Irrigation Development in Eritrea: Potentials and Constraints

Proceedings of the Workshop of the Association of Eritreans in Agricultural Sciences (AEAS) and the Sustainable Land Management Programme (SLM) Eritrea

14 – 15 August 2003
Asmara, Eritrea

Editors:
Tadesse Mehari and Bissrat Ghebru

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Contents

Images

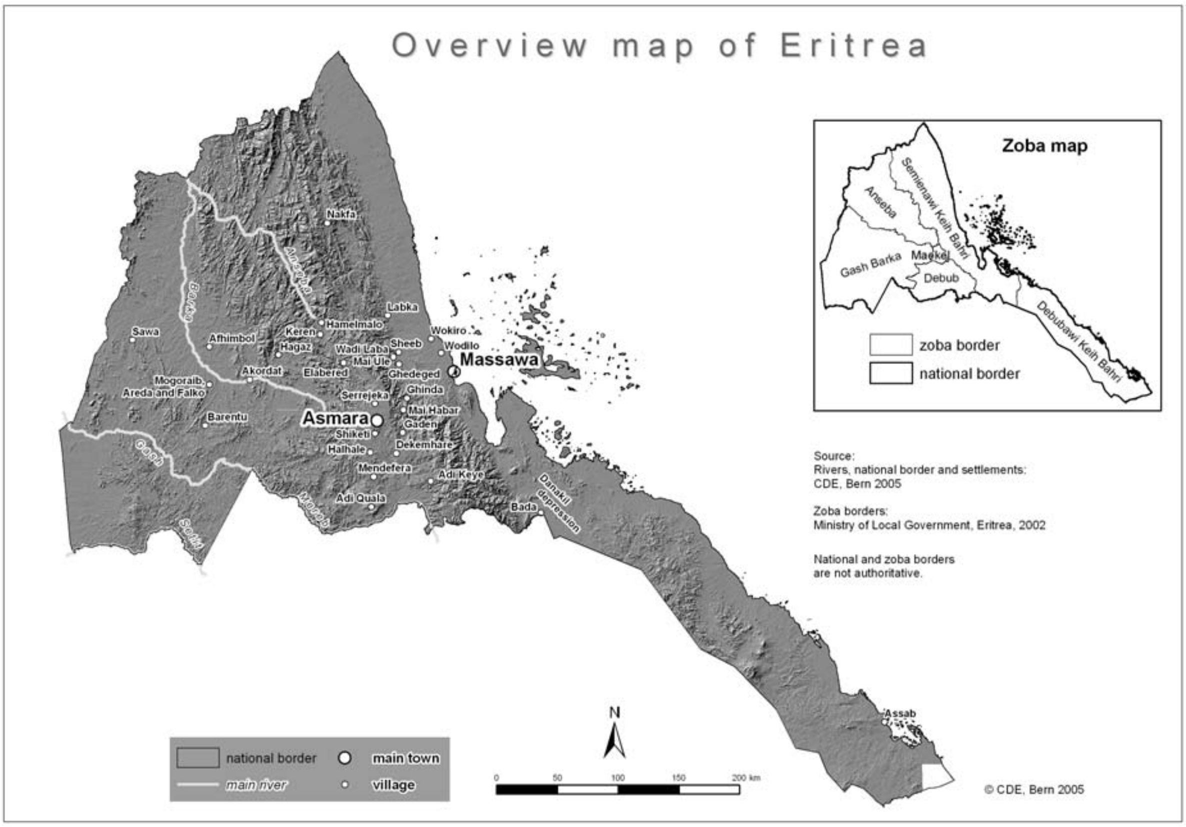
Figures

Tables

List of abbreviations

ACORD	Agency for Cooperation in Research and Development
AEAS	Association of Eritreans in Agricultural Sciences
AMIT	Affordable Micro-Irrigation Technology
BDS	Business Development Service
CA	College of Agriculture
CDE	Centre for Development and Environment
CHIHDP	Central Highland Irrigated Horticulture Development Project
DARHRD	Department of Agricultural Research and Human Resource Development
ECD	Early Childhood Development
ECS	Eritrean Catholic Society
ESAPP	Eastern and Southern Africa Partnership Programme
FAO	Food and Agriculture Organisation
IDE	International Development Enterprise
IIMI	International Irrigation Management Institute
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IFAD	International Food and Agricultural Development
LWF	Lutheran World Federation
MLWE	Ministry of Land Water and Environment
MoA	Ministry of Agriculture
PRA	Participatory Rural Appraisal
RIS	Runoff Irrigation Systems
RRC	Relief and Rehabilitation Commission
SFSA	Syngenta Foundation for Sustainable Agriculture
SMCP	Saving and Micro-Credit Program
SZSCS	Southern Zone Saving and Credit Scheme
TDR	Time Domain Reflectrometry
UoA	University of Asmara
WRD	Water Resource Department

Reference map Eritrea



Acknowledgement

The AEAS would like to acknowledge the contributions of those who made tremendous efforts to make the workshop and the publishing of its proceedings a success. It would like to first recognise the valuable efforts made by the AEAS executive board to organise such a meaningful and timely workshop. The organising committee members nominated for this task, Dr. Bereke-Tsehai Tikue, Dr. Tadesse Mehari, Dr. Bissrat Ghebru, Mr. Asmerom Kidane and Mr. Asghedom Tewolde need special thanks and recognition for the commendable efforts they have made to organise such a successful workshop. The contributions made by the organising committee and Dr. Woldeamlak Araia in the initial compilation of the workshop papers was also an effort worth mentioning.

The Centre for Development and Environment (CDE), University of Berne, also needs a special recognition for the encouragement and assistance given throughout the workshop period and for the contribution made by Ms Brigitta Stillhardt. Dr. Thomas Kohler needs a special mention for his continuous assistance and follow up. The AEAS would like to thank both organisations that covered the financial burden of the workshop: the Syngenta Foundation for Sustainable Agriculture and the Eastern and Southern Africa Partnership Programme (ESAPP). In this line, it would also like to thank Ms Sarah-Lan Stiefel-Mathez, Mr. Felix Nicolier and Dr. Andrew Bennett for facilitating the process.

Mr. Mebrahtu Iyasu and Mr. Abraham Mehari need to be acknowledged for translating the abstracts into Tigrigna. In addition, the AEAS extends its appreciation for the contributions made by the workshop rapporteurs: Mr. Abraham Mehari, Mr. Simon Abay and Mr. Sirak Mehari. Finally the AEAS would like to thank the Ministry of Agriculture for all the support that it provided in the running of the association.

Preface

The Association of Eritreans in Agricultural Sciences (AEAS) in collaboration with the Sustainable Land Management Programme (SLM) Eritrea, has, for the second time, organised a joint workshop. This workshop was on 'Irrigation development in Eritrea: potentials and constraints,' held in the National Confederation of Eritrean Workers Hall, Asmara, Eritrea, on August 14-15, 2003 (see Annex 1 for programme).

The aim of the workshop was to address the key issues on irrigation development in Eritrea among which are:

- the legacy of modernisation of irrigation systems and equity,
- alternatives to canal irrigation systems,
- strengthening farmers' potential in irrigation water management,
- gender and irrigation development, and
- experiences of institutions and NGOs' role in irrigation development.

The workshop was attended by over 130 professionals from institutions such as the Ministry of Agriculture, Ministry of Land, Water and Environment, University of Asmara, University of Berne, other ministries, UN organisations, private sector, and local NGOs (see Annex 2).

The workshop was a perfectly timed window of opportunity for the key issues of irrigation to be discussed in such a wide audience. This was further stressed by the delegate of H.E. Mr. Arefaine Berhe, Minister, Ministry of Agriculture, who remarked that the workshop was held at the juncture of the transformation of the country towards irrigated agriculture and thus commended the AEAS for correctly timing it.

This proceeding contains the keynote lecture and 16 papers presented at the workshop. The papers presented, for the sake of simplicity in referencing, have been grouped into five themes:

Theme1: Spate irrigation systems
Theme2: Small scale irrigation systems
Theme3: Climate and irrigation
Theme4: Socio-economic studies on irrigation and
Theme5: General topics on irrigation

Moreover, the abstracts of the papers were translated into Tigrigna for the benefit of participants from the farmers' associations and zoba offices (Annex 3).

The editors

Introductory remarks by the Organising Committee

Ladies and gentlemen,

On behalf of the workshop organising committee and myself I would like to welcome you to this important workshop on "Irrigation Development in Eritrea: Potentials and Constraints.' The Executive Board of the Association of Eritreans in Agricultural Sciences (AEAS) appointed the organising committee, consisting of Dr. Tadesse Mehari, Dr. Bissrat Ghebru, Dr. Bereke-Tsehai Tikue, Mr. Asghedom Tewelde and Mr. Asmerom Kidane who made this happen today.

In the current deliberations, a total of 17 contributions will be presented addressing different themes of the workshop. The organising committee has also prepared the abstracts of the papers that will be presented, both in English and in Tigrigna. Tigrigna abstracts are prepared for ease of understanding of the scientific papers by the representatives of the farmers' associations and zoba offices.

The organising committee would like to inform participants that the proceedings of the workshop will be available for all. There are three rapporteurs assigned for this workshop who will be documenting all our deliberations and contributions. The organising committee once again welcomes you all to the workshop.

14 August 2003
Bissrat Ghebru
Representative of the
Organising Committee

Opening statement by the delegate of the Minister, Ministry of Agriculture

Dear participants, ladies and gentlemen!

It is indeed an honour for me to participate in a workshop that is extremely timely and important. I would thus like to thank the Association of Eritreans in Agricultural Sciences (AEAS) and the Sustainable Land Management Programme (SLM) Eritrea for organising this workshop.

Agriculture is by far the most important sector in Eritrea's economy. It is the source of the livelihood for more than 80% of our population. Its contribution to the national GDP is, however, not as high as its importance for a variety of reasons. The reliability of our agricultural system on rainfall and its traditional nature are the most important causes for its extremely low productivity. Rainfall is unreliable both in its total amount and its distribution thus cannot enable the country to be food secure even in the best years. Food insecurity has been a bitter experience of Eritrea ever since its independence. This country cannot rely on food aid forever while the potential for boosting agricultural production exists. This very fact urges the government to introduce drastic changes. Changes that lead the country not only to be food secure but to shift to irrigated agriculture so as to produce surplus and support economic growth.

The government is fully aware of the seriousness of the issue at hand and is giving the fullest attention to transforming the country to one that rates irrigated agriculture high on its agenda. This workshop is thus being held at the juncture of the transformation of the country towards irrigated agriculture. I would thus like to commend the AEAS for correctly timing it.

It is my sincere hope that the papers that will be presented in the next two days will fully enrich the policy changes that the government is pushing for. I would like us to have a successful workshop and deliberations that will assist in enhancing the speedy development of irrigated agriculture in Eritrea.

I thus declare the workshop open and thank you for your attention.

14 August 2003
Ministry of Agriculture
Director General
Semere Amleson

Opening address by the AEAS chairperson

Mr. Semere Amlesom, representative of His Excellency Mr. Arefaine Berhe, Minister, Ministry of Agriculture, dear participants and invited guests. On behalf of the Executive Board of the Association of Eritreans in Agricultural Sciences (AEAS) and on my own behalf, it is with great pleasure and pride that I extend my heart-felt welcome to all of you to this important event.

First and foremost, let me take this opportunity to say few words about the association. The Association of Eritreans in Agricultural Sciences was established in 1995 with the following two major objectives:

1. Developing professional skills and technical capability of Eritreans in the field of agricultural science, and
2. Promoting environmental protection, and productivity and transformation of agricultural systems in Eritrea.

These being the main objectives, the association is also entrusted with:

a Organising all Eritrean professionals in agricultural sciences within and outside Eritrea,

b Promoting and developing the interest of government and non-governmental bodies within and outside the country in the development of agricultural sciences,

c Promoting environmental protection and sustainable development,

d Organising seminars, workshops and in-service trainings in various areas of agricultural sciences in order to promote the skills of Eritreans,

e Contributing in the review and development of curricula in agriculture related technical schools and colleges in Eritrea, and

f Promoting research in agricultural sciences and disseminating the findings.

Today, the association is eight years old and has about 280 members within and outside the country. It, however, has not fulfilled much of its anticipated objectives and the related activities, for various reasons. The incumbent Executive Board has almost finished its two-year term in office. The board had passed through a lot of hurdles and it cannot boast that it had performed better than its predecessors.

As one of its main objectives the association has to create awareness among its members and to discuss agricultural development issues with experts in the field and stakeholders. On the basis of this objective, the AEAS has today organised a two-day workshop on Irrigation Development in Eritrea: Potentials and Constraints.

Eritrea small in size as it may be, is gifted with varied ecological zones and endowed with broad genetic resources of plants and animals. Given Eritrea's available limited water and land resources, however, its agricultural development has to focus more on intensive rather than on extensive farming. Furthermore, Eritrea is naturally prone to erratic and torrential rain patterns, with frequent drought cycles. Hence, we as agriculturists are faced with an immense challenge to persistently search for types of scientific alternative agriculture, which would be less susceptible to the ever-changing weather patterns we are clearly experiencing.

The erratic character of Eritrea's rains coupled with the apparent reduced precipitation, in recent years, during the critical growing months of June to September, do not guarantee that rainfed agriculture has the capacity to secure our food. In fact, Eritrea records a large food deficit even in years of good rainfall. As a result, even in years of good harvest the agricultural sector, including livestock and fisheries (according to the reports of the World Bank) contributes only 25% of the country's GDP. It is in view of these facts that Eritrea's agricultural development should focus on and shift towards irrigated and intensive farming. This, however, requires full understanding of the system and careful planning in order to properly address the key issues on irrigation development in Eritrea.

The world today is using highly advanced water saving irrigation technology and related farming practices, from which Eritrea can learn a lot. In fact some of these technologies have already been transferred and are being applied in some parts of Eritrea and the results are promising. We are, therefore, sincerely hoping that this workshop shall be the venue for learning and exchanging experiences with those agriculturists who are engaged in the improvement and development of irrigated agriculture in Eritrea.

This workshop is, therefore, expected to explore the potentials and constraints of the various irrigation systems practiced in Eritrea so that a possible alternative based on irrigated system of production could be recommended which can supplement the unreliable rainfed agricultural system in the country thereby enabling it to attain food security.

I would also like to take this opportunity to acknowledge the unprecedented financial contribution made by the Syngenta Foundation for Sustainable Agriculture and ESAPP (Eastern and Southern Africa Partnership Programme) towards organising this workshop through the Sustainable Land Management Programme (SLM) Eritrea, that is coordinated jointly by the Syngenta Foundation and the Centre for Development and Environment (CDE) of the Univercity of Berne. Financial support for the publication of the workshop proceedings is also promised by the Syngenta Foundation. This was only made possible by the efforts of Dr. Thomas Kohler, Ms Brigitta Stillhardt and Mr. Felix Nicolier. May I therefore kindly ask the audience to join me congratulate these people by putting our hands together for their efforts to make this workshop happen.

Last but not least, on behalf of the Executive Board of the Association I would like to thank the members of the Workshop Organising Committee for their relentless efforts in meticulously planning and organising this workshop to make it a reality today.

I wish you all a fruitful and successful workshop. Thank you very much.

14 August 2003
Tadesse Mehari
Chairman AEAS

Executive Summary

General remarks

Eritrea, a small country in the Horn of Africa, belongs to the semi arid and arid region of the continent, which suffers from insufficient and unreliable rainfall in occurrence and in distribution. Although Eritrea has an arable land ranging from 1 to 2 million ha, the crop production under rainfed agriculture has never met the basic food demands of the population. This is mainly due to the highly erratic nature and unreliability of the rainfall. Rainfed agriculture alone will also be increasingly incapable of coping with the additional mouths to be fed in the years to come, unless, among other things, investments are done in the remodelling of the existing irrigation systems and the establishment of new ones.

If the right irrigation systems for the right soil and crop types, and water qualities are properly designed and managed, they can adequately address the irregularity of frequency and amount of rainfall. This can ensure a better control of when and how much water should be supplied, ultimately making a significant sustainable contribution towards the main agricultural goal of Eritrea- the attainment of food self-reliance and/or food security.

At a global level, the arable land is estimated at about 1.5 billion ha. Irrigation only covers about 18% of this, but is responsible for about 40% of the worldwide food production and is a source of employment for nearly 30% of the rural population in the developing countries. Nevertheless, in regions where irrigation systems that are incompatible with the soil types, water quality, cropping systems, and with the technical and financial capacities are implemented, irrigation had a very adverse impact. The most serious negative impact has been and still is the degradation of arable land due to mainly salinity build up. To date, about 500 million ha, nearly one third of the total arable land, is affected by severe salt concentration. 60 million ha of this or about 22% of the total irrigated land suffers from salinity entirely caused by bad irrigation. Semi-arid and arid countries, such as Eritrea, are particularly vulnerable to salinity problems.

This workshop, held in Asmara on 14-15 August 2003, with its focus on the potentials and constraints of irrigation systems, was hence very relevant. Because if we are to minimize the negative impacts of irrigation and build up on the positive aspects, the first step would be to identify the potentials and the limitations of the current irrigation systems and establish new ones. The natural resources (land and water), technical abilities (human and material), socio-cultural set-ups (gender issues of irrigation) and level of economic development (financial capacities of the targeted beneficiaries) are among the important aspects that need to be considered when addressing the issue of irrigation potentials and constraints.

The different papers presented have covered large and small-scale surface and drip irrigation systems and touched upon the potentials and constraints as far as the above stated resources are concerned.

Individual contributions

The summary of the papers that focused on the **drip irrigation systems** is as follows. The paper on the large-scale drip irrigation system in Afhimbol (Western Lowlands), has shed light on the significant contributions the conventional drip irrigation is making to the vegetable and fruit demands of the nation. But it has also revealed the major problems faced by the scheme notably the clogging of the drippers. It has also shown a trend of the salinity build up due to the application of drip irrigation, which although was moderate, it was significant in particular in two wells that needed urgent remedial steps. The other papers outlined the preliminary results on the socio-technical, economical and agronomic aspects of the systems. The papers conclude that the low initial capital outlay has significantly contributed to the high interest shown by the farmers to test the system, and that unlike the conventional drip systems, they have a potential to improve the living conditions of the rural poor that form the bulk of the farming community in Eritrea. Moreover, the systems have been found to have a potential of being more preferable and of higher benefit to many rural women as they are easy to operate and manage and can be installed in the backyards. On the other hand, like the conventional drip systems, they were subject to the same or even higher degree of clogging. Thus, it was recommended that there is a need to improve the filtration systems by adding filter clothes, but even then it is highly unlikely that the systems can fit to very poor quality water. Water quality assessment is hence essential when disseminating this technology. Furthermore, it can be inferred from the papers that choosing the right crops, planting the right numbers at the right site around each dripper, flushing the system pipes bi-weekly, could make a difference in the production levels and the economic returns of the systems.

The papers presented on **surface runoff irrigation systems**, focused on the challenges of the development of large and small-scale spate/runoff irrigation systems in the Eastern and Western Lowlands of Eritrea and the small-scale dam-fed surface irrigation systems in the Highlands. The paper concerning the Western Lowlands has noted that most of the newly constructed diversion structures are done without proper knowledge of the flood discharges and sediment concentrations of the flow, which has led to the frequent breaching of the structures and blocking of the canal network gates with sediment deposits tremendously lowering the amount of diverted water. It also identified that the fields lacked proper levelling and grading and the bunds were insufficient for the retention of adequate amounts of water and sediments that are vital for the effectiveness of runoff irrigation systems. The paper on the Eastern Lowlands of Eritrea has provided the reasons that led to the replacement of traditional stone, brushwood and earthen structures with concrete weirs. The main reason was to improve the water diversion efficiency from 45% to 80% thereby increasing the irrigable area by almost 100%. The paper has also highlighted the level of dissatisfaction of the farmers with the modern structures, which failed to meet the expectations and outlined some of the modification requests made by farmers such as the changing of the earthen breaching bund to concrete. Both the run-off and spate irrigation papers made a firm conclusion that the functioning of the traditional systems need to be studied in depth so that future development activities can be more successful.

The paper on the dam-fed small-scale **surface irrigation systems** was a very important contribution. It has revealed the social problems (based on farmers' perspectives) that led to the non-utilization of about 30 dams for the purpose they were primarily built to serve supplying water for irrigation. It has provided a clear picture that any development that is not need-based and demand-driven is deemed to be unsuccessful.

In order to make assessments of whether certain irrigation systems are successful or not, which some of the papers attempted to do, it is of utmost importance that there are some primary **performance indicators** that are agreed upon by the engineers, managers and policy makers in the country. The workshop hence accommodated a paper that outlined and discussed some of the key indicators- equity, reliability, regularity and durability of irrigation systems. The paper also gave examples, in simple terms, of how these indicators can be quantified and analysed.

All the papers presented in the workshop were important and have given a general picture of where we stand as far as irrigation development in Eritrea is concerned. However, it has to be acknowledged that most of them were inventories and baseline surveys, which reminded us of the need to conduct demand-driven and priority-targeted scientific research. Moreover, the papers presented highly variable figures of some basic data. For example, the arable land ranged from 1.5 to 2 million ha, potential irrigable area varied between 100,000 to 600,000 ha, and potential spate irrigable area ranged from about 60,000 to 137,000 ha. It is therefore important to underline the urgent task that irrigation/water managers and engineers need to do – the comprehensive and reliable assessment of the available and potential land and water resources in Eritrea. It is worth noting that this is the bottom line for embarking on the road to irrigation development.

Making in-depth research will need setting priorities and coordinating and sharing human and material resources among different local institutions, mainly the Ministry of Agriculture, the Ministry of Land, Water and Environment and the University of Asmara. It will also necessarily require establishing lasting linkages with international research institutions and universities. Moreover, the human capacity building efforts underway by the different local institutions must be coordinated so that, among other things, unnecessary waste of the limited capital resources be minimized and the required skilled personnel and equipment can be made available in a much shorter period of time.

The overall conclusion that was reached in the workshop, and which is worth emphasizing, is that if sustainable irrigation development in Eritrea is to be achieved, it must necessarily be supplemented with need-driven scientific research.

The editors

Keynote presentation

Review of irrigation development in Eritrea

Semere Amlesom
Director General, NARI, MoA, Asmara, Eritrea

Introduction

Out of the total land area of Eritrea, which is about 126,000 km_2, 1.5 million ha are currently classified as arable land, out of which 400,000 ha (28%) are under rainfed cultivation. Furthermore, out of the total 600,000 ha of land with irrigation potential, only 28,000 ha (4.5%) are irrigated.

Crop production systems are rainfed subsistence farming to semi-commercial rainfed agriculture and irrigated agriculture, 90% of which is spate. Traditional rainfed agriculture accounts for more than 90% of the estimated 400,000 ha of cropped land. The availability of rainfall and soil moisture with little or no modern agricultural inputs is the determinant factor of the traditional system. Traditional farmers produce mainly cereals, pulses and oil crops on average farms of less than 1 ha in the highlands and 2 ha in the lowlands. The average production of cereals, pulses and oil seeds (1991-1999) is 0.65, 0.50 and 0.43 tons/ha respectively. This is far below the Sub-Saharan Africa and the world averages.

Role of irrigation

The last ten years of post-independent Eritrea have clearly exhibited the fact that agricultural production has not been able to keep pace with the increasing demand for food. Even in years of good rainfall such as that of 1998 production covered only about 70% of consumption. This is clear evidence that food security cannot be attained through the current production system, which is based on unreliable rainfall patterns. The government should thus seek ways to improve and stabilize agricultural production to cater for the food needs of its population. The biggest potential for increasing agricultural production lies in the development of all potential areas in general and those in the Eastern and Western Lowlands in particular. Production increase with the use of irrigation alone goes as high as 150%. If the currently potential irrigable land under irrigated agriculture, which is only 4.5%, is raised to say 25% (150,000 ha) it would, at the minimum, have a substantial contribution to the attainment of food self-sufficiency.

Contribution of irrigation to the national economy

Rainfed agricultural production is highly dominant in Eritrean agriculture. It is traditional by nature and is a low-input low-output system. Due to the unreliability of rainfall, both in total amount and distribution, the use of production-boosting inputs such as improved seeds, fertilizers and chemicals for the control of insects, diseases and weeds is not fully encouraged. Irrigated agriculture on the other hand, if properly handled, is a high-input high-output production system. Irrigation and rainfed agriculture are however complementary in nature and are not mutually exclusive.

Where water is considered as a major constraint, irrigation can assist in agricultural diversification, enhance food self-sufficiency, increase rural incomes, generate foreign exchange, and provide employment opportunities. Food security, employment creation and settlement of foreign exchange are thus considered to be the major contributions of irrigation to the national economy.

Food security

In the Eastern Lowlands of Eritrea i.e. *Sheeb, Wadi Labka, Foro, Bada*, etc., farming systems based on spate irrigation have a relatively higher yield per ha as compared to rainfed farming systems elsewhere in the country. Average yields from spate-irrigated lands ranged from 2.0 to 3.0 tons per ha while those in rainfed areas ranged from 1.0-1.5 tons per ha only. This is a clear indication that with the modernisation and expansion of spate irrigated agriculture in both the high potential areas of the Eastern and Western Lowlands of Eritrea food security could be achieved in the shortest possible time.

