been a critical issue. It has been in short supply for many years, but the situation is alarming now. Fodder is also another scarce resource, which is linked to the water scarcity.

Since 1996, the Somali Region has been either in a state of drought, recovering from a drought or moving into a new drought. If this trend continues, as it is now, the future of the pastoralists in Ethiopia as a whole will be at risk, because there will be devastating consequences for the environment, for the livestock, for the pastoralists and their health, for their economy and for the peace and stability of the affected areas.

These frequent droughts have seriously affected centuries-old way of life, the economic system, the heritage of wealth and above all, the pastoralist culture. Due to the lack of holistic planning both at the National and the Regional levels, little efforts have been done to rescue the pastoralists and their livelihoods or even to mitigate their sufferings.

What is Water-harvesting?

We simply define water-harvest as the ‘catching of rain where it falls’. There are no universally accepted uniform techniques and technologies for water harvesting in the world, but there are a lot of similarities in their aims and objectives and the systems used. All techniques and methods used for water harvesting give due consideration to the social and cultural aspects, which are specific to the different areas of concern as they are paramount and will affect the success or the failure of the techniques implemented. A water-
harvesting scheme will only be sustainable if it fits into the socio-economic context of the area and also fulfills a number of basic technical criteria pertinent to the physical features of the concerned area. As a result, water harvesting depends on the amount of rainfall in the concerned area.

Water Resources

Water resources in the Somali Region are always scarce and valuable. Traditionally, residents of the Region use both natural and man-made ponds and boreholes for both domestic consumption and for animals. The optimal output of this method is dependent upon the seasonal rains. The followings are the normal seasons in the Region:

1. **Gu**: the main rainy season (April – June)
2. **Jilaal**: is the long dry season (Dec. to March)
3. **Karen**: is associated with "Keremt" (July to Sept.). This rain doesn’t go beyond Jigjiga zone.
4. **Deyr**: is a very important season for the pastoralists (Oct. and Nov.). If the Deyr rain fails, the situation becomes very critical for the pastoralists during the long dry season (Jilaal).

How Water-Harvesting is done in the Eastern Part of Somali Region?

Water harvest is done in three ways in the eastern part of SNRS. They are through:

- “Birkas”;
- Earth Dams; and
- Haffir Dams.

A) “Birkas”

In normal circumstances, traditional way to harvest rainwater in this part of the Region is to collect and store the water in Cisterns (known as Birkas) for human and animal consumptions. This system of preserving water was first introduced in the early 1920³ by an Indian Military Engineer, who was a member of the British troops in the ex-British Somali land Protectorate. This water-harvesting technology spread very fast within the Somali land territory and was introduced in Aware and Misrak Gashamo in the early 1940⁴, which was then part of the ex-Somali land protectorate, and reached its pick in the early 1970⁵ and late 1980⁶. People have done and are doing everything within their power to ensure their own water supply by constructing family owned Birkas.

How does ‘Birka’ work?

Birkas are usually family owned and are well managed. They are also well maintained since unnecessary seepage cannot be afforded. Every drop of water is valuable and high value is attached to it. Prior to construction, site selection is done in respect to its water catchment and the suitability of the soil against erosion. Once the site is selected, excavation work of the Birka starts. For the construction of the Birka, specific soil requirement is not necessary, since the walls and the floor are lined with a non-porous concrete and have usually a rectangular
shape. The entire Birka is lined with a stone and mortar walls and floor. The size of the Birkas depends according to the need and resources available to the owners.

B) Earth Dams

Earth-dams exist in many places in the Region. Some are natural depressions, while others are man-made. The man-made ones are done by hand or by earth moving machines. Earth-dams, man-made or natural, are unprotected and unmanaged. Animals and human beings have direct access to the dam. Both animals and human beings drink from the same place. Nobody feels responsible earth-dams. There is no management in place and no maintenance is carried. So, their water is not clean and the gradual silt deposits decrease their capacities every year.

C) Haffir-Dams

Haffir-Dams are different from the earth-dams because:
1. Their sizes are bigger and have bigger capacities;
2. All silts and other materials are deposited in the silt-trap or the sedimentation basin;
3. Only clean water passes to the main reservoir from the sedimentation basin;
4. Haffir-Dams are fenced, well-protected and well-managed;
5. Neither animals nor human beings have access to enter the Haffir Dams;
6. Water is collected from the shallow wells, which are constructed 50 m away from the shallow-wells.
7. After each rain, silt is removed from the sedimentation basin and proper maintenance and cleaning is done.

Modern Birkas and Haffir Dams

Both the Dams and the Birkas have become indigenous innovations for collecting rainwater in the Somali Region and particularly in the eastern part that has access to Somali land. Both the Birkas and dams require little maintenance, have a long operational life and are culturally accepted as a means to collect, store and retrieve water for both human and domestic animal purposes.

Both the constructions of Birkas and Dams have been modified and modernized in the recent years. For the Birkas, the construction of the sedimentation chamber has been added to the normal construction of the Birka, where sand and other materials are deposited. The sedimentation chamber passes only clean water to the main Birka reservoir. In the same manner, the old dams construction technology has been modernized and the new modern dams are known as Haffir Dams. The Haffir-Dams are introduced into our area recently in 1994, by UNHCR. The name and the technology of the Haffir-Dam are originally from the Sudan. ‘Hope for the Horn’ has taken over this new technology from UNHCR, which we have modified and improved. We are grateful to UNHCR for this appropriate technology, which is going to be a great help not only for our Region, but also to other places with the similar problems.

These new dams have silt-trap chambers or sedimentation basins, which are constructed like Birkas and are used to trap the silt and pass to the main dam (Haffir-Dam) clean water. They are also installed with culverts, which allow water to pass from the main reservoir to the attached shallow wells. As a result, water extraction occurs through the shallow wells.
connected by the underground conduit from the reservoir (Haffir-Dam), which are usually located 50 m away from the reservoir (Haffir-Dam). Then comes the construction of the animal water-troughs, for sheoats, cattle and for camel separately.

So far, the expected life span of the dams are not determined, but at least an operational life of several decades could be expected, since they are a time-proven method of water collection and storage. If properly maintained, the new Haffir-dams would remain in tact for many centuries.

When all these sources dry-up, water tankering operation is the next option to be taken into consideration and it has been exercised during the recent droughts in the Region.

**Water Management in Relation to Gender**

The demand of water is great in most parts of the Region as it is in the neighboring Regions too. But the management aspect of the water supply is very poor everywhere and the communities are now conscious about it.

The water in the Birkas is properly managed and both the demand and the supply are well regulated by the families.

Normally, the women manage the water in the Birkas, since they are mostly available at the sites. But the men do the maintenances. Women participate in the decision-making of water supply and demand for the families. Women do not own the Birkas but if they have children, even if divorced, the ownership remains, with her own family and in case the man marries a second wife, the ownership remains with the first family but the second family is not also denied to use it.

Women and children usually do collection of water from the sources. Strong water management system is required in all water points, since there is a great water-wastage to be observed. The burden on women and children to collect water is changing now over time, since there is a growing desire to reduce the time and the efforts spent by women and children on collecting water. Within the pastoralist culture, particularly in the Somali Region, women are equal partners when families create property rights over natural resources. Women are also consulted when it comes to access for washing and to access for livestock drinking. During the dry seasons or drought periods, when all the sources dry-up, water prices are accepted or rejected by the women, since they have to sell part of their animals for the water-payment. Depending on the scarcity of water, prices fluctuate from 0.25 cents to 0.75 cents per liter at the critical times.

**Recommendation**

1. During an emergency operation only saving lives are given priority not the environmental concerns. In order to avoid frequent droughts, environmental problems have also to be addressed during the emergency.
2. Emergency assistance should not be taken and planned in isolation, but has to be addressed holistically to avoid its reoccurrence and to limit or mitigate its future negative impacts.
3. Risk identification and disaster mitigation strategies have to be worked out since they are not in place.
4. Enough water points, mainly cisterns and Haffīr dams have to be constructed or rehabilitated where boreholes are not available.
5. Working and effective livestock (pastoralist) early warning system have to be developed;
6. Effective emergency preparedness is required, since it is not in place.
7. Fodder storage facilities are badly needed at district levels in order to avoid expensive transportation of forage during critical drought situations.

**Conclusion**

The lack of rain and the subsequent drought conditions have resulted in an exceptional loss of livestock, the main livelihood and means of sustenance for the people of the Somali Region. Lack of rain is always accompanied by an acute lack of grazing fodder, which had caused an extremely high death rate to the livestock.

Rainwater harvesting is the only option for the eastern part of the Region, namely, Harshin, Aware and Gashamo districts. Studies and surveys made in the area indicate it is difficult to obtain underground water above 500m, which is very deep for drilling. So, Haffīr dams are the only appropriate technology to collect enough rainwater to increase the storage capacity in order to reduce the vulnerability of the pastoralists to droughts.

This technology is not only appropriate to the SNRS but to wherever there be a scarcity of water and rainwater harvesting is the only choice.

The point to note here is that the pastoralists were already using every mechanism at their disposal to survive the droughts. It is therefore essential that every external assistance given to them have to strengthen the appropriate traditional know-how or techniques in their coping mechanism. If this is not the case, the assistance kills the creativity of the people, will erode their pride and sense of efficiency, and will create dependency, which could be difficult to reverse.

**E. CoSAERT’s Experience on Small Scale Water Harvesting Techniques**

By G.Medhin Tesfay and Hadera Haile

**CoSAERT**

a) **Definition**

Commission for Sustainable Agriculture and Environmental Rehabilitation in Tigray.

b) **Purpose**

To promote irrigated agriculture in the arid areas of the region and help the food self-sufficiency and food security effort of the region.

*Types of Small Scale Water Harvesting Techniques applied by SAERT*

a) **Micro dams**
Dams constructed using machinery as well as available local labor force, which have a capacity of 0.50 to 2 Mm$^3$, and can irrigate up to 200ha of land.

b) River Diversion

Diversion weirs to divert flood of the river to off stream reservoir, or summer base flow of the river direct to irrigation networks.

c) In-stream and/or off-stream Ponds

Dams constructed using local available labor force as a major input, which have a capacity of less than 0.50Mm$^3$, and mainly used for supplementary irrigation.

Phase of study

a) Site identification

*Site Selection Criteria (for Dam)*

- Topography of the site; at a narrow gorge with opened upstream for large storage.
- Sufficient catchment area to generate the required flood.
- Command area and the canal network must be located at the downstream to irrigate by gravity.
- Spillway site; Presence of efficient and economical spillway route
- Geological condition; the stream bed has to carry the weight and prevent percolation through underneath the dam.
- Sediment load; should be as less as possible
- Availability of sufficient construction material in the vicinity
- Water tightness of reservoir; the bed and the side flanks of the reservoir upstream of the dam must be watertight.
- Cost aspect; the minimum construction cost as well as minimum operation and maintenance cost.
- Accessibility; sites should not be very far from roads.
- Social and Environmental aspects; sites should have as less social and environmental impact as possible.

b) Reconnaissance and pre feasibility study: Under this phase of study the following fields are conducted.

- Water shed study
- Hydrology study
- Geological and hydro geological investigation
- Soil and Agronomy study
- Environmental impact assessment
- Engineering design
- Socio economic study

c) Feasibility and detail design
Hydrology

*Catchment yield (Water potential)*
- Catchment characteristics (runoff coefficient computation)
- Dependable rainfall computation
- Monthly yield computation

**Reservoir Planning**
- Elevation Vs Area Vs Capacity
- Seepage losses computation (Seepage through dam body as well as through foundation)
- Evaporation losses computation
- Water Demand computation
- Water balance analysis

**Design flood computation**
- Design storm computation
- Design flood computation
- Flood routing

**Reservoir sedimentation and service life of the reservoir**

**Dam and Appurtenant**

**Dam design**
- Type
- Fixing dam height
- Crest width
- Embankment side slope and dam stability analysis
- Dam slope protection (Upstream and downstream slope protection)
- Drainage of earth fill dam
- Foundation treatment

**Design of outlet structure**
- Function
- Position
- Design discharge and design head
- Intake structure
- Conduit
- Control device
- Terminal structure
• Surplus channel
• Evacuation of reservoir

**Spillway design**

• Function
• Location
• Approach channel
• Control structure
• Discharge channel (chute)
• Terminal structure

**Problems and/or constraints**

*a) Man power*

• Availability of technical staff (experts) in number as well as quality
• Lack of experience
• High turnover of technical staff (60-70% of the employed staff was leaving the institution after getting experience)

*b) Equipment and Information (Data)*

• Scarcity of data/information (such as hydro-meteorological data and other soil and land use information)
• Quality of the available data and information
• Shortage of maps (such as topo-map to a required scale and Arial photos)
• Lack of Surveying and Drafting Equipments
• Lack of Field investigation and testing equipments
• Office materials (such as computer hardware and software, other stationers)
• Laboratory facilities
• Literatures and research output at local level

*c) Policies and/or Institution*

• Lack of clear water policy
• Lack of clear and defined Irrigation policy (such as system of commissioning, system of cost recovery)
• Lack of system/ institutional set up (such as lack of clear and defined institutional set up for operation and maintenance, catchment rehabilitation, and development of Water Users Association, WUS)
• Lack of standard manuals and guide lines
• Lack of proper planning and monitoring
• Lack of proper integration and co-ordination with in the institution (such as integration and co-ordination between Study & Design and Construction Departments)
• Lack of integration and co-ordination SAERT and other institutions or stakeholders (such as BoA, MU Agricultural research Mekelle branch)
• Public Participation

**Effect and/or Impacts**

• Incomplete design
• Schemes couldn’t generate the expected/estimated yield of water
• Schemes couldn’t irrigate the designed command area fully
• Excessive seepage/deep percolation
• Higher sediment inflow to the reservoir and sedimentation
• Improper and inefficient use of irrigation water
• Frequent damage and breakage of irrigation infrastructure

Present situation of SAERT

a) Integrated Rural, Agriculture and Water Resources Development Valley Study:-
Beside to the study of specific water harvesting technique, SAERT is now exercising the integrated agriculture and water resource development valley study approach. This study includes:

• Surface water potential study
• Shallow Ground Water Potential study
• Deep Ground water Potential study
• Rain fed Agriculture study
• Watershed management study

Conclusion and Recommendation

• The regional economic sector is mainly depending on the agricultural activities being the largest livelihood of the rural community like wise other part of the country. In the agricultural sector water is the crucial and the first limiting factors in crop production. Beside its importance rainfall amount and distribution is inadequate and unreliable to satisfy the water demand for crop production. There fore the issue of water is put as top priority in the regional agricultural policy and strategy in order to attain food security.

• To over come such problems and promote irrigated agriculture, establishment of COSAERT, as specialized institution was a necessary. During its commencement of its objective, it was new in its type in the region and even at national level. There were no or few experiences in study, design and construction of micro dams, diversion weirs and irrigation infrastructures. There was also critical shortage of professional staff specially design engineers and other senior staffs. Moreover there were shortage of materials and equipments such as geological investigation equipments, hydro-meteorological data, laboratory facilities, topography maps at required scale, and others.

• Therefore the outputs under the above listed problems are affected as following; estimated run off amount (catchment yield) was not harvested, command areas designed to be irrigated was not fully irrigated, excessive seepage & deep percolation, and higher sediment inflow to the reservoir.

• Facing such problems and having such lesson, an effort was made to fulfill the required equipments and facilities. So big improvements have been shown in study, design and construction quality and efficiency. There is also a change in approach towards Integrated Rural, Agriculture and Water resource Development Valley study.
Since there is no way and means to utilize the water potential of the region and overcome the prevailing food shortage, strengthening the institute in material and manpower would be advisable. In doing so farther study should be done in assessment of the problems and constraints of the water harvesting technique and expansion of irrigation development in the region. Though investigations should be done in study and design process and construction quality to the required standard. Beneficiaries should get enough support to be organized in Water Users Association, that enable them to take over the completed schemes. They should also proper training and know-how in order to carry out efficient operation and minor maintenance.
F. Water Harvesting, the key to successful crop production and resource management in Water Stress Environments: Eastern African Experience

Dr. Kidane W/Giorgis

Ethiopian Agricultural Research Organization

Introduction

Ethiopia Arid and Semi-Arid Lands (ASAL) cover about 66.6% of the total landmass and are the home of substantial livestock resource of the country. They are areas of low and poorly distributed rainfall, which adversely affects growing crops. As the human population rises, the impact of drought and subsequent food shortage in these areas is increasing in severity. Food security has therefore become a major concern.

Prospects for agricultural development in dry areas are largely misunderstood. These areas are commonly called "low potential" rather than "low rainfall" areas. Besides livestock, ASAL areas are the source of millets, sorghum, cotton, cowpeas, dolichos, pigeon peas, oranges, mango, grapes and passion fruits. Appropriate technology for these areas has been lacking; yet paradoxically, the future of the expansion of Ethiopia's food production is in these areas.

The major constraint to successful crop production in the dryland areas is water stress and this is the common denominator to all dryland areas in the world. Therefore, the first step to improve crop production in the dryland areas is to develop water-harvesting techniques and then use the limited water efficiently.

Once there is more effective management of available water (not necessarily from irrigation), the returns to soil fertility improvements are increased and the risk of this activity are reduced. With a little more water and improved soil fertility, drylands have a comparative advantage over higher rainfall regions due to (a) reduced disease pressures; and (b) more sunlight. The highest crop yields in the world are then obtained in these areas once water availability is moderately increased and supplemented with inorganic (and organic) fertilizers. This new agronomic environment also gives a much higher return to plant breeding.

Besides, in the dryland areas crops grow fast and land is more plentiful. What is needed is the development of alternative and sustainable technologies, which farmers can use profitably. The most suitable technology is water harvesting. So sufficient investment in water harvesting needs to be not only a higher priority for the semiarid regions but also for the entire country.

Potential in situ Water harvesting Technologies in the Semi-arid Areas

Development of appropriate water harvesting techniques is influenced by factors including soil type (texture and structure including crusting and compaction) and fertility status and organic matter content, topography and degree of slope. Weather conditions particularly rainfall characteristics amount, distribution, intensity and type of crop and cropping systems.

In soil with low organic matter, fine texture, compacted soil surface with low infiltration rates high runoff and soil loss tie ridge (ridging with additional cross in the furrow at short intervals) has efficient and effective method for conserving soil moisture. The main reasons
for effective soil water conservation through tied ridges include high rates of water penetration into the stirred soil, the action of tie-ridges in preventing run-off from the rain and increasing the opportunity time for infiltration. Thus, it enhances rapid build-up of soil moisture needed for rapid seed germination, and early plant growth.

The work done on the effect of ridging with different soil types (red soils, ash soils and black soils) in Tanzania by Dagg and McCartney (1968) illustrates the influence of soil types on soil water conservation and yield response of the use of tie ridging. The results indicated that on the red soils, only the maize grown on the flat showed signs of moisture stress at tasseling. Whereas on the ash soils, despite the early superiority of the crop plants on the ridged plots over the other treatments, moisture stress apparently was severest at the time of tasseling. They concluded that ridges made on black soils conserved the largest amount of moisture followed by those on the red soils. The ridges made on the ash soils conserved the least amount of moisture.

Tied ridges were also found to be effective in controlling runoff and increasing the infiltration opportunity time. These are particularly true on fine-textured soils with low infiltration rates, where temporary surface storage of water can reduce runoff. Jones and Clark, 1987 also observed that tied ridges (known as basing listing in the US) are effective methods for retaining surface water until it can infiltrate. In addition, according to Clark and Jones (1981) tied ridges prevented runoff from a 24-hour, 114-mm storm in Kenya on a clay loam soil in Texas. Similar results were observed in the semi-arid of Eastern at Katumani, a medium potential area, on a sandy clay soil Kenya tied ridges was found very effective and controlled runoff even from a large storm of 70-mm day$^{-1}$ (Lal 1976). On the other hand, conventional tillage with or without farmyard manure resulted in controlling only about 40% of the runoff loss.

Kilewe and Usaker (1984) also reported that tied ridges in combination with stover mulch conserve more water and lead to higher dry matter and grain yields of maize compared to minimum tillage. Maize stover effectively controlled runoff through increased surface water storage, which in turn increased the time available for infiltration and also minimized evaporation, surface sealing and crusting (Table 1). It is also reported that, when a combination of tied ridges and maize stover mulch were used a crop of maize was realized for a season of extremely low rainfall season of 171 mm whereas no yield was obtained from the conventional tillage plots with or without farmyard manure.
Table 1. Soil moisture and Runoff arising from 122.1 mm rainfall

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Soil water storage (mm)</th>
<th>Runoff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stover mulching</td>
<td>128.0</td>
<td>-</td>
</tr>
<tr>
<td>Tie-ridging</td>
<td>86.0</td>
<td>13.7</td>
</tr>
<tr>
<td>Farmyard manure</td>
<td>69.0</td>
<td>38.0</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>65.8</td>
<td>42.7</td>
</tr>
</tbody>
</table>

M'Arimi (1978) reported from a tillage study on an alfisols in Semi-arid Eastern Kenya, that at the end of the rainy season soil water content was highest under tied ridging (Table 1). This resulted in significantly higher dry matter and grain yields of maize.

Table 2. Effect of tillage methods on soil moisture content in Kenya

<table>
<thead>
<tr>
<th>Soil moisture content (% volume)</th>
<th>Minimum tillage</th>
<th>Conventional tillage</th>
<th>Tied Ridging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil depth (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-30</td>
<td>15.7</td>
<td>16.1</td>
<td>17.9</td>
</tr>
<tr>
<td>30-60</td>
<td>19.7</td>
<td>19.4</td>
<td>21.9</td>
</tr>
<tr>
<td>6-100</td>
<td>19.6</td>
<td>19.0</td>
<td>21.1</td>
</tr>
<tr>
<td>100-150</td>
<td>16.3</td>
<td>16.5</td>
<td>16.7</td>
</tr>
</tbody>
</table>

Source: (A’Arimi 1978)

Table 3. Effect of tillage methods on crop biomass (M'Arimi 1978).

<table>
<thead>
<tr>
<th>Period</th>
<th>Crop</th>
<th>Crop yield (kg ha(^{-1}))</th>
<th>Minimum tillage</th>
<th>Conventional tillage</th>
<th>Tied Ridging</th>
<th>SE(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long rains</td>
<td>Maize (total dry matter)</td>
<td>1068</td>
<td>1047</td>
<td>1105</td>
<td>±63</td>
<td></td>
</tr>
<tr>
<td>Short rains</td>
<td>Maize (total dry matter)</td>
<td>2040</td>
<td>1920</td>
<td>1760</td>
<td>±0.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize (grain)</td>
<td>337</td>
<td>221</td>
<td>513</td>
<td>±51</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) SE = Standard error

Njihia (1979), working on the same Alfisol in the same region, investigated the effects of tied ridges, conventional tillage, crop residue mulch, and farmyard manure on soil and water conservation. He found that maize stover effectively controlled runoff through increased surface storage, which in turn increased infiltration opportunity. Maize stover also minimized evaporation, surface sealing and crusting.

The high degree of efficiency of tie-ridges in controlling runoff and soil erosion was also demonstrated earlier in the late 1960s (by Periera et al 1967) in the highland areas of Kenya. The soil types were Kikuya red loam latosols on 10-12 percent slope under rainfall intensities often exceeding 2 inches per day and tied-ridges controlled runoff efficiently under
continuous arable farming. Keiome et al (1995) also reported that tied-ridges were effective means of controlling soil loss, runoff and improving crop production.

The effect of tied ridges in soil and water conservation is also influenced by degree of slope. For example, Fournier (1967) studied the effects of ridging on the control of soil erosion in different parts of Africa and concluded that the less steep the slope the greater the effect of ridges. In his studies, erosion was reduced seven-fold at Adispodoume, Ivory Coast on 7% slope, five-fold at Bouake (4% slope) and thirteen-fold at Safa, Senegal (1% slope). Runoff was reduced eight-fold at Bouake but was thirty seven times less at Safa. His conclusion was that ridging was extremely important for the control of runoff and soil erosion.

**Crop Yield Response to the Use of Water and Fertilizer Application and improved cultivates**

As in indicated earlier most Semi-arid areas of the Horn both water stresses and low soil fertility is the major constraints to successful crop production. These problems should be addressed simultaneously to increase crop production on sustainable basis. There are several experimental evidences, which indicate that, the combined use of soil water conservation through tied ridges and fertilizer application is more effective and resulted in sustainable increase crop production than the use of tied ridges or fertilizer use alone in Semi-arid areas of Africa.

For Example, in farmer managed trial in Burkina Faso; sorghum grain yield was higher with fertilizer and tied ridges than with either fertilizer or tied ridge alone (Nagy et. al,1990). In Zimbabwe sorghum yields were increased from 118 to 388 kg ha$^{-1}$.using 1.5-m tied ridges and 1071 kg ha$^{-1}$ when 50 kg ha$^{-1}$ N was applied to tied ridges during below average rainfall season (Nyakatawa 1996). Kidane (1999) also reported similar increase both grain and biomass yield increases of sorghum and maize when both tied ridges and fertilizer (N and P) were used together. There is also experimental evidence, which show that the combined use of these technologies is economically profitable under smallholder farmers in the semiarid areas (Sanders et. al 1996).

In the semi-arid areas of Ethiopia tied ridges have been found to be very efficient in storing the rain water and lead to substantial grain yield increase in some of the major dryland crops. This increase of the use of tied-ridges in yield of the major crops including maize, sorghum wheat and mung bean was obtained regardless the different planting patterns used, i.e. planting in the furrow or top of the ridge compared to the flat seed-bed (farmers practice) particularly in drier seasons (Table 1). The average grain yield increase ranges from 50 to > 100% compared to the traditional practice depending on soil type, slope, rainfall and the crop grown in some of the dryland areas, Kobbo and Melkassa (Table 4).
Table 4. Effect of tied ridges in situ water harvesting technology on grain yield of sorghum, mung bean, and maize in the Semi-arid areas of Ethiopia

<table>
<thead>
<tr>
<th>Soil conservation method</th>
<th>Average grain yield t ha(^{-1})</th>
<th>Kobo</th>
<th>Melkassa</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat planting (farmers practice)</td>
<td>1.6</td>
<td>0.80</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Tied Ridges planting on ridge</td>
<td>2.9</td>
<td>3.0</td>
<td>2.95</td>
<td></td>
</tr>
<tr>
<td>Mung bean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat planting (farmers practice)</td>
<td>0.4</td>
<td>-</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Tied Ridges planting on ridge</td>
<td>0.7</td>
<td>-</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat planting (farmers practice)</td>
<td>1.2</td>
<td>-</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Tied Ridges planting in furrow</td>
<td>2.7</td>
<td>-</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

Ridge height = 35 cm, Ridge spacing = 40 cm for mung bean, 75 cm for sorghum and maize, Ridges tied at 3 m interval. **Source:** (Kidane and Rezene 1989)

The response of crops to fertilizer application in dry areas is low compared to areas with optimum soil moisture. As a result, field trials were conducted to determine the effect of moisture conservation on the yield of maize and sorghum with and without fertilizer application in the Semi-arid areas of eastern Ethiopia.

The results of these experiments show that a substantial yield increase was obtained from the water conservation practices (Tables 1, 2 and 3). On the average yield increase of more than 50% was attributed to the water conservation practices under unfertilized conditions. Under fertilized conditions the overall yield increase was not relatively high (27%). However, in terms of absolute yield, the combination of moisture conservation and use of fertilizer gave the highest attainable yield. The results indicate that fertilizer application gives better yield than either fertilizer or moisture conservation alone.

Table 5. Mean grain yield (t ha\(^{-1}\)) of five improved maize varieties grown in the Semi-arid Eastern Ethiopia under unfertilized conditions

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Grain yield t ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without tied ridges</td>
</tr>
<tr>
<td>Alemaya composite</td>
<td>2.8</td>
</tr>
<tr>
<td>KCC</td>
<td>2.6</td>
</tr>
<tr>
<td>EaH-75</td>
<td>2.6</td>
</tr>
<tr>
<td>Ca 5</td>
<td>2.3</td>
</tr>
<tr>
<td>Bukri</td>
<td>2.0</td>
</tr>
<tr>
<td>Mean</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Source:** (Tamire Hawando et al 1984)

Table 6. Mean grain yield (t ha\(^{-1}\)) of five improved maize varieties grown in the Semi-arid eastern Ethiopia under fertilized conditions

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Grain yield t ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without tied ridges</td>
</tr>
<tr>
<td>Alemaya composite</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Itabari and coworkers (J.K Itabari, KARI unpublished data) compared the effect of tillage methods and fertilizer on yield and water use efficiency of sorghum in semi-arid Eastern Kenya and found that tie ridges, Zai pitting and fertilizer increased grain yield and water use efficiency.

Table 7. Effects of in situ water harvesting and fertilizer on grain yield and water-use efficiency of sorghum at Masinga in Kenya.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>ET (mm)</th>
<th>WUE (kg ha(^{-1}) mm(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Cultivation - fertilizer</td>
<td>190</td>
<td>299.0</td>
<td>0.64</td>
</tr>
<tr>
<td>Flat cultivation + fertilizer</td>
<td>380</td>
<td>299.2</td>
<td>1.27</td>
</tr>
<tr>
<td>Tied ridging - fertilizer</td>
<td>360</td>
<td>297.8</td>
<td>1.21</td>
</tr>
<tr>
<td>Tied ridging - fertilizer</td>
<td>820</td>
<td>300.5</td>
<td>2.73</td>
</tr>
<tr>
<td>Zai pitting - fertilizer</td>
<td>850</td>
<td>297.9</td>
<td>2.85</td>
</tr>
<tr>
<td>Zai pitting + fertilizer</td>
<td>1010</td>
<td>298.8</td>
<td>3.38</td>
</tr>
</tbody>
</table>

Source: (Itabari et al unpublished)

Sanders et al. (1990) at Burkina Faso reported that 5 to 56 % of the farms in the field trials would have lost their cash investments had they used inorganic fertilizer alone. However, the use of both tied ridges and fertilization resulted in no loss of money for farmers in five of the village sites in 1984. Moreover, the combined technologies resulted in a substantial decrease in the number of farmers losing money in both years across almost all of the sites, as compared with sites using fertilizer alone.