Irrigated agriculture is practiced in some parts of the highland areas and on the banks of the big seasonal rivers of *Anseba, Gash* and *Barka*. It contributes to the national food security by producing horticultural and other crops that play a big role as they are available in the local markets of the national and regional capitals at affordable prices.

Employment creation/Foreign exchange

Irrigated agriculture makes use of several production inputs such as intensive land preparation, row-planting, inter-row cultivation, chemical application for weed, pest and disease control, harvesting and post harvest activities. These activities make irrigation a labour-intensive system. It is estimated that irrigation, depending on the type of crop cultivated, is able to generate up to 700 person-days of labour per irrigated ha. Hence, irrigation makes a substantial contribution to job creation.

The opportunity for growing crops that earn foreign exchange is provided with the expansion and intensification of irrigated agriculture. The growth of the horticultural industry and the production of crops that could compete with foreign markets in their quality and constancy of supply have the potential of earning the country's dire need of foreign currency.

Categorization of irrigation development in Eritrea

Public/Parastatal irrigation schemes

Of notable importance in this category is *Ali-Ghider* Settlement Scheme for demobilized fighters. The fighters were allocated 2.0 ha each and were assisted by *Ali-Ghider* Agro-Industry to cultivate cotton, which is a high value cash crop. *Ali-Ghider* agro-industry is a parastatal irrigation scheme engaged in the production of cotton as a main crop and sorghum and sesame as sideline crops. The estate has during the current cultivation season reached its maximum since independence and is cultivating 4000 ha of cotton, sesame and sorghum.

Elabered is an integrated agro-industrial estate engaged in the production of dairy cattle, pigs, horticultural crops such as citrus and leafy and fruit vegetables in a total area of 300 ha.

Processing of tomato paste and pasteurised milk from its products is part of the agro-processing activities the estate performs.

Sawa and *Afhimbol* Agro-Industry is a parastatal enterprise engaged in the production of high-value horticultural crops targeted for both internal and external markets. Both farms make use of pressurized irrigation systems (mostly drip) in a combined area of 800 ha of land.

Smallholder irrigation schemes

These schemes can further be grouped into two types:

1. Schemes where modern irrigation infrastructure have been constructed or are in the pipeline and the MoA is taking care of the management of the system together with community leaders. A typical example of this type is the Eastern Lowlands Wadi Development Project, which covers *Laba*, *Mai-Ule* and *Labka* diversion structures, and the development of the command area downstream of these structures.
2. Schemes that are run by informal/traditional water users associations are another category of irrigation development. In this case community leaders are shouldered with the responsibility of distributing water to all members of their association/ community.

Private commercial farms

Commercial farming for the purpose of producing high-value horticultural and floricultural crops is at its infancy. Floricultural products are currently produced and exported by one commercial farm in the environs of Asmara. Other commercial farms of some significance are *Gash* Farm (300 ha) and *Barka Wedi Legges*s Farm (600 ha). These enterprises employ furrow irrigation and need major improvements or a shift to pressurized irrigation.

There are commercial farms of different size and degree of sophistication in different parts of the country. The quality and quantity of their products however need a long way to go before they qualify for quality-seeking local consumers in general and exporters of these products in particular. Currently commercial farming is spreading rapidly in the highlands as well as in the Western Lowlands. In the latter case, the potential for the intensification of existing commercial farms and their expansion to new areas is high which may have problems. Giving more emphasis to crop production should be carefully weighed so as not to make it at the cost of downsizing the livestock sub-sector's development.

Evolution of irrigation development

Historical development of irrigation

The history of irrigation in Eritrea dates back to the Italian colonisation. Colonial records reveal that various trials related to the cultivation of commercial crops such as cotton and tobacco were undertaken as early as 1901. Agricultural research stations were established at different locations of the country. In the lowlands, in addition to high value earning, rainfed crops, some horticultural crops such as date palm, bananas, papayas, citrus fruits and various other tropical plants were cultivated on an experimental basis. In the highlands, large-scale tests were made on potatoes, medicinal plants and various types of legumes. In the years that followed, massive areas of agricultural land were leased to Italian investors for growing commercial crops for export. Eritrean farmers were also encouraged to change their traditional agricultural habits by cultivating cash crops and by working in the lowlands as sharecroppers. By 1930 a total area of only 9,000 ha was cultivated commercially in both the Eastern and Western Lowlands of Eritrea. The *Tessenei* Irrigation System, with an area of 3000 ha, was completed in 1928 and formed part of this commercial production system.

Under the British administration, efforts to make Eritrea self-sufficient in vegetables, fruits and grain was further pushed. This was originally motivated by the difficulties of importing these crops during World War II. Several thousands of hectares of land were given as concessions to Italian market gardeners. By 1950, they were not only meeting the local European demand for fruits and vegetables, but were also exporting a small surplus to Yemen and Saudi Arabia. Commercial farming continued to expand both in the highlands and lowlands during the Federation/Annexation period (1952-1962). The *Elabered* and *Ali-Ghider* Estates, the horticultural farms in the *Barka* region and their expansion to *Ghinda*, *Dekemhare* and *Mai-Aini* are leading examples. Some of the vegetables and fruits such as green pepper and banana were exported to Europe and Saudi Arabia.

Irrigation development during pre-independence

The start of the armed struggle in 1962 and its intensification in the early 1970s led to the drastic decline of commercial agricultural development. The nationalization of the commercial farms of *Ali-Ghider* and *Elabered* by the Ethiopian Government led to the further decline of irrigated agriculture. As the war intensified, agricultural development activities deteriorated further, to the point where almost all research stations were abandoned, commercial farms were closed and exports came to a halt.

The first part of the armed struggle (from 1962-1974) was dominated by the fight for the sustenance of the struggle for the liberation of the country. In 1975, the Eritrean Peoples Liberation Front (EPLF) started to produce part of the food needs of its fighters and commenced crop production activities with the support of spate irrigation in *Mersa Gulbub*. A structure for agriculture was created after the first EPLF congress in 1977. This marked the beginning of the Front's involvement in different aspects of agriculture including irrigated horticultural production in concessions that were in the liberated areas. With the liberation and rehabilitation of the *Ali-Ghider* scheme in 1985 the production of irrigated crops began. In 1984 the Commission for Agriculture was established with soil and water conservation as one of the sub-commissions. The commission was restructured in 1986 and was defined by five sub-commissions and land resources was one of the sub-commissions responsible for the development of irrigated agriculture through the construction of ponds, diversion structures and soil bunds for field embankments. This led to the establishment of farmer-managed irrigation schemes in different parts of the Eastern and Western Lowlands of the country as well as in the liberated areas of the Central Highlands.

Irrigation development during post-independence

After the total liberation of Eritrea, a conference on economic policy was held at the University of Asmara on 22-24 July 1991. The following were among the specific objectives spelt out in the future agricultural development agenda of Eritrea as related to irrigation:

- To expand the building of dams and irrigation canals as well as to exploit subterranean waters in order to alleviate water shortages and to effectively use our limited water resources in a manner that does not entail ecological imbalance and damage;
- To expand on cash crops as a source of foreign currency, but not at the expense of food crops; and
- To expand agricultural ventures that employ modern machinery, techniques and technology to reinforce and supplement, but not at the expense of the agricultural activities carried out by a broad participation of the population.

A phased approach for the reconstruction of the country was thus prescribed after an assessment of the grave economic situation the new nation faced. These are: a) a short-term rehabilitation and reconstruction phase (1993-95) to be followed by b) a medium-term reconstruction phase (1996-2000); and c) a sustainable long-term development phase (beyond the year 2000).

The preparation of technical studies for the potential for irrigated agriculture and the provision of technical assistance to investors in small and large irrigation projects was part of the medium-term rehabilitation/reconstruction phase. Unfortunately, the second phase was disrupted in mid-1998 with the eruption of the border conflict with Ethiopia. The long-term development phase (2000-2010) gives more emphasis to irrigation work and proposes the construction of dams, diversion structures and culverts, and the promotion of spate irrigation in potential areas such as *Hazemo, Sheeb, Wadi-Labka* and *Gash-Barka*. This aims at targeting about 70,000 farmers growing cereals, fruits and vegetables, and rearing livestock. These policies and strategies are presently under revision and are to be incorporated in the national poverty alleviation and food security strategy, which is currently under formulation.

Institutional development

As indicated in the preceding sections, irrigation development as related to horticultural and cereal crop production was given high prominence. But due to lack of investment capacity from the part of the government and the private sector, irrigation has not developed to the desired degree. Institutionally, irrigation was consistently kept at division level throughout the different organisational structures formulated and implemented in the MoA. The most recent reorganisation of the MoA in 2003, gives high prominence to irrigation as a discipline. Together with extension and mechanisation, irrigation is one of the major divisions in the new Department of Agricultural Promotion and Development. The Government of Eritrea in general and the MoA in particular believe that food security could not be achieved through agricultural practices that are based on rainfed production systems. This is because rainfall has been totally unreliable both in its total quantity and distribution over the last several years. The conservation and use of run-off water at village, sub-zoba, zoba and national levels for boosting agricultural productivity has thus been initiated by the government and is gaining momentum. The concentration of human, budgetary and other resources for boosting agricultural production through irrigation supported agricultural activities in selected promising potential areas *(Sheeb, Hazemo* and *Guluj*) has thus been given a very high priority. The success of these initiatives in these pilot areas will set an example for following suit in wider areas elsewhere in Eritrea.

Trends in irrigation development

Irrigation potential

The knowledge of the irrigation potential of any country is essential because it serves as a base for the formulation of irrigation development strategies. Moreover, it gives a benchmark for monitoring progress within the irrigation sub-sector. In estimating the irrigation potential, factors such as surface and ground water resources, availability of suitable land, cropping patterns and the irrigation technologies to be used should be taken into consideration. Such studies have not been fully conducted in Eritrea. Estimates of Eritrea's irrigation potential have been made at different times. The government launched one study, under a project title "Water Resources and Irrigation Potential of Eritrea," with EU funding back in 1996. Its objective was to conduct an exhaustive study on both surface and ground water resources and directly relate the findings to the irrigation potential (availability of suitable land) of the country. The study was not completed for various reasons. It has however obtained satisfactory results in some specific areas such as surface water and some aspects of agriculture (cropping patterns, land suitability etc.).

The irrigation potential of Eritrea, though roughly estimated at about 600,000 ha does not have a good basis for being accepted for strategy formulation purposes. There is a wide disparity in the estimated irrigation potential of Eritrea, ranging from as low as 100,000 to as high as 600,000 ha. The need for accurate estimates and thus for the completion of the above-mentioned study by the concerned government bodies i.e. the MoA and the Ministry of Land Water, and Environment (MLWE) becomes a very timely and crucial issue.

Irrigation development

The dominant irrigation systems in Eritrea are spate and furrow/basin irrigation. The Yemenis introduced spate irrigation to the Eastern Lowlands while the Italians introduced furrow irrigation to land that they grabbed from Eritreans in different corners of the country. Both events took place towards the turn of the twentieth century.

Out of the 28,000 ha under irrigation (i.e. 4.5% of the irrigation potential), 22,000 ha (79%) is under spate irrigation. The remainder 6,000 ha (21%) is under furrow/basin irrigation. Despite the slow rate of irrigation development in Eritrea there are a number of promising irrigation technologies with high water-use efficiency being implemented in small and medium scale schemes. These include the *Hagaz* and *Alebu* family drip irrigation systems and the medium-scale drip and sprinkler irrigation systems in *Ala*, *Keren, Hagaz, Sutur*, and *Sawa-Afhimbol*. A number of these recently introduced techniques seem to be gaining more attention and popularity in Eritrea. Increase in the acreage resulting from these technologies is however not significant enough to be of any influence to the national statistics of irrigated agriculture.

Factors affecting irrigation development

High cost of irrigation development

Initial capital investment costs in irrigation development in general are much higher than those for rainfed agriculture. Further cost escalation is encountered if horticultural production, which is highly capital-, labour-, and input-intensive, is considered. Costs incurred in pump-fed irrigation schemes are also generally higher than those of gravity-fed schemes. Another dimension of investment cost escalation is the technology used i.e. drip, sprinkler, gated pipe, furrow etc.

Farmers' access to credit facilities

Farmers engaged in irrigated agriculture in general and those in the smallholder category in particular lack financial resources to invest in irrigation activities. Credit from commercial financial institutions is available only with the provision of a collateral. Financial institutions at the same time find it risky and expensive to administer such credits, which adds to the problem of their availability.

Lack of clear policy on irrigation development

The lack of a national policy that would create an enabling and conducive environment for irrigated agriculture has constrained irrigation development in Eritrea. The 1994 Macro-policy document of the government on irrigation development states that it is the policy of the government to promote "improved agricultural production through the development of irrigated land and by enhancing the productivity of peasants, pastoralists and agro-pastoralists". This should be further elaborated if irrigation development is to be implemented effectively.

Support services for irrigation development

In the majority of cases, areas with high potential for irrigation development are located outside of the main road system of the country. These areas are characterized by inadequate infrastructure such as access roads, marketing outlets, extension services, etc. The slow pace of irrigation development in some parts of Eritrea is attributed to these factors. Smallholder farmers face serious problems of marketing fresh horticultural products. Inaccessibility of some schemes due to bad roads, lack of diversification and controlled production coupled with the manipulation of markets of horticultural products by middlemen are some of the underlying reasons.

Water allocation for irrigation in the future

Agriculture in general and irrigation in particular consume a great deal of water. There is an inefficient use of water for irrigation while the demand for the expansion of irrigated agriculture is, at the same time, high in the country's development agenda. The need for the introduction of measures that will foster sustainable increase in the productivity of water (kg of produce per m3 of water) through better management of irrigation is of utmost urgency and importance.

In Eritrea water is considered as a free commodity. Farmers are not required to pay for the water they use for irrigation purposes. They are thus reluctant to make the most efficient use of the water which they get at no cost. The need for levying charges for irrigation water thus becomes another timely and urgent issue. Recently the Gash-Barka regional administration has introduced measures in line with this principle. It is hoped that farmers will refrain from using water lavishly for fear of paying high costs thus being pushed to producing more from a limited quantity of water.

Evaluation of irrigation development

There is a need to evaluate past and current irrigation development in Eritrea in order to map out sustainable future strategies. There are a number of innovative approaches being developed and adopted by farmers. These approaches are inexpensive and easily manageable. They include low-cost drip irrigation techniques distributed by the Centre for Development and Environment (CDE), University of Berne in collaboration with the College of Agriculture (CA), UoA. The family drip system being introduced by an NGO, CONCERN International, in *Hagaz* and *Alebu* is a case in point that deserves mentioning.

These new technologies have not been evaluated in light of their technical and socio-economic performances. The possibility of introducing high level technologies of pressurized irrigation such as green house and open-field farming systems to small-scale users need to be explored. Such an evaluation could assist in identifying constraints and opportunities for future strategies that address water scarcity and the securing of food at household and national levels.

The evaluation should be conducted with the primary objective of understanding the factors affecting the viability of irrigation development in Eritrea, with the aim to:

- evaluate the trend of irrigation development in Eritrea,
- identify and analyse underlying socio-economic factors influencing irrigation development,
- identify challenges and opportunities for improving irrigation schemes,
- review health and environmental issues related to irrigation,
- determine governance issues such as water rights, access to and use of water, and water abstraction permits,
- identify promising technologies, especially water-efficient irrigation technologies to be promoted, and
- contribute to the technical, economic and social evolution of irrigation development in Eritrea.

Conclusion and way forward

The main source of agricultural growth in Eritrea should be based on better water control and use. The pace of the development of irrigated agriculture has so far been very slow.

The development of small areas in the highlands and the rehabilitation of colonial estates have so far not impacted the national statistics of irrigated agriculture. The commissioning of a national survey of surface and ground water resources, though incomplete, was a promising step in the right direction.

The incompleteness of the irrigation development strategy and the lack of adequate numbers of trained people have hindered the development of irrigated agriculture. The implementation capacity of the MoA should thus be commensurate with the need for boosting agricultural production through irrigated agriculture. Hence the way forward would be:

- to complete the study on water resources and irrigation potential for the country, and use it to define priority areas for irrigation development based on technical, financial and social analyses,
- to urgently improve the capacity of the MoA in the design and implementation of irrigation projects both at ministry and zoba levels, and
- to give enough public support to smallholder irrigation schemes in the form of technical assistance in the design and construction of irrigation infrastructure, capacity building in water and farm management and in the formation of viable water users associations.

Theme 1 Spate Irrigation Systems

Performance measurement in canal-fed surface irrigation systems

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Abstract

Eritrea is not a "physically" water scarce country; but its current technological capabilities do not allow the extraction of water, sufficient to meet the food production demand of the population. At present, the annual water withdrawal rate is estimated at 4% of the renewable water resource. This needs to be increased to at least 25%, if Eritrea is to adequately feed the 2025 projected population of 8.5 million. One way of achieving this is by introducing feasible irrigation technologies that extract and distribute water efficiently. In line with this, some activities are being carried out to improve traditional irrigation schemes practiced in the lowlands of Eritrea. However, no systematic study has been conducted to measure the performance of these irrigation schemes. Performance measurement could only be beneficial and relevant, if an agreed set of performance indicators exist among the irrigation engineers and managers, researchers and irrigation policy makers. With this set of indicators, irrigation engineers and managers can maintain a clearer sense of priorities and goals, they can set targets, and their staff incentives can be based upon achievement of these targets. The researchers working on different irrigation systems can find a common ground for saying whether one system is performing better or worse than the other and policy makers can make proper and coherent evaluation of policy alternatives. This paper therefore attempts to address questions like 'What is a good performance?' 'What are the performance indicators for canal irrigation systems?' and 'How can we measure them for impact assessment?'

Key words: Canal irrigation, Eritrea, performance indicators, performance measurement

Introduction

Eritrea, a small country with a total land surface area of 121,320 km^2, is located in the Northeastern part of Africa between latitudes 12°40' and 18° 02' N; and longitudes 36°30' and 43°23' E. About 80% of the 4.3 million people in Eritrea depend on agriculture for their basic food needs. Agriculture mainly consists of subsistence rainfed crop production, irrigation and pastoralism.

Irrigated agriculture currently covers about 28,000 ha (FAO, 1997) with a potential variously reported at about 300,000 ha and 600,000 ha (FAO, 1994). In Eastern and Western lowlands of Eritrea, traditional canal-fed runoff irrigation systems have been and still are widely practiced. Since 1993 however, these systems have been subjected to modernisation that mainly focused in replacing them wholly or partially. To-date, an agreed set of primary irrigation performance indicators has not been developed and there are no systematic studies conducted to assess the performance of these modernised schemes.

Therefore, this paper attempts to address the issue on how to measure the performance of large-scale, smallholder multiple-user 'canal'-fed irrigation systems, and the most important indicators to be considered.

The term "canal" is used here to refer to earthen- main, secondary, tertiary and quaternary field canals. The majority of the smallholder farming households in Eritrea who are involved in irrigated agriculture have a land holding of 2 ha or less. Most farmers utilizing the macro-catchment runoff irrigation systems in the eastern lowlands of Eritrea have irrigable areas ranging from 0.25 to 1 ha (Mehari *et al.*, 2003). While majority of the farmers involved in micro-catchment runoff irrigation, such as those in *Bultubyay, Areda* and *Fanko*, own fields ranging between 1 and 2 ha. Different researchers quantify 'large-scale' differently between countries and within a country. In this paper, any irrigation scheme with a total irrigable area of 200 ha or more is considered to be a large-scale. This will validate almost all the runoff irrigation systems in the eastern and western lowlands for the discussions presented in the following sections.

Characteristics of good performance

The main agricultural policy of Eritrea is ensuring food self-sufficiency and/or food security. The primary purpose of modernising the traditional irrigation systems is therefore to enhance production of food and fibre both in quality and quantity. As argued by Abernethy (1986), irrigation systems are built to boost crop production and it is on the bases of their agricultural crop output that they ought, first and foremost, to be assessed. This statement may be slightly diluted, when dealing with a "welfare" irrigation system. A welfare irrigation system, which is not uncommon in Eritrea, is a system where the major drive for modernisation is the provision of improved quality of life for some less fortunate region or social group, rather than making any significant contribution to national agricultural production. Nevertheless, even in those cases, a certain modernisation project cannot make much sense unless it results in a higher agricultural output.

It is however difficult to adopt 'increase in production' in total land area and per unit piece of land, as the main indicator of irrigation systems' good performance. Yield increase can be induced by a very wide range of factors, among which are: a change in the accounting system of the organisation that manages and purchases the product and a rise in the price, which has little or nothing to do with the quality of irrigation.

If the performance of an irrigation system is to be measured, the first thing that needs to be answered is how irrigation differs from rainfed agriculture, and what its primary functions are. So, one clear yardstick is whether the irrigation system fulfils these functions and to what degree. Irrigation is generally defined as a system for artificial provision of water at times and places where crops can utilize it (Till and Bos, 1985). This definition however needs to be fine tuned to fit to the functions performed by each of the different types of irrigation systems. In the case of the large-scale, smallholder, and multiple user irrigation system, the definition should read, irrigation is an artificial delivery of water where and when it is needed in right quantities, regularly, reliably and equitably. Therefore, if such an irrigation system is to be labelled as a good performing system, it must be durable and last its whole design life, while at the same time fulfilling the functions outlined in its definition.

Performance indicators

Many irrigation performance indicators are described in literature. Rao (1993) provides the most comprehensive review. More recently, the International Irrigation Management Institute (IIMI), has proposed and begun testing a "minimum set of performance indicators", of which, the most crucial describes additional economic value of irrigated agriculture per unit quantity of water (Perry, 1995). The application of a universal indicator (set of indicators) for the performance evaluation of all irrigation systems is however impossible. This is mainly due to the fact that there is no agreement among irrigation specialists on what such a universal indicator (or set of indicators) might be, because of the variation in the types of irrigation systems, in their physical, social, and economic conditions, and in their objectives. Gillot and Bird (1992), argue that the method of performance assessment and the nature of the indicators required are dependent on the objective of the assessment, which in turn are related to the viewpoint of the assessor.

In this paper, as stated earlier, the type of irrigation system has been identified, and the objectives of the performance assessment is assumed to emerge from the definition of a selected irrigation system. Therefore, a set of the possible primary indicators could be suggested. The presence of an agreed set of indicators could help irrigation engineers and managers to maintain a clearer sense of priorities and goals, to set targets and base their staff incentives on the achievement of these targets. Researchers will find common basis for saying whether a certain system is performing better or worse than another similar system. Policy makers could also find a common ground for making proper evaluation of irrigation policy alternatives.

The primary indicators considered to be relevant for the selected irrigation system are: equity, regularity and reliability of water distribution and durability of the system itself. These indicators will be first discussed in detail and finally, the "cost of operation and maintenance" will be presented as a possible important secondary performance indicator.

Equity

Equity, spatial uniformity, or fairness of water distribution, is a very important parameter that should be met by an irrigation infrastructure and the engineers and managers working in multiple user irrigation systems. In this context, 'equity' does not necessarily mean that all the farmers involved must receive the same quantity of water for the same unit of irrigable land. As is the case in many irrigation systems in developing countries, certain farmers (due to, for example, their higher contribution to the maintenance of the system and/or their traditionally accepted higher status in the village) could receive more water than the rest. No matter how big a share this group of people take, if the majority of the farmers perceive it as acceptable, the distribution could still be considered as 'fair' and 'equitable'.

Inequality of water distribution has a direct influence on productivity, because it implies very poor utilization of some of the water. The area getting less water than its agronomic requirement will operate below its productivity potential. Whereas, the sites receiving excess water, will not show any yield improvement as the extra water is not serving a productive purpose.

Equity of water distribution, which is what is being discussed here, is not necessarily the same as the equity of income distribution. The case could be that in irrigation systems where there is inequitable water distribution between the head and tail end farmers, the upstream land could have higher price. Hence, farmers in the tail end may be able to buy or rent land much more easily and they could relatively have larger land holding. It is therefore difficult to assume that the head-end farmers get higher income per unit family than the tail-end farmers, before looking at the farm size and land values.

Inequity could occur at the field level, between users of a common field canal, and at the main system distributing water to the field canals. The inequity at these three levels could be quantified, but requires different methods and types of data. Measuring inequity at field level requires soil moisture measurements at numerous points, preferably using the gravimetric method and/or the Time Domain Reflectrometry (TDR) instrument. It is an expensive research, if it is to be done properly. It is however only necessary to do these measurements if a major rehabilitation, where levelling and grading is the major component, is to be implemented. Quantifying the degree of inequity at the field canal level requires data collection at the inlets of the canals. Inequity in smallholder, multiple user irrigation systems is very critical for evaluating the performance of the organisation in charge of water distribution. Unfairness at this level of the system usually causes fierce conflicts among irrigators and the members of the responsible organisation. Undertaking measurements at this level will provide a useful data on the quality of farmer managed tertiary units, leading to making decision on whether to provide farmers a higher responsibility, i.e. the control of the main system or just resort to help them develop monitoring mechanisms to better manage their tertiary units. The quantification of the inequity at the main system level only needs few water flow measurements at the off takes of the major canals, where in most cases measuring devices are in place. This is important for evaluating the performance of the responsible irrigation agencies.