Soil water conservation should also be integrated with other improved agronomic practices so that the soil water retained could be used effectively. Weeds should be controlled to avoid completion and other improved crop practices used to improve water use efficiency (Table 8).
Table 8. Water Harvesting plus Improved Agronomic Practices on Maize Grain Yield

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcasting, no fertilizer, late weeding 6 weeks after emergence, flat planting (check)</td>
<td>1.309</td>
</tr>
<tr>
<td>no fertilizer, late weeding 6 weeks after emergence, flat planting</td>
<td>1.7 (37)</td>
</tr>
<tr>
<td>Late weeding 6 weeks after emergence, tied ridges</td>
<td>1.9 (46)</td>
</tr>
<tr>
<td>No fertilizer, early weeding 3 weeks after planting, tied ridges</td>
<td>2.3 (73)</td>
</tr>
<tr>
<td>Row planting, 40 N 46 P₂O₅, early weeding 3 weeks after planting, tied ridges</td>
<td>2.9 (117)</td>
</tr>
</tbody>
</table>

Numbers in parenthesis indicate percent of grain yield increase over the check, farmer’s practice.

Source: (Kidane and Abuhay 1997)

A comprehensive five-year experiment compared tillage methods on the Gerudud soils in western Sudan. First contour dikes at ten-meter intervals were constructed to slow runoff. Then within these intervals, four tillage treatments were evaluated. Ridges without tying increased sorghum yields over no till 134% from 299 to 701 kg/ha. Broad bed furrows (elevated production on 80 cm beds with 70 cm furrows) resulted in a yield increase over no till of 182% to 842 kg/ha. Chisel plowing resulted in an improvement over no till of 384% to 1, 448 kg/ha. (Table 9).

Table 9. Effect of different tillage methods yield (kg ha⁻¹) and other plant Characteristics of sorghum in Eloheid area, Kordofan State.

<table>
<thead>
<tr>
<th>Tillage Systems</th>
<th>Plant stand (000)</th>
<th>% of plants with heads</th>
<th>Grain yield (kg/ha)</th>
<th>Strawt/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel</td>
<td>100 (95%)</td>
<td>83</td>
<td>1448 (389%)</td>
<td>4.0 (167%)</td>
</tr>
<tr>
<td>Broad-bed Furrow</td>
<td>72 (68%)</td>
<td>70</td>
<td>842 (107%)</td>
<td>2.3 (74%)</td>
</tr>
<tr>
<td>Ridge Furrow</td>
<td>54 (480%)</td>
<td>54</td>
<td>701 (72%)</td>
<td>2.5 (60%)</td>
</tr>
<tr>
<td>No-till (control)</td>
<td>44 (42%)</td>
<td>47</td>
<td>299 (15%)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: The above data are averages of three years of data. The experiment was carried out over five years but two years of data were lost due to rats and grasshoppers. (The numbers in parentheses above are the percentage increases over the control.) Source: Omer and Elamin, 1997, p. 239.

These are impressive and even dramatic results clearly demonstrating the advantages of various water retention techniques on guarded soils. These results need to be aggressively demonstrated to farmers. Over time it will be necessary to combine the water retention treatments with inorganic fertilizers as the initial fertility advantage of opening up new soils is lost and the nutrients depleted.

These results illustrate the importance of first retaining the water by preparing the soil with any method that is going to slow down runoff. The chisel plowing facilitates infiltration of rainwater further by extending the depth to which the soil profile is broken compared to tie ridging and broad bed furrows. Hence, this treatment has the largest effect in increasing yields.
All three improved tillage systems not only resulted in grain yield increases but also in more straw, which is important as animal feed. Smallholder farming systems include both livestock and crops. The combination of the contouring at 10 m and the chiseling was also shown to be highly profitable by a factor of 2.3 times the return of the no till (Omer and Elamin, 1997, p. 239).

In the dry land research activities the following research gap in addressing the two major biophysical constrains water stress and low soil fertility in the dry land areas have been identified:

- Limited research on water harvesting
- Weak or limited research in water use efficiency studies involving different crops and cropping systems
- Limited research on agro-climatology to back up runoff control and water harvesting studies
- Weak research base on soil-water-plant relationship studies
- Fertility studies were not based on soil types, fertility status, climatic conditions and cropping systems
- Fertilizer studies were mainly conducted on research stations little verification or follow up on farmers’ field and therefore there were little feedback from end users
- Limited economic studies
- Lack of multi-disciplinary approach, which does not involve key researchers such as soil experts, agronomists, physiologists, economists and breeders plus extension workers and farmers
- Lack of integrated nutrient management studies.

**OUTSTANDING ISSUES**

The growing concerns for food security and sustainability of agricultural resources underline the urgency and importance of tackling drought and environmental degradation which remains as the most important factors threatening the survival of people in the dryland areas. Drought has been with us and there is evidence that the problem is becoming more serious. Decline in soil fertility and water is taking place at alarming rate.

In many parts of the dryland areas agricultural productivity is declining. Traditional land management systems that allowed soils to rejuvenate (e.g. following, transhumance live stock movement) are being abandoned as producers exploited more land to increase crop production. Land use systems that degrade the resource base must be replaced by sustainable systems. Improved soil water and nutrient management as suggested in this document are required to satisfy the greater food demands. Soil, water, nutrient management research should be holistic, multilocational, process oriented, relevant and sensitive to socio-economic, policy and environmental issues.

The drylands’ scarce resources need to be allocated in the first instance to alleviate the universal stresses (nutrients, water, crop genetic variability, and management practices). Long-term investments to arrest the land degradation processes are urgently needed.

**REFERENCES**


G. Water resource potential of Aba’ala area (Northern Afar), Ethiopia: A Prefeasibility study.

By KIFLE WOLDEAREGAY

Introduction

Water scarcity is a critical issue for many developing countries in general and for those in the arid to semi-arid areas of the world in particular. It has long been understood that an intensive water resource development can have a decisive role in the economic and social development of a country and in alleviating drought problems. Alleviating food scarcity related to drought and famine through sustainable agriculture and environmental rehabilitation requires a short and long-term planning of water resource of an area.

In general, the Afar region is among the areas, which have been affected by severe drought and famine for the last years. Even though there are some wells and springs, one of the critical problems in the study area is scarcity of water for livestock, irrigation, water supply and domestic use. Present supply of water for the small towns in Afar region in general and the Aba’ala area in particular is from wells, springs, and rivers. As indicated by Yirgalem (1998), the people living in most parts of Aba’ala area have to go up to 10 Km to fetch water for domestic uses and 4 to 7 days travel to get water for livestock in the dry season.

The rapid growth of population in the small towns and rural areas has tremendously raised the water demand for various purposes. This consequently resulted in acute water shortage in the Aba’ala area. The agro-pastoral societies in the study area depend highly on the floodwater coming from the highlands to produce dryland crops, for livestock and for drinking (Diress, et. al., 1999).

Today’s agricultural production in the Aba’ala area is mostly dependent on seasonal rainfall, which in turn is characterized by its erratic behavior. Although no meaningful irrigation scheme exists except for few hectarage of traditional irrigation, the potential for irrigated agriculture in Aba’ala area is subsequently large.

Except for some reconnaissance survey, the Aba’ala area is not well studied for its water resource potential. As mentioned by Yirgalem Asegid (1999), the rainfall is not reliable in the Aba’ala areas, and he indicated the need for storage and utilization of ephemeral flows coming from the highlands of Tigray (at a larger scale). Tesfaye Chernet (1993), mentioned that the rainfall intensity of areas with arid type of climate is usually high (with intensity more than 100mm/day in the lowlands) leading to high runoff volume, and the intensity of rainfall in the highlands is mostly less than 50mm/day.

The domestic and non-domestic water requirements dictate the necessity to study the water resource potential (surface and groundwater) of the Aba’ala area. The main objectives of this study is, therefore to assess the hydrogeology of the study area, to study the surface water and groundwater resource potential of the study area, to determine options for water resource development, and to evaluate the engineering and environmental difficulties that should be considered in the study area.

1 Mekelle University, P.O.Box 231, Mekelle, Ethiopia; Tel. 251-04-402270/407500/400512; Fax: 251-04-400793; e-mail: kiflewold@yahoo.com
The Study Area

**Location.** The study area is located between 13°15’N and 13°30’N latitudes, and 39°35’E and 39°55’E longitudes, covering parts of eastern Tigray and Aba’ala plain area.

**Climate.** The fact that the study area includes both the highlands of Tigray and the lowlands of the Aba’ala plain results in high range of climatic differences in the study area. The moisture conditions vary from humid in the highlands to arid in the lowlands of the Aba’ala plain. The temperature also varies from relatively cold in the highlands of Tigray (annual average temperature between 15°C and 20°C) to hot conditions (annual average temperature between 25°C and 30°C) in the Aba’ala plain.

**Hydrology.** According to the hydro meteorological data of the Aba’ala station (Ethiopian hydrometeorological data of the years 1972-1999), the study area receives a bimodal rainfall ranging from 315 to 450 mm/year (with annual average rainfall of 340 mm) with the major amount of rainfall occurring within a short duration (three to four hours and heavy storms in few days) followed by droughts in the critical hours of crop growth. According to the hydro meteorological data of Quiha station (Ethiopian hydrometeorological data of the years 1972-1999), the highlands of Tigray receive annual average rainfall that varies from 450 to 750mm (with annual average rainfall of 480mm).

As the evapotranspiration potential of an area is found to vary with altitude and location, the Ethiopian hydrometeorological data of the years 1972–1999 indicates that high evapotranspiration potential values known in the lowlands of Aba’ala plain ranges 1400 to 1700mm/year (average value of 1500mm/year), and the values in the highlands ranges from 800 to 1150mm/year (with average value 950mm/year).

**Geomorphology and topography.** The average elevation of the Aba’ala plain is about 1500m above sea level with a range of 1300-1700m above sea level. The western escarpment of the rift valley is characterized by rolling hills with steep sloped mountains (with elevation range of 2000 - 2300 m above seal level) and with steep slopes adjoining to the flood plain. Very steep fault scarps with tremendous altitude contrasts of up to 1000m characterize the borders of the rift valley. The terrain is generally characterized by a topography, which ranges from flat at the Aba’ala plain to steep slopes at the escarpment.
Materials and methods used

a) Materials
The materials and equipment used in this research include: Aerial photographs and Topographic maps at scales 1:50000, Tracing paper and millimeter paper, Stereoscope, Geological compass, Geological hammer, Global Positioning System, Dipper (for water level measurement), Electrical Conductivity Meter, pH meter, Atomic Absorption Spectrometry, and Current meter.

b) Methods
To study the water resource potential of Aba’ala area (at pre-feasibility level), the following methods and study approaches were employed: (a) Reviewing previous studies, which included collection of data (from literatures, existing reports, maps and other relevant data), (b) Evaluating the hydrology and general climatic condition of the study area (from existing data), (c) Interpretation of aerial photographs and topographical maps of the study area (at 1:50 000 scale) for identifying the geological structures, types of rocks/soils, and for characterizing the catchment area, (d) Conducting geological, geomorphological, and hydrogeological field survey, (e) Assessing the surface water and groundwater condition of the study area, (f) Interpretation of the collected data and evaluation of the water resource potential of the area, which included integration of the hydrological, geological, geomorphological, and hydrogeological data.

Results of the study

a) General geology of the study area
The major rock and soil types mapped in the catchment of the study area, from the oldest to the youngest, are Glacial Tillite, Adigrat Sandstone, Antalo Limestone, Agula Shale, and Alluvial soils.

Glacial Tillite. It is represented by shale (silt and clay) unit with drop stones. The Glacial Tillite is overlain by the Adigrat Sandstone. It is grey and purple silt, very well laminated and interbedded with thin beds of silty limestone.

Adigrat Sandstone. It is represented by medium to coarse grain, red to brown sandstone with some shale and laterite bands. It is friable in places where it is iron cemented but massive in areas where it is cemented with silica.

Antalo Limestone. This unit is characterized by yellow to white fossiliferous limestones and marls. The lower part is sandy, hard limestone (well jointed) while the upper part has large proportions of shales and marls. The Antalo Limestones show karstification and travertine deposits with noticeable cavities and small caves.

Agula Shale. This unit is characterized by grey, green and black shale with marl and clay. It is interlaminated with finely crystalline black limestone containing disseminated pyrite. It has 10 to 20% limestone beds, with the rest either of the jointed hard or soft powdery shales. Some gypsum beds are also noticed.

Alluvial Soils. Two major types of alluvial sediments are recognized: those spread out in alluvial plains, and those that occur as thin strips along streams. Large stretches of the flat land in the Aba’ala plain is dominated by the alluvial soils, which are mostly derived from the
highlands of Tigray, where large amounts of sediments are transported as a result of the pluvial process. The material distribution in the alluvial flat plains of Aba’ala area is represented by coarsening up the slopes.

**Geological structures.** Different types of geological structures characterize the study area, among which are faults, lineaments, joints and bedding planes. The study area is dominated by NE – SW trending major fault systems with nearly E-W trending conjugate fault systems. The study area includes the western escarpment of the Ethiopian rift valley, and has created a large altitude difference between the highlands of Tigray and the lowlands of Aba’ala areas.

**b) Hydrogeological characteristics of the rocks and soils in the study area**

**Glacial Tillite**

*Permeability and infiltration capacity.* It is dominated by fine materials and is generally considered as a rock with low permeability and low infiltration capacity. It acts as an aquiclude, manifested by the presence of springs at the contact with the overlying rock, beneath the Adigrat Sandstone.

*Aquifer Characteristics.* Since the unit is having low porosity and low permeability, it could be categorized as a rock with poor aquifer characteristics for groundwater development.

**Adigrat sandstone**

*Permeability and infiltration capacity.* It is generally categorized as a unit with medium to high permeability and high infiltration capacity. In rare cases, these rocks have low permeability as a result of cementation. The Adigrat sandstones are considered as good recharge zones to the regional groundwater systems, as these rocks are mountain (ridge) forming.

*Aquifer Characteristics.* Though these rocks are represented by high porosity and high permeability, their geomorphological expression dictates their suitability as recharge zones to the regional groundwater system. These ridge forming rocks are categorized as poor aquifers for groundwater development.

**Antalo Limestone**

*Permeability and infiltration capacity.* The Antalo limestone is generally characterized by medium to high permeability and moderate infiltration capacity. Its geomorphological expression favours recharges to the regional groundwater systems.

*Aquifer Characteristics.* Though the permeability of these rocks is high, the geomorphological expression of the areas underlain by the Antalo limestone is suitable for recharging groundwater systems. The unit is generally classified as a poor aquifer for groundwater development. In many places, cold springs emerge at the contact of the limestone beds with the intercalating shales and marls. A few of these springs have large discharges (greater than 10 lit/sec in the wet seasons), but most have discharges 2 – 8 lit/sec in wet seasons and no discharges in dry seasons.