A number of irrigation engineers have proposed various measures of inequity. Christianson (1942) suggested a coefficient, which is widely known as Christianson Uniformity Coefficient, Till and Bos (1985), the standard deviation, and Abernethy (1986), the inter-quartile ratio. The inter-quartile ratio provides a data that could be easily interpreted and communicated to farmers. It is therefore considered here to be the best parameter and is discussed in detail below.

The original inter-quartile ratio (I1) is defined as h75/h25, where h25 is the depth of water such that a quarter of the whole land receives less than this and h75 is the lowest limit of the most favoured quarter (Table 1). When the data available is limited, which usually is the case, h75 and h25 are not distinctly defined. This problem has made it necessary to develop a modified inter-quartile ratio (I2), which is also defined as h75/h25, but h75 and h25 are taken as the average depth of water received by the best and the poorest quarters respectively (Table 1).

The original and modified inter-quartile ratios of 1.5 and 3.2 indicate that the fortunate farmers at the head end that only occupy a quarter of the total irrigable area, received respectively one and half, and just over three times as much as water as the tail-end farmers irrigating the most disadvantaged quarter of the whole holding.

Table 1 Water distribution data for Determination of I1 and I2

Holding number	Area (ha)	Water received (mm)
1	4	7
2	4	7
3	4.5	7
4	2.5	9
5	19	12
6	3	13
7	7.5	15
8	1.5	15
9	6	16
10	4	16
11	8.5	17
12	17	19
13	6	19.5
14	6	19
15	3	21
16	5.5	22
17	10	23
18	11	27
19	8	29
20	17	30
Total	148	

Source: Hypothesized by author
Original Inter-quartile ratio (I1)= h75/h25 = 23/15 = 1.5;
Modified Inter-quartile ratio (I2)= = h75/h25 = 29/9.2 = 3.2

Regularity and reliability

Regularity and reliability of water are other important performance indicators. Regularity, here is not simply the uniformity in time, but delivery of water according to set irrigation schedules that match with the crop water demand during the various growth stages, namely the initial, development, mid season, and late season stages. Irregularity of water distribution implies waste and/or scarcity of water, as at times, the deliveries are either greater or smaller than needed.

Like regularity, reliability also deals with the time dimension of water supply. While regularity mainly focuses on whether the amount of water will be delivered according to schedule, reliability particularly deals with whether the water supply will happen according to the time schedule. The nature of regularity and reliability highly influences farmers' attitude to water. If experiences teach farmers that the field canal system does not ensure the supply of water as planned and thus the arrival of water is unreliable and irregular in amount, farmers can react in at least two ways. Firstly, farmers who are at the head-end, or those who have influence on members of the managing institutions, will strive to take more water than they actually need from the first delivery, assuming that the second delivery will be delayed. This could induce inequality and possibly conflicts among the users and the responsible irrigation institution staff. Secondly, farmers, particularly those at the tail end, being left with no other option, could use drought resistant varieties to cope with the scarcity of water they may be frequently subjected to. This may cause yield reduction.

When measuring the degree of irregularity or unreliability of water supply, it is not only a matter of counting up the number and amount of deviations from the design schedule, which is what the Christianson method suggests. Continuous water shortages and/or lack of any delivery for about 3 weeks will have more negative impact on the crop yield than the same sort of water shortage occurring at occasions widely distributed over the whole crop life period. Moreover, poor regularity and reliability of water will have more profound impact on certain crop growth stages, than in others. In run-off irrigation systems in Eritrea, crops have to grow during their entire life period on the amount of water and nutrients supplied prior to sowing, during the months of July to September. In such systems, the month during which the irregularity happens greatly matters. Farmers are very sensitive to poor regularity of water (i.e. to poor ability of the system to divert each flood occurrence) in July than in September. This is mainly because the floods in July are assumed by farmers to be rich in nutrients (organic manures) and have a cooling effect on the soil. Furthermore, in surface irrigation systems, unlike in pressurized systems, water cannot be supplied on daily basis, but on a weekly or even biweekly basis. Therefore, there is high reliance on the water holding capacity of the soil, to make sure that the intermittently supplied water is available for continuous uptake by the crop. Hence, in any methodology applied to measure whether water is being adequately delivered or not, water holding capacity of the soil and the crop's response to water must be incorporated.

The best approach to assess the impact of irregularity on the system performance is the concept of relative water productivity (Abernethy, 1984). In this approach, first the water demand curve during the whole growth period of the crop should be constructed for both the moment and amount of water supply. This can be done using the necessary climatic, crop and soil data with the help of the Modified Penman and/or computer models like the CROPWAT model. The data could then be compared with the actually delivered amount of water, which could be measured using gauged stations, where possible, or applying simple velocity-area methods. Finally, with the help of crop-water response tables, such as those in FAO (1992), the loss in the productivity during the times when the delivery of water was below or in excess of the actual demand, could be calculated for each growth stages of the crop.

Durability

Durability, often referred to as sustainability, is a rather more difficult parameter to put into numbers. It can be defined as the ability of the system to last its whole design life span, while reasonably delivering the right quantities of water: equitably, regularly and reliably. One of the major threats to the durability of irrigation systems, particularly in arid and semi-arid countries like Eritrea, is soil salinity build up; but also fertility degradation plays a significant role. Worldwide, about 500 million ha, nearly one third of the total arable land, is affected by severe salt concentration. Of these, 60 million ha (about 22 %) of the total irrigated land suffer from salinisation entirely caused by bad irrigation (Hofwegen, 1998). It is therefore very important that regular soil survey is conducted and soil and water samples are tested for salinity levels. Based on this assessment, remedial measures, among which is installation of adequate drainage facilities, and application of appropriate frequency and amount of leaching, could be introduced.

Durability is also directly influenced by poor maintenance of the system infrastructure, commonly referred to as the "Hardware". Often, modernisation of the "Hardware" is done without proper consideration of the capacity of the managing institutions in place, the "Software". The mismatch between "Hardware" and "Software" is usually reflected in a poorly maintained system. Canals, particularly in spate irrigation systems, become frequently silted up, reducing their water delivery capacities. Sediment or gravel traps retain excessive sediments, levelling the off takes of rejection weirs in the middle of a flood season, which induce loss of water. In addition, command area development structures, partially or wholly destroyed by floods, remain damaged or poorly maintained causing loss of water in some parts of the system. These problems result in inequity and irregularity and unreliability of water delivery and are potential causes for conflicts among the farmers.

Hence, it is worth discussing the issue of whether the "cost of operation and maintenance" could be considered as the major performance indicator. This parameter has a direct link with durability; but low-cost of operation and maintenance cannot be put as a goal by itself. Doing so will most probably not lead to attaining the major goals we have set. It is only after we have properly measured and obtained a dependable data on how well we achieve our primary goals, we can proceed to investigate what is going to happen to the system performance, when we reduce or increase the operation and maintenance costs.

Conclusion

Performance measurement in irrigation systems is important, as it will provide valuable and credible information on where in the system and what kind of improvement interventions are needed. Performance measurement could however be only meaningful and beneficial, if there are a set of primary indicators and goals, agreed upon by at least the irrigation engineers, researchers and policy makers working in different parts of Eritrea, but in similar irrigation systems.

In this paper, an attempt was made to show that the major goals of a large-scale, smallholder, multiple user, canal-fed irrigation systems are attaining equity, regularity, and reliability of water delivery and the durability of the system. When attempting to quantify these indicators, it is very important to use easy parameters, such as the modified inter-quartile ratio for equity and the relative water productivity for regularity to be able to communicate with a laymen audience. It is also equally important to investigate the root causes that have led to the data obtained on the major goals, as this will help to design and implement appropriate technical and/or institutional remedial measures.

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Runoff irrigation systems in Western Lowlands of Eritrea: Potentials and constraints

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Abstract

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

Key words: Eritrea, irrigation design, runoff irrigation, Western Lowlands.

Introduction

Irrigation is one of the methods used to increase food production in arid and semi-arid regions. It can enhance food security, promote economic growth and sustainable development, create employment opportunities, improve living conditions of small-scale farmers and thus contribute to poverty reduction and protects the environment from pollution. Furthermore, it increases subsurface water levels and recharges ground water. On the other hand, if irrigation is not properly managed, it can have adverse effects on the environment and the users. For example, the irrigation water in the channels could create a climate, conducive for mosquitoes to multiply, thus contributing to the spread of malaria and other water borne diseases. Apart from this, irrigated agriculture supplied with poor drainage infrastructure may lead to salt build-up in soils and the groundwater.

It is estimated that 70-80% of the population in Eritrea makes a livelihood on the production of crops, livestock and fisheries. The population is expected to rise from 4.3 million in 2001 (CIA, 2002) to 5.4 million by 2010. On the basis of 0.16 ton of annual food requirement per person (World Bank, 1994), the total annual food requirement by the year 2010 would be 864,000 tons. According to CIA (2002), the total potential arable land in Eritrea is estimated at 1.5 million ha, with nearly 50% of which is found in the arid lowlands and semi-desert agro-ecological zones. These two zones receive, on average, 200-400 mm of rainfall, which is low for agricultural production unless otherwise supplemented by irrigation.

Using the average grain yield of 0.74 ton/ha (World Bank, 1994), about 1.2 million ha of land should be cultivated to satisfy the food requirement of the population in Eritrea by 2010. However, there exists only about 750,000 ha land suitable for rainfed agriculture (CIA, 2002). Therefore, increasing agricultural production could be realized only if intensification of agriculture complements rainfed agriculture. Intensification of agriculture, through developing new irrigation systems (e.g. drip irrigation) and improving the existing systems (e.g. runoff irrigation system) in the potential irrigable areas of Eritrea, would enhance food security and sustainable development.

Runoff irrigation systems (RIS)

Principles and practices of runoff irrigation

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

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

Runoff irrigation systems have two main parts: the catchment area, where runoff is generated and the field area, where runoff water is concentrated. According to Tauer and Humborg (1992) two basic requirements must be met to establish a runoff irrigation system. First, there should be a mountainous or hilly topography that generates run-off and adjacent low-lying fields on the same plain or at the foot of the slope to which the runoff water can be directed. Secondly, the fields should have deep soils that are capable of storing ample moisture to supply the crops during periods of no precipitation. This is because in runoff irrigation systems, plants receive their supply of water during a dry period following a rainfall event exclusively from the moisture thus stored in the soils.

Two different types of runoff irrigation systems are employed, depending on the slope of the terrain. One is for locations where the catchment area and the fields lie adjacent to each other on the same plain called micro-catchment system. The second is a catchment area located on a slope with the usually terraced fields at the foot of the slope, called macro-catchment system. The ratio of the catchment area to field area in micro-catchment runoff system varies from 1:1 to 10:1 and in macro-catchment systems from 10:1 to 100:1. Some of the advantages and disadvantages of these two systems are explained in Table 2. In micro-catchment, there is no loss of potential arable land caused by the presence of the catchments, because the catchment areas are sloppy and thus are unsuitable for agriculture. Whereas in micro-catchment system, there is loss of arable land because the catchment basin and the fields lie on the same plain adjacent to each other.

Table 2 Comparison between micro- and macro-catchment runoff irrigation systems

Catchment	Advantages	Disadvantages
Micro	Low investment - Structures easily built and manageable	Loss of potential arable land Existences of homogenous relief
Macro	No loss of potential arable land-Possible expansion of fields	- High investment - High risk of runoff water

The micro-catchment and the macro-catchment runoff irrigation systems are both practiced in Eritrea (Figure 1). The spate irrigation system, believed to have been practiced in the Eastern Lowlands of Eritrea for over 100 years (Tesfai, 2001), is an example of macro-catchment runoff irrigation. Most of the runoff irrigation systems practiced in the Western Lowlands of Eritrea, such as those found in *Bultubyay, Areda* and *Falko* are of a micro-catchment type.

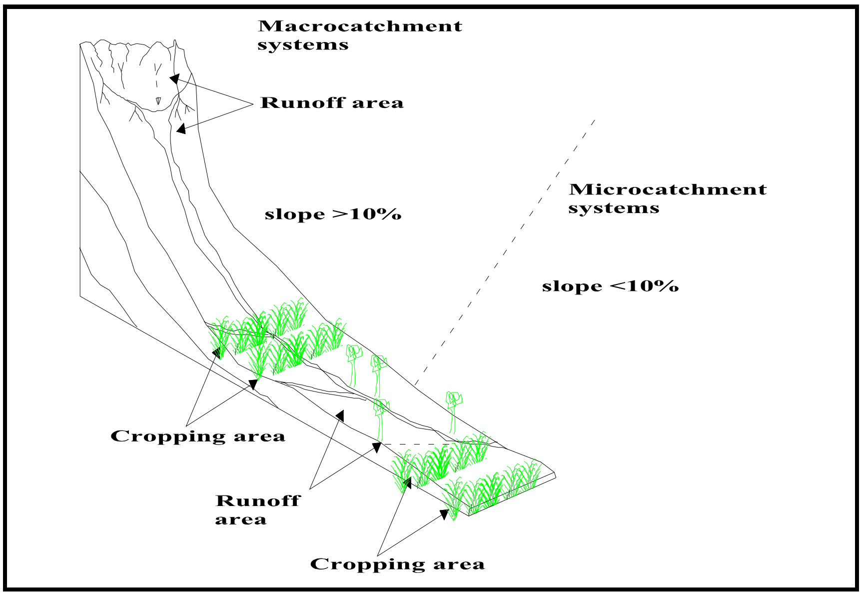

Figure 1 The runoff irrigation systems in Eritrea

The aim of the paper is to describe the principles and practices of the runoff irrigation systems in the Western Lowlands of Eritrea, their potentials, constraints and possible improvement interventions.

Materials and methods

Four runoff irrigation schemes (i.e. *Areda, Bultubyay, Falko*, and *Mogoraib*) were selected as a case study to identify the constraints of the RIS and their development potentials in the western lowlands of Eritrea. The methods employed to collect information and data on the RIS include literature review, field surveys and group discussion.

Prior to field survey, secondary data with regard to land and water resources potentials of the western lowlands were collected and studied. Thereafter, field surveys were made in two controlled RIS in *Areda* and *Falko* and two uncontrolled RIS in *Bultubyay* and *Mogoraib* schemes to observe how the systems operate. Field observation and discussion with the farmers and the MoA extension agents were held at the sites. The discussion focused on the constraints of the runoff irrigation systems and their possible solutions. Moreover, observation was made on design and construction of the diversion head works, irrigation canals and field layouts in both systems.

Results and discussion

A. Potentials of runoff irrigation systems

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

Water resources

Unfortunately, Eritrea is not well endowed with fresh water resources owing to the arid climate prevailing in the country and due to shortage of rainfall. Eritrea has five main drainage basins, namely the *Mereb-Gash*, the Setit, the *Barka-Anseba*, the Red Sea and the enclosed *Danakil* basins (Table 3). All these rivers (except the Setit River) are ephemeral which flow during the rainy season from July to September. The *Mereb-Gash*, the *Barka-Anseba* and the *Setit* rivers all flow into the western lowlands, and discharge towards the eastern Sudanese plains. The *Mereb-Gash* is a narrow westward oriented basin covering the area from the southern part of the central highlands to the Sudanese border. The *Setit* River has perennial flows along the southwestern zone, which shares a common border with Ethiopia. The *Barka* and *Anseba* rivers originate from the northwestern slopes of the central highlands and flow northward to a confluence close to the Sudan border in the extreme northwest of Eritrea. Although the annual rainfall volume of the *Barka-Anseba* basin is estimated at 14,815 million m^3, the annual flow volume is projected at only 41 million m3. This is probably because much of the flow is rapidly infiltrated into the sandy plains of the river valleys (FAO, 1994).

Table 3 Estimated catchment area, flow, volume, and rainfall of the major drainage basins in Eritrea

Drainage basin	Catchment area	Catchment mean annual rainfall	Catchment mean annual rainfall vol.	Annual flow volume	Mean annual runoff coefficient
	(1)	(2)	(3)=(1) x (2)	(4)	(5) = (4) : (3)
	km^2	mm	mio. m^3	mio. m^3	–
Red Sea	44,689	350	15,641	444	0.028
Barka-Anseba	39,506	375	14,815	41	0.003
Mereb-Gash	23,455	600	14,073	532	0.038
Danakil basin	10,532	200	2,106	135	0.064
Setit basin	7,517	650	4,886	49	0.010
Total	**125,699**	–	–	**1,201**	–

Source: WRD (2000)

Land and soil resources

The currently irrigated area in Eritrea is estimated at 28,000 ha (FAO, 1997), out of which spate irrigation covers about 50%. Table 4 shows the estimated potential irrigable command areas of the major river basins in Eritrea. Estimates on the total potential irrigable area of the river basins have been reported differently as 300,000 ha by EVDSA/WAPCOS in FAO (1994) and about 600,000 ha by the MoA report in FAO (1994). The former does not cover the eastern lowlands where a macro-catchment runoff irrigation system is practiced, and some minor potential areas in the highlands. The latter estimate covers all land areas assumed to be suitable for irrigation without considering the availability and accessibility of water and the suitability of soils for irrigation. Therefore, both estimates cannot be considered reliable and should be treated with caution.

Table 4 Estimates of irrigation potential of the river basins in Eritrea

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

Adopted from FAO (1994). NA: not available

The total potential area that can be developed to runoff irrigation system in Eritrea is estimated to be 187,000 ha. Out of this, nearly 50,000 ha are found along the major river basins in the western lowlands and the rest along the coastal plains in the Eastern Lowlands of Eritrea, where the spate irrigation system is predominately practiced.

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

Table 5 Runoff irrigation types and their irrigated areas in zoba Gash-Barka

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

Source: MoA, (2003)

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

B. Constraints of runoff irrigation systems

The constraints of runoff irrigation systems in the western lowlands based on field observations and discussions held with the farmers and staff of the MoA in the zoba *Gash-Barka* is given below.

Structural irrigation design and construction

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

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

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

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

Operation and maintenance

The farmers in the study area lack the technical know-how and skills of constructing and maintaining irrigation, and soil and water conservation structures. Furthermore, these farmers were not involved during the preparation of design, construction and implementation of the runoff irrigation structures. This has probably misled the farmers to assume that the operation and maintenance of the irrigation system is the responsibility of the MoA. Hence, most of the farmers are often reluctant to participate in the maintenance of the irrigation structures.

Absence of farmers' organisations

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

Concluding remarks

By and large, the Western Lowlands of Eritrea have potential for the development and expansion of runoff irrigation systems. However, the runoff irrigation systems are functioning under several constraints, which include; poor design of irrigation structures, lack of technical know-how, and absence of farmer's organisation. The following intervention measures are therefore suggested to improve the existing runoff irrigation systems to make them more productive and also to develop new runoff irrigation sites in the Western Lowlands of Eritrea.

- Feasibility studies and primary data collection mainly on runoff discharges, sediment concentrations (using velocity-area method) and soil characteristics through systematic soil survey must be carried out.
- Construction of field bunds (at least 50 cm in height) and proper levelling and grading of the irrigated fields is necessary.
- Capacity building of farmers and extension agents could be promoted through training and field visits to runoff irrigation systems in the Eastern Lowlands of Eritrea.
- Establishment of water users' associations and strengthening institutional and organisational structures of the schemes through training, provision of incentives etc. is very important.

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The challenge of spate irrigation development in Eritrea: The case of Eastern Lowlands

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Abstract

This paper briefly discusses the development and management of spate irrigation with special emphasis on the uncontrolled (traditional) and controlled (improved) systems in the Eastern Lowlands of Eritrea. The study is based on the primary data collected from the large spate irrigation areas of *Bada, Ghedeged, Afta Zula, Labka* and *Sheeb*. This study focuses on two major areas. The first is on the traditional aspects of spate irrigation. This part demonstrates the socio-technical aspects such as diversion, type of traditional structure *(Agim)*, local farmers institution, traditional water distribution and other spate related water management aspects, and the advantages and disadvantages of the system. The second part explains the comparison of improved spate diversion versus the traditional system. Basically, this is based on the case of *Wadi Laba* and *Mai Ule* diversion head works. It highlights the farmers' perceptions to the improved system and the socio-technical challenges in development of this system. The paper concludes by proposing recommendations to future development of spate irrigation systems in the study areas.

Key words: *Agim*, improved system, spate irrigation, traditional management

Introduction

Spate irrigation, introduced by the Yemenis at the beginning of the nineteenth century, was first practiced in the *Zula* area of Northern Red Sea region. These areas get runoff floods from the highlands during the months of July to September, and in some places a small runoff during the months of October to March. Recently this type of irrigation has been introduced in other parts of the country to supplement the water requirement of various crops under rainfed agriculture.

Spate irrigation, or Wadi agriculture, also known as Arroyo agriculture in America (Barrow, 1987) is the term for floodwater farming. In the context of Eritrea, it can be defined as a pre-planting system that uses short duration floods from the highland catchments areas to irrigate low-lying land where rainfall is insufficient for crop cultivation (Haile, 2000). The term spate irrigation is applied to systems of earthen or stone bunds designed to spread water over the ground to moisten it and/or to trap wet silt that can then be planted with crops (Barrow, 1987).

In spate irrigation, floodwater is diverted into canals by constructing water diversion structures using brushwood, riverbed materials, stones or combination of them. Fields are bordered by earthen bunds, thus allowing inundated water to infiltrate into the soil (UNDP/FAO, 1987). Water is conveyed from higher to lower fields by intentional breaking of the earthen bunds or as in some areas water is conveyed with permanent distribution structure, to attain the desired level of irrigation water. Depending on the water holding capacity of the soil, one or two deep applications are enough for crop cultivation and the crop grows using the retained moisture of the soil profile. In spate systems, irrigation is performed before planting to avoid water logging to the developing crops due to flooding. Due to deep spate soils, most farmers are flooding their fields only once or twice and are able to grow two or even three crops (ratoons) in sequence from the residual moisture of the soil.

The aim of this study is to describe the main bottlenecks in traditional spate management that hinder the development of improved spate irrigation systems.

Materials and methods

The study was implemented in the Eastern Lowlands of *Bada, Ghedeged, Afta Zula, Labka* and *Sheeb* area where spate irrigation is practiced. Methods and techniques have been selected in such a way that reliable data can be collected. The study employed an exploratory approach, where both quantitative and qualitative methods of social inquiry were done. It focused particularly on the perception of smallholder farmers regarding spate irrigation practices in their respective areas. Various data collection methods such as interviews with the farmers, group discussion with key informants (formal and informal) and direct observation in the sites were done in conducting the study. Beside the primary data, all available secondary data sources that are appropriate to the study were reviewed and helped to derive relevant data from previous studies made by different institutions.

Results and discussion

Spate diversion systems can vary greatly in their hydrology and water management practices. However, in Eritrea, the system can be classified in two main parts, as traditional (uncontrolled) and improved (controlled) spate systems based on the method of management of the diversion systems. Currently, controlled diversion system is used in only 4530 ha (2880 in *Laba,* 850 in *Mai Ule* and 800 in *Afta Zula)* of land.

Traditional spate diversion system

In traditional spate irrigation, diversion structures *(Agim)* are temporarily made of local materials like soil, stone, riverbed sand and gravel, tree trunks and brushwood. They are normally constructed across a riverbed to divert river flow into farm area to irrigate fields. Agim is a local name for the diversion structure, which is also called *Ogma* in Yemen (UNDP/FAO, 1987) and *Ghanda* in Balochstan (Steenbergen, 1997)

The riverbed topography changes after almost every medium to heavy floods because of degradation and deposition. Therefore, during heavy floods, these structures are partially damaged or washed away completely. During reconstruction of these structures their location and shape are readjusted to suit the existing riverbed condition. The efficiency of this diversion is estimated at 45% (Halcrow, 1997).

Although traditional flood diversion methods seem to be elementary and generally productive, they are labour intensive and environmentally unfriendly. Several indigenous techniques have been developed to divert seasonal spate floods and irrigate farm areas. The structures developed are not permanent and can be adjusted structurally as required. If the flood is very high and beyond the capacity of the main diversion *(Agim)*, normally the structure immediately breaches. This saves the farmers from the destruction of main canals locally called *Mushga* or *Bajur* and field embankments, locally called *Kifafs*.

The farmers have a method of traditional diversion structures, which, can be classified into three types as: deflector, weir and free intake. The three methods of diversion structures, more or less, have the same operational features. They do not have silt excluder, so the sediment carried by the floodwater is allowed to enter into canals and fields uncontrolled. The diversion structures do not have flow controlling mechanisms. Once they are constructed, the amount of floodwater entering from the river to the main canal cannot be regulated or stopped when there is a need to do so.

The three types of diversion structures perform very well when there is low stage flow. During a low stage flow, the flow is manageable and the damage to the diversion structure is minimal. Thus for small to medium size spates the diversion structures are mostly effective. While for medium to large spates, very often, the diversion structures are washed away with strong spate flood and a lot of effort is needed to repair or reconstruct them. As there is no provision for a spillway, during a large spate, the diversion structure is either breached immediately or it is overtopped as the flood rises and breached. Many times a major section of such structure is washed away, just before the whole command area could have been irrigated. Repair works have to be carried out as soon as possible and before the next spate flow arrives; otherwise an additional irrigation will be missed. How soon this can be effectively achieved will depend on subsequent river flows and the availability of labour and animal power. Usually this laborious task is done communally.