**Agula Shale**

*Permeability and infiltration capacity.* This unit is represented by low permeability and low to medium infiltration capacity. Temporary marshes are common in the flat lying areas that are underlain by the Agula Shale.
Aquifer Characteristics. Due to their low permeability, these rocks contain shallow groundwater providing mostly low yield. This formation is characterized by large numbers of springs, which issue at the contact of overlying limestone beds with shale or with intrusive igneous rocks (mainly dolerites and diorites).

Alluvial Soils
Permeability and infiltration capacity. The alluvial soils in the study area have variable permeability and infiltration capacity, which ranges from low to high. In the plains of the Aba’ala area, fine and coarse-grained sediments are characteristic. Those materials with low to moderate permeability (silt and clay) have low to moderate infiltration capacity while those materials with high permeability (sand and gravel) have high infiltration capacity. Based on field observation, the alluvial soils located near the escarpments have relatively coarse sediments of high permeability while those soils located at the central parts of the Aba’ala plains have low permeability.

Aquifer Characteristics. Alluvial soils along streams are some of the most common shallow groundwater aquifers, which can be tapped by larger diameter hand-dug wells. In most cases, they also have chemically fresh groundwater. The productivity of these soils varies from place to place depending on their grain size, sorting and thickness. Except for their thickness limitations and lateral extent, these formations are categorized as good aquifers.

Those alluvial soils in the plains of the Aba’ala area have variable aquifer characteristics ranging from poor to good. Though the materials near the escarpments have higher permeability, data from the existing boreholes indicate that the soils have poor groundwater yield. For groundwater development in the alluvial soils, the distribution of the alluvial materials (their vertical and lateral extent) and the surface water and/or groundwater recharge potential of the area should be determined.

Geological Structures
Permeability and infiltration capacity. The fault zones in the soft materials like Glacial Tillites and Agula Shales are mostly dominated by crushed materials and result in zones with low permeability. On the other hand, geological structures in hard rocks (Adigrat Sandstone, Antalo Limestone, and Volcanic rocks) are mostly dominated by fractured rocks and result in high permeability zones.

Aquifer Characteristics. Depending on the types of rocks and other recent geological processes, such structures could create zones of low, medium or high productivity for groundwater development. The geological structures in the catchments of the Aba’ala plain are enhancing recharge to the plains of Aba’ala. The geological structures underlying the soils of the Aba’ala plain, as observed from lineament analysis, need further verification in terms of their potential for groundwater development.

c) Water resource potential of the study area

Rocks of the Antalo Limestone and Agula Shale mainly characterize the highlands in the western escarpment of the Aba’ala area. The Antalo limestone is cliff forming and is underlying the Agula Shale.
The highlands of Tigray, is therefore, the main recharge (surface and sub-surface) zone to the Aba’ala area. The Aba’ala plain is surrounded by hills and ridges and water flows towards the plains either as surface runoff and/or as a base flow. Data from previous boreholes indicate that the Aba’ala area is having moderate to high productivity.

The only two perennial rivers contributing to the recharge of the Aba’ala plain (as springs and rivers) are the Aba’ala and Shugala rivers. As a result of base flow, the Aba’ala river is estimated to have a lean flow of about 1m$^3$/min. in the dry period and a flow of about 120m$^3$/min. during the rainy season. The average flow of the Aba’ala River, due to base flow, is estimated to be 3m$^3$/min.

On the other hand, the Shugala river is estimated to have a lean flow of about 3m$^3$/min. during the dry period and a flow of about 200m$^3$/min., as a result of base flow, during the rainy season. The average flow of the Shugala River is estimated to be about 5m$^3$/min.

For the catchments of Aba’ala and Shugala rivers, a mean annual excess rainfall of 420mm is considered. The mean annual excess rainfall for the sub-catchment in the lowlands of the study area, contributing to the surface runoff into the Aba’ala plain is considered to be 310mm. The total catchment area contributing to the surface water flow into the Aba’ala plain is about 254 Km$^2$. The catchment areas for the Aba’ala and Shugala River are about 75Km$^2$ and 122.5Km$^2$ respectively. The sub-catchments within the lowlands of the study area contributing to surface runoff to the Aba’ala plain are 61Km$^2$.

**Surface water resource potential**

The total surface water resource potential of the Aba’ala area is estimated to be the sum of three components: (1) Surface Runoff from Mountains/Plateau, (2) Surface water from springs flowing from the valleys, and (3) Surface water from direct precipitation.
The *Surface Water Inflow (SWI)* to the plain is, therefore, given by the relation:

\[
SWI = Km \cdot Pm \cdot Am + \sum Qsp \cdot T + Pv \cdot Av
\]

Where,

- \( SWI \) = Surface Water Inflow;
- \( Km \cdot Pm \cdot Am \) = Surface Runoff from Mountains/Plateau;
- \( \sum Qsp \cdot T \) = Sum of yearly discharge of surface water from springs and rivers flowing into the Aba'ala plain (m³/year);
- \( Pv \cdot Av \) = Surface water from direct precipitation in the plain; \( Km \) = Coefficient of runoff for mountains and plateau;
- \( Pm \) = Average Precipitation in the Mountains and Plateau (m);
- \( Am \) = Area of Mountain and Plateau (m²); \( \Sigma Qsp \) = Sum of daily discharge of springs and rivers (due to base flow) into the valley (m³/day);
- \( T = 365 \) days; \( Pv \) = Average Precipitation in the Valley Plain Area (m); \( Av \) = Area of Valley fill (m²).

### Surface water recharge to the Aba’ala plain

<table>
<thead>
<tr>
<th>Catchments</th>
<th>Parameters</th>
<th>Surface water recharge (Mm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Km</td>
<td>Pm (m)</td>
</tr>
<tr>
<td>Aba’ala</td>
<td>0.6</td>
<td>0.42</td>
</tr>
<tr>
<td>Shugala</td>
<td>0.6</td>
<td>0.42</td>
</tr>
<tr>
<td>Other areas except the plain</td>
<td>0.5</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>Total surface water recharged into the Alluvial plain</strong></td>
<td><strong>63.5</strong></td>
<td></td>
</tr>
</tbody>
</table>

(Table 1: Surface water recharge to Aba’ala plain from the surrounding catchments)

*For Aba’ala, river: \( \Sigma Qsp = (3m³/minute) \cdot 60 \) minutes \( \cdot 24 \) hours) = 4320m³/day. For Shugala river: \( \Sigma Qsp = (5m³/minute) \cdot 60 \) minutes \( \cdot 24 \) hours) = 7200 m³/day, and \( T = 365 \) days.*

### Surface water recharge from direct precipitation

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Parameters</th>
<th>Water resource potential (M m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ab’ala plain</td>
<td>Av (m²)</td>
<td>Pm (m)</td>
</tr>
</tbody>
</table>

(Table 2: Surface water recharge from the direct precipitation in the Aba’ala plain).

*The total surface water recharge to the Aba’ala plain (from surrounding catchments and direct precipitation in the plain) is therefore, estimated to be 63.5 M m³ + 46.8 M m³ = 110.3 M m³.*
Groundwater resource potential

Though it is difficult to determine the groundwater reserve in the Aba’ala Plain, at pre-feasibility level, the yearly groundwater recharge potential is estimated using the following formula:

\[ GWR = \delta s (Km*Pm*Am) + \delta s(\Sigma Qsp * T) + \delta v(Pv*Av) \]

Where, GWR = Ground Water Recharge.  
\( \delta s*(Km*Pm*Am) \) = Recharge from Surface Runoff from Mountains/Plateau.  
\( \delta s*(\Sigma Qsp * T) \) = Recharge from Surface water from Springs and Rivers flowing from the valleys.  
\( \delta v*(Pv*Av) \) = Recharge from Surface water from direct precipitation in the plain.  
\( \delta s \) = Coefficient of groundwater recharge from runoff.  
\( \delta v \) = Coefficient of groundwater recharge of the valley from precipitation of the valley plain area.

The Coefficient of groundwater recharge from runoff (\( \delta s \)) is estimated using the following formula:  
\[ \delta s = (CR - 20)/(Cgw - 20) \]

Where,  
CR = Total Dissolved Solids (TDS) (mg/lit) of river water, and  
Cgw = Total Dissolved Solids (mg/lit) of groundwater.

Results of chemical analysis, average values, for Total Dissolved Solids of water samples taken from groundwater and river water (three samples from each) is found to be 1400mg/lit and 800mg/lit respectively, and the factor \( \delta s \) is calculated to be 0.565. The coefficient of groundwater recharge (\( \delta v \)) is estimated to be 0.15. Based on these parameters, the groundwater recharge potential of the Aba’ala plain is indicated in the following table.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groundwater recharge(^2) [Mm(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta s )</td>
<td>0.565 ( \delta v )</td>
</tr>
<tr>
<td>( \delta s*(Km<em>Pm</em>Am) )</td>
<td>33.49 ( \delta s*(\Sigma Qsp*T) )</td>
</tr>
</tbody>
</table>

(\textit{Table 3: Groundwater recharge potential of the Aba’ala plain})

d) Options for water resource development

This pre-feasibility study indicates that the Aba’ala area possesses good water resource potential, which could be used for various purposes. Different methods could be used to develop the surface water and groundwater resource potential of the study area.

\(^2\) Groundwater recharge (GWR) = \( \delta s (Km*Pm*Am) + \delta s(\Sigma Qsp*T) + \delta v(Pv*Av) = 0.565(18.9Mm\(^3\) + 30.87 m\(^3\) + 9.5 Mm\(^3\)) + 0.565(1.6 Mm\(^3\) + 2.68Mm\(^3\)) + 0.15*46.8Mm\(^3\) = 42.86 M m\(^3\)/year].
Surface water resource development

The two rivers, Aba’ala and Shugala are perennial and supply water to the alluvial soils of the Aba’ala plain. The surface water resource potential of the Aba’ala area could be developed applying different methods of water resource management, among which are the following:

a) **Cisterns.** Surface water could be harvested by constructing Cisterns but the construction of such structures should be done in areas where there is relatively low sedimentation hazard. Except for sedimentation problems, which need further consideration, Cisterns are among the best alternative methods of surface water resource development in the plains of Aba’ala area.

b) **River Diversions.** Though diversions could be applied for surface water development in the Aba’ala area, the high surface runoff and flood in the area could cause problems to the safety and stability of the structures. The maintenance cost could be very high in this regard. The use of diversions for surface water resource development should be considered as the least priority.

c) **Dams.** The construction of dams for surface water harvesting in the Aba’ala area could be associated with different problems: sedimentation hazard (the major problem), foundation problems because of the loose alluvial soils, and slope stability problems of the banks of the rivers and the escarpments. Due to these and related problems, dam construction in the Aba’ala area is given least priority. The construction of dams could be used as alternative methods of surface water harvesting in the central parts of the Aba’ala plains, as the sedimentation problem, slope instability, and other hazards are relatively minimum.

d) **Sub-surface reservoirs.** Sub-surface reservoirs (aquifers) might be utilized to store surplus water at no or minimum cost and conserve it by reducing evaporation losses. This will need identification of areas with good sub-surface storage potential and evaluation of other hydrogeological conditions of the area so that integrated water resource development can be thought and implemented.

e) **Storage tanks.** Storage tanks and series of check dams, with storage ponds and sand filled dams can be used for domestic uses and livestock in the Aba’ala plains.

Groundwater resource development

The study area has good groundwater recharge potential. Water wells could be used to develop the groundwater resource potential of the Aba’ala plain. The central part of the Aba’ala plain is the most potential zone for groundwater resource development. Integrated method of surface and groundwater development is also another option that could be adopted for optimum utilization of the water resource in the area.

e) **Engineering and Environmental problems of the study area**

In the Aba’ala area, the following engineering and environmental problems are the most critical issues, which need consideration in planning water resource development in the study area:
a) Sedimentation hazard. The foot of the escarpments of the Aba’ala area is an active zone of sedimentation (deposition) and hence construction of hydraulic structures and other engineering structures could be affected by such hazards.

b) Erosion hazard. The soils in the Aba’ala plain are dominated by clay, silt, sand, and gravel materials. The fine materials are susceptible to surface and sub-surface erosion (as the area is characterized by dynamic water movement) and this needs consideration in the planning of water resource development in the area.

c) Earthquake hazard. The Aba’ala area is within the main Ethiopian rift valley and the effect of earthquake on the stability and safety of engineering structures is expected to be high in the study area.

d) Flood hazard. Flooding is one of the problems in the Aba’ala area and is associated with the runoff from the highlands. This problem could cause critical problems not only for water resource development in the area but also for planning the Aba’ala town.

e) Slope instability. Most of the slopes at the escarpments in the Aba’ala area are potentially unstable. These unstable slopes could cause problems for the future construction of surface hydraulic structures near the escarpments and for other infrastructural development in the study area.

CONCLUSION AND RECOMMENDATION

Conclusion

From this study, the following points are concluded:
1. The Aba’ala plain has annual surface water recharge potential, which is estimated to be about $110.3 \text{Mm}^3$ [from rivers, springs, and direct precipitation].
2. The annual groundwater recharge potential of the Aba’ala plain is estimated to be about $42.9 \text{Mm}^3$, [including recharges from springs, rivers, and direct precipitation].
3. The thickness of the alluvial soils is estimated to vary from few meters (near the escarpments and near the zones where rocks are exposed) to about 100m (at the central parts of the alluvial plain). Lithological logs of three boreholes drilled to depths of 45m, 65m, and 70m in the plains of Aba’ala show that the materials along the borehole profile are represented by alluvial soils.
4. Data on the static water level of the previously existing wells shows that the depth of the static water level varies from 40m to 65m (below surface) depending on the site condition. The wells at the central part of the alluvial plain have relatively shallow static water level as compared to the wells near the escarpments (near the Aba’ala town).
5. For optimum utilization of the surface and groundwater resource potential of the area, integrated method of surface and groundwater resource development is one of the possible options in the Aba’ala plain.

Recommendation

From this study the following points are recommended:
1. This study was done at pre-feasibility level and it is necessary to evaluate the groundwater reserve in the Aba’ala plain before applying large-scale water resource development.
2. To evaluate the surface water resource potential of the area, detailed investigation on the hydrological condition and evaluation of the discharge of rivers is required.
3. Since the study area is represented by difficult ground conditions, detailed evaluation and analysis of the engineering problems should be done before the design and construction of engineering structures in the area.
4. Since sub-surface reservoirs (aquifers) could be utilized to store surplus water at minimum cost and help to conserve water by reducing evaporation losses, it is highly recommend to identify areas with good sub-surface storage potential and to evaluate the detailed environmental condition of the area so that integrated water resource development can be thought and implemented.
5. Though the pre-feasibility study shows that the hydrology and hydrogeology of the study area is favourable for conjunctive use of the water resource, detailed investigation of the water resource potential, hydrogeological characteristics of the soils and rocks, and the cost of development is recommended.
6. For sustainable natural resource management in the study area and in other potential areas of Aba’ala Woreda, detailed and integrated basin study is highly recommended.

ACKNOWLEDGEMENT

The author would like to thank the Dryland Husbandry Project (DHP) for funding the study. The support provided by Mr. Diress Tsegaye, Project Coordinator, is highly commended as he took the initiative to study the water resource potential of the area. The author is grateful for the support provided by Mekelle University.