Missing a spate flow can have a negative effect on yield and sometimes leads to total failure of crops. The construction costs of the traditional spate irrigation systems are relatively low. Human as well as animal labour and local materials like wood and *Wadi* bed material is all what is needed. Once these structures are washed away, the reconstruction or maintenance costs in most cases are the same as the initial construction costs.

Water distribution system

In the traditional spate irrigation systems, floodwater distribution is accomplished by means of canal systems. A canal is often subdivided into branch canals on its way downstream. Larger canals are subdivided into smaller canals until water reaches the different fields. Depending on the size of the farm, there can be primary, secondary, tertiary, etc. field canals. These canals have different local names and the water distribution is governed by rules.

At field level, two types of water distribution systems exist: field-to-field and individual field. Field-to-field distribution system is common in most of the large spate irrigated farms in the country. In such system, about 10-15 fields are grouped into a block and receive their share of water from one canal. Inside the block, there are no division structures or canals. Each field is provided with an inlet and an outlet. In individual field distribution system, each field receives its share of water independently, directly from a canal. This system is practiced in few places like *Bada* and *Afta Zula* areas.

Informal farmer organisations

The farmers in the traditional spate-irrigated farms are well organised into sub-groups of 15-45 farmers traditionally called *Tashkils*, and groups of 6-31 *Tashkils* make up a *Parta*. Different committees also exist for various functions. The farmers elect their group and sub-group leaders, agricultural and irrigation committee and sub-committee members directly, without any intervention of others. In general, leaders are elected for an unlimited period of time. These organisations enable the farmers to maintain, manage and operate a very complicated system of spate irrigation on which they depend for their livelihood. It would have not been possible to run a spate-irrigated farm of large magnitude without efficient farmers' organisations as well as full participation and commitment of the farmers.

Constraints in developing traditional spate system

The following are some of the constraints identified that hinder the development of traditional spate irrigation systems.

- The types of *Agim* adopted in the system fail after every medium to high flood. The breaching of *Agim* has a consequence of spending much time and effort to restore the *Agim* again. Moreover the repetitive construction of brushwood *Agim* in the area causes a negative environmental impact.
- The conveyance and the distribution system is not well developed and operates on first-come-first-serve basis. The fields at the top of a block always receive relatively high amount of water, while those at the tail end receive smaller amounts or sometimes even not at all.
- The system is quite ineffective with regard to sediment transport. Nearly all the sediment carried by the floodwater is not conveyed to all fields equally. Most of the sediments are deposited in the first top field in a block and deposition decreases as it goes down the fields. This results in highly varying field elevations in a given block and in high erosion during irrigation.
- In the present system, the actual benefits are not proportional to the labour contribution by the farmers during the construction of *Agim*. Each individual farmer is obliged to contribute labour in proportion to his land size irrespective of the area actually irrigated. As the floods cannot be predicted, it is not known which field can be irrigated from which *Agim*. Another complication of the system is, every *Agim* constructed covers a different area.

Improved spate diversion system

The development options for improved spate system, in general, are dams and spate breakers, ground water development and spate diversion structures. All these options were reviewed and the last was found more appropriate for these areas. Wadi Laba and Mai Ule diversion structures were recently constructed in Eastern Lowlands of Sheeb, to properly acquire and distribute water more efficiently than the traditional system. Prior to this project intervention, there was no establishment of similar type or size of modern structures in Eritrea. The main objective of this improved structure is to increase the magnitude and duration of flow into the existing traditional canal. The annual average expected irrigable land is 3730 ha. The following Table illustrates the principal features of the diversion system after the project intervention.

Table 6 Main features of the spate diversion system before and after intervention

	Average irrigable area (ha)		Diversion efficiency (%)	
Wadis	Before intervention	After intervention	Before intervention	After intervention
Laba	1192	2648	45	80
Mai Ule	281	676	45	80

Source: Halcrow (1997)

The improved system has main head regulator, scour sluice, sediment stilling basin, weir, twin culvert and a breaching bund. The design analysis was based on insufficient hydrological data however; even with reliable data the knowledge to solve the technical problem of dealing with destructive floods and high sediment loads is still limited. The structure is assumed to divert all small floods, 80% of medium floods and no wild floods. This is because the economic return realized through spate system is so low that it does not encourage the employment of expensive design (UNDP/FAO, 1987). To minimize the cost of this improved system a breachable bund or fuse plug is included. Apart from that, time to peak flood is characteristically rapid i.e. less than 40 minutes (Halcrow, 1997). The risk to control these floods is very high and the benefit is low. At present, the total cost of diversion for *Laba* is Nakfa 18,330/ha and for *Mai Ule* Nakfa 33,680/ha. These different costs of both Wadis show that, despite the low return of spate irrigation, the development strategies for improved system should be considered for large farms only.

Farmer's perception of improved system

Based on the interviews and meetings conducted, the farmers of both Wadis (*Mai Ule* and *Laba*) are still reluctant on the implementation of the diversion structures. The farming communities wanted to have the following improvements on the structures: raising of the head works because too much water is going over them during floods, breaching bunds to be made up of solid materials to prevent them from being washed away during large floods, breast wall to be removed from the head works and gates be wider in size and the scour sluice and rejection weir to be closed.

The farmers prefer to have a permanent infrastructure on the improved system because they would not have to spend time on maintenance and this helps them to capture all the water from the floods. The above list of issues demonstrates a serious lack of understanding of the aim of the improved head works. In reality, the infrastructure reduces the amount of time and effort the farmer spends on maintenance of the traditional diversion works. This provides them with more time to work at field level and capture water from more floods- a practice which is more reliable than ever before. The above issues raised by farmers show that, hydraulic structure in the Wadis is just one aspect of development and it would have been more fruitful if this could be integrated with the socio-economic settings of the end users.

Operation and maintenance of the improved system

The farming community accomplishes all construction and maintenance activities in the traditional spate diversion system. The operation and maintenance of improved spate systems requires a completely new approach due to the very specific characteristics of the system. Spates will often arrive at night and the sediment removal facilities at the diversion structures are essential to avoid entry of large quantities of course sediments into canals and fields. This is mostly based on the gate operator curiosity to follow up the operational procedure of the gates. The annual estimated operation and maintenance cost for *Laba* is Nakfa 40 while that for *Mai Ule* is Nakfa 1,007 /ha. The system is designed to remove 80% of the sediment and the remaining 20% is assumed to be distributed. The annual maintenance cost such as repair of concrete, masonry, preparation of equipment for operation and maintenance need to be budgeted annually. All the external skills such as mechanics, machines operators and other skilled labour needs make the farming community more dependable. Nowadays the project's main problem particularly on the improved system is to sustain the operation and maintenance by assisting the farmers to secure the required manpower and machinery. Thus, to run this improved system sustainably, fundamental changes in farmers' attitude and approach of irrigation are highly required.

Constraints in developing improved spate system

The main constraints for developing the improved spate system were identified to be:

- Spate irrigation improvement work does not encourage investments due to high capital costs and low return,
- The uncertainty in estimating extreme flood return period greatly increases the cost of the system,
- Lack of sufficient data on spate hydrology to allow detailed analyses,
- A limited knowledge of appropriate concept for developing improved spate system and the technical problems dealing with destructive floods and high sediment,
- The lack of ownership and adequate provision for operation and maintenance after completion of improved system, and
- Adoption of new technologies and concepts by the farming community needs more time, personnel and budget than expected.

Conclusion and recommendations

Before the construction of *Wadi Laba* and *Mai Ule* diversion schemes, the communities were practicing only the traditional diversion system of stone and brushwood *Agims*. This system was very risky, had low return and was hazardous to environment. There was no improved spate irrigation system in Eritrea. The construction of improved schemes will definitely ensure reliable water diversion and increased crop yields, which can help to attain food security. However, shift from the traditional to improved system of spate irrigation requires a fundamental change in attitude of both the government and the farmers. The improved system is chosen because it avoids the risk of floods and uncertainty, increases incomes of farmers and restores the environment. However, farmer capacity is still low to manage the improved system because of lack of know-how and economic constraints. Thus, a constant backup from the government is required especially with regard to the operation and management of the project in general and the structure in particular.

The following recommendations are proposed for the traditional and improved spate irrigation systems of the study area.

- Traditional spate irrigation systems are poorly studied and documented. A better documentation of the special environments and networks that currently allow parts of spate irrigation systems to keep working is a pre-condition for any improvement. A more detailed study on spate problems such as diversion, distribution, and field-to-field conveyance system has to be made. Soil and land potential, catchment hydrology and the water rights of the area together with other social and environmental aspects should also be studied further.
- To ensure a more fair water distribution and to avoid the continuous construction of *Agim*, floods have to be better controlled. Changing the construction of existing *Agim* and the conveyance structures is needed to control the flood in a manageable manner. Thus, government intervention is highly required, because improvement measures in spate irrigation demand high skill and investment, as it is beyond the capacity of the local communities.
- Investment in improved diversion structure works should be linked to the probability of spate and the incremental benefits of irrigation. At the same time the operation of these structures should remain simple and manageable by farmers. A structure must also be durable enough to avoid unnecessary and repetitive maintenance and rehabilitation work.
- To build confidence in design, to avoid cost escalation of projects and high risk of failure of structures, any *Wadi* development needs to establish a long-term data collection programme within the framework of the government.
- To build farmers awareness and responsibility in improvement works, serious effort should be made parallel to the infrastructure development.

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Theme 2 Small scale irrigation systems

Introducing small-scale irrigation technology in Eritrea: Lessons and experiences

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Abstract

Eritrea is a semi-arid country. Rainfall is not scarce in total amount; but its erratic nature is increasingly resulting in frequent failures of rainfed agriculture. If food security, which is a cause of serious concern to Eritrea, is to be achieved, irrigated agriculture must supplement rainfed crop production. In Eritrea, attaining household food security is the basis for realizing national food security. Introducing affordable small-scale irrigation technologies that are compatible with the small (< 0.5 ha) plots of the rural poor farmers is one way of achieving household food security. International Development Enterprise (IDE) micro-irrigation kits were introduced to Eritrea in 2000, and pre-feasibility and feasibility studies were conducted. This paper mainly focuses on the lessons and experiences learned during the whole study period. It gives an in-depth assessment of what were the reasons for the discrepancy observed between the initial willingness of the farmers to test the kits, and the low rate of usage and adoption that was witnessed later. It provides a detailed analysis of how the theoretically advocated higher water; labour and time saving advantages of the kits (as compared to surface irrigation systems) were reflected in practice. It presents the steps and the approaches followed during the dissemination of the technology and discusses their shortcomings. The paper also offers some insight on the gender suitability of the kits. It concludes with recommendations on how to overcome some of the major bottlenecks for technology adoption in Eritrea.

Keywords: Adoption rate, Eritrea, food security, irrigation kits

Introduction

Eritrea is a small country in the Horn of Africa with a population of about 4.3 million and a total land surface area of 121,320 km2. Agriculture is the main stay of the economy engaging about 80% of the population and contributing to 16% of the GDP (CIA, 2001).
Eritrea has a total potential arable land of about 1.5 million ha. 50% of this lies in the semi-arid and semi-desert agro-ecological zones, where rainfed agriculture is impossible, as the mean annual rainfall is less than 200 mm. The currently irrigated area in the country is nearly 28,000 ha (FAO, 1997). The estimate of the potential irrigable area varies from 270,960 ha by Water and Power Consultancy Service (WAPCOS) to 576,000 ha by the MoA (FAO, 1994). The smaller estimate does not cover the Eastern lowlands where runoff irrigation is practiced and some minor potential areas in the highlands, and hence cannot be considered exhaustive and should be treated with caution. The largest estimate covers all land areas topographically suitable for irrigation, regardless of the water availability and its technical extraction feasibility. It is therefore also not a dependable value.

The rate of annual population growth in Eritrea is estimated at 3% (CIA, 2001), which is one of the highest in the world. At this rate, the population is expected to rise from 4.3 to 5.4 million in 2010. On the basis of 0.145 ton of food requirement per person per year (World Bank, 1994), the annual food requirement by 2010 would be 783,000 ton. If this is to be produced only from rainfed agriculture, based on an estimated average grain yield at 0.74 ton/ha (World Bank, 1994,), nearly 1.1 million ha of land is required. There are however only 750,000 ha suitable for rainfed agriculture. It also has to be noted that even in this "so-called" suitable land, rainfed agriculture has been and is still frequently failing, mainly due to the erratic nature of the rainfall. Channelling investment to the introduction of new irrigation technologies and/or modernising the existing ones is therefore necessary if food security is be achieved in Eritrea.

In Eritrea, the first step towards attaining national food security must be ensuring that the rural poor households are food secure. Most of these households own small farm plots (less than 1 ha), which are usually irregular in shape. Some household members, mainly women, also engage in a backyard gardening to produce some of the basic food items. Introducing small-scale irrigation technologies that are affordable and compatible to the local, physical and social settings could be one of the means of realizing household food security in Eritrea. Currently, there are a number of small-scale micro-irrigation technologies in use, and IDE, Chapin and Netafim kits are among the common. These kits, like the conventional large-scale systems, enable a slow (0.5 to 2.0 l/h) and regular application of water to the vicinity of plants, wetting only the part of the soil in which the roots grow. With these irrigation systems, water can be supplied frequently, sometimes everyday if required, which is very suitable for plant growth (Mehari *et al.*, 2003).

Micro-irrigation kits are designed to cover small irrigation plots and are produced at a low cost. Their production is aimed at addressing the problems of the poor farmers who cannot afford the initial investments required by the conventional drip and sprinkler irrigation systems. Some irrigation engineers call these kits, the "HELPFUL" (H=high frequency, E= efficient, L=low volume, P=partial area, FU= Farm Unit, L=low cost) (Hillel, 1997).

In the year 2000, the College of Agriculture (CA), University of Asmara, and the Centre for Development and Environment (CDE), University of Berne initiated a joint project that aimed at introducing and assessing the technical and socio-economic feasibilities of IDE bucket, vegetable, horticulture and sprinkler kits (Stillhardt *et al.*, 2003). All the kits have main and lateral lines, micro-tubes, filter, fittings and pegs. The remaining features are presented in Table 7.

This paper is based on the results of the project and aims at analysing a) the motives behind the initial willingness to test the kits and the later low rate of usage and adoption by the farmers; b) the reasons why the superiority of the kits (as compared to surface irrigation systems) in water, labour and time saving were not influential enough to convince the majority of farmers to use the kits; and c) the realities that made the few women involved in the study to be interested and use the kits successfully. Furthermore, the paper presents the shortcomings of the approaches followed during the dissemination of the kits and concludes with recommendations on how to overcome some of the major bottlenecks for a new irrigation technology adoption in Eritrea.

Table 7 Main features of the introduced micro-irrigation kits

	Types of kits			
Features	Bucket	Vegetable	Horticulture	Micro-sprinkler
Irrigable area (m2)	20	100	130	160
No. of micro-tubes	36	150	50	15
Required height of water source (m)	1	1	1	10
Micro-tube discharge (l/hr)	2-3	2-3	2-3	40-50
Required size of water container (l)	20	200	200	500
Min and max no. of plants/ kit	36-144	150-600	50	Used for closely spaced crops
Type of plants	Vegetable crops	Vegetable crops	Perennial fruit crops	Vegetables, pulses, flowers, cereals etc.

Materials and methods

The project had two study phases: pre-feasibility and feasibility studies. During the pre-feasibility phase, 25 kits, mainly bucket kits were distributed in *Mendefera, Shiketi, Maihabar, Sheeb, Dekemhare, Hagaz* and *Hamelmalo* Agro-technical Schools and *Halhale* Research Station (Stillhardt *et al.*, 2001). The distribution during this phase was mainly based on individual approach to farmers and their willingness to participate in the study.

During the feasibility phase, 240 kits were planned for distribution: 100 bucket, 100 vegetable, 20 horticulture and 20 sprinkler kits. The total number of kits distributed and areas of distribution are presented in Table 8. The kits were distributed under the following conditions:

- In order for the farmers to feel a sense of ownership, a value was put to the kits and they were sold at half price: with a bucket kit costing 60 Nakfa, vegetable and horticulture kits 200 Nakfa each, and sprinkler kit 250 Nakfa (1 USD = 14 Nakfa). If after trying, they decide that the kits are not useful, they can return the kits back, but with no missing parts and in good condition, and they can collect their money back.
- In cases where the farmers could not afford, but were ready to try the kits, they were given free at the start and were asked to pay if satisfied with the performance at the end of the growing season. If they are not satisfied, they should return the kits back in good condition.
- The kits were provided free of charge for *Halhale* Research Centre, the two agro-technical schools and some farmers, with a precondition that they will give a written feedback.

At the time of distribution, users were given detailed on site demonstrations about the installation, operation and maintenance of the kits (Images 1and 2). Manuals translated in two local languages (Tigrigna and Arabic) were given as appropriate. Field visits were organised to the different locations to monitor and evaluate the progress of the installation and usage of the kits. At the end of the project period, a structured questionnaire was prepared and filled by the researchers in the test sites. Open-ended questions were also prepared and on site discussions were held with farmers on the practical applicability and limitations of the kits. The questionnaires were filled only in cases where the farmers have used the kits. In cases where that didn't materialise, the possible reasons for not using them were collected and analysed.

Table 8 Distribution of IDE kits in the various administrative regions

Administrativeregions/ zobas	Location/Institute	Types of kits			
		Bucket	Vegetable	Horticulture	Sprinkler
Anseba	Keren	1	1	0	2
	Hamelmalo school	6	2	9	3
	Hagaz school	17	6	5	–
	Afdeyu	10	10	–	–
	Hagaz	4			7
Gash-Barka	Agordat	–	–	–	1
	Barentu	–	2	1	–
Debub	Adi Keih	16	16	–	–
	Adi Wegera	–	2	–	–
	Mendefera	4	2	–	–
	Adi Zarna	1	1		–
	Adi Mongonti	3	–	–	–
	Maado	–	1	–	–
	Dbarwa	2	6		–
	Dekemhare	4	2		–
	Halhale Res. Center	6	1		–
	Adi Quala	3	3	–	–
	Adi Jemel	1	–	–	–
N. Red Sea	Maihabar	5	3	2	
	Gindae	3	3	–	–
Maekel	Commercial farms	–	3	–	–
	Individuals	14	3	1	4
	College of Agriculture	–	2	–	–
	TOTAL	100	69	18	17

Results and discussion

The results provided in this section are mainly those of the feasibility study. Out of the 240 kits, 204 (85%) were distributed. Out of these, 74 kits (36%) were used by the farmers. The kit that was used by many was the bucket kit and 12 % of them were used by women (Table 9). When compared to other countries, the rate of adoption and irrigation development in Eritrea is not a disappointing figure. Gleick (2000) assessed the rate of irrigation development in 40 African countries for 12 years (1985- 1997) and found that 13 countries showed no growth at all. These include Botswana, Mauritania and Senegal, countries identified as being highly dependent on irrigation. The highest rates and percentages achieved in the majority of the countries most actively engaged in irrigation are less than 500 ha/year and 50% respectively.

Image 1 Very keen farmers participating during the demonstration of a bucket kit

Image 2 Farmers curious on the wetting patterns of the micro-drippers and students taking care of their vegetable kit

Table 9 Kits distributed and their percentage usage

	Bucketkit	Vegetablekit	Horticulturekit	Sprinklerkit
Intended for distribution	100	100	20	20
Actually distributed	100	69	18	17
Used	52	16	3	3
Percent usage	52	23	17	18

The data gathered from the farmers and the institutions differ remarkably, and for convenience they are presented separately.

Data from farmers

The sprinkler kit was not used by many of the farmers, as it required pressurized water source, which was not available in almost all the rural areas. Only one commercial farmer in *Agordat* used the kit for successful seedling production for transplanting to large-scale drip irrigation. Despite his success however, he said that the size of the kit is a limiting factor for adoption. He prefers if the kit could have covered at least a quarter of a hectare.

Only one farmer in *Barentu* installed the horticultural kit. He used it for papaya production and was able to use it until the fruit setting stage of the plants. However, his field was destroyed by heavy rain and part of the kit was lost. The horticultural kit being mainly beneficial for perennial tree production does not generate short-term benefits to the farmer. In addition, the land tenure system in the highlands does not encourage long-term investment as land may be redistributed after 5 to 7 years. Furthermore, it was difficult to customize the kits to the existing spacing of the citrus trees, which ranged from 5 by 5 to 6 by 6 m. These did not encourage the farmers to install and use the horticultural kit.

During demonstration, there was high willingness of the farmers to use the kits. Despite this however, the rate of adoption was only moderate to low, with only 52% of the bucket kits and 23% of the vegetable kits used. In many cases farmer's initial acceptability and purchase of the kits was not a true reflection of the farmers' ability, willingness and readiness to use them. During the follow up trips, most of the purchased kits were not installed since many of the farmers required further follow up and assistance from the extension agents in the area of distribution. It has to be noted that 'small-scale' does not necessarily mean 'simple'. The different components of the system such as coupling, fitting and control valves could make the simple IDE kits appear complex for smallholder farmers who are using them for the first time (Mehari *et al.*, 2003). In some areas, where the demonstrations were done in the presence of some government officials, some farmers revealed that they purchased the kits simply to please the officials, and not because they knew they were beneficial to them.

It is notably true however, that the used bucket and vegetable kits showed substantial successes. The farmers were able to grow pepper, okra, tomato, lettuce, flowers, maize and potato using the kits. All those who successfully used the kits appreciated the advantages of the micro-drip irrigation (as compared to their traditional systems) in saving water, labour and time.

The water saving advantage of the kits, although recognised, was not however an incentive by itself for many farmers to use the kits, particularly those who had a shared water source. In many areas where farmers own small plots, one farmer owns the well but the farmers around may share the water. The owner of the well makes a water delivery schedule, usually once per week, during which time he opens the tap and leaves it to flow for a whole day. He doesn't measure how much water each irrigator has used and does not charge money per unit quantity of water utilized. It is only at the end of the growing period that each farmer pays either one third of the produce or an equivalent amount of money.

Under acute water scarcity and where water has to be fetched from distant areas, the issues that the kits save water, labour and time, although acknowledged, were not immediately given much weight and did not encourage many farmers to use the kits. Where water was in short supply, obviously priority was given to drinking water. In many highland areas, water needs to be brought by women usually on their backs sometimes from distant places (3 to 4 hrs walking). The women needed much thinking to weigh the extra labour and time required to water the plants using the kits. They explained that they would only use the kits once they are convinced that the benefits they get are remarkably high compared to the investment. They can only know this however, if they see that some women under the same circumstances have successfully used the kits. This would need women who can take the lead and the risks involved.

As stated earlier, most farmers acknowledged that micro-irrigation kits save labour and time, but there were some who argued that the kits induce additional labour and time, and they considered this as the main reason for non-adoption. These farmers contest that the kits consist of delicate items such as the micro-tubes and pegs and hence require fencing, continuous watering and closer supervision to function effectively. Their traditional basin irrigation systems instead, need watering only in four or five days giving them a chance to be engaged in other activities. Although majority of the farmers shared this opinion, few of them were willing to test the kits and practically see how much time and labour they will need. But they explained that they only would do so, if the kits were given free.

Compared to traditional surface irrigation systems, the advantage recognised by the farmers who used the kits, was the rare incidence of insects, weeds and diseases. This was expected, because if properly installed, the kits wet neither the leaves nor the stems of the plant, and they only wet the area near the root-zone, prohibiting insect, and weed or pest outburst.

All the interviewed farmers considered the price of the micro-irrigation kits affordable. But almost all also commented that the size of the kits is too small and they prefer to buy kits that could cover at least a quarter of a hectare.

Data from institutions

The results from schools and institutions provided more scientific insight on the potentials and constraints of the introduced kits. Comparative study of the kits versus furrow irrigation system was studied in both the *Halhale* Research Center and the two agro-technical schools. In *Halhale*, a potato trial was conducted for one growing season.

The results showed that a bucket kit utilized 6000 litres of water during the three months growing period whereas furrow irrigation consumed 15,660 litres. It was possible to accurately measure the amount of water supplied to the furrow irrigation systems as the plots were irrigated using a plastic hose. With these consumptions, the bucket kit produced a yield almost twice that of the furrow irrigation. However the average tuber weight was 19.5 g using the bucket kit compared to 24.1 g using furrow irrigation.

In Hagaz, the efficiency of the furrow irrigation was compared to that of the drip kits (Table 10). The drip kit was found to be twice as efficient as the furrow. The observations from the *Hagaz* trial indicated that the infiltration depth of water was 80 cm with the drip kits and 150 cm with the furrow system. This makes vegetable production under the kits more water efficient as the effective root depth of most vegetables is in the range of 60 to 80 cm (FAO, 1998).

Table 10 Comparison of water use between drip and furrow irrigated tomato plants

Application period	Applied water ('000 litres)		Percolated water('000 litres)		Water used by crops('000 litres)		Efficiency (%)	
	Drip	Furrow	Drip	Furrow	Drip	Furrow	Drip	Furrow
1st – 38th day	1.4	26	0.6	18	0.8	8	60	30
39th – 75th day	2.7	50	1.2	42	1.5	8	55	16

Conclusions and recommendations

Technologies and methodologies designed and introduced entirely from outside cannot be blindly accepted and adopted. They need to be tested under local circumstances to see the suitability to the priorities of the intended beneficiaries. This can only be done with the assistance of progressive farmers who have an open mind to new technologies with eagerness and willingness to change. When introducing new technologies, such as the micro-irrigation kits, it is very important to first identify such farmers and channel all technical and other supportive advices and assistance towards them. It is also imperative that these farmers live in an area where there are capable and motivated local extension agents who can provide them with useful day-to-day support.