REFERENCES


Mezmure Hailemeskel (1983). Hydrogeology of the Southern Afar and adjacent areas (Ethiopia) supported by Interpretation of Landsat Imagery. ITC, The Netherlands.


**Abstract**

In an effort to address the problems of recurrent drought, famine and food insecurity, attempts are made to harvest run-off water in micro dams for use in small scale irrigation schemes. It is recognized that construction of micro dams with proper irrigation and agronomic services and vital support for proper watershed management will result in microclimatic and environmental changes with positive impact on sustained productivity. Notwithstanding the importance of these positive impacts on increased agricultural productivity and improved community welfare, the potential negative impacts of water sources development require constant assessment, monitoring and evaluating on the environmental changes. A study was carried out on 14 micro dams on different ecological zones in Tigray to monitor the changes in socio-economic condition and in salinity on the harvested water and the irrigated soils. Farmers living in the vicinity of the micro dams are aware about the problem of land degradation, understand the effect of sedimentation on the reduced capacity of the dams to store water to be used for irrigation and were willing to invest on sustainable land management systems. Dams at lower altitudes in general exhibited statistically significant higher salinity levels as compared to dams situated at higher altitudes. Salinity of the harvested water varied with season during the dry season where the water volume is low, salinity levels increased.

Salt content of the irrigated fields nearer to water outlets was significantly higher than on fields at the tail end of the schemes. However no significant yield reduction was observed on onion and maize planted on soils with different salinity classes. Major cause for the changes on the increase in salinity of the land is attributed to mismanagement of the distribution of water and for the absence of drainage to reclaim excess water from the irrigated fields.

Health studies conducted on 7000 children indicate that villages near to micro dams have increased risk of malaria. Community participation in draining excess water and bed nets have reduced the risk.

**Introduction**

Tigray’s agriculture is based on plough cultivation for predominantly cereal production. The level of subsistence, except for periods of good rains, has declined radically during the past decades, with almost everything produced being consumed at the farm household level. Tigray’s agriculture depends entirely on the availability of rainfall; because of this, agricultural production is erratic, showing high temporal and special variability in yield.
Agricultural production operates with very low modern external inputs, resulting in depletion of soil nutrients. Increasing loss of top soil through erosion has exposed the region to serious environmental and ecological imbalances (Yibabe and Mitiku, 1997). The agrarian system has superimposed on it a fast accelerating population growth and a high arable land to population density, which far exceeds the carrying capacity of the land. Recurrent drought, pest infestation, and unfavourable climatic factors contribute to poor production performance. The inevitable result of these prevailing conditions has been a gradual and steady decline in soil and labour productivity.

In an effort to address the problems of recurrent drought, famine, and food insecurity, the government of Ethiopia had given priority to the implementation of a major rural development programme called “Sustainable Agriculture and Environmental Rehabilitation in Tigray (SAERT)”. The principal objectives of SAERT are to change the agrarian system of Tigray to one geared to widespread irrigation, to minimize dependence on rain-fed systems, and to gradually attain self-sufficiency in food production (SAERT, 1994). A major means of rehabilitating and reconstructing the natural resources base will be water resources development. That, water is the single most critical variable in Tigray’s agricultural production, has been long recognized. The volume of annual run-off from the basins draining Tigray is estimated to be nine billion cubic meters (SAERT, 1994).

Through the SEART programme, 500 micro dams were to be built, 200,000 hectares of agricultural and agro forestry lands terraced, and millions of seedlings planted as part of the necessary task of increasing food production, afforestation and improving general soil conservation and farm management practices.

It is recognized that construction of micro dams with proper irrigation and agronomic services and vital support for proper watershed management will result in microclimatic and environmental changes with positive impact. Change from rain-fed agriculture to small-scale irrigation through the use of run-off harvesting in micro dams will increase agricultural productivity. Irrigation will enable production of 4.5 tones more wheat and an additional 16 tones of potatoes per year per hectare of irrigated land (SAERT, 1994). If this potential can be achieved, the implications are enormous. Irrigating 50,000 hectares will result in production of 200,000 tones of grain equivalent, enough to feed and extra 930,000 people, who without the project would almost surely be dependent on food aid.

Additional positive impacts of the project are anticipated. Following 10 years of SAERT project interventions, it is expected that degraded areas will show signs of recovery. The millions of planted seedlings will result in soil protection and increased forest products. Availability of forage for livestock will improve substantially. With storage and utilization of seasonal surface run-off water, many prevailing social and economic problems should be alleviated communities will decrease women’s burdensome and time consuming responsibilities for fetching water and thus improve women’s and children’s welfare.

Introduction of fishery development could improve the diet of the community and serve as a supplementary source of income to families.

Notwithstanding the importance of these positive impacts on increased agricultural productivity and improved community welfare, the potential negative impacts of water resources development require constant assessment, monitoring, and evaluation. Introducing micro dams for irrigation in semi-arid and arid areas has the potential to increase land
degradation through salinization of the scarce arable land in the potentially irrigable micro dam sites. If improperly designed, drainage systems will intensify the degree of salinization.

The impact of prolonged available surface water in newly developed irrigation areas is on water and vector-borne diseases. Areas that were periodically affected by malaria and schistosomiasis are exposed to continued year round attack. Peak transmission that coincides with seasonal onset of the big and small rains in the region will be prolonged to other months, which were relatively free of malaria. Mosquitoes and snails will have ideal environmental situation to breed, subsequently prolonging the transmission period.

A study to document the effect of water harvesting in micro dams on the socio-economic condition of the community, the salinity of the irrigated lands and incidence of malaria and schistosomiasis was undertaken in 14 micro dam schemes that were constructed by SAERT and prior to the establishment of SAERT.

**METHODS AND MATERIALS**

**Socio-economic studies**

To understand the perceptions made by the community on the problems of land degradation a survey was conducted through structured questionnaires including focused group discussions. Fourteen micro dam schemes (Map 1) were used to undertake the study. All households with irrigated land and ten percent of households without irrigated land, in total 783 households living in two paired (one nearer and another far away) villages around 14 micro dam schemes were included in the study.

**Soil and Water Studies**

Surface soil samples were collected from the irrigated lands along a transect according to the FAO (1988) guideline including fields nearer and far away from the reservoir. In all cases fields at the head and tail (fields irrigated first and last) end of the scheme were included in the sampling frame. In the laboratory samples were air dried and sieved to pass 2 mm sieves. Electrical conductivity and pH measurements were made on 1:2.5 water) extracts.

For the water study, samples were collected from the reservoirs, seepage water, irrigation canal and drainage ditches. Moreover samples were also taken in June, August, October and January to coincide with the dry, wet, and land preparation and beginning of irrigation periods.

Samples were collected in one liter plastic bottles labeled and transported to the laboratory and electrical conductivity and pH measurements were made.

**Health Studies**

Seven thousand children living in villages near to dams (<2 km radius) and away from dams (>2 km) were monitored for incidence of malaria and schistosomiasis. The survey was conducted for three years every month.

**RESULTS AND DISCUSSIONS**
Socio-economic studies

Out of the total households interviewed with regard to seriousness of land degradation only 20 percent said that the problem is very low (Table 1). However households with irrigated land consider land degradation to be less serious owing to the fact the lands are situated in relatively flat areas (Table 4). On the other hand land degradation is considered severe on farms, which are situated on sloppy and non-irrigated areas. The cause for land degradation was ascribed to soil erosion caused by over cultivation, deforestation and population pressure. Soil type, slope degree and slope shape were considered as important land related factors that increased land degradation (Table 2). Responding to whether investing in soil and water conservation activities would secure and ownership 82 percent of the farmers felt secured when they make any form of investment in soil and other conservation activities. Investment is viewed by farmers in the form of participation in terrace building, maintenance of broken bunds, removing stones and planting trees and grasses on bunds as an individual effort rather than through campaigns. This view was expressed by farmers in other parts of Ethiopia (Dessalegn, 1998; Yeraswork, 1995; Alemneh, 1990). Traditionally farmers in Konso, Wollo and Tigray developed land management systems that are sustainable and compatible to the resource endowment of the locality (Fetein et al, 1998).

In addition to the above all households engage in land improvement activities including destining, leveling, draining, derricking and combination of these (Table 5). However households with irrigated plots remove stones to obtain more volume of soil with out much concern for leveling and derricking. Households with non-irrigated fields depending on the nature of the terrain are forced to engage in derricking, leveling, and draining low laying fields exhibiting impeded drainage. Invariably all interviewed farmers indicate salinity not to be a problem at present. This is because the lands are put into irrigation just recently. About 72 percent of the households interviewed feel that they are expected by their community to participate in undertaking soil and water conservation activities. Farmers (91 percent) feel encouraged to make decisions to invest in soil and water conservation activities on their own land irrespective of whether their neighbours are engaged in similar activities. Fifty nine percent of the households indicate that extension agents have contacted them with regard to soil and water conservation. In spite of this only 52 percent received government support to invest on soil and water conservation activities. Even if support was not provided by the government 62 percent indicated that they would still continue to invest on conserving soil and water because they feel that plots of land which are conserved produce higher yield of crop and grass and will secure land tenure. However lack of working capital and shortage of land were considered as major limiting factors for investing in the activities (Table 6). Households with non-irrigated land indicated shortage of draught animals constraining agricultural productivity. Moreover households with irrigated fields consider inadequacy of rainfall as a problem as opposed to the non-irrigated holders. This is because micro dams will be holding less water if rainfall is low, thereby reducing the size of irrigated land. Asked on how they would invest additional income, 71 percent preferred to invest in agricultural activities. Government supports for soil and water conservation is viewed by the householders with irrigated land to be primarily in providing credit and farm inputs whereas farmers with out irrigated fields preferred the intervention to focus mainly for extension activities (Table 7).

Access to credit facilities is available to 55 percent of the respondents and is obtained from banks, service co-operatives (farmers associations), traders, relatives and friends, and others
which credit is obtained from different sources (Tables 3). Both categories consider using credit as working capital for agriculture (35 percent), working capital for non-farm activities (7 percent), investment in non-agriculture activities (34 percent) and for a combination of the above activities (24 percent). Invariably none of the households use credit for household consumption (Table 8). The major source of credit is borrowing from friends and relatives followed by credit from Farmers Associations. A few number of households obtained credit services from banks and from traders. In terms of diversity of credit services, most households indicate that they borrowed from a combination of different sources (including the local monks) as available in good time. Repayment is either in cash or in kind. Banks, NGOs, and governmental organizations require payments in cash including an annual interest of 5-15 percent. Friends and relatives are repaid in combination of both but with higher interest rate. Most prefer to get credit from NGOs because of ease of access and timeliness.

The introduction of irrigation schemes assumes intensive use of labor for farm activities, however households with irrigated fields use only 28 percent external labor, which is not significantly higher than the dry land farmers (27 percent). Both systems rely on available family labor. Family labor is considered contribution of labor to farm activities from members of the immediate family (husband, wife and children).

Forty two percent of households sell livestock to purchase items for consumption at a household level, whereas the remaining 58 percent sell their livestock to pay taxes, repayment of debt, medical expenses and school fees. Farmers tend to sell poultry and poultry products, small ruminants (sheep and goats), cattle and honey to generate cash for the different forms of payments indicated above.

To replace livestock 62 percent of the farmers buy their livestock from extension services and very few purchase from other farmers and from middlemen.

**Soil and Water Studies**

The location of the studied micro dams is shown on Map 1. Soil salinity levels in the irrigated areas vary according to altitude and the sampling site (Table 9). Soils found at lower altitudes in general have higher salinity level. The lowest was recorded at Felege representing higher altitudes and the highest at May Abakat representing the lower altitudes. The pH values range from 5.79-8.51 and the lowest and highest values were observed in Meskebet and GumSellassa respectively (Table 9). The soils in Meskebet and GumSellassa are classified as Luvisols and Vertisols respectively. Where high pH values were recorded the soils exhibited less aggregation, were dispersed impending water movement. The salt content of irrigated fields nearer to the embankments were generally higher than fields either in the center or at the tail end (Table 9). This might be due the relative rising of the water table (profile pits had water at 1.5m), which increased and raised the salinity. Another contribution to the high salinity is the continuous application of water to the soil concentrating the soluble salts at the surface since the irrigation schemes are not provided with efficient and well-designed drainage ditches to remove excess water. Similar observations were made at Melkasedi and Metehara where poor irrigation scheduling, inadequate water management systems and lack of appropriate drainage ditches contributed to the increased salinity on the surface (Tadelle, 1996; Girma et al., 1996).
On the basis of the criteria for classification of salt affected soils (USSLS, 1954; Bohn et al. 1985) all the soils are categorized as saline soils. However the salinity level at present is not high enough to interfere with the growth of plants to substantially reduce the yield (Table 10).

Comparisons made in fields with different salinity levels indicate a non-significant change on the yield of maize and onion. Since this is the second season of production, the effect of salinity build-up will be more perceptible after successive irrigation seasons. In non-irrigated lands at the same locality yield of maize is very low (2Q/Tsmdi) and onion is not produced as a rain fed crop.

For various reasons the yield of maize is not very high for irrigated condition. The variety used was a short duration crop and the fertilizer recommended was for a rain-fed variety, which is very low for irrigated crop. Moreover since irrigation schedule was not according to the crop and soil requirement, some fields were flooded for a longer period whereas other fields were water stressed.

The yield of onion obtained is considered high for irrigated areas and observations were made where a single bulb measured about one kg. The variety used was an improved crop that responds to fertilizer under irrigated condition.

However with the current water management practices observed in some of the micro dams, the absence of well-designed drainage ditches and the high clay content of the soils, the increase in salinity is eminent as observed elsewhere in Ethiopia (Tadelle, 1996; Girma et al., 1996).

Irrigation schedules are not commensurate with the properties of the soil, the crop characteristics and weather variability. Recommendations are given as a package without considering the specific site conditions. This is because of the lack of databases for soils and long-term climatic variables.

The salinity level of the water changed over time (Table 11), hence in the peak rainy season (July-August) the salt content of the harvested water was low as compared with the dry season (May-June). This period coincides with high temperature and subsequent evaporation concentrating the soluble salt content. Similar observations are made on the salinity level of the irrigated soils. After the peak rainy season, because of the leaching of the soluble salts, salinity of the soils was lower than in the dry season where the amount of irrigation water was reduced resulting in concentration of soluble salts at the surface.