At the early stages of the introduction of new technologies, the IDE kits in this case, expectations on the fact that the advantages of the kits in remarkably reducing water, labour and time wastage need to be realistic. The outcome is determined more by the capacity of small-scale farmers to adopt new technologies. It has to be realized that most Eritrean smallholders, as those in the rest of the developing world, use the strategy of minimizing risk for survival. If they perceive adopting a certain technology is even slightly risky, they will give priority to their long used production systems, as these will give them some basic security from starvation and guarantee them some degree of survival. As stated earlier, for example, some farmers shed doubt on the ability of the kits to save labour and time; some women clearly explained that they need some time to weigh the benefits against the additional labour and time they will need to invest. All these are indications that the farmers are not prepared to take the minimum risks involved. Under such circumstances, government and non-government development institutions have to provide positive incentives and/or subsidies and share the risks involved, knowing that there is no risk involved in so doing. These could help promote adoption of the kits.

It has to be underlined however that the study has proved that when and where the kits were properly used, the outcome was rewarding in terms of subsistence/household production. Given the necessary training and follow up, the kits could be a means of generating additional income, particularly for women.

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Agronomic considerations of low cost micro-irrigation systems

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Abstract

It is widely recognized that many countries are entering an era of severe water shortages. Recently developed, low cost micro-irrigation technologies can offer significant livelihood benefits for millions of poor farmers throughout the world, where there is scarcity of water. Micro-irrigation systems have been introduced to Eritrea and showed positive results, with some limitations. There are various agronomic benefits of micro-irrigation, however, to ensure a successful use of the technology by farmers, it is important to combine guidance on agronomic practices with the technical guidance. Appropriate agronomic training, which fits with the kits, is critically needed. Crops suitable for specific micro-irrigation kit should be selected. Spacing, staking and pruning have a significant role in the performance of the crop. Number of plants per dripper needs to be specified for specific crop. The amount of soluble chemical fertilizers to be applied should be given to the farmers, as most of them are not familiar with fertigation. In most cases, evapo-transpiration demand of the crop determines the amount of water to be applied but not always. Vegetables that are set for transplanting require irrigation for crop establishment in excess of crop evapo-transpiration demand. Crops such as broccoli, cauliflower and lettuce grow rapidly, by absorbing large amounts of water and nutrients until the date of harvest. On the other hand, tree crops like mango require little water for their survival during non-flowering and non-fruiting growth period. Off-season production of vegetables and fruits could also show a shift from the normal season. The number of refills for example for drum and bucket kits should be in accordance with the aforementioned idea. Since micro-irrigation systems are relatively new it is possible to define and recommend agronomic practices to accompany these technologies by modifying and parameterizing the requirements of crops. This paper addresses agronomic practices, which should be incorporated to the adoption processes of micro-irrigation kits by establishing relationships with the existing technical know-how.

Key words: Low cost, micro-irrigation

Introduction

Many countries are entering into an era of severe water shortage. Arid and semi-arid countries, like Eritrea, being on the frontline desperately seek for technologies, which could alleviate this problem. International Development Enterprise (IDE) has developed irrigation kits, which can be used by smallholder farmers in water scarce areas. The kits have been tested in various countries like India, South America, and some African countries including Eritrea and have strong potential for improving nutrition and food security at household level.

Low cost micro-irrigation systems have been introduced to Eritrea in the past few years. The technology is very attractive to smallholder farmers not only because of its low cost and economy of water and labour but also because of its simplicity in operation, maintenance and management. Farmers have confidence in using the technologies provided that proper technical as well as agronomic guidance is given to them mainly during the introduction of the technology.

Technical guidance on how to assemble, dissemble and maintain the kits has been a part of the adoption processes in Eritrea and elsewhere. Yet, there seems to be a gap on the agronomic practices, which the farmers should be aware of while using the kits. In order to ensure the farmers' success with the low cost micro-irrigation technologies, IDE is evaluating the amount of agronomic training required by the farmers and combine the kits with other agricultural inputs like seeds, fertilizers, pesticides etc. as a complete starter package to the farmers.

Benefits of micro-irrigation

Micro-irrigation systems have been merited for their suitability to most crops, soils, slopes and quality of irrigation water as well as other benefits like, soil moisture retention, water saving, uniformity and labour. Despite their great benefits, the advantages of micro-irrigation kits in relation to crop growth and performance seem to be less addressed.

Crops grown under micro-irrigation systems often show higher yields. Yield increase of 33% in tomato, 88% in watermelon and 44% in chillies have been recorded in India (AMIT, 2003). The quality of vegetables and fruits under this irrigation system was found to be better in most cases. Fruit quality of tomatoes is improved when N and K are applied by drip as compared to applying the whole fertilizer before planting (George and Allen, 1997). Such increase in yield and quality is mainly due to efficient irrigation and fertigation.

Less diseases and insect damages have been observed when micro-irrigation was used for vegetables and fruits due to less wet foliages, which otherwise could have created favourable conditions for diseases and insects. Crop growth can be better controlled when micro-irrigation is used under saline conditions by pushing salts away from the root zone. Other advantages of the system include lower weed infestation, efficient application of fertilizers and other chemicals like herbicides, and fungicides. Vegetables grown under micro-irrigation systems normally take shorter time to mature, as compared to the conventional irrigation systems, which could reduce the cost of production.

Compact fruit crops can be produced by controlling the frequency and the amount of water applied through the micro-irrigation system enabling easy harvesting and pruning. Furthermore, offseason production of vegetables has been one of the success stories of micro-drip irrigation in many countries. In West India, about two third of the farmers were able to produce crops during the dry season. Farmers in Nepal have converted paddy fields to cash crops and capitalized on their agro-climatic comparative advantages to the extent of growing flowers, medicinal herbs and temperate fruits (AMIT, 2003).

This paper will highlight some problems and possible solutions regarding the agronomic practices, which should go parallel with the technical guidance.

Agronomic problems in the adoption processes

Most of the time appropriate technical assistance was given to farmers using the low cost micro-irrigation kits. However, agronomic training, which goes parallel with the technical know-how of the kits, is critically needed. Agronomic issues to be addressed include: selection of crops or varieties for specific types of kits, fertilizer use through the system, water requirement of the crop at different growth stages, spacing, pesticide and fungicide applications, off season production, crop production under saline conditions, disease and insect control, climatic conditions, soil type, weeding, and control of time of harvest, yield and quality.

Selection of crops suitable for the kits is important. Crops suitable for micro-irrigation include: tomatoes, peppers, eggplants, ladyfingers, strawberries, cucurbits (water melon, pumpkin and cucumber), cole crops (cabbage, cauliflower, and broccoli) and fruit crops like papaya and mango. Micro-sprinklers are suitable for closely growing plants like onion, garlic and nursery plants. The number of plants to be planted per dripper or number of plants per m2 for sprinkler micro-irrigation systems is not defined at a crop level. However, the plant density has a great impact on the yield and quality of fruits and vegetables. Such recommendations also need to take soil type into account.

Most smallholder farmers in Eritrea have until recent never used micro-drip irrigation systems and hardly know the possibility of applying fertilizers through the system. But fertigation could enhance yield and quality of products significantly. The amount and rate of fertilizers (N and K) to be applied per bucket or per drum should be well defined for specific crops.

Water requirement of crops at different growth stages in relation to the amount and rate of water application must be taken into account. Furthermore, the recommendations should be made for agro-ecological zones. The simplest way of recommending the amount and rate of irrigation water to farmers is to determine the number and interval of refills of the buckets and drums. However, they should not be uniform throughout the growth period and the same to all crops, since water requirement at different growth periods vary for different crops. Crops can be grouped and climatic conditions defined to give recommendations close to the water requirements of the crop.

Offseason production of vegetables could be of great interest to smallholder farmers due to higher prices of the products and the advantage of double harvest. Certain agronomic practices like time of planting, frost protection techniques and other cultural practices, should be given to the farmers so that they could be encouraged to grow vegetables during the dry period. Apart from this, farmers could also have early harvest by controlling the amount of water applied to the crop. This would enable them to exploit the market.

Possible agronomic considerations

Low cost micro-irrigation can improve the livelihood of farmers who are able to practice high value horticulture while living in water scarce areas. But technical assistance should always be coupled with agronomic, financial and social factors.

List of crops suitable for micro-irrigation kits is needed for the country. Experiments to be conducted and the kind of crops to be used must be prioritised based on farmers' preferences for various agro-ecological zones. In Zimbabwe, tomato, maize and cabbage were selected as the most suitable crops and IDE at the moment is identifying high value crops suitable for the kits (AMIT, 2003). Depending on the country and agro-ecological conditions, specific recommendations at cultivar level can produce better results. Preliminary results on pepper under micro-drip irrigation in *Halahale* Research Centre, Eritrea, have shown bigger pod size in chilli varieties Marcofana, Alaba and Slimlong compared to crops grown under furrow irrigation. In addition, papayas grown under horticulture kit in *Barentu* and *Hamelmalo* have shown excellent growth (Stillhardt *et al.*, 2001). Trials on ladyfinger (Bamia) using drip can be of interest in the lowlands of Eritrea. Alfalfa can also be grown using sprinklers for dairy production. Such trials might help to complete the list of crops for specific kits in specific agro-ecological zones.

The kits have fixed spacing between plants and between rows. General recommendations were given on the number of plants to be sown or transplanted per dripper, ranging from one to three. The number of plants per dripper needs to be determined for specific crops (e.g. 3-4 plants/dripper for lettuce, 2 plants/dripper for crops like tomato, okra, and peppers and 1 plant/dripper for papaya). The number of plants per given area needs to be defined for micro-sprinkler irrigation (e.g. 42-60 plants/m2 for onion). Such recommendations could also take soil type into account, with the possibility of establishing more plants per dripper in heavy clay soils.

Fertilizer application, methods, rates, and intervals need to be clearly defined. The method of fertilizer application needs to be demonstrated to the farmers in Eritrea since the idea of fertigation is new for most smallholder farmers. The amount and interval of application of specific fertilizers should be defined per crop and per bucket or drum. The blanket amount of NPK fertilizer rate in Eritrea is 100 kg of nitrogen, 50 kg of phosphorous (P2O5) and 150 kg of potassium per ha for most of the vegetables, though it seems relatively low. N and K fertilizers are soluble in water and hence can be injected through the system to the plants. Phosphorous fertilizers must be applied directly to the soil. By parameterizing the rates and intervals for the kits, simplified recommendations can be given in terms of amount and interval of application per bucket or drum. The above recommendation would roughly mean 16 g of N and 25 g of K per bucket (of 20 l of water) per application assuming that fertigation is done once a week for tomatoes. Similar approaches can be followed for chemical application per crop and user guide tables can be produced for the kits. Interval of fertilizer applications could also follow growth and development patterns but could be more complicated for practical reasons.

Plant growth follows sigmoid curve, thus the amount and frequency of application of water and fertilizers should fit into the growth curve. A plant experiences rapid growth initially by exploiting resources followed by a continuous steady growth as it reaches maturity and slows down till no growth occurs. Water and fertilizer application rates and intervals should thus follow this growth curve. Two to three re-fills of the bucket and the drum was recommended to the farmers when the kits were introduced. But such uniform application of water does not allow the growth of the plant to fit the curve. Thus it can be done by more re-fills per day at the beginning and by gradually reducing the number of re-fills finally to once a day. The tomatoes grown in *Halhale* Research Centre were smaller compared to the plants grown under furrow irrigation despite the vigorous vegetative growth (Stillhardt *et al.*, 2001). This could be due to uniform application of water throughout the growing season, which causes plants to grow luxuriously and produce less if the amount of water is not controlled after maturity. However, the recommendations should also be based on trials for specific crops and agro-ecological zones.

Crops such as broccoli, cauliflower and lettuce grow rapidly, by absorbing large amounts of water and nutrients until harvesting time, and uniform number of re-fills could be followed throughout the growing season. On the other hand, tree crops like mango require little water for their survival during non-flowering and non-fruiting growth period requiring minimum number of re-fills. In most cases evapo-transpirational demand of crops determines the amount of water to be applied but this is not always the case. Vegetables that are set for transplanting require irrigation for crop establishment in excess of evapo-transpiration because they need more energy to adjust to the new environment. Climatic conditions greatly modify the number of re-fills even within the same agro-ecological zone. Hot, dry and windy areas need frequent refilling compared to cold, humid and less windy areas. Other cultural practices like spacing, staking and pruning, which are crop specific, can have a significant role in the performance of the crop and should be given as a part of the recommendation package.

Recommendations

List of suitable crops for specific micro-irrigation kits should be developed for a country as a part of IDE effort in producing list of potential high value crops. The list could further be categorized based on specific agro-ecological zones and grouped based on agronomic requirements of the crops. In addition, the number of plants per dripper for drip irrigation kits and plants/m2 for sprinkler kits should be parameterized based on the knowledge of other irrigation systems. Fertigation should be introduced by determining fertilizer requirement rates and intervals by adopting recommendations from other irrigation systems. Moreover, the number of re-fills should follow crop growth curves and should be crop specific, and cultural practices should be part of the recommendation packages.

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The role of development organisations in promoting the adoption and dissemination of AMIT in Eritrea

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Abstract

Agricultural activities in Eritrea depend on erratic, unreliable and low rainfall. Staple food crops are generally grown under rainfed conditions and are normally used for home consumption. Despite the fact that water is one of the scarce resources in Eritrea, most of the irrigation schemes, use furrow and basin irrigation. Extensive use of these methods leads to water wastage as runoff, deep percolation and evapo-transpiration. In order to economise water and decrease its wastage, it is crucial to introduce drip irrigation technology. Lack of appropriate and affordable irrigation technologies geared towards poor farmers on small plots is a major constraint to the spread of irrigation in Eritrea and elsewhere in Sub-Saharan Africa. To address this problem, appropriate technologies, which have the potential to earn high return to investment, need to be identified, adopted and disseminated in the country. Some pilot programs and feasibility studies carried out so far have shown promising results. However, the potential for these systems is still not exploited because of many factors that include rampant poverty, lack of information, as well as lack of intervention of government and non-governmental organisations (NGOs).
This paper mainly focuses on increasing participation and role of NGOs and international development organisations in promoting the introduction and adoption of affordable micro-irrigation technology (AMIT) for small-scale farmers at household level. It also emphasises on business creation to rural poor by linking micro-finance schemes with drip irrigation technology and capacity building of the private sector to ensure a reliable supply chain.

Introduction

As in many countries in Sub-Saharan Africa, agriculture in Eritrea, is the main source of livelihood of its citizens. Although the country has a variety of agro-ecological systems, less than 4% of the land area is considered arable under rainfed conditions. Out of the total 5% potential land for irrigation, only 0.2% is irrigated (Africare, 2001). Most part of the country experiences recurrent drought, which is the major constraint to agricultural production. In addition, the long struggle for independence has adversely affected agricultural productivity and exhausted the existing coping mechanisms. Consequently, this has resulted in decreased groundwater, decreased pasture and rangeland, and scarcity of drinking water for humans, livestock and irrigation.

To solve the increasing demand for food, the government has expanded the land under conventional irrigation in *Sheeb, Bada, Naro, Sawa, Afhimbol*, etc. This being the case, the introduction of drip irrigation focused to subsistence farmers is important to maximise production per unit of water used and to enable production during dry season on otherwise fallow land. This is expected to ameliorate the livelihood of rural households.

Smallholder drip systems need a low initial capital. Nevertheless, the low initial investment of US $ 10, 20 and 200 needed for the IDE bucket, drum and eighth acre kits, respectively, could still be expensive for the poor farmer (Sijali and Okumu, 2000). This could impede adoption of the system, as most farmers will not risk their limited resources to a newly introduced technology. Therefore, NGOs and international development organisations should come forward to make the initial investment as well as the required infrastructure for facilitating adoption and dissemination of the micro-irrigation technologies to the resource-poor farmers in rural Eritrea.

The aim of this paper is, therefore, to assess the role of NGOs in the introduction, adoption and dissemination of micro-irrigation technologies to the resource-poor households through micro-finance schemes. It also emphasises on of the promotion strategies of AMIT in Eritrea.

Drip irrigation systems in Eritrea

Introduction of small-scale drip irrigation systems to Eritrea at household level can be traced to Refugee Trust, an Ireland based international NGO, few years ago. The next initiative was taken by Centre for Development and Environment (CDE), University of Bern, Switzerland in collaboration with the College of Agriculture (CA), University of Asmara. The CDE and CA team had tested and distributed different kits to farmers in different agro-ecological zones and conducted pre-feasibility and feasibility studies. An MSc student from CDE conducted evaluation of the kits distributed and their socio-economic impacts. The tests and feasibility studies conducted show promising results for the acceptance of the technologies (Stillhardt *et al.*, 2003). However, there is a long way to go for large -scale adoption and dissemination of these technologies to rural households in a sustainable manner through establishing a reliable supply chain of the private sector.

Small-scale drip irrigation technologies

Small-scale drip irrigation systems try to retain the benefits of conventional drip irrigation whilst removing the factors preventing their uptake by smallholder farmers, such as the high purchase cost and the complexity of maintenance and operation. The basic components of small-scale drip system are a water tanker at certain elevation, couplings, valves, filter, main lines, laterals and emitters (Sijali, 2001). The bucket kit system can easily grow sufficient vegetable for home consumption with users even selling the excess. The drum system is fivefold in its capacity compared to the bucket. An eight-acre system has a twenty-fold capacity in growing plants compared to the bucket kit (Sijali 2001).

Addressing rural poverty requires a focus on smallholders who make up the majority of the rural poor. Smallholders as those engaged in subsistence agriculture on small plots of land, typically less than 2 ha (IDE, 2002). Improving irrigation productivity on large farms alone will not solve the continuing problems of rural poverty, which are getting worse in Sub-Saharan Africa. Increasing the agricultural productivity and income of the majority of farmers in developing countries who cultivate less than 2 ha is relatively untapped opportunity for finding practical solutions to rural poverty.

Opening smallholders access to affordable small plot irrigation is a critical first step to wealth creation for the rural poor. Low cost drip irrigation systems not only open the door to a path out of poverty, they are also a path to saving water and doubling irrigation productivity on small farms. For smallholder farmers, drip irrigation provides a means of maximising returns on their crop land by increasing the economic biomass production per unit of water and increasing cropping intensity by also growing crops during the dry season.

Economic impact of AMIT

Most Eritrean farmers own less than 2 ha of land and few livestock. Grains produced from this land area hardly sustain them for about 6-10 months on average. For the rest 2-6 months, the family has to either sell labour or some of its few livestock in order to cover the months of food shortage. However, once irrigated production starts, the family can benefit in two ways: first by consuming the products and second by selling the surplus to generate income. In addition, bigger kits, such as the drum kit or an eighth-acre kit, can create self-employment opportunities.

Enabling conditions and constraints

The enabling conditions required for the implementation of AMIT include: shortage of water, access to source of water (e.g. well), market, basic agronomic guidance, availability of seedlings and other inputs, and support of NGOs (AMIT, 2003).

Regardless of the importance of micro-irrigation systems, the introduction, adoption and dissemination of the technology could be hampered due to some socio-economic, environmental and technical constraints. These include: limited access to credit, communication, transportation, input and information; absence of reliable data on the availability of water resources; lack of technology and business development packages; and lack of a private sector involvement to ensure a reliable supply chain and spare parts for AMIT (IDE, 2002).

Role of NGOs and international development organisations

Poverty is probably the greatest challenge to adoption of small-scale irrigation technologies. Resource-poor farmers living below the poverty line do not have resources to take off because access to capital is the main prerequisite. Along with the technologies, therefore, ways and means should be found for such farmers to access to the necessary capital. NGOs and development organisations can play a crucial role to jump-start the process with loans, demonstrations, training and publicity.

Majority of the registered international and national NGOs in Eritrea, have rural community development programs in water harvesting, irrigation, food security and micro-finance schemes. Considering the fact that the introduction of AMIT could possibly alleviate rural poverty at household level, these international partners can play a vital role through funding.

Promotion is more than advertising, it implies a two-way communication with the customer. Mass media plays an important role in promotion. Rural customers need to see what they buy (Heieirli, *et al.*, 2001), they never buy anything, which they have not seen in operation, or even better, which their neighbour has not yet bought. For this reason, demonstration is an important tool for promotion. The establishment of prominent demonstration plots where actual farmers make money from crops grown with micro-drip irrigation systems would be a good marketing strategy. Promoting appropriate technologies to the potential beneficiaries at household level is also a challenge, which can determine their adoption and dissemination. Thus, conducting promotion campaigns, through various mass media techniques, that convince smallholders to invest in income generating activities is very essential. NGOs can therefore play an important role in this regard.

To make the equipment widely available and on a long term basis, independent profitable supply chains in the private sector need to be in place. A market for micro-irrigation equipment with high demand and supply needs to be created. This can be done through the 'awareness, information, desire and action' (AIDA) model (Heierli and Polak, 2000). In this respect, NGOs could make efficient use of the MoA extension service to promote the technology.

Integration of micro-irrigation into micro-finance schemes

The government and different NGOs are already implementing micro-finance schemes in some parts of the country. One of these is the Southern Zone Saving and Credit Scheme (SZSCS) run by ACORD. Impact assessment survey of ACORD (2002), showed that 75% of the clients are involved in agricultural activities, and use the credit mainly for the purchase of oxen and few for horticultural production. Though this rural saving and credit programme is efficient in loan provision and saving services, it lacks business development services or market creation approach. The micro-irrigation technologies could be very attractive to fill this gap if effectively promoted and integrated.

Organisations, which run micro-finance programs, can purchase micro-dip irrigation technologies and can provide their clients in village banks and sub-zonal branch offices of SZSCS on a loan basis. Presently, the minimum loan provided by the scheme is about 2,000 Nakfa. A loan of 5,000 Nakfa is given for the purchase of oxen with two years repayment period. On the other hand, this money can purchase a number micro-irrigation kits per household. Beneficiaries of the scheme can start production of high value vegetables and can pay back their loans during the scheduled period of repayment or even before. Experiences in India and Kenya show that the kits have high return and can pay back the full cost of the equipment in one or two seasons.

As access to credit is one of the key constraints for the adoption and dissemination of AMIT in Eritrea, its integration into rural credit schemes could be a better alternative to create the financial capital needed to access micro-irrigation technology. The experience of ACORD and Saving and Micro-Credit Programme (SMCP) in micro-finance schemes can be shared by NGOs that plan to transfer micro-irrigation technologies. This approach could have great impact in income generation and improving livelihoods of the smallholders. Success of the technology transfer could be ensured through the integration of the NGO activities with those of the extension and research services of the MoA.

Transferring affordable micro-irrigation technologies in a country with resource-poor farmers having very limited awareness of the new technology and hardly any purchasing power, cannot be achieved with short-lived programs. Hence, NGOs have to design long-term development programs, which include broad baseline surveys and pilot projects. Their presence for 3-5 years is of ultimate importance in the sustainable adoption and dissemination of AMIT.

Extension capacity building and Sustainability

Extension service is the backbone for the success of the introduction of AMIT, as the technology alone cannot bring increased production. Improved agronomic practices, know-how on crop water requirement and up to date market information are very essential to the farmer. Thus, extension agents should be well equipped to efficiently assist beneficiaries of the technology through continuous training, workshops, visits, etc. This requires the support of NGOs for networking and sharing of experiences from such programs elsewhere.

The sustainability of the new technology will depend on the availability of technical and agronomic support from the NGOs as well as MoA, continuing availability of minimum water requirement, the presence of a viable market for AMIT produce, the ability to access the market and the effectiveness and efficiency of the supply chain (AMIT, 2003).

The changes in the farming system required by adopting AMIT are fairly substantial, often requiring a significant input by farmers in order to master the use of AMIT. Furthermore, the promoters, NGOs or private sector organisations, have also to expend considerable resources (human and financial) as a follow up and after the sale of the kits. Without this input the sustainability of the technology is in question. Major trust is placed upon a promoting body that must provide considerable and lengthy investment in market chain establishment, training and on-going technical and agronomic support.

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Theme 3 Climate and irrigation

Rainfall input to irrigation development in Eritrea: Potentials and constraints

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Abstract

Successful planning and development of irrigation projects should be based on careful understanding and assessment of inputs such as rainfall. Rainfall/water is one of the main determinant factors of the surface and sub-surface water availability. Due to paucity of well-organised climatic data, only one meteorological station (Asmara) with relatively adequate and complete data (1914-2002) was used to write this paper. A variety of statistical methods were used for the analysis. Empirical formulas for water balance model were used to demonstrate the water loss through potential evapo-transpiration, and runoff and the balance as deficit/surplus as well as soil moisture storage was illustrated. Results of the study indicate that the unpredictability as well as the traditional orientation towards rainfed agriculture has led to the misconception of the amount of moisture that could be gained from rainfall resources. Otherwise, there is ample amount of water, which could be used for irrigation if proper management is in place. The high variability particularly during summer rains *(kiremti)* results in poor predictability of rainfall. The decreasing trend also marks an alarming situation mainly for rainfed agriculture. Community sensitisation and participation, multi-disciplinary research, modern information management system, improved rainfall harvesting systems as well as soil and water conservation measures are among the recommendations that could alleviate the pertinent problems. The main objective of this paper is, therefore, to analyse and discuss some issues related to the potential and constraints of rainfall resources for irrigation development in Eritrea.