Table 1. Response of households to seriousness of land degradation (n=783)

<table>
<thead>
<tr>
<th>Seriousness level</th>
<th>Number of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>138</td>
</tr>
<tr>
<td>High</td>
<td>235</td>
</tr>
<tr>
<td>Medium</td>
<td>355</td>
</tr>
<tr>
<td>Low</td>
<td>55</td>
</tr>
<tr>
<td>Total</td>
<td>783</td>
</tr>
</tbody>
</table>

Table 2. Response of households to the causes of soil erosion

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Deforestation</td>
<td>20</td>
</tr>
<tr>
<td>Soil type</td>
<td>23</td>
</tr>
<tr>
<td>Slope of land</td>
<td>22</td>
</tr>
<tr>
<td>Over cultivation</td>
<td>20</td>
</tr>
<tr>
<td>Over population</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 3. Response of households to access to credit facilities

<table>
<thead>
<tr>
<th>Access to credit</th>
<th>Number of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>400</td>
</tr>
<tr>
<td>No</td>
<td>383</td>
</tr>
<tr>
<td>Total</td>
<td>783</td>
</tr>
</tbody>
</table>

Table 4. Severity of land degradation according to land use as observed by households (n=783)

<table>
<thead>
<tr>
<th>Degree of severity</th>
<th>Irrigated % response</th>
<th>Non-irrigated % response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very severe</td>
<td>12.83</td>
<td>24.04</td>
</tr>
<tr>
<td>Severe</td>
<td>24.08</td>
<td>35.91</td>
</tr>
<tr>
<td>Not serious</td>
<td>56.02</td>
<td>34.12</td>
</tr>
<tr>
<td>Not at all</td>
<td>7.07</td>
<td>5.93</td>
</tr>
</tbody>
</table>

Table 5. Land improvement methods used by the surveyed households (n=783)

<table>
<thead>
<tr>
<th>Land improvement category</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
</tr>
<tr>
<td>De-rocking</td>
<td>2.60</td>
</tr>
<tr>
<td>De-stoning</td>
<td>25.78</td>
</tr>
<tr>
<td>Leveling</td>
<td>4.669</td>
</tr>
<tr>
<td>Draining</td>
<td>2.86</td>
</tr>
<tr>
<td>Combination of the above</td>
<td>64.07</td>
</tr>
</tbody>
</table>

Table 6. Constraints for agricultural production (n=783)

<table>
<thead>
<tr>
<th>Constraint</th>
<th>% of household response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-irrigated</td>
</tr>
<tr>
<td>Shortage of capital</td>
<td>39</td>
</tr>
<tr>
<td>Shortage of land</td>
<td>26</td>
</tr>
<tr>
<td>Inadequate rainfall</td>
<td>11</td>
</tr>
<tr>
<td>Quality of land</td>
<td>9</td>
</tr>
<tr>
<td>Shortage of draught power</td>
<td>12</td>
</tr>
<tr>
<td>Shortage of labor</td>
<td>3</td>
</tr>
<tr>
<td>Tenure insecurity</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 7. Priority areas for government support (Intervention) (n=783)

<table>
<thead>
<tr>
<th>Type of support</th>
<th>% Response</th>
<th>Non-Irrigated</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit</td>
<td>26</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td>50</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Farm inputs</td>
<td>22</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Priority of investment if there is additional income (n=783)

<table>
<thead>
<tr>
<th>Type of support</th>
<th>% Respondents</th>
<th>Non-Irrigated</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>In agriculture</td>
<td>71</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>In non-agriculture</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>For home consumption</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Education of children</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Building of new house</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Saving</td>
<td>1</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Salinity level (µS/cm) of irrigated soils at selected micro dam sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Altitude m.a.s.l.</th>
<th>Soil Sampling Site</th>
<th>Top end</th>
<th>Center</th>
<th>Tail end</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GumSelassa 2100</td>
<td>150 (8.5)</td>
<td>290 (7.8)</td>
<td>150 (7.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 May Abakat 1900</td>
<td>200 (8.3)</td>
<td>750 (7.5)</td>
<td>800 (7.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Meskebet 1730</td>
<td>520 (6.5)</td>
<td>105 (6.6)</td>
<td>95 (6.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Felege 2590</td>
<td>100 (8.2)</td>
<td>95 (8.0)</td>
<td>75 (8.1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ): pH of soils

Table 10. Yield of irrigated maize and onion on soils of different salinity levels at GumSelassa (n=60)

<table>
<thead>
<tr>
<th>Salinity class µS/cm</th>
<th>Yield (Q/Tsmdi*)</th>
<th>Maize</th>
<th>Onion</th>
</tr>
</thead>
<tbody>
<tr>
<td>350-450</td>
<td>8.07</td>
<td>26.033</td>
<td></td>
</tr>
<tr>
<td>200-350</td>
<td>9.02</td>
<td>28.567</td>
<td></td>
</tr>
<tr>
<td>0-200</td>
<td>9.22</td>
<td>30.267</td>
<td></td>
</tr>
</tbody>
</table>

| X                    | 8.77              | 28.289|
| Sd                   | 0.4946            | 0.469 |

1 Tsmdi = 0.25 ha
Table 11. Seasonal changes of salinity level (µS/cm) at selected micro dam sites

<table>
<thead>
<tr>
<th>Microdam</th>
<th>Sampling site</th>
<th>January</th>
<th>June</th>
<th>August</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GumSelassa</td>
<td>Reservoir</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>Seepage</td>
<td>1220</td>
<td>1200</td>
<td>1100</td>
<td>1120</td>
</tr>
<tr>
<td></td>
<td>Canal</td>
<td>405</td>
<td>400</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Drainage</td>
<td>890</td>
<td>1250</td>
<td>790</td>
<td>810</td>
</tr>
<tr>
<td>2 May Temen</td>
<td>Reservoir</td>
<td>175</td>
<td>180</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Seepage</td>
<td>200</td>
<td>210</td>
<td>48</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Canal</td>
<td>250</td>
<td>430</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Drainage</td>
<td>400</td>
<td>610</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>3 Meskebet</td>
<td>Reservoir</td>
<td>50</td>
<td>200</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Seepage</td>
<td>410</td>
<td>950</td>
<td>400</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Canal</td>
<td>ND</td>
<td>250</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Drainage</td>
<td>ND</td>
<td>300</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>4 Felege</td>
<td>Reservoir</td>
<td>210</td>
<td>210</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Seepage</td>
<td>400</td>
<td>1000</td>
<td>800</td>
<td>810</td>
</tr>
<tr>
<td></td>
<td>Canal</td>
<td>250</td>
<td>280</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Drainage</td>
<td>300</td>
<td>290</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

ND: Not determined

The salinity of the water in the reservoir was invariably lower than the salinity of water in the seepage, irrigation canals and the irrigation ditches where available (Table 11). Some of the seepage water is not only from the embankment but from some springs that have developed (e.g. GumSelassa, Felege) in the area. These springs are also used to irrigate the fields. The increase in salinity of the drainage water is attributed to the leaching of the soluble salts, and the concern is this water is also being used as irrigation water at low laying fields increasing the salinity of the soils.

In some fields (GumSelassa) irrigation canals have induced seepage and created water logged condition in some fields. After the moisture level recedes salt encrustations are formed inducing salinization of the soil. Observations are also made where salts sleek and barren spots are formed due to sodicity (GumSellassa, Hizaeti Wodicheber and Felege).

**Health Studies**

Incidence surveys conducted show a seven-fold increased risk for children living in villages adjacent to micro dams (Tedros et.al., 1999). One component of the malaria study has been to identify the risk factors for the increased malaria risk. Some of these documented risk factors were open eaves, earth roof, no separate kitchen, crowding, keeping animals in living houses and irrigation. Identification of such local risk factors for malaria is important for the planning of malaria control in the region (Tedros et.al., 2000).

To mitigate the risk of malaria, insecticide impregnated bed-nets were distributed to micro dam villages (under a cost-recovery scheme). Malaria incidence was measured by the same
methodology. Preliminary analysis of the data has shown that the incidence of malaria in children living near dams was 1.8 fold.

Two cross-sectional surveys were undertaken to determine the incidence of schistosomiasis. Of those tested, 97% of children and 92% of adults had three stool specimens examined. Overall prevalence of infection was 39%, 48% in near dam villages, and 30% at remote-from-dam villages.

Implications for Control

Earthen dams can be a risk factor for malaria and schistosomiasis infection. Health education, construction of latrines, washing facilities and watering troughs for animals at dam sites are important interventions needed to prevent the environment from being contaminated. Community participation in draining ditches holding water that serve as vector-breeding site is very important. In communities where this is practiced, the number of mosquito larval has decreased.

Use of impregnated bed-nets has proved to be efficient in reducing the risk of malaria. Credit schemes are important venues for undertaking this venture. Cost-recovery has been found to be promising. The major point of departure is the benefit that is occurred from the use of the irrigation schemes. In the schemes where economic benefits are obtained the farmers are willing to pay for the extra cost of prevention of malaria (Lampietti et. al., 1999)

Snail control through use of endod (Phytolacca dodecandra) products is currently being investigated and may be feasible at dam sites. Mass treatment of communities with prevalence greater than 20% has been suggested by WHO, but may not be cost effective without other interventions because of high risk of re-infection.

CONCLUSION

Farmers living in the vicinity of the micro dams are aware about the problem of land degradation. They understand the effect of sedimentation on the reduced capacity of micro dams to store water to be used for irrigation. Apparently they are willing to invest on land management systems that are sustainable, productive and effective in reducing sediment load. Water stored in the reservoirs is of very low salinity, which could be used for irrigating the soils. However continued monitoring is required to evaluate the increase in salinity of the irrigated soils. Proper drainage system should also be installed to drain excess water. In view of the scarcity of water, efficient irrigation agronomy practices should also be designed to optimize the yield of the crops cultivated by the farmers.

Further study is needed to characterize the ionic composition of the water and soluble salts in the soil and to investigate the need for improved water and soil management practices to control the increased salinity.

The health studies indicate that villagers living near to dams that are built in the lowlands (below 2000 m.a.s.l.) are faced with the risk of increased incidence of malaria. Community participation in draining excess water that can be a breeding ground for mosquitoes coupled with the use of impregnated bed nets has decreased the incidence of malaria. The use of endod to control mollusks around the micro dams should be investigated to minimize the risk of schistosomiasis.
Acknowledgement

This project was funded by Sida/SAREC, Sweden, and supported by the UNDP/world Bank/WHO special Programme for Research and Training in Tropical Diseases (TDR). We are grateful for the contributions made by support staff at the institutions involved, the village-based enumerators and the villagers who agreed to participate.

Further background information is available at http://www.Members.aol.com/PeterByass/Tigray/index.html

REFERENCES


I Water harvesting for crop production in semi-arid areas of North Eastern Ethiopia: A case study of floodwater diversion in Aba’ala agro-pastoral area:

Mitiku Haile and Diress Tsegaye

Introduction

In arid and semi-arid areas water is an important limiting factor to crop growth. Floodwater harvesting makes dry valleys and flood plains more productive. A variety of crops such as fruit trees, forage crops and cereals. Farmers modify the flood plain ecosystem by intentionally planting certain crops and selectively encouraging or discouraging volunteer plant populations in Tunisia, Jordan, Burkina Faso, China, India, Israel and Mexico (Reij et al., 1991). Similarly, agro-pastorals in Aba’ala produce mainly sorghum and maize by diverting rivers through use of shrubs/trees, stone and soil every year. They started producing crops following the 1983 to 1985 drought due to loss of livestock and to supplement livestock production whenever there is good rainfall or flood. Although the average annual rainfall is estimated between 300-550 mm/year, the distribution may be poor or can occur within a short duration followed by early cessation before the critical hours of crop growth, or there could be meagre rainfall for three to four years and heavy storms in few days of the other years. “Reliance on average annual rainfall in arid and semi-arid areas gives only a rough picture”.

Floodwater diversion techniques are those, which force the water to leave its natural course, which it would, no do without manipulation (Reij et al. 1991). The study area receives ephemeral or seasonal stream flows from the highlands of Tigray. Though adequate data is not available, it is obvious that the runoff yield from the highlands of Tigray with an annual precipitation of 600 mm flowing through Myshugala, Aba’ala and Murga rivers are used for crop production (Yirgalem, 1999; Diress, 1999). The total catchment area contributing to the surface runoff into the Aba’ala plain is about 254 km² (Kifle, 2001). By pooling community labour force, people divert from flows in ephemeral or seasonal streams and convey to cultivated fields through a system of channels. They prepare these channels every year by use of available trees/shrubs, stones and soil since it is destroyed by flash flood every year. It takes more than three months to construct or maintain diversion channels every before the next rainy season. Through time, however, riverbeds are widened and big gullies are formed inside cropping fields and people are unable to divert the flood into their cropping fields as they wish. In addition, failure of rainfall in the highlands areas of Tigray compounds the problem because of flood insufficiency.

To alleviate their problems to certain extent, the Dryland Husbandry Project (DHP) and Afar Integrated Pastoral Development Programme (AIPDP) built diversion structures and opened
traditional channels by using bulldozer in Myshugala, Aba’ala and Murga rivers. Although it assists people to get a better yield in the years where implemented, siltation and change of river courses makes the practice unsustainable.

Therefore, it seems necessary to give more attention on the effective management of the surface water resources of the area and suggest alternative methods of water harvesting to alleviate water shortage problems for crop production, domestic uses and for livestock. As a matter of fact, the strategy should include the storage and utilization of surface water resources from adjacent runoff multipliers (macro catchments). Hence, sufficient amount of water can be harvested after the run-off attains the peak discharge so that the structures would not be threatened by sudden flash flood. Depending on the climatic, topographic and objective of the structure, storage tanks, a series of check dams with some storage ponds and cisterns (sand filled dams) may be recommended. Therefore, there is need to assess the impacts of diversion and suggest technically and socio-economically sound water harvesting scheme to the floodplain. The objectives of this study were thus:

- To assess the impact of traditional and project assisted flood diversion practices for crop production in the semi-arid (agro-pastoral) area of Aba’ala.
- To suggest alternative and economically viable methods of surface water harvesting for crop production, domestic uses and livestock.

**Study Area**

The study area is located in Aba’ala Wereda, Zone Two of Afar Regional State and lies approximately between 13° 15' and 13° 30' N latitude and 39° 39' and 39° 55' E longitude about 50 kilometers east of Mekelle town. The study area consists of flat plains occasionally interrupted by few undulating hills and a series of elongated ridges, surrounded by high broken hills with very few outlets joined to other areas (Diress, 1999). The average elevation of the area is approximately 1500m above sea level. The distribution of the soils varies according to the landscape. Along riverbanks deep alluvial soils occur that are coarse in texture with both sands and gravel present (Hunting and MacDonald, 1976). In the plains an association of soil types are observed including Cambisols, Vertisols and Fluvisols.

A semi-arid type of climate receiving bi-modal rainfall characterizes the study area. The area received an average of 422mm rainfall annually for the period 1972-1979 (Ethiopian Meteorological Agency, Shiket station records). Rainfall intensity is usually high leading to high runoff volume, and this coupled with high evaporation rate makes the available rainfall insufficient for crop production. The ago-pastoral societies in the study area thus, depend highly on the floodwater coming from Tigray highland to produce dry land crops.

Vegetation of the study area consists of wooded bush land dominated by *A. etbaica* with many associated trees and shrubs (Diress 1999; Hunting and MacDonald, 1976).

**Methods**

Community water-harvesting practices for crop production and associated impacts were reviewed using the available literature and personal observations and/or experiences in the Aba’ala agro-pastoral area. The Dryland Husb andry Project (DHP) and Afar Integrated Pastoral Development Programme (AIPDP) water harvesting experiences, study reports of
practical attachment students and other similar studies in the area were utilized to compile this study. Local people were also consulted during various occasions (during repeated project site visits, field days, etc.).

**Sources of water for crop production**

Some farmers who have access to Aba’ala river water are growing maize, some vegetables and papaya using traditional irrigation practices in the dry season. Though their potential is limited, Aba’ala and Shugala rivers can be used for small-scale irrigation. At present, the river water is mostly used for livestock and human and the river water sinks in the sand before it reaches the cultivated area. So the main sources of water for crop production are seasonal floods coming from ephemeral flows through Aba’ala, Shugala and Murga rivers during the main rainy season (June-September). Since the rainfall situation is poor, crop production is effected through flooding. In Table 1, it is shown that 73.3% of households in the six villages of Aba’ala (Wakrigubi, Adiharemle, Hidmo, Assengola, Irkudi, Undassngola) do get water from the floods (Solomon, 1998).

**Table 1. Response of households on source of water for crop production**

<table>
<thead>
<tr>
<th>Source of water</th>
<th>No of households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>31</td>
<td>26.5</td>
</tr>
<tr>
<td>Rainfall and flood irrigation</td>
<td>86</td>
<td>73.5</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Maize and sorghum are mainly cultivated using the available flood and rainwater during the rainy season. However, due to the late start and early cessation of the rains, people were unable to produce especially late maturing local sorghum varieties for the last five years.

**People water-harvesting practices in Aba’ala floodplains**

**a) River diversion for crop production**

It is stressed that rainfall situation in every aspect is poor in the area. Therefore, rain fed agriculture alone does not help the local community. Floods come to the area mainly by three major rivers. These rivers are Abala, Shuguala and Murga. The rivers are wide which reach approximately 50m on average. These rivers increase their width with increase in the size of the floods and change in the flow to the edges. It is the width that looks a threat and should be controlled. Physical structures are preferable instead of agronomic measures just on top of the edges to check the advance of the width. Physical structures like gabion can prevent the further widening of gullies and rivers (Morgan, 1995). But as a simpler remedy, the stones and boulders brought up by floods and left on the beds of the rivers can be removed. This helps the flow to pass in the middle of the rivers.

Diverting from these rivers there are many waterways that run into farms. In total there are about 27 primary channels diverted from the three rivers (AIPDP, 2000). The diversion channels are made by digging an open channel both at the left and right banks of the rivers and strengthened by stone, boulders, shrubs and logs of trees. This is a common water harvesting technique in low rainfall areas for crop production. When there is flood almost all farms get water. Within the farms there are narrow furrows covering the entire field. These
furrows distribute and can carry water for some time. The furrows are made in intimate succession to one another and slightly against the contour.

The other advantage of floods is that the soil they bring from the highlands. Crop production is not hampered by soil fertility due to the continuous renewal of soil by flooding in the area. This implies not much fertility is lost due to depletion and other factors (FAO, 1987). To ascertain this fact the soil has well depth, as some cross sectional cuts of soils at different places are observed. So, the furrows are also used to retain the soil in addition to water retention.

To utilize the available floods properly, some farmers construct soil and stone bunds in their cropping fields. Table 2, gives the proportion of households who use bunds (Solomon, 1998).

Table 2. Distribution of households on presence/absence of bunds in their farms.

<table>
<thead>
<tr>
<th>Response</th>
<th>No of households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farms with bunds</td>
<td>28</td>
<td>23.9</td>
</tr>
<tr>
<td>Farms without bunds</td>
<td>89</td>
<td>76.1</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>100.0</td>
</tr>
</tbody>
</table>

It is said that Aba’ala is a dryland area with shortage of rainfall. But low rainfall doesn’t mean less erosion by water. Since there is no enough plant cover there is severe erosion in the area as in other areas of drylands. Apart from this the area has other dryland environment characteristics.

The people experienced that out of two years one year faces rainfall shortage. For example, they said that there was good rainfall this year (the rainfall figure collected by DHP from January-October 2001 indicated 523 mm). But this year the rainfall distribution was very poor.

As is the case in many flood plains, use of floods has many associated problems in Aba’ala. For instance, beneficiaries of Murga River mentioned the following problems:

- Upstream and downstream users do not share the flood flowing through the river equitably.
- Technical faults in developing local diversion canals that could lead to change of the original river course
- Improper secondary and tertiary canals that could lead to creation of gullies in the cropping fields.
- Large amount of sand deposition in the canals and even in the cropping fields.
- Traditionally built canals were found to be incapable of supporting pressurized water flows and needs maintenance every year.

Due to lack of strong diversion canals in Murga River, about 400 hectares of previously cultivated cropping lands are abandoned. Considering the situation in the area, studies were made by DHP and AIPDP in consultation with the community and two sites were selected for diversion from the three rivers each in addition to the previously constructed diversion dike at Shugala River.

These include:
• Sherifo and shagla canals from Aba’ala river
• Wakrigubi/Adiharamele and Adayle from Shugala river
• Mohamed Yasin and salih Shki Ali from Murga river

Based on the recommendation of the study, a diversion dike has been built at Mohamed Yasin site in Murga River this year by AIPDP. Four other small diversion dikes were also constructed in Murga along with the above dike. The people benefited from these diversion dikes although the four small dikes were damaged by the unusually high flood occurrences of this year. The problem was created due to lack of long-term rainfall and flood characteristics that are very crucial in designing appropriate structures for diversion.

The local people were participated in the construction of these dikes starting from selection of sites and by contributing their free labour in the excavation, stone and sand provision and other similar activities. The built structures together with using bulldozers may assist people temporarily but the lessons gained so far indicated that the practice is not sustainable. Appropriate structures, gully stabilization and catchment treatments are needed and these need big investment.

b) Community water use management
Although the frequency of irrigation depends on the occurrence of floods in the rivers, people in the area have water use rules. Those beneficiaries participated in the construction of the diversion dike and in the making of small canals that are re-branched from the main diversion canals have the right to use flood irrigation. People are organized in groups to make sub-water line canals that start from the main diversion dike and stretched up to the individual farms. Every user opens his canal at the top end to share the available flood. Depending on the amount of floodwater, upstream users have more access to flood water than downstream users. But, if the floodwater is not enough to irrigate all cultivable land in the area, only few individuals near to the upper end are benefited.

If an individual attempts to close the canal of another individual and used the water for himself, he will be fined by the local water use committee up to 50.00 Birr. Women headed households are allowed to irrigate their farmland have the right to use nearest canals. However, they are supposed to co-operate in the making of water canals, if they have brothers or one able to send a daily labourer to build the canals. There is a need to maintain flood canals every year before and during the rainy season.

c) Advantages and disadvantages of flood irrigation
As the amount and distribution of rainfall over the growing period of long season crops is very low, the crops planted in the lowland areas of Aba’ala valley, particularly sorghum and maize suffer from moisture stress during the later stages of growth (from seed filling to full maturity). To overcome this problem, people traditionally divert floodwater as a supplementary irrigation. But, there are positive and negative sides to its use (Table 3).

Surface flood irrigation plays a key role in alleviating the existing moisture stress problem in the area. So far the frequency of irrigation depends on the occurrence of flood in the river. The floodwater is not held in reservoirs, rather diverted and used immediately during the rainy season.
Table 3. Positive and negative aspects of flood irrigation

<table>
<thead>
<tr>
<th>Positive aspects</th>
<th>Negative aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture deficit problem is alleviated</td>
<td>Soil nutrients are leached due to excessive flood water</td>
</tr>
<tr>
<td>Enough flood water enables farmers to cultivate</td>
<td>Uncontrolled excess flood water cause soil erosion and takes away the top fertile</td>
</tr>
<tr>
<td>previously uncultivated land</td>
<td>soil</td>
</tr>
<tr>
<td>Alluvial soil from highlands is deposited and</td>
<td>There is an increase in the population of annual, biennial, and perennial weeds</td>
</tr>
<tr>
<td>fertility of the soil may increase</td>
<td>that their seed is brought by flood water</td>
</tr>
<tr>
<td></td>
<td>The top soils of the area may be buried by sand and gravel</td>
</tr>
<tr>
<td>Cynodon dactylon and other grasses are grown in the</td>
<td>Due to lack of drainage system, excess flood water creates water logging and may</td>
</tr>
<tr>
<td>grass strips and around the fields, which are used for</td>
<td>reduce growth of crops</td>
</tr>
<tr>
<td>livestock feed</td>
<td></td>
</tr>
</tbody>
</table>

d) Use of ponds *(Horoye)* as a source of water for domestic use

People in the study area obtain water for domestic and livestock uses from different sources such as perennial rivers and shallow ponds *(Horoye)*. In dry season beginning from November-June the watering point for livestock and domestic use are Aba’ala and Shugala rivers. The distribution of ponds and time spent to fetch water for domestic use in Aba’ala are shown in Table 4. Rainfall in the area is not only needed for agricultural activities but also to supplement drinking. The ponds are used to harvest rainwater, which is common practice in arid areas.

The ponds are small and circular which have more depth opposite to the water entry side. It has a radius that is not more than 10 meters. They are entirely made from soil. Soil is dug and bunded about 1-2.5 meters high as the biggest at one side. The bunding height decreases as one moves towards the entry side along its circumference. These ponds used only for few months during the beginning of the dry season and women are forced to fetch water walking for about six hours a day.

Table 4. Distribution of ponds in the villages

<table>
<thead>
<tr>
<th>Villages</th>
<th>No. of ponds</th>
<th>Average period of services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidmo</td>
<td>2</td>
<td>4-6</td>
</tr>
<tr>
<td>Assengola</td>
<td>4</td>
<td>2-4</td>
</tr>
<tr>
<td>Irkudi</td>
<td>1</td>
<td>4-6</td>
</tr>
<tr>
<td>Wakrigubi</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
The people said that the ponds do not last more than a few months and the major problems of the ponds are mentioned as follows:

- The farmers do not compact the soil well that could lead to seepage loss
- Since the waterway is made by digging the soil and is unlined, soil gets into the pond with water by erosion
- In addition, the ponds are open so are exposed to every externality and
- Seepage loss, sedimentation and evaporation minimize the water content drastically.

Discussion was held with the community members to express their views how to solve problem of water mainly for domestic use. Sites for better pond construction are selected in consultation with the community. These include Edagube, Waedu and Lawede (Assengola); and Mendefera (Irkudi); Ingola (Adiharemele).

e) Impacts of river diversion and pond construction and peoples’ attitude

Generally, yield is a function of many factors, such as soil fertility, rainfall (amount and distribution), and natural resource management practices, quality of seeds, weeds and insect pests. The interaction of these factors and other plant factors determines the yield obtained from a particular crop. Although soils and other factors are suitable, there are serious moisture stress problems in semi-arid areas. Those farmers, who use floodwater from diversions made using bulldozers in the three rivers and a diversion dike in Shugala River, indicated that their crops were at good condition and the yield increased dramatically. In addition to this, abandoned cropping fields were cultivated because of enough supply of floods. As a result of this, farmers of the area have now a positive attitude in this regard. Beneficiaries, however, indicated that there is significant decrease in yield through time as a result of late start and early cessation of the main rains. As a result, people are unable to produce the local late maturing sorghum varieties such as Degalit. Since the flood repeatedly damages diversion structures, maintenance is needed every year. This made the people to seek support from DHP-Ethiopia and AIPDP for the maintenance of the diversion canals every year. Farmers are always willing to contribute free labour in the process of maintenance if assisted technically and materiaily. But the question is for how long?

There was a problem of sedimentation in the upper part of the river diversion dikes in Murga and Shuguala rivers, which are filled by sands and stones. This is due to high floodwater coming from the Tigray highlands during the rainy season.

The sustainability of the traditional water harvesting practices and project interventions are therefore under question due to the high floodwater, which results in breakage of structures and sedimentation. For sustainable use of floodwater from the rivers and ephemeral flows, there is a need to undertake a master plan study that leads to the construction of permanent structures. However, this needs big investment. In this regard DHP can play a catalyst role to attract the government or other NGOs to involve in master plan study and associated development.

Projects involved in water harvesting in the area implement activities based on a trial and error basis since there are no enough basic data to design and construct appropriate structures. People are also resource poor to maintain the structures every year at this time.
Although people indicated that the benefits of additional large pond construction for both livestock and domestic purposes, they indicated that utilization of ponds has its own disadvantages. These include:

- Cause land degradation due to attraction of many animals
- Difficult to manage as the pond belongs to every body
- Overcrowding and deciding who served first
- Water borne diseases

**Due to the above management problems people mainly recommend small ponds or cisterns that could only serve for domestic purposes for each village as animals could still travel to the perennial rivers.**

River diversion has also the following long-term negative impacts in the area even if it seems accepted by the community at this time:

- Encourages sedentarization and transformation of pastoralists to agro-pastoralists in the area where crop production is not sustainable due to insufficient rainfall.
- Crop production is not sustainable in the area unless well co-ordinated irrigation system is not used. Only few data as yet support the assumption that the use of water harvesting techniques in semi-arid Sub-Saharan Africa leads to substantial and sustained yield increases (Reij et al., 1991). Lessons gained so far in the lowland areas of Ethiopia indicated that crop production is always a failure.
- Encroachment of cultivation into key grazing areas mainly used as dry season grazing for the majority of the pastoral communities. For enrichment of grasses low cost water harvesting could be used.
- Hinders mobility, which is one of the best strategies to utilize feed and water that are heterogeneously distributed in space and time and to avoid risks during drought.

### Alternative solutions for water harvesting in the study area

Greater part of the catchment area under study is degraded steep slope hillside with rock out crops and sparse vegetation (Yirgalem, 1999). Therefore, the infiltration rate is estimated to be between 0.1-0.5 cm/hr, which is very low according to Rycroft (1988). The preliminary study on the runoff hydrograph shows that there is high yield of runoff for a given rainfall amount. This could be because the degraded steep slopes, the high drainage texture and sparse vegetation cover of the area giving rise to little time for infiltration and causing a brief storm. In fact, all structures, which harvest water from this flash flood, will silt up through time. Nevertheless, direct flow of the sediment-laden flood to the reservoir would shorten the life span of the reservoir.

According to Barrow (1993), “if small reservoirs are constructed where vegetation cover is sparse and seasonal rain or storm deliver brief heavy run-off, they face the threats of sudden silt charge flow or during dry period evaporation losses and risk of percolation losses. Taking the advantage of the geological suitability of the area (a flood plain with alluvial soils of few meters deep), other alternatives such as storage tanks, sand filled dams and check dams for artificial recharge need to be given attention.

(i) **Storage tanks**
Storage tanks are the first alternatives to temporally store surface water minimizing evaporation and percolation losses compared to other structures. Apart from this since aquatic animals and mosquitoes can be controlled a greater emphasis needs to be given to the use of tanks. Also, the rate of sediment discharge into the tank can be reduced by diverting the concentrated runoff using spreading ditch at the gully bottoms and allowing gentle overland flow to wards the tank. Tanks are placed so as to reduce risk of flood damage and siltation; ideally they collect only gentle overland flows or slower moving channel flows both of which are free of silt. Even after all this technical strategies, if the storage tank silts up it would not be expensive to remove the sediment compared to other structures. Even the best-sited tanks do in time silt up, but because they are shallow it is not too difficult to clear them out at the end of the dry season (Barrow, 1993).