Key words: Rainfall resources, rainfed agriculture

Introduction

In most developing countries including Eritrea, subsistence rainfed agriculture predominates. Most often it is characterized by limited capital resources, traditional method of production, low productivity of land and labour, as well as limited technological resources. This form of agriculture does not generally provide substantial contribution to the economy, producing barely enough food for human survival. Hence, countries that rely solely on rainfed and subsistence agriculture with few natural resources tend to be poor. Thus, their rainfed agriculture should be supplemented by irrigation.

Water availability is one of the limiting factors for the expansion of irrigation development. A precise figure may not be readily available regarding the minimum amount of rainfall for rainfed agriculture and where and when irrigation supplement will be required. Because the latter depends on many factors including altitude, soils, climate and water requirement of the crop. Seasonality of rainfall/water availability has considerable implications for irrigated agriculture since it affects flow regimes of rivers and level of reservoirs. Variability of seasonal flows may be interpreted not only in terms of water deficit and low flow, but also in terms of flooding. Floods may occur if the total annual rainfall amounts are received over a very short period or in the event of high intensity in localized areas. Rainfall in Eritrea is highly variable in time and space, leading to corresponding variability in runoff, soil moisture, and stream flow and water availability for irrigation projects.

The paper, therefore, attempts to analyse and discuss some of the potential and constraints of rainfall resources for irrigation development in Eritrea and focuses on rainfall trends in time. Due to paucity of well-organised historical climatic data (Mengisteab and Robert, 2001), only one meteorological station (Asmara) with relatively adequate and complete data (1914-2002) was used to generate the discussions.

Materials and methods

Asmara is located at 15^{0}17' North and 38^{0}55' East and 2,325 m.a.s.l., in the central highlands of zoba *Maekel*. River catchments like *Anseba, Mereb* and other rivers, which flow towards Sudan and Red Sea, emanate from this region. Numerous reservoirs, dams and ponds in the region also gain from rainfall during wet seasons and serve as a main source of water for human and livestock consumption as well as for irrigation development.

The main sources of information for the rainfall data were various Italian documents for the period covering 1914-1950 (Fantoli, 1966), and Meteorology Unit of Asmara Airport for the period covering 1951-2002. The Potential Evapo-traspiration (PET) data was from FAO agro-climatic data. Statistical methods such as frequency distributions, standard deviation, coefficient of variation, and Z-score were used for analysis (Gumbel, 1972). With the aid of frequency distribution, some patterns in the data were discerned and the number of times a range of rainfall group occurred each year was illustrated. Bar charts were also used to display the relative frequencies of two or more variables like average rainfall, maximum rainfall and standard deviation of respective periods. The standard deviation was used to characterise the various measures of variation in rainfall. The coefficient of variation (the ratio of standard deviation to the mean of the same series of rainfall) was also computed to assess the annual, seasonal and monthly variability of rainfall.

Cheap and simple empirical soil-water balance models were used to analyse the water budget since the main factors which control soil moisture are the amount and seasonal incidence of rainfall, the ability of soils to absorb and store water, and moisture losses through evapo-transpiration and sub-surface flow. Soil infiltration capacity is strongly influenced by soil structure, which in turn depends on soil texture, and soil organic matter, plant cover and soil biota. To promote such analysis, the model devised by Slatyer (1960), to predict variation in soil moisture storage in Australia, at Katherine in the Northern Territory was used in this analysis. The model gives estimates of monthly balance in relation to crop production based on the following assumptions: a) the soil-water reservoir retains 100 mm of rainfall in the top 1.5 m of topsoil, b) no runoff or deep drainage occurs until the soil-water is recharged and 100 mm is available and c) further input is considered lost as runoff or as deep drainage below the rooting depth. The unreliability and lack of historical data in different agro-ecological zones and lack of detailed soil information limits any reasonable assessment at country level.

Results and discussions

Potential water availability

Looking at the amount of rainfall record of Asmara (1914-2002), the average and absolute maximum daily, dekadal, monthly, seasonal and annual rainfall indicate that, there is a potential of getting sufficient water for irrigation. The average annual rainfall amounts to 493mm (range between 102 to 885mm) and the frequency of distribution was: 102 to 297mm (14%), 298 to 493mm (39%), 494 to 689mm (30%), 690 to 885mm (12%) and more than 886mm (5%).

The absolute maximum rainfall for Asmara for the period covering 1914 to 2002 compared to average annual rainfall is given in Table 11 below.

Table 11 The absolute maximum rainfall for Asmara compared to the annual rainfall

Absolute maximum rainfall	Amount (mm)	Year recorded	% of annual average
Annual	957	1916	194
Seasonal “kiremti”	853	1916	173
Monthly	442	July 1916	90
Dekadal	281	3rd Dekad of July 1953	57
Daily	143	14th August 2001	29

On average, the maximum rainfall recorded for each day of the rainy months (i.e. one day of maximum rainfall in each month) accounts for about 30% of the seasonal rainfall (June 5%, July 10%, August 11% and September 3%)

Seasonal distribution of rainfall during short rains *(azmera)*, summer rains *(kiremti),* and winter rains accounts for 17%, 76% and 7% respectively. The *azmera* rains during March (4%), April (40%), and May (46%) account for 17% of the average annual rainfall. The absolute minimum and maximum rainfall ranges between 2.2 mm (1938) and 223.4 mm (1937). The *kiremti* rains (373 mm) rains during June (10%), July (43%), August (41%) and September (6%) account for 76% of average annual rainfall. The absolute minimum and maximum *kiremti* rainfall ranges between 45 mm (1956) to 853 mm (1916).

The computed long-term monthly water-balance indicates that some moisture is stored in the soil particularly during the rainy months of July and August. In wet years, some water is lost as runoff (Tables 12-14). For example in 2001, a total of 137 mm, which accounts for 41% of long-term average seasonal rainfall, was lost in the form of runoff.

Table 12 Long-term average water balance for Asmara (1914-2002)

	June	July	August	September
RF(mm)	37	160	152	24
PET(mm)	132	114	113	114
Deficit	95	-	-	5
Surplus	-	-	-	-
Storage cumulative	-	46	85	-

Table 13 Water balance for Asmara in dry year (2002)

	June	July	August	September
RF(mm)	29	89	179	45
PET(mm)	132	114	113	114
Deficit	103	25	-	3
Surplus	-	-	-	-
Storage cumulative	-	-	66	-

Table 14 Water balance for Asmara in wet year (2001)

	June	July	August	September
RF(mm)	74	206	258	48
PET(mm)	132	114	113	114
Deficit	58	-	-	34
Surplus	-	-	137	-
Storage cumulative	-	92	100	-

Constraints

The high annual, seasonal and monthly variability of rainfall makes the water availability unpredictable. The decreasing annual and seasonal trend is also a situation, which requires proper mitigation measures to alleviate any relevant problems that might occur.

a. Variability

Rainfall in Eritrea is characterised by high variability. Annual rainfall variability amounts to 40%. Seasonal variability during *azmera* amounts to 64% (March 125%, April 98%, and May 105%). The seasonal variability during *kiremti* amounts to 43% (June 83%, July 60%, August 53%, and September 101%).

b. Trend

The trend analysis using the five-year moving average for the period covering 1914 to 2002 shows some patterns. As a whole, the annual rainfall decreases at a rate given by $Y= -0.3549x+509$. However, the seasonal rainfall indicates that the *azmera* rains are increasing at a rate of $Y= +0.3329x+67.9$, while the *kiremti* rains are decreasing at a rate given by $Y= -0.7472x+407$. The *azmera* rain increase for every month is given by:

Y=+0.1296x+5.7 for March, Y= +0.1417x+26.7 for April and Y= +0.0616x+35.6 for May. On the other hand, the decrease in *kiremti* rains for every month is given by: Y= -0.1625x+44.7 for June, Y= -0.1080x+155.4 for July, Y= -0.4517x+172.3 for August and Y= -0.2410x+34.7 for September.

Conclusion and recommendations

Irrigation and reclamation are powerful means of increasing land productivity. Adding irrigation water can overcome drought limitation and improve both the quantity and quality of production. The uneven spatial and/or temporal distribution, seasonal concentration as well as the traditional orientation towards rainfed agriculture have lead to the misconception of not having enough rainfall in Eritrea. Otherwise, there is ample amount of water, which can be used for irrigation if properly managed. Appropriate measures to alleviate some of the problems are recommended below.

- Successful irrigation development demands well-organised and improved information management system. The gaps in information should be identified properly and efforts should be made to fill the data gap in an integrated manner. The capacity of pertinent ministries and/or departments should also be improved in this regard.
- Good knowledge of water balance and water requirement of crops is a necessity for successful planning and development of irrigation projects. Multi-disciplinary/multi-sectoral research will therefore be required for the adoption or development of appropriate water balance models and crop water requirements that suit the Eritrean situation.
- Behavioural change of communities is essential on water conservation and management of rainwater, an important natural resource as it is, at household and community levels. This requires some efforts on sanitization and should be adopted as a culture. Mass media should play great role in this respect. Active participation of the community in the planning and design of such water management practices could promote successful irrigation projects.
- Irrigation through diversion is limited by the size of stream flows during dry seasons. Efforts should be enhanced to harvest rainwater. Land surfaces could be treated to decrease infiltration and make more runoff water available for irrigation and other uses whenever necessary. The runoff could be stored in a reservoir to supply water in small fields. Ditches could be used to harvest rainwater from hillsides or gentle slopes where the soil permeability is slow. Whenever storage reservoir is needed and where evaporation loss is a problem, a deep reservoir with minimum surface area could be used to reduce evaporation losses.
- Feasibility of some new practices in rainwater harvest should be searched. Some practices like decreasing soil permeability (unnecessary loss) by treatment with sodium salts, or using water repellent compounds such as asphalt, paraffin, or silicone to resist infiltration can be implemented. Some projects produce runoff by using large sheets of plastic covered by a layer of gravel. Harvested rainwater may be guided directly to a field or garden and distributed through some form of irrigation system. A simple water spreading system can be very helpful in dry areas if the soil is deep enough to store additional water.

- Water that flows from the highlands to the lowlands saturates the soil in some pocket areas within the arid lowlands. These wet spots can often be used as sources of water for household consumption or livestock needs. Some of these larger spots can be developed as water sources for irrigation. In this regard, efforts should be made to identify and utilize these pockets properly.
- Artificial recharge of underground water should also be encouraged. This technique normally involves spreading of water over an area of porous soils than overlie part of the aquifer. Good supplies of ground water depend on porous rock layers that hold water loosely and have surface connection so that they can be recharged. Mostly gravel and sand layers in valleys are good sources. Sandstone, limestone and basalt flows are potential sources since recharge rate limits long-term use of wells.
- The decreasing trend of annual rainfall as in all sub-Saharan African countries requires proper attention particularly by developing drought-resistant and short-maturing crops for the rainfed agriculture hand in hand with the expansion and development of irrigation.

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Application of seasonal climate forecasts to water resources management

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Abstract

The development of water resources has altered the natural flow of rivers around the world. Natural hydrological variations play a major part in structuring the biodiversity within river ecosystems as they control key habitat conditions within the river channel and the flood plain. A range of intra and inter-annual variations of hydrological regimes, as well as associated characteristics of timing, duration and frequency and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic eco-systems. The paper focuses on the value of climate information to seasonal rainfall situations and its implication to the water balance. It also focuses on the use of seasonal stream flow forecasts for making management decisions in order to improve water use efficiency in irrigation systems. Sustainable development of agriculture and livestock products can be achieved only if climate information is factorised to social and economic planning and implementation. The overall aim of the paper is, therefore, to provide information on water availability based on climate forecasts that will lead to improved water use efficiency and sharing of water resources between the environment and consumptive users.

Key words: Hydrological indicators, seasonal climate forecasts, water resources, water use efficiency.

Introduction

Eritrea is poorly endowed with water resources. The annual rainfall ranges between 150 and 900 mm. The rainfall is not evenly distributed and varies enormously from one area to another and from year to year. Irregular torrential rains and high potential evaporation rates characterize the climate. Hence, nearly all streams and rivers in this country are seasonal with widely variable flows. Moreover, there are no water bodies such as lakes in inland Eritrea. The driest parts of Eritrea are located in the southeastern lowlands, which may possibly be one of the driest regions in the world (Euroconsult and Walingford, 1998).

Despite the undependable rainfall and semi-arid conditions of the country, the majority of farmers are engaged in rainfed agriculture. Along with factors such as high rates of soil erosion, deforestation, poor infiltration and plant and animal diseases, it is not surprising that agricultural productivity in Eritrea is very low. Hence food security and by implication 'water security' are major issues confronting this country (Woldetzion, 1991).

Ground water, though apparently limited, is often the most dependable source of fresh water in Eritrea. However, the unregulated digging and drilling of wells and the continuous pumping of water from these wells has led to a decline in water levels in many places.

Sustainable development may result from the creation and utilization of four forms of capital: manmade capital (infrastructure and technology), human capital (education, health and nutrition), natural capital (natural resource base, including climate) and social capital (human institutions and social links that facilitate collective action in favour of the community well-being) (Serageldin, 1996).

The wealth or poverty of nations should take into account not only one form of capital, but all four. The World Bank has done some estimations of the wealth of nations using these criteria. How to measure progress and sustainable development and in particular, how to value environmental goods, is an issue. It is easy to value a machine or a factory; however, it is difficult to measure the value of a watershed, an ecosystem, a biodiversity reserve, or the local climate. Natural capital embodies different kinds of environmental assets (Munasinghe, 1993).

Unlike the other environmental assets, climate is subject to a great degree of natural variation. The normal pattern of climate in a certain region includes intra and inter-annual variations of different magnitudes. Such variations often cause climatic events like droughts, floods, temperature peaks and freezes. These events impact on society, on the economy and on the environment (Parry *et al.*, 1988). Recent scientific development by the climate community has made impressive progress with regards to climate prediction, so that it is now possible to have an idea about the characteristics of the climate in the next season. This information may be highly valuable in regions that are more vulnerable to such events.

Three aspects of information regarding climate are necessary for sustainable development planning and implementation. First, climate information is necessary to diagnose the natural capital endowment of a given region. Second, the knowledge of the impacts of climatic variability (social, economic, environmental vulnerabilities, etc.), how the impacts occur, and causality chains are important. Third, the information on climate prediction with regards to the next season, allows decision makers to prompt themselves for action in order to reduce adverse impacts or enhance positive effects of climate variations (Malglheas, 2000).

The experience of development planning so far has not given due attention to climate information, either as a component of the natural capital base or as trigger of socio-economic crises. In order to deal properly with climate in the process of sustainable development planning and implementation, the knowledge base should be expanded to the regional climate (including climate prediction), impacts, adaptation and mitigation policies (Malglheas, 2000).

At the local level, particularly in the less developed regions, there is still much to do to improve climate information. Climate is a component of the natural capital and as such is an important element of sustainable development. There is a need for better information on climatic patterns, precipitation, temperature, seasonal and inter-annual variations, and possibilities of climate prediction. In face of adverse climatic events, policy makers and producers have to decide on how to act. Though the local climate may be well known, there is much uncertainty on when and how a drought or a flood will happen and how intense it will be. Climate prediction helps to reduce this uncertainty. Information on climate prediction facilitates the decision making process for the next season (Malglheas, 2000).

The main objective of this paper focuses on a) the application of seasonal rainfall forecast for June to September 2000 into stream flow modelling and b) to see the correlation of the simulated flow with the actually observed flow of *Anseba* River Basin.

Methodology

Because of the thirty years of war most of the rainfall stations are destroyed, the only stations that have over 50 years record of rainfall are Asmara, Massawa, and Assab. As the rainfall duration of Massawa and Assab do not represent the central high ground of Eritrea, in most cases only the Asmara data is useful for zone-1 and that of Assab and Massawa are used to see the behaviour of zone-3 (Fig. 2).

The data used to forecast the season's rainfall are: Monthly rainfall records for the months of June, July, August and September from 1961-1999 (Meteorology Office, Asmara International Airport), Global Sea Surface Temperatures (SSTs) from 1961-2000 (DMCN, 2000) and SST of the global oceans for the month of April 2000.

The following were used to run the Stream Flow Model: USGS Stream Flow Model, rainfall record of 2000 for Asmara Airport, *Gejeret, Hazega* and *Afdeyu*, and Stream Flow Data of Anseba River (Fig. 2) from *Halibmentel* gauging station for calibration.

Results and discussion

The Drought Monitoring Centre in Nairobi (DMCN) usually develops a consensus climate outlook for each season. The forecast are based on the following information (DMCN, 2000):

- The state of the global climate system and its implications for the sub-region was reviewed.
- The evolution patterns of the sea-surface temperature anomalies over various parts of the global oceans were taken into account as principal factors. These include the warmer than normal SSTs that have been observed over western Indian and tropical Atlantic Oceans as well as SSTs anomalies over other parts of the global oceans.
- Products from coupled ocean-atmosphere models and physically based statistical models from several major climate centres are considered in the development of the consensus climate outlook.
- Products from various centres such as DMCN, University of Nairobi, the International Research Institute (IRI) for climate prediction, National Oceanic and Atmospheric Administration/National Centre for Environmental Prediction (NOAA/NCEP), European Centre for Medium Range Weather Forecasts (ECMWF) and the United Kingdom Meteorological Office, were utilized.

The current status of seasonal to inter-annual forecasting allows prediction of spatial and temporal averages, and may not fully account for all factors that influence regional and national climate variability.

Climate outlook for Eritrea

Based on the above methodology the rainfall forecast for Eritrea from June-September, 2000 is indicated in Fig 2. The predicted versus the observed rainfall for the same season in the year 2000 for zone 2 is also given in Fig 3. The forecast is normal to nearly below normal for zone 1 and below normal for zone 2 and for zone-3 the forecast probability is climatological i.e. any of the three categories can happen (Tsehaye, 2000). The number in a box for each zone indicates the probabilities of rainfall in each of the three categories: above, near and below normal. The top number indicates the probability of rainfall occurring in the above normal category, the middle number is for the near normal category, and the bottom for the below normal category.

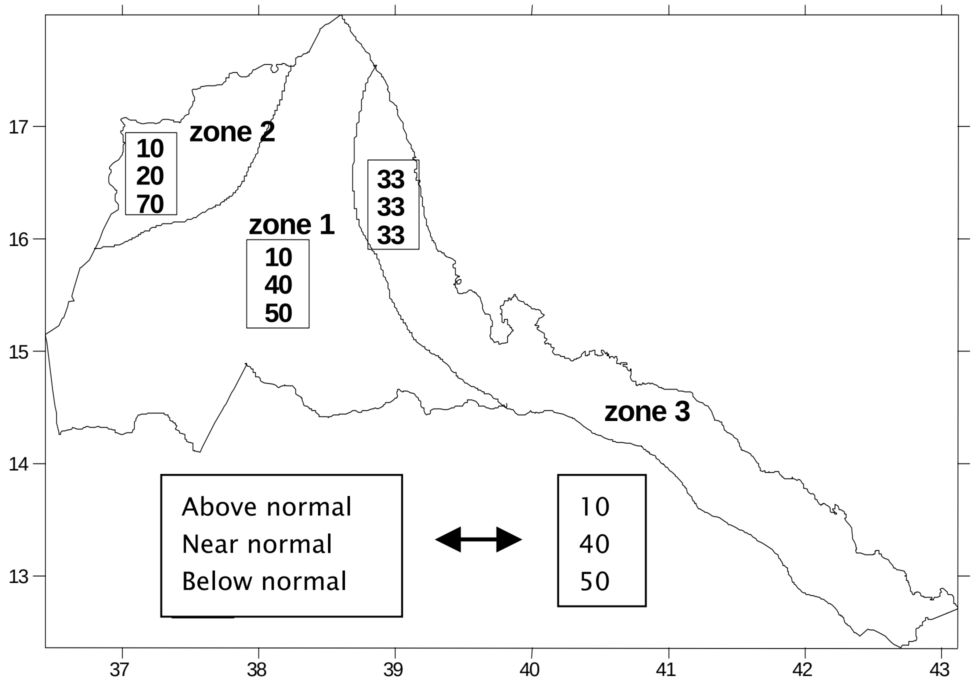

Figure 2 Rainfall forecast for Eritrea (June-September 2000)

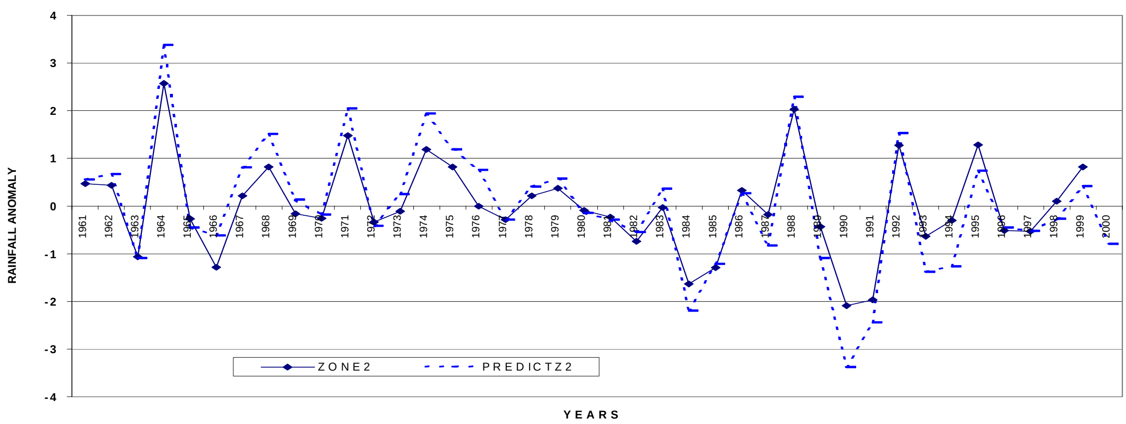

Figure 3 Eritrea: Predicted vs. observed rainfall for the season of June to September 2000 for zone 2

The Anseba River basin

The total catchment area of Anseba River basin is 12198 km^2 and the gauged catchment area at *Halibmentel* is 1140 km2 (Euroconsult and Wallingford, 1998). The *Anseba* River rises from the vicinity of Asmara and flows northwest through a rough terrain between the road and the old railway that connect Asmara and Keren. The river crosses both the road and railway flowing northeasterly only to change its course towards the north. It then joins the *Barka* River near the border and flows to the Sudan and finally drains into the Red Sea. The runoff reaches the sea only during good rainy season. Even though the *Anseba* River drains a small watershed, on the average, the unit runoff is relatively high (Woldetzion, 1991).

Rainfall characteristics

The main synoptic features that play significant role over Eritrea's weather and climate are: Inter Topical Convergence Zone (ITCZ), the Monsoons, Tropical Easterly Jet Stream, Subtropical Westerly Jet Stream, subtropical highs, high latitudes troughs, and local tropical disturbances (Tsehaye, 2000).

The supply of water in the highlands and semi-arid western lowlands of Eritrea is rainfall. The rainy season that supplies water to these region comes in the summer months starting during the second week of May, extending to mid-September. The maximum rainfall occurs during the months of July and August and accounts for large percentage of annual rainfall. The rainfall is high in its intensity and short in duration during the first and last one-third of the rainy season. It is believed that during the first month of the season, a large portion of the rainfall and the resulting runoff is infiltrated causing a much flatter hydrograph. During the middle month of the wet season especially in the month of July, most of the streams in this climatic region and particularly at higher elevation manifest relatively uniform and well-sustained flows. By this time of the rainy season, most natural water bodies are filled and the ground is saturated, or at least has reached its field capacity, causing a high proportion of the rainfall to come runoff. The amount of runoff produced for an equal amount of storm during the beginning one-third of the rainy season increases dramatically during the mid-portion of the rainy season due to ample storage of antecedent moisture (Woldetzion, 1991).

Importance of climate forecast to hydrological and stream flow forecasts

The monitoring and forecasting of droughts and floods depends upon rainfall magnitude and spatial distribution. Remote sensing rainfall estimation techniques describe the spatial distribution of precipitation. Using the Forecast Interpretation Tool (FIT), it is possible to translate the forecast into estimates of expected rainfall and its anomalies (i.e. quantitative interpretation of the estimated rainfall). GIS-based hydrologic modelling could improve the quality of flood forecasting efforts. Hydrologic derivatives yield the data set consisting of basin delineation, stream networks bearing topological identification numbers, grids of flow direction, flow accumulation, slope, and other variables.

A stream flow model has been introduced on an experimental basis to model and calibrate rainfall runoff model for the *Anseba* River flow. The model takes into consideration rainfall data from selected stations and run the stream flow model. The simulated rainfall-runoff stream flow model of *Anseba* corresponds the observed information, however needs a lot of calibration works so as to be applicable to water resources management. Moreover the model showed flood accumulation and inundation areas that will be a basis for flood control and water resources development and management activities.

Based on the above, the model was run and the result showed that the peak flow has corresponded with the peak rainfall as indicated in Figs. 4-7.

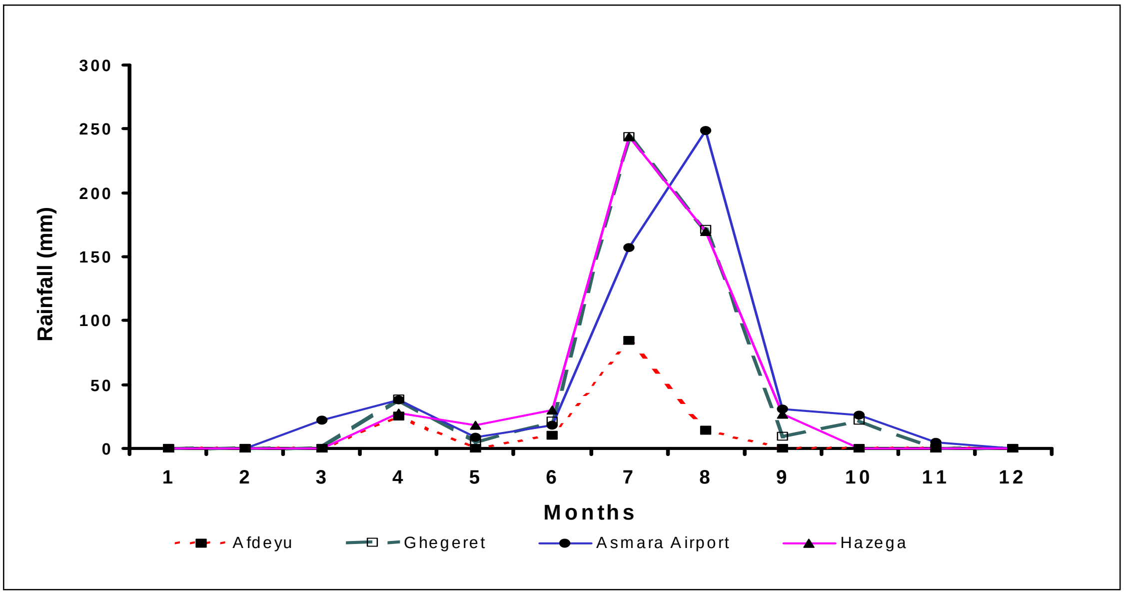

Figure 4 Rainfall distribution for the selected stations

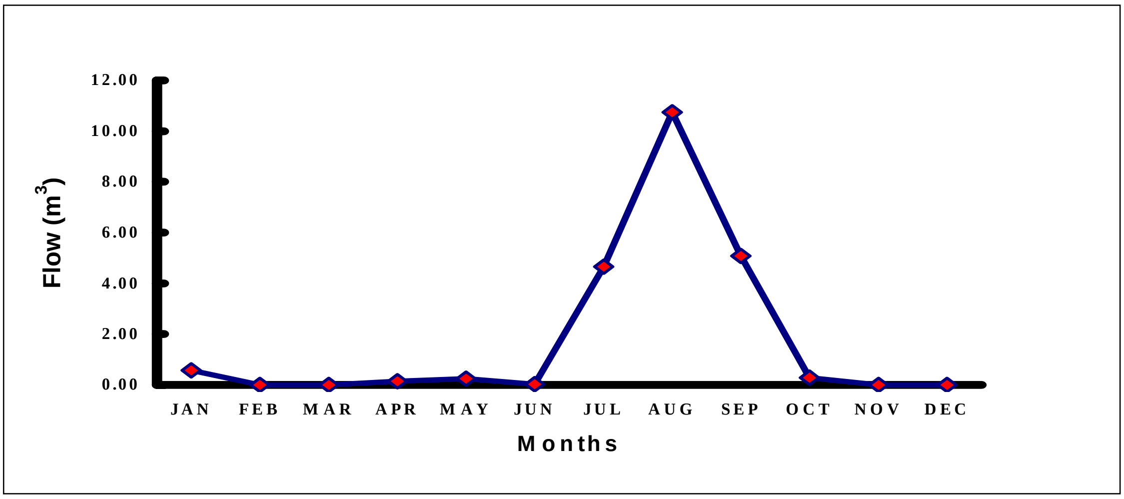

Figure 5 Monthly flow of Anseba River

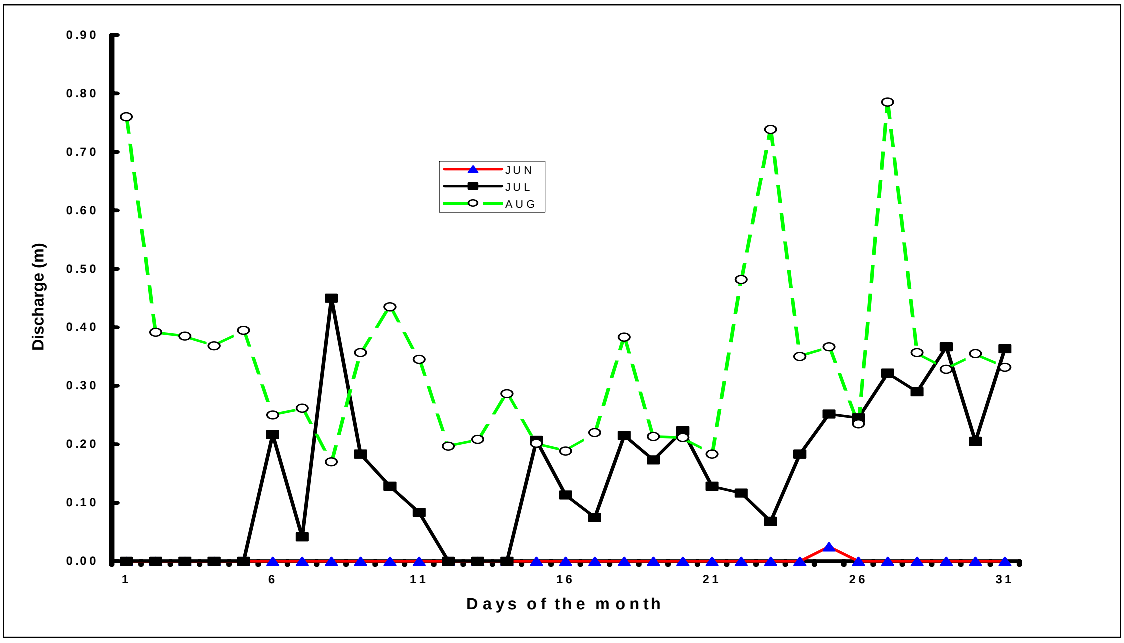

Figure 6 Daily flow of Anseba at Halibmentel

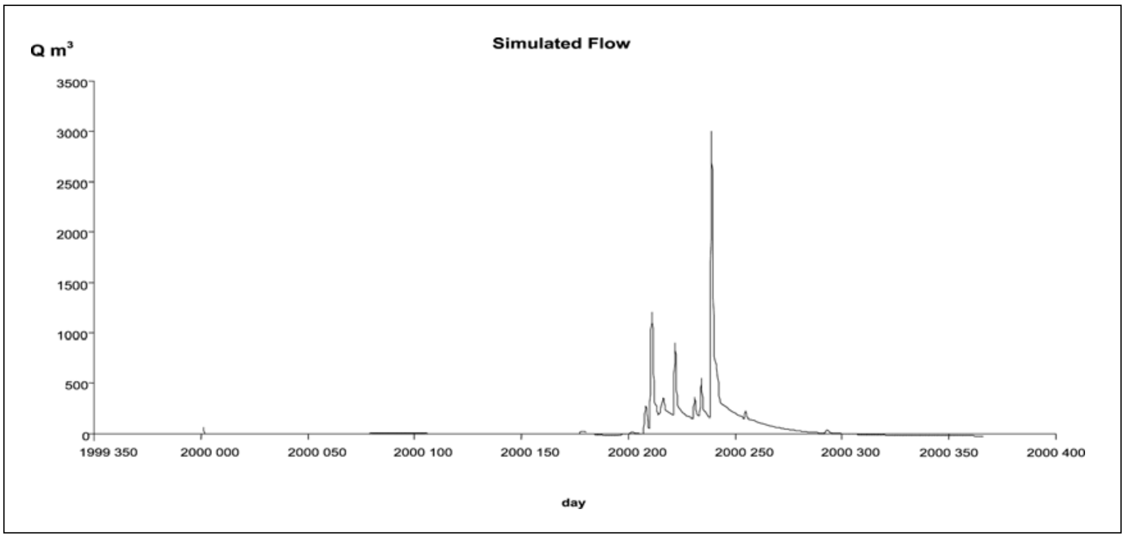

Figure 7 Simulated flow of the Anseba River

Importance of stream flow forecast to management of water resource systems

Water management is often difficult because of the high level of climate variability. Water management aims to satisfy the needs of drought mitigation; irrigated crop production; urban water supplies; high water quality to avoid salinity, blue-green algae and pollution; as well as the correct design of new water storages.

Introduction of a computer software package, which aims at improving management of climatic risk and rainfall analysis will help water managers and farmers to better plan their water allocations. Seasonal forecasting of stream flow using the latest techniques will provide the best available information about the next season's water supply. Thus, seasonal stream flow forecasts are used to improve management of water resources. In recent years, significant breakthroughs have been made in seasonal climate forecasting. These include growing knowledge of climatic phenomena such as El Niño, use of climatic forecast tools such as the Southern Oscillation Index (SOI) and SSTs, as well as the development of delivery processes and mechanisms such as CLIM-LAB, SEASAT, Rainman, and Stream Flow Modelling (SFM) packages.

To date, the idea is to gather the required software packages so as to make use of the existing data and run the models and carry out a pilot test with some of the products in one of the catchments. Its application in water resources planning and management should be evaluated. The findings will definitely influence the data collection and analyses and help develop policies related with the management of water resources of the country.

Data and software requirements

The following data and software are required to support and enhance hydrological forecasting as a management tool:

a The surface water data requirements are: series of monthly and annual runoff volumes, low flow frequency distribution, frequency distribution of high discharge and large volume flood, shape of typical flood hydrograph, sediment transport, quality of water, and stage discharge rating curve/ table.

b The meteorological data requirements are: precipitation and evaporation distribution in space and time, data on heavy rainfalls and floods, ground water level, distribution of air temperature and wind, sea-surface temperatures, and satellite remote sensing imagery.

c The software type requirements are: remote sensing rainfall estimation techniques (RFE), Forecast Interpretation Tool (FIT), CLIM-LAB, SEASAT, Rainman, and Stream Flow Modelling.

Climate information and water management

To improve water management, seasonal climate forecasts need to include stream flow and runoff estimates. Assessment of the usefulness of the forecasts in improving management of water resources for urban, rural, agricultural and environmental needs is also important. The knowledge and skills of water users and managers should be developed so as to cope with languages of the expertise of forecasting agencies.

Eritrean water users will benefit through: a) better management of water by public agencies for community supply and by farmers for crop production, b) good knowledge and use of historical records of local stream flow with information about averages, probabilities and droughts, c) access to information about the next season's water supply, and d) substantial public involvement in water resources' decision-making.

Changes in management strategies

When there is a prediction of drought, decision-makers at all levels need to prepare adaptation and mitigation plans. In flood case, as preventive action, mapping of vulnerable areas may be necessary. The social and economic effects of climate on the vulnerable population and on the natural resources should be identified. Causality claims between a given climate event and its final impact are hence established for the proper identification of sustainable policy measures.

People involved in irrigation practices and managers need to introduce irrigation scheduling based on the information they receive. Adopting modern water management techniques can help operate their irrigation systems efficiently. Real time forecasting of the water balance may also help them to manage their reservoir based on the available water.

Concluding remarks

Information on water availability based on climate forecasts will improve water use efficiency and sharing of water resources between the environment and consumptive users. Hence, it is necessary to mainstream the climate variable into the development planning and implementation processes.

The problem of communication between scientists and policy makers needs to be addressed through mobilization of resources to promote research into the processes, which govern the hydrological cycle and those that control the interaction of climate with freshwater bodies. Development of useful forecast/modelling products will also provide a good basis for better decision-making. Moreover, understanding the impact of climate variability on society at national, regional as well as at community levels, and on resource availability and management is important.

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Theme 4 Socio-economic studies on irrigation

Gender and irrigation development

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Abstract

Women are playing a leading role in agricultural activities in Eritrea. On top of the household tasks, they provide most of the labour required for planting, weeding, harvesting and even during processing after harvest. Community-based irrigation development programs financed by Early Childhood Development (ECD) and UNICEF, involving groups of women farmers are underway in certain parts of the country. The aim of the study is to assess the role of women farmers in agriculture in Eritrea thereby identifying the main constraints for their involvement in agriculture, especially in irrigation. Sample farmers involved in the project, from randomly selected seven villages of three zobas (administrative regions) of *Maekel, Debub* and *Anseba* were interviewed. Women's responsibility in undertaking these programs has proven to be very successful. The benefits are that women farmers in the group have increased responsibility and improved their skill of managing irrigation projects including water management systems. They have increased their financial capacity to improve the livelihoods of their families. However, the main constraining factors in the development of these programs especially for women in the sample villages include; shortage of labour adding workload to them over the house hold tasks, capital constraint and lack of knowledge especially in water management. Lack of inputs and distribution of land also have significant effects in these programs. Therefore, introducing labour saving irrigation methods and improving the credit schemes for farmers to have easy access to credits, are among those prerequisites for successful development. As farmers’ awareness of modern technology is very limited, strong extension services of all kind and training of farmers, especially in efficient irrigation methods, is highly required.

Key words: Credit associations, gender, irrigation

Introduction

The term gender refers to social, economic and cultural roles and relations between women and men. This includes their responsibilities in a given culture or location (IFAD, 2000). Gender development is a development programme that addresses both women and men putting special emphasis on utilizing participatory approaches to involve women in all the development plans. To formulate such projects, vast information of the specially constructed roles and responsibilities of women and men, the pattern of their access to and control over resources and benefits, their perceived problems and priorities must exist and be analysed to design, implement, monitor and evaluate the project successfully.

Gender in agricultural development gives special emphasis to investigating rural women's capacities and knowledge on a wide range of agricultural practices such as: animal production, irrigation, forestry, and fisheries. It takes into account the local division of labour in various farming systems. In irrigation development, gender is considered in issues of access to resources such as land, water, market, knowledge and the financial power for investment. It is also equally important to verify the actual division of labour in a particular locality, ethnic group and farming system.

Both women and men play critical roles in agriculture throughout the world, producing, processing and providing the food we eat. Rural women in particular are responsible for half of the world's food production and produce between 60 and 80% of the food in most developing countries. Although women farmers are assuming an increasingly prominent role in agriculture, they remain among the most disadvantaged of the population. War, rural to urban migration of men in search of paid employment and rising mortalities attributed to HIV/AIDS, have led to a rise in the members of female-headed households in developing countries (FAO, 2000).

Agriculture is the most important sector in the Eritrean economy, employing about 80% of the population, including both men and women. The role of women in agriculture dates back to the early days in the Eritrean history. In all ethnic groups, tradition doesn't hinder women from participating in most of the agricultural activities. Especially in the past ten years agriculture has done a lot of gender-related developments. Women's participation has increased as their access and control over resources has opened. While men do the ploughing and planting, women participate in the initial land clearing and preparation, weeding, harvesting and threshing. Once crops are harvested women farmers also provide most of the labour for post-harvest activities taking responsibilities for storage, handling, stocking, processing and marketing.

Rainfed agriculture in Eritrea is becoming increasingly unreliable due to the erratic nature and meagre amount of rainfall. Thus, the government's approach is to mitigate this problem through irrigated production. On the other hand, as it is the case in most developing countries, Eritrean women farmers currently are increasingly taking charge of rural homestead and farms as their men folk leave for the country’s marshal plan and also migrating to towns in search of paid jobs. This ‘feminisation of agriculture’ coupled with the advancement of irrigation, places a considerable burden on the women’s capacity.

Therefore, the impact of gender related issues in this sector of the economy is highly significant and should be addressed in all activities related to agricultural development. The main objectives of the study are to:

- assess the role of Eritrean women in agriculture, particularly in irrigation, and
- identify constraints that hinder women from being involved in agriculture, especially in irrigation, thereby paving the way for their solution.

Materials and methods

Seven villages were randomly selected in three zobas; *Maekel, Debub* and *Anseba.* Two women farmers from each village participating in the community based irrigation development programs financed by ECD and UNICEF were interviewed. In addition, a review of different publications on gender related issues was made.

The interview aimed at gathering information on: water management (source of water, water delivery, plot size), workload of the family members (division of labour), constraints for women's involvement in irrigation, ultimate benefits of the program, ideas in solving the existing constraints and access to resources (water, land and credit). The data collected from the interview was analysed according to the main constraints of the individual village.

Results and discussion

The problems identified by women in sample villages are categorized as: access to resources such as land and water (availability of water sources, competing water needs, water management, land tenure and its legacy); capital (access to credit); design limitation (plot size and allocation, and labour); and training and extension.

Access to resources

Availability of water source

In determining the suitability of the different water sources, the distance from the irrigated fields to farmers' homesteads has to be considered. A certain distance from the source to their homestead should be agreed upon by both women and men farmers. The quality of the water also determines the suitability of the source. In the sample villages studied, the water source was not too far from their homesteads. Out of the seven villages, three use well water and two use dam water. The sixth village had still to construct a well. The seventh village has not been involved in the program. All the villages use traditional method of irrigation (furrow irrigation).

In zoba Debub, sub-zoba Segeneiti, in the village of *Maereba*, a woman farmer who is the representative of the group described the problem of water availability as follows: "There are 60 women in the group and the husbands of most of them have left to do their national service. These women were selected to participate in this development programme supported by MoA in collaboration with ECD and UNICEF, which started five years ago. They were supplied with water pumps for irrigation and this has lifted the burden of fetching water from distant water sources." Three years later, however, the water level in the well has declined leading to acute water crisis for the group. Financial limitation has interfered with the construction of wall lining the well to protect it from collapsing. Moreover, further excavation of the well to reach the water table level has been so difficult for the group for the same reason. Their well is located on the down stream of the village's dam. The community uses the dam for all its needs. The capacity of the dam has become very low as a result of siltation and hence could not supply the required water for the various activities of the community. Therefore, the group in this area has critical water shortage and irrigation frequency has been reduced from once or twice a week to once in three to four weeks. This has ultimately resulted in sharp decline in production to the extent of abandoning the program. To reactivate the programme rehabilitation of the dam is necessary.

Competing water needs

In addition to the irrigation water requirements for crop production, the estimated need of water for other purposes, for example, drinking water for humans and cattle, irrigation of homestead agriculture and trees should be considered in the design of irrigation development to avoid possible conflicts between different water users. It is also important to identify and anticipate the hydrological, infrastructural and social linkages between the different uses of water. Apart from quantifying the amount of water to be used for different purposes, the timing of water provision needs consideration. Water consumption of livestock needs to be seriously included in the overall water plan. Although livestock are important in the livelihood of the farmers, they might compete when water is scarce.

In zoba *Maekel* sub-zoba *Berikh*, in the village of *Tseazega*, a water crisis has occurred throughout the village in the dry season. A conflict arose between the irrigating farmers and the cattle herders. The government had to intervene and priority was given to the animals and as a result irrigation at the tail end was stopped. Irrigation of the women's fields however continued. The decreasing supply of water is caused by degradation of the dam combined with the expansion of traditional irrigation schemes, a high influx of cattle and a growing population in the area. Conflicts also arose around the gates that control the water flow. The women's fields were, however, far from the conflicting center because they irrigate from the upper side of the dam.

A proper design of the technical and social water management structure is a crucial step in the design of irrigation scheme (Jordans, 1996). Water management includes design of a water delivery system and social organisation of water management.

Water delivery system

To efficiently irrigate all plots in a scheme, the actual availability of water and the technical considerations determining the optimum water delivery system are important. In addition, irrigation scheduling that includes the following factors needs to be considered.

a Irrigation schedules must be simple particularly in irrigation schemes where many farmers are involved.

b Farmers need to discuss the various alternatives and come to an agreement, which satisfies all parties involved.

c It is important to guarantee that all groups of farmers, small and large, head end and tail end, women and men are properly represented.

There are twenty women in the village of *Adelges*, participating in an irrigation development program. Out of these, ten own land in the irrigation potential area while the other ten have land far away in the marginal area. Those who are landless arrange for leasing or sharecropping of land. The women who participate in this irrigation programme said that water is not a problem but the water delivery system is. The members in the group have increased resulting in reduced irrigation frequency from every six days to every three weeks. This has also increased workload to the pump making it work day and night, yet not capable of covering all the plots. Unlike the other villages (e.g. in *Adi-Logo*), men farmers in *Adelges* using the group's pump do not pay for the services. This has become an additional burden to this group of women farmers involved in the program.

Shortage of water conveying pipes is another problem as there is no legal agreement among the group members, that own different plot sizes and have lands at different distances from the source, over how to manage the irrigation water. The water has to be conveyed over a longer distance to reach to some of the fields and this incurs additional expenses and results in the loss of water in different ways from the canals.

On demand water delivery system ensures an adequate and timely water supply to the farmers in cases where water is not limiting. Given the workload of women in agricultural activities, on demand water delivery is often convenient for them in terms of flexibility in planning their work. The disadvantage might be that influential, male irrigators can better defend their interest than vulnerable or female irrigators, whose demand may not be heard. Especially during peak periods such as land preparation or transplanting, less influential farmers, notably women farmers, could have problems to secure their water turn (Jordans, 1996). A woman farmer whose field was located at the tail end had difficulties to get her turn to irrigate. She had to go frequently to the water distributor and convince him whenever she wants to irrigate her field. A scheduled water delivery or rotation system, on the other hand, has the advantage that it guarantees a regular supply of water to each plot although timing might be less convenient and quantity not always adequate, especially in the tail end of the scheme.

Land tenure and its legacy

The land tenure system in Eritrea has been one of the constraining factors to develop appropriate and sustainable land management systems. The *'Diesa'* system (where land is redistributed every five to seven years) and the *'Tsilmi'* system (where land is transferred permanently to generations within the family) have a significant effect in the land management systems. In all the sample villages, an amendment to the land law guarantees equal access to land for both women and men.

In zoba *Anseba,* though the existing land legislation allows open access to women and men, the programme didn't attract women. The women group was asked to participate in the irrigation development program. They were pledged to be supplied with water pumps and other irrigation facilities but showed strong reluctance to participate. As a result there was no irrigation development programme for women in the zoba. The main reasons seem to be that the inhabitants are dominantly cattle herders and agricultural activities might have less priority or women traditionally are not allowed to participate in agriculture or previous land tenure system *(Tsilmi)* has the influence. Therefore seeking other means to involve women in irrigation is required. Some of these options are to introduce traditional homestead-based activities like family kit irrigation method in their backyard gardens.

Where there is much resistance to land rights for women, a first strategic step can be the allocation of land to groups of women. In proposing community-based irrigation project that involves groups of farmers, the participants in the scheme are partly determined by land ownership and by the topography that determines the accessibility of the land from the command area (water source). Landless people and farmers who own land far away or on sloppy areas are thus excluded. Participants will most probably be landowners from various socio-economic groups with land in the command area. However, there is a room to involve those excluded through: redistribution, lease and sharecropping of land.

Moreover, digging additional wells and constructing other water harvesting structures could also solve the problem.

In zoba *Debub,* sub-zoba *Dekemhare*, the irrigation development programme in the village of *Korbarya* failed to attract sufficient interest of farmers. As a result, most of the women who were members of the programme stopped participating. A contributory cause was that most of these women have fields far away from the water source, which has made water accessibility very difficult. In this particular area, however, there is a potential for extending the irrigation area. Digging more wells and developing new irrigation plots that could be allocated to farmers, can be a solution. Equity considerations are important in this situation and existing land legislation and customary rights related to land use, as well as the land tenure system need to be considered.

Credit saving

Limited access to credit and agricultural inputs is often one of the main constraints for smallholder farmers to increase their productivity. Expected results of irrigation schemes, i.e. increased crop production and thus increased income, will not fully materialize if certain groups of farmers are excluded from access to credit. Short-term credits like the one provided to farmers by *Self Help Project* in zoba *Debub* has a significant impact in improving the livelihoods of the farmers. When it comes to irrigation, however, farmers have to be provided with long-term credits because without access to credit they may not be able to invest in irrigated agriculture.

In all the sample villages studied, capital was the common limiting factor as mentioned by both women and men farmers practicing irrigated agriculture. As a result, in the current situation, they cannot afford to rehabilitate their wells and to buy irrigation water pipes, quality seeds, fertilizers and farm implements. With irrigation increasingly becoming a private investment, access to capital becomes a determining factor for access to land and water. A strategy to increase women's access to land and water should ensure their accessibility to capital and credit. In addition, access to capital and credit is crucial for a productive use of land and water. Once rights are established, access to credit influences the ability to control land for longer term.

Design choice limitation

In each irrigation scheme, design choice should include several technical issues that need to be decided upon. These may include choices such as plot size, infrastructure layout and facilities for other uses through participatory approaches.