(ii) Series of check dams
Intervention can be made with a series of cheek dams, associated with shallow excavated tanks so that it can catch creeping flow. This has successfully worked in Ethiopia (Heathcote 1983), and a quick return was obtained from hand dug shallow wells after artificial recharge took place. Technically, if sediment laden flood is allowed to fill up check structures with a given proportion of its height constructed from impervious material (usually 1-2m high) and the remaining proportion pervious for removal of fine sediments, pure water can be exploited from underneath. When the check is full, a permeable gabion can be re-built on top of it. This encourages free passage of fine sediment form recurring floods and retains boulders and coarse gravel. The water from such dams is clean and the structure has a key role in preventing malaria since mosquitoes do not get water on the surface.

(iii) Sand and/or gravel filled dams
Where the ephemeral flows carry much detritus it may make sense to allow a reservoir to silt up, indeed it may be difficult to avoid such occurrence but it can retain 25-30 % of un-silted reservoir. In addition, sand and gravel filled dams (cisterns) can with stand flash floods and supply clean water for domestic and small-scale irrigation. Such harvesting structures are widely used in Mexico and in Arabic countries.

Conclusion

Both the traditional diversion practices and project-assisted diversions are not sustainable in the study area. As a result, large cropping fields are abandoned due to shortage of floodwater and formation big gullies. The study area needs an in depth study and big investment to utilize the available flood from ephemeral or seasonal stream flows.

Storage tanks seem easily adaptable due to the existing indigenous practices, which can enable us to overcome people’s skepticism of the effectiveness of soil and water conservation. A series of check dams in association with small ponds can also be cheaper but reliability for how long they can provide water needs further study. If it is ensured that only coarser sediment, not fine silts, accumulate so that there is adequate interstitial space for water storage. In such cases, the use of sand filled dams enables to confine and provide water even during droughts, provides good quality water and enriches the ground water, which can be simply tapped by shallow wells. However, the impacts of altering the existing land use should be studied in detail.

Finally, before construction of any of the structures it is important that the amount of flood within a given water shed, sedimentation processes in the water ways and the socio-economic
and socio-cultural aspects in the area should be studied. Irrigation development requires basic investment for irrigation structures that enables long-term development (Admasu, 1996). Pastoralists/agro-pastoralists living in the floodplains could not be encouraged to consider crop production as alternative under the existing water harvesting practices unless well-designed diversion structures appropriate to the area are invested.

REFERENCES

AIPDP. 2000. A feasibility study on possibilities for establishing a flood diversion dike and pond in Aba’ala Wereda. Study report of AIPDP, Mekelle University.
AIPDP. 2000. A study on site identification and subsequent evaluation for alternative diversion dikes and pond establishment in Aba’ala Wereda.
J Water Harvesting Practices in Raya Valley Integrated Agricultural Development Programme Observation areas:

Gebremedhin Tikue

Expert, Soil and Water Conservation
Raya Valley Integrated Agricultural Development Program

Introduction

Raya Valley Integrated Agricultural Development Programme is established to assure food security of its mandate area through improving moisture availability. The area is endowed with good potential of land resources and has the highest concentration of livestock in the region. One of the possible choices of exiting water source is rainfall, which is not as such sustained in amount and distribution especially in the low and mid lands of the programme area. There are two aspects of water harvesting traditions, which are dictated by the size of the catchment produced run-off and direct in-situ rainfall.

Catchments produced flood (collected run-off) emanates from the upper escarpment of the programme area where relatively rainfall amount is higher and well distributed. The run-off flows to the lowlands in streams, which are dry most of the year.

The second option, which is largely implemented on areas that are not flooded is through in-situ water harvesting.

To satisfy the water needs for livestock and crops, farmers use traditional system of water harvesting mechanisms, that efficiently utilize water, sustain diverting structures and minimize erosion of soil by water.

Catchment produced flood irrigation which is also known as spate, is practiced by constructing temporary structures (diverting ditch) by using tree branches, boulders and soil mass. Farmers are forced to divert the flood from shallow gullies only because of the lack of technical capacity and resources to construct permanent weirs.

Flood irrigation is also used for livestock consumption by harvesting it in ponds, locally called horoye. Constructed ponds are not only used for watering livestock but in some cases also for growing fruits and vegetables around homesteads. Major problems that need to be addressed are, siltation of the ponds and percolation of water that results in the reduction of the volume of water harvested.

The second option is insitu water harvesting. This is encouraged, by establishing deeper and wider furrows at certain distance from each other than the usual furrows. These furrows are not tied though to enhance infiltration at a time on the spot.
The third option, which is not yet widely practiced by majority of farmers but implemented in the valley by some innovative farmers, is harvesting of water using different structures like trends and basins.

As previously indicated the programme is at its initial stage of establishment and implementation. Some possible solutions to improve the existing water harvesting mechanisms are attempted. These are construction of spate weirs, introduction of water harvesting techniques & farming tools and adoption-diffusion of all possible strengthening approaches of existing water harvesting traditions, in addition, to ground water exploitation.

**General Description of the Programme Area**

Raya Valley Integrated Agriculture Development Programme is located in the north part of Ethiopia, in Tigray. It is bounded by Afar in the east, Amahara in the south and southwest and covers about 2430 km2.

Topography of the project area is mainly mountainous comprising plateaus, undulating plains and flat lands, with an altitude range of 1400 to 3300 m.a.s.l. Rainfall pattern varies spatially across the valley. The lowland part of the valley is characterized by erratic and unreliable rainfall pattern, while in the highlands rainfall amount and distribution is relatively reliable and adequate for rain-fed crop production.

**Mean Annual Rainfall of Representative Sites**

<table>
<thead>
<tr>
<th>Station</th>
<th>Mean Annual rainfall (mm)</th>
<th>Year</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>max.</td>
<td>min.</td>
<td></td>
</tr>
<tr>
<td>1 Alamata</td>
<td>953</td>
<td>362.4</td>
<td>1957-1995</td>
</tr>
<tr>
<td>2 Chercher</td>
<td>927</td>
<td>270</td>
<td>1977-1983</td>
</tr>
<tr>
<td>3 Mehoni</td>
<td>581</td>
<td>332</td>
<td>1977-1981</td>
</tr>
<tr>
<td>4 Korem</td>
<td>1563</td>
<td>243.4</td>
<td>1977-1995</td>
</tr>
</tbody>
</table>

There is also a significant temperature variation in the project area, which is higher in the low lands and lower in the highlands.

Dominant soil types of the valley are Fluvisols and Vertisols on the plains and bottom lands, Regosols and Leptosols on hill and mountain side slopes and Cambisols on foot slopes of the mountains.

The project site is considered to be one of the most productive farming areas in the region in terms of crops and livestock production. Sorghum is the dominant crop cultivated across the valley. Teff and Maize occupy second and third place according to their importance, respectively. Most of the Sorghum fields are located where adequate soil moisture is comparatively maintained by flood irrigation. Wheat and Barely are the dominant crops grown in the highland part of the project area. Livestock potential of the valley holds about 22%, 7%, 3%, 67%, and 12% of cattle, Sheep, goats, camels, and equines of the region's total livestock population. Livestock population is higher in the lowlands than in the highlands.
Rainfall conditions and Water sources of the Valley

Dominants part of the project area, adjacent to the Afar region, which prevails erratic and unreliable rainfall pattern, is highly surface water scarce for growing crops and livestock consumption. Mean annual rainfall of the area varies between 450 to 700 mm. During the main rainy season interruption for 10 or more days is very common and at this time water stress is observed. It is clear that, there is higher need of water harvesting mechanisms to fulfill the requirement, as the major source of water of the area is rainfall.

Traditional Water Harvesting Practices

Water harvesting is a traditional practice in the valley. However this is not yet well strengthened or developed into optimal efficient use. There are no permanent structures, which makes it laborious and time consuming during the peak flooding.

These are:

- Utilizing flood for irrigation and livestock watering on (collected in ponds), which are very common activities.
- Construction of ponds for growing fruit trees, spices and other cash crops like Rehuminus prenoides is also undertaken.
- Construction of consecutive basins (trapezoidal, Rectangular, Half moon like)
- Construction of bench terrace for growing fruit trees, vegetables spices and forage grasses
- Construction of deep furrow (not tied) in farm lands.

Major constraints faced in the process of implementations are:

- Inappropriate site selection for diverting where the diverted volume of water and capacity of canal is not equivalent.
- Structures destroyed by peak run-off in one rainy season.
- Depth & Width of gullies are increasing periodically.
- Farmers are not used to constructing bunds in farmlands to enhance, infiltration.
- There is no possibility of diverting large amount of flood at a point as needed
- Distraction of Vegetation.
- All possible volume of flood flowing at a time is not used for irrigation, because of lack of overnight storage facilities.

Strengthening Water Harvesting Traditions

Strengthening the traditional practices includes capacity building of experts and users, resource provision (gabion, grain), undertaking resource demanded constructions (spate weirs, canals), introduction of catchment treatment (appropriate soul and water conservation techniques-physical & biological measures) and mechanisms of reducing water percolation in ponds, encouraging introduction & adoption-diffusion of water harvesting techniques (Basins, Bench terrace, Trench and soil bund, Tie ridging etc)

**Capacity building** - includes vocational training, attitudinal change, awareness creation, experience sharing.
Catchments treatment - the main objective of this intervention is to minimize soil and soil mass displacement by encouraging vegetation cover of the area. Grazing land improvement is also another objective of the intervention.

Percolating water reduction in ponds - this should be practiced in smearing by selected soil material and/or cement mixed and covering by plastic sheets in side part of the pond but not yet undertaken.

Achievements:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unit</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Building</td>
<td>No</td>
<td>18</td>
</tr>
<tr>
<td>Weir Construction</td>
<td>&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Catchments treatment</td>
<td>ha</td>
<td>1350</td>
</tr>
<tr>
<td>Gabions</td>
<td>m³</td>
<td>4240</td>
</tr>
</tbody>
</table>

Conclusion and Recommendation

Water harvesting practice is not yet well developed and needs further research on how to integrate physical and biological measures, impact assessment and improve existing water harvesting practices not only in farmlands to produce certain field crops but also on fruit trees and other tree, shrub and grass species.

All possible existing traditional water harvesting techniques should be assessed, inventorised and complied to be studied, improved and for possible dissemination.
Terms of Reference

« Workshop on water harvesting in Ethiopia »

Background:
The economy of Ethiopia is agrarian, and mainly relying on household labour. Agricultural production is aimed at self-subsistence and dependent on forces of nature. As such, success in production in the lowland agro-ecology is severely affected by climatic variability. The total annual rainfall is inadequate for crop production, since often the rainfall distribution is erratic. The most common shock to which mainly the lowland inhabitants are exposed is insufficient agricultural production resulting from moisture stress. Techniques to improve soil moisture retention or water harvesting is not known to most farmers or not commonly practiced.

The nutritional security of the project area is affected not only by the factors influencing household food security but also by access to clean water. Currently only about 25 percent of the population have access to potable water.

Water harvesting systems have been successful utilized by people in some parts of the world where water shortage exists. The application of water harvesting techniques although potentially high is still actually low in practice in Ethiopia. In order to meet the water demand for various purposes, sustainable systems of water harvesting and managing should be developed. Local approaches and indigenous experiences have to be encouraged and be applied easily at both village and household levels.

Objectives:
DCG would like to arrange a workshop where its member and partner organizations could meet to present and discuss their practice of and experiences with water harvesting projects. Such sharing of experiences and coordination is likely to enhance the quality of water-harvesting projects carried out. The workshop’s focus will be presentation and discussion of local/indigenous practices for water harvesting and their possible consequences.

The workshop’s specific objectives are:

- To create a forum for experience sharing
- To strengthen the technical capacity of field staff on basic principles and practical aspects of different types of water harvesting projects
- To discuss possible unintentional effects of such projects

Scope and methodology:
Each participating organization should present their experiences with different water harvesting methods. The presentation will be discussed, facilitated by experts, and recommendations will be made.
Participants:
Mekelle University, which will be hosting the workshop, is responsible for distributing invitations to possible participants. The participants should include representatives from members and partners of DCG Ethiopia-Sudan. Representatives from other NGOs, governmental and research institutions that have experiences with water harvesting can also be invited when relevant and if the workshop budget allows for it.

Workshop agendas:
- **Introduction:**
  - Water Harvesting overview (at the national level)
  - Water harvesting definition and classification

- **Rainwater harvesting for domestic water supply:**
  - Presentation of best practices of rainwater harvesting in drylands
  - Rainwater harvesting in Ethiopia (both indigenous and introduced techniques)
  - Domestic water security through rainwater harvesting compared to other sources (wells, springs, rivers etc.)
  - Domestic rainwater harvesting technology
  - Development of low cost rainwater harvesting
  - Limitation of rainwater harvesting
  - Water quality and health aspect of rainwater harvesting

- **Water Harvesting for crop production:**
  - Micro Catchments Water harvesting System
    - Semi circular bunds
    - Sunken bed
    - Contour ridges
  - Macro catchments water harvesting system
    - Stone contour bunds
    - Floodwater farming system
    - Floodwater diversion system/Spate irrigation

- **Water harvesting system design and management:**
  - Important planning and design consideration
  - Management of water harvesting system
  - Maintenance of water harvesting system

Composition of team:
Mr Sorssa Natea Merga from CARE Ethiopia and Dr Mitiku Haile from Mekelle University will facilitate the workshop. Two local consultants will have 20 working days each. This includes 9 days for preparing the workshop, 3 days for workshop facilitation and 8 days for writing the workshop proceedings.
List of Publications:


Drylands Coordination Group Addresses in Norway:

**ADRA Norge**, P.O. Box 6897 St. Olavs Plass, 0165 Oslo, Norway  
Tel: +47 22 11 20 80, Fax: +47 22 20 53 27  
e-mail: 102555.2157@compuserve.com

**CARE Norge**, Universitetsgt. 12, 0164 Oslo, Norway  
Tel: +47 22 20 39 30, Fax: +47 22 20 39 36  
e-mail: care.norge@online.no

**The Development Fund**, Nedregt. 8, 0551 Oslo, Norway  
Tel: +47 22 35 10 10, Fax: +47 22 35 20 60  
e-mail: u-fondet@u-fondet.no

**Norwegian Church Aid**, P.O. Box 4544 Torshov, 0404 Oslo, Norway  
Tel: +47 22 09 27 99, Fax: +47 22 09 27 20  
e-mail: nca-oslo@sn.no

**Norwegian People’s Aid**, P.O. Box 8844 Youngstorget, 0028 Oslo, Norway  
Tel: +47 22 03 77 00, Fax: +47 22 20 08 70  
e-mail: norsk.folkehjelp@npaid.no

**Stromme Foundation**, P.O. Box 414, 4601 Kristiansand, Norway  
Tel: +47 38 12 75 00, Fax: +47 38 02 57 10  
e-mail: postkrs@stromme.org

**Noragric, Centre for International Environment and Development Studies**  
Agricultural University of Norway, P.O. Box 5001, 1432 Ås, Norway  
Tel: +47 64 94 99 50, Fax: +47 64 94 07 60  
e-mail: noragric@noragric.nlh.no