Plot size and allocation

If an opportunity of enlarging community based irrigation farms is to surface, women and men need to be consulted on the optimal plot size and allocation, as there are conflicts that might arise on these issues. In the village of *Tseazega*, a conflict arose between the community and the participating groups. The community is reluctant to allow permanent holding of fertile land to the women farmers group. The community claimed such land would be equally reallocated to all other members of the community for rainfed agriculture, according to the land distribution system in the village.

Labour

Irrigation causes an increase in workload to farmers in general and to women farmers in particular. One of the ways to reduce the workload is to introduce labour saving technology for the most labour intensive tasks. In most of the sample villages studied, women indicated that their workload is on plot preparation, constructing furrows and waterways, cultivating, and weeding coupled with household tasks. Taking the net effect of certain constraints into consideration, labour is highly required during time of peak water requirement. Due to shortage of the required labour therefore farmers, especially women, will be forced to irrigate a limited area of land. In the village of *Adelges* a woman farmer owns about 0.5 ha, which is one of the smallest plots among the other irrigating farmers, yet it was very hard for her to manage this field due to shortage of labour. She has the intention to expand the irrigated field but the labour problem has restricted her.

Training and extension

In irrigated agriculture, both men and women farmers need to be involved in extension and training programs, including the operation and maintenance of pumps, water delivery, water management, etc. All the women participating in the irrigation development programme get training every year for about a week on fertilizer application and general crop management. However, it was indicated by the participating farmers, that the need for training in water management and other low cost irrigation methods is very crucial. Equally important is also training on simple field methods of determining the moisture status of the soil to decide on the appropriate time of irrigation.

The different problems presented in the previous paragraphs are summarized in Table 15, which shows the overlap and the differences of the constraints of participation of women in irrigated production. Analysis of the information covers causes of the problems, current coping practices and interventions for development.

Table 15 Summary of problem analysis of women's participation in irrigated production and possible interventions

Problems	Causes	Coping practices	Interventions
Lack of capital and inputs	– poverty – lack of credit to purchase inputs	– use own seeds – hire pipes – leaving land fallow – reduced use of fertilizers and water – sharing wells – reduce plot sizes	– access to credit – multiplication and provision of seed at local level upgrading the water catchments – digging new wells and rehabilitating the existing ones
Increased work load and lack of labour	– more burden to household tasks – husbands & sons are in national service – no financial capacity to hire more labour	– under-aged children involved – reduced plot size – use leasing or sharecropping of land	–access to labour saving technology – improve division of labour among the household and increase credit opportunity to hire more labour
Lack of adequate services	– lack of effective extension system to reach all farmers	– use of traditional knowledge	– strengthen the extension system (e.g. through mass media) – training of farmers, field demonstrations

Conclusion and recommendations

Women have the potential as men, to manage and play a leading role in agricultural activities especially in irrigation. The number of farmers, especially women, practicing irrigated agriculture is tremendously increasing because more benefits are obtained from irrigated projects to improve the livelihoods of the family.

As more water harvesting structures are widely constructed, more farmers are encouraged to invest in irrigated agriculture. However, lack of adequate training, low access to credit and shortage of labour, have significantly affected the capacity of the farmers to invest in irrigation, especially to women farmers. Thus, development of community-based irrigation programs involving women, should take the following into consideration.

- Introduce labour and capital saving irrigation methods such as low cost hose irrigation and family drip kit for the existing plot sizes, provide training to farmers and improve their access to credit.
- Seek ways of optimising the traditional furrow irrigation methods.
- Provide farmers with simple resource maps at village level, which can help them to easily describe and understand features presented.

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Socio-economic and institutional aspects influencing the adoption of micro-irrigation technology in Eritrea

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Abstract

It is well known that success or failure of the introduction of any new technology to potential users requires that it is technically adapted to the local conditions and is of good quality. In the successful introduction of micro-irrigation technology to small-scale farmers, less attention was paid to the social, economic and institutional framework required. Some of the crucial factors influencing farmers' perception and willingness to test a new technology are: local or regional water management practices; access to resources such as land, irrigation water, tools, finance and knowledge; costs and time of return on investment; changing responsibilities in terms of gender specific workload; size and shape of provided irrigation kits; and knowledge transfer at all levels.

Keywords: Affordable micro-irrigation technology, technology transfer, IDE, Eritrea

Introduction

This paper is based on the outcome of a feasibility study that was conducted in 2002 and 2003 on the adoption of affordable micro-irrigation technology (AMIT) in Eritrea (Stillhardt *et al.*, 2003). This was followed up by a master's research from the University of Berne carried out in the highlands of Eritrea that focussed on social, economic, ecological and institutional settings and their effect on the acceptance of farmers towards the technology (Nidecker, 2004).

The technology used for the study was developed by International Development Enterprises (IDE) in collaboration with local Indian farmers (IDE, 2002) and was manifold tested in India, Nepal and Bangladesh (IDE, 2003). Mackay (2003) also assessed the success and failure of drip irrigation technology transfer as well as local farmers' perception/acceptance in some comparative case studies in Asia and Africa. For the selection of IDE as hardware provider, it was also important that the recently developed kits were sold at a comparable cheap price. Affordability for small-scale farmers was an important goal of IDE during development of the micro-irrigation kits Therefore a research approach including market creation aspects as formulated by Heierli (2000) was used for the feasibility study.

Success or failure of implementation depends on many factors, one of the most important being, the technical feasibility/suitability. Compared to other factors, technical suitability is relatively easy to assess. In addition, there are several established and well-known studies, mainly focussing on technical topics (Cornish, 1998; Kamundia, 2002). It is also known that during a short-term feasibility study many social, economic and environmental impacts and restrictions cannot be assessed. FAO/IPTRID (2001) conclude that a successful technology transfer needs a mid- to long-term project perspective because an annual increase of the area under irrigation of about 5 % is realistic.

Discussion

A feasibility study was carried out to assess the adoption of AMIT in Eritrea. This was followed by a masters research focussed on the socio-economic aspects of the adoption in the rural and sub-urban highlands of Eritrea. Both studies were carried out under the lead of Centre for Development and Environment (CDE), University of Berne in collaboration with College of Agriculture (CA), University of Asmara.

Water

The main goal of the micro-irrigation technology is to save water and to make cropping possible during the dry season. Therefore it is not surprising that water is one of the most important issues to consider. Not only the availability of water, but also local water management structures, water pricing, water quality, etc. are becoming highly disputed topics in discussions between farmers, implementers and researchers. Drip irrigation has higher water use efficiency than other irrigation technologies e.g. furrow or basin irrigation (Cornish, 1998; FAO/IPTRID, 2001). Depending on the environment and the crops, daily application of water is needed when drip irrigation is used. In areas where tank water is used, water delivery happens often only once or twice a week. Farmers' statements in such areas are therefore rather clear: "If availability of water is not permanently secured, we prefer to flood our fields and store the water for the coming days in the soil" (Nidecker, 2004).

When water is freely available and no water management concept is regulating prices and access to water, it is very difficult to create awareness of water as a scarce natural resource. As long as farmers do not have any direct benefit, saving water is not a real problem for them. It was observed that the interest in micro-irrigation technology is much higher in areas where farmers have to pay for water because saving water can also save money to farmers (Stillhardt *et al.*, 2003; Nidecker, 2004).

If installed and used properly and under convenient environmental conditions, micro-irrigation can save labour i.e. there is less need for weeding, seedbed preparation is easier, and often application of water is easier, etc. On the other hand, introduction of micro-irrigation technology can lead to a higher workload; for example, the additional amount of water used for irrigation must be fetched and carried to the field. This is often part of children or females' work, resulting in an increase of their total daily workload. Therefore, the availability of human labour for fetching water and a short distance to the water source are essential factors for farmers' acceptance of the new technology and must at least be compensated by a felt economic benefit within a short period of time.

When farmers use irrigation technologies other than drip, they often own a motor pump and irrigate their fields pumping the water through channels. Introduction of AMIT in this case can also create additional workload because water must be fetched at the outlet of the pump and then carried to a bucket or barrel. The kit will also need continuous checking and follow up adding to the workload of the farmers (Nidecker, 2004).

Area under irrigation and expected benefit

The irrigation kits introduced, include a bucket kit, vegetable kit, horticulture kit and a micro-sprinkler kit covering areas of 20,100,130 and 160 m^2, respectively (Stillhardt *et al.*, 2003). Results of the feasibility study as well as in-depth interviews carried out by Nidecker (2004) showed clearly that the area under irrigation is too small. The covered area is not sufficient for market production in Eritrea. Interviews with the farmers indicated that surplus production from areas under drip irrigation for the market was rare.

Calculations based on farmers' information and assessment of market prices (Nidecker, 2004) proved that farmers can cover the costs for the kit within about two years depending on the crop, time of harvest, proportion of yield sold on the market, consumer demand and season within the year. Nevertheless, about 75% of the visited households used the additional crops mainly or exclusively for home consumption. This increased the food quality of the respective household, but was not registered as an economic benefit.

Farmers who wanted to produce off-season crops had difficulties to find seedlings and if available, the price was often rather high. Even when market prices for vegetables were much higher during off-season, the high prices for seedlings and the high uncertainty of agronomic success led to a high economic risk for farmers (Nidecker, 2004). If production for the market is intended, farmers need access to marketing structures or markets with a more or less permanent demand for the offered products. In the highlands, and especially in the main roads that lead to Asmara roads, big markets, constant demand and short transport distances encourage investment in cash crop production under micro-irrigation. Even in such cases, the size of the area under irrigation must be suitable to the needs of the farmers. Such an adaptation can only be reached when the technology as well as the technical knowledge for customisation is locally available and installations can be designed according to farmers' needs and wishes (Stillhardt *et al.*, 2003). In addition, intensive agronomic knowledge, support and access to market information must be available to farmers.

Price comparison for some micro-irrigation technologies available in Eritrea

Micro-irrigation is a technology developed mainly for semi-arid environments with the purpose to save water. When it comes to the introduction of micro-irrigation technology to farmers, one of the most often heard arguments is that it helps to generate additional income (Heierli, 2000). Under certain circumstances this is true, but it often needs, as partly explained above, the adaptation of many other factors until micro-irrigation becomes profitable to farmers.

The rough estimation of prices of different drip irrigation technologies available in Eritrea are shown in Table 16. The prices are partially based on estimations and other costs (e.g. for a bucket or a barrel, a fence, seeds or seedlings etc.) are not included in the calculation. Prices could have changed in the meantime, but the comparisons could still be similar. Depending on the type of kits, the price ranges between 45,000 and 70,000 Nakfa per hectare, which is a very high investment for farmers, especially if they don't know the technology. The comparison shows that especially the IDE vegetable kit is cheaper than the other products. Considering the area under irrigation, the table shows that it is not the technology itself but the simplicity and the applicability of the AMIT to smaller plots of land that makes it affordable. Thus, one should take two important things into consideration when introducing micro-irrigation:

1. It is not the technology itself that makes micro-irrigation affordable for small-scale farmers but the small size of the IDE kits.
2. Additional costs for fencing, tanks, barrels, spare parts, diesel pumps, irrigation water, seedlings, access to market, etc. need to be included in the above calculation and can considerably increase the total cost of the kits to a range of 70,000 to 100,000 Nakfa per hectare (Mackay, 2003; Stillhardt *et al.*, 2003; Nidecker, 2004).

Table 16 Assessment of costs for different micro-irrigation products in Eritrea

Type of irrigation kit	Area under irrigation (m2)	Price per kit (Nakfa)	Price per ha (Nakfa)
IDE bucket *	20	135	67,500
IDE vegetable *	100	445	44,500
Netafim *	500	3726	74,500
Chapin Watermatics	500	3500	70,000

Source: Stillhardt *et al.*, 2003* Price ex factory x 2 (service charge, shipment costs, custom clearing) plus 15 % retailer's margin). – Exchange rate: USD: Nakfa = 1:13.5 (October 2001)

In general market prices of agricultural products are fluctuating rather fast. For example prices between 2.5 and 18 Nakfa per kg of tomato were reported within eight months in 2002. Fluctuations can partly be explained by the seasonality of the products and partly by inflation. In addition, product prices also depend on the onset, distribution, amount and intensity of rainfall. For farmers without the necessary knowledge and access to market information, it is difficult to decide what vegetable to produce at what time. Farmers newly introducing the drip irrigation technology on their fields also need consultation and support in the agronomic practices since the introduction of micro-irrigation technology might often require different cultivation techniques. Most of the farmers who are selling surplus crops to the market are those who produced either green pepper or okra. Especially okra was reported to always have good price in the market (Nidecker, 2004).

Eritrea is a small country and the market for a new technology is very small. The possible small market for micro-irrigation equipment in the country may not encourage the introduction of different and incompatible types of kits. Thus, it is crucial that spare parts for the kits and local knowledge for the customisation of the kits are available. The rate of successful implementation could certainly be increased when all stakeholders in Eritrea share and exchange their knowledge.

Gender aspects

It is the policy of the government of the State of Eritrea to ensure gender equity. Tremendous efforts and progress have been made in the last ten years toward the same. Achieving gender equity, particularly when it comes to division of labour for indoor and outdoor activities, however, requires behavioural change, which in turn calls for decades of sustained hard social work. In many rural highland areas, traditional beliefs and rules prohibit women from participating in outdoor farm activities, except within their own backyard. This confinement to non-income generating household tasks makes women almost entirely dependent on men, even for the purchase of basic food items, and has a negative impact on household food security (Mehari *et al.*, 2003).

The IDE smallholder bucket and vegetable kits could enable women to be breadwinners (while still respecting traditional obligations) because these kits can be installed in backyards to produce some basic food items. This could improve household living conditions and greatly reduce women's dependence on men.

Interviews with members of a women self help group near *Mendefera* (testing bucket drip kits in backyard gardens) showed the implementation of irrigation kits can substantially help to increase the livelihood of female headed households. With a small financial input, vegetables can be grown near the house and can either be sold or used for home consumption if the additional workload can be covered (Nidecker, 2004). In some cases, male farmers argued that since part of the responsibility for food production changed successfully into women's hands, males can take life more easy and produce less field crops for home consumption (farmer, testing a 500 m2 Netafim kit in *Hagaz*). The larger size of the Netafim kits makes them more useful for market production. The most unexpected and surprising finding was that the new technology was used to change the males' workforce and load to that of the females and not to increase the household income.

Conclusion

Success and failure of the introduction of micro-irrigation technology depends on a large number of factors: social, economic, ecologic and institutional. These include: availability of and access to water, water management and pricing and sufficient human labour for fetching water. The following points need to be considered when introducing micro-irrigation technologies.

- Affordability of the tested kits refers mainly to the small size of the kits and not to the price per hectare.
- All new technologies introduced may not necessarily alleviate poverty at the beginning of the project because the limited resources of poor, subsistence farmers do not allow them to take any risk. Thus, a mechanism of assisting the farmers at the initial stage becomes imperative.
- The small IDE kits are mainly used to increase food quantity and quality and sometimes sell the surplus. However, farmers do not perceive the better nutritional status as an economic benefit, although it contributes to the household's food security.
- Better knowledge, agronomic and technical support, and better access to infrastructure and markets are needed besides larger kits for cash-crop production
- Availability of system components and spare parts, and more local knowledge about how to customise kits according to farmers' needs are essential factors for success.
- In some cases, the introduction of the micro-irrigation technology may lead to a substitution of men's workload by female's (or children's) workload, which is not a desired outcome.

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Farming system survey under agro-pastoral spate irrigation in Coastal Plane Zone (CPZ) of Eritrea: A case of Sheeb, Wekiro and Wodilo

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Abstract

A diagnostic farming systems survey in the coastal areas of Eritrea in *Sheeb (Menshib, Dimnet Dige, Bises, Tiluk* and *Sheeb-Ketin*), *Wekiro* and *Wodilo* was conducted from 1995-1996. This is a potential production area with a mixed farming system based on spate-irrigation *(Gerif)*. Row planting, cow traction, spate irrigation, animal feed using zero grazing are practiced and make this agricultural system unique. The objectives of the survey were to describe and understand the farming systems, and identify and prioritise the major production constraints so as to assist farmers in providing appropriate solutions. Participatory Rural Appraisal (PRA) as well as the use of structured questionnaire at household level was employed to collect data. Direct field observation on natural resources and enumeration on vegetation were undertaken. In this study, the major natural vegetation types, crops, livestock and the factors affecting the spate irrigation production system were identified and described. The major constraints were shortage of water and grazing land, weak irrigation infrastructure, and low crop and livestock productivity. Among the solutions identified or recommended are appropriate land use practices, effective pest control, appropriate veterinary services and construction of reservoirs, additional wells, and irrigation infrastructures.

Key words: Agro-pastoral, coastal plane zone, farming systems, spate irrigation

Introduction

A diagnostic farming systems survey was carried out in the villages of Sheeb, Wekiro and Wodilo in the Northern Coastal Plains of Eritrea. This area is of particular interest because it is one of the potential production areas in Eritrea, which is located in the Northern Red Sea administrative region of the country and is found at about 30-60 kms north of Massawa (FAO, 1994). It is part of the semi-desert agro-ecological zone with dry and very hot climate. It receives an annual rainfall of less than 200mm per year. The rainfall is not sufficient for arable crop production without irrigation; hence the farming system is based on spate irrigation in which the seasonal floods are diverted to the agricultural fields. The soils of the area are coarse textured with sandy, loamy sand and sandy loam texture. The soils are mostly alkaline outside the irrigated areas and very low in organic matter whereas in the irrigated fields alluvial deposits brought by the seasonal streams flowing from the highlands dominate the soil (Bojo, 1995).

The seasonal rivers originate from the highlands of the Eastern Escarpment with wadis such as *Wadi-Laba, Mai-Ule* and *Wekiro*. These *wadis* are lined with riverine vegetation. The first two *wadis* are the source of spate irrigation in *Sheeb* and the latter in *Wekiro*. The water source in *Wodilo* instead originates from the hills in the vicinity of the village. The government has recently introduced irrigated agriculture where it started constructing soil and water conservation structures to exploit the surrounding catchment areas for water harvesting.

Subsequent to planning and implementing research activities, it is very important to identify the production constraints and opportunities under spate irrigation system. Therefore the objectives of this study were to:

- describe and understand the bio-physical environment, particularly, the natural vegetation and soils,
- understand the different components of the farming system in terms of livestock and crop production, and
- identify and prioritise the major farming systems constraints and socio-economic conditions.

Methodology

The research team was multi-disciplinary to cover all aspects of the study. In collaboration with the representatives of the local administration and the Ministry of Agriculture (MoA), 10-15 knowledgeable contact farmers were identified from each village. These farmers, which comprised of different age groups, participated in all the discussions and were also involved in data gathering. The elders contributed substantial information on the historical profile of their respective areas. Three village areas were taken from *Sheeb* sub-zone as focal points for the survey. These areas are *Sheeb, Wekiro* and *Wodilo. Sheeb* is composed of the following villages: *Menshib, Dge, Tiluk, Bises, Dumnet Dge* and *Sheeb Ketin*. In this study, data was gathered at three levels: Rapid Rural Appraisal (RRA) (Franzel, 1992; Adugna *et al.*, 1995), questionnaire at household level and direct field observation. RRA was used to gather information at village level like seasonal calendar, crop and livestock husbandry, gender issues, trend line, vegetation management, identification of problems, opportunities and solutions. The questionnaire was used to gather information on quantitative data at household level. Direct field observations were made, together with the farmers to describe the overall environmental setting.

Results and discussion

Socio-economic conditions

The trend line on population showed that there was an increase between 1960 and 1975 but declined between 1975and 1988 mainly due to the war of liberation, which forced people to migrate to nearby towns and neighbouring countries to seek refuge. The population increased after 1991 due to returnees from nearby towns, which resulted in the shortage of agricultural lands with spate irrigation, drinking water, school and medical facilities. The farmers have tried to address some of these issues by building temporary classrooms made out of grass and wood and by digging well to solve the water problem.

During the Italian and the British colonial administrations (1890-1940), individual land holdings were confiscated in favour of commercial agriculture. Accordingly, all the lowlands of Eritrea including the coastal areas were declared state lands (Mesghina, 1988). In spite of this, however, farmers maintained their traditional grazing areas. The population was nomadic pastoralist that wandered in the coastal areas. Land holding had not been a serious issue, as such, until the introduction of spate irrigation system. Thus there was no scarcity of land before 1980 and 1 ha (4 *tsimdi*) of land is allocated to a married person and 0.5 ha (2 *tsimdi*) to a single. Above 18 years old females are also entitled to 0.5 ha of land. Land distribution is through village committees each composed of 12 people. A village committee forms a screening committee composed of 3 people whose responsibility is to identify people entitled for land. Family members carry out the individual land management themselves while the streams, wells, and the land around settlement areas are owned communally and managed by the village council.

Married women do not fetch water; girls and boys participate in all activities until their marriage. Widows or divorced women get help from their relatives except on occasion where they also go for hired work. The women recall that during the Ethiopian regime the men were forced to take their wives to the field so that they help in the farming activities. Apparently this did not change the situation, as this is not part of their culture. Married women are limited to domestic activities. The confinement in the house of the individuals has its own problems and is by no means less work. The women even have a difficult task at home, if they do not work, in the fields. The domestic work is quite demanding and takes a lot of their time and energy. They work long hours to cater for their family. They have to grind flour for their meals, as there are no grinding mills in the area. There is a general tendency to prefer male children compared to females for reasons such as helping the family in labour, herding, in generating income, and as security in old age. Among the respondents there were considerable percentages who said were sending their male children only to school. In the area polygamy is practiced depending on how wealthy the man is. The role of gender in agricultural activity is shown in Table 17 with some variation among the villages.

Table 17 Gender related activities in the study area

	ploughing	sowing	weeding	mowing	carrying andcollecting	harvesting	marketing	fetching water	fetching wood	house work	village council	committee	training
Sheeb and Wekiro													
Women	x	x	√	√	x	x	x	√	√	√	x	x	x
Girls	x	x	x	x	√	√	√	√	√	√	x	x	x
Men	√	√	√	√	√	√	√	√	√	x	√	√	√
Boys	√	√	√	√	√	√	√	√	√	x	√	√	√
Wodilo													
Women	x	x	x	√	√	√	x	√	√	√	x	x	x
Girls	√	√	√	√	√	√	√	√	√	√	x	x	x
Men	√	√	√	√	√	√	√	√	√	x	√	√	√
Boys	√	√	√	√	√	√	√	√	√	x	√	√	√

x Do not participate √ Participate (rarely above the age of 18)

Vegetation types

Mostly the area is barren with semi-desert annual grassland and dwarf shrubs. Occasionally stunted deciduous bush land and some perennial woodland along Wadis and major drainage channels are common. Commonly encountered trees and shrubs are listed in Table 18. As the area is sparsely populated, sites around spate-irrigated fields are still occupied by evergreen trees including *Tamarix nilotica* and *Saueda monoica*. Outside the spate-irrigated fields however, the vegetation cover is very low and hence the soil is vulnerable to wind and water erosion. Major factors for deforestation are drought (34.7%), woodcutting for fuel (25.7%) and the construction of agim (21.3%).

Table 18 Major trees and shrubs and their use in the study area

			Uses				
Local name	Scientific Name	Habit	Construction	Fuel	Agim	Browse	Medicinal
Chea	Acacia ehrenbergiana	T	√	√	√		
Kedad	Acacia mellifera	S		√	√		
Gemrot	Acacia oerofota	S		√	√	√	
Akba Keih	Acacia seyal	T	√	√	√		
Akba	Acacia tortilis	T	√	√	√		
Kog	Balanites aegyptica	T	√	√	√	√	
Asten	Cadaba farinosa	S				√	
Gindae	Calotropis procera	S		√		√	
Serob	Capparis decidua	S		√		√	√
Adai	Salvadora persica	T	√	√		√	
Hichum	Suaeda monoica	T	√	√	√		
Ubel	Tamarix nilotica	T	√	√	√		
Ksla	Ziziyphus spinachristi	T	√	√	√	√	√

T= tree S=shrub

Irrigation water management

The study area receives mean annual rainfall of 200 mm,which is not enough for crops as well as forage production without suplementary irrigation. To cope with this problem, farmers have adopted, a century ago, a traditional irrigation system locally known as *Gerif* (spate irrigation system). This system works as follows: the flood water from the rivers of *Wadi Laba* and *Ule* in *Sheeb* area, and the *Wokiro* River in *Wokiro* are diverted using *agim*. An *Agim* is a divertion canal, which is constructed using locally available materials such as branches of trees, shrubs, stones and soil.

This temporary structure, however, is frequently broken by floods and farmers are obliged to reconstruct it several times during the crop production season. Because of this, the vegetation in the area is completely cleared and farmers collect the necessary materials from distant areas. Once the irrigation water is diverted through the main canal, it is further re-distributed through secondary and teritiary canals, locally known as *'Mesga'*. During periods of drought, the distribution of of water in the farms is not uniform and as a result of this, farms located in the upstream near the main canal get more water compared to downstream farms. On the other hand, when the frequency of floods increase, farmers face frequent damage of canals in the upstream with severe erosion and gully formation. In this study, farmers emphasized the need for government intervention for the construction of permanent diversion structure using concrete. This will not only reduce the deforestation rate but also would enable farmers to get water under controlled conditions.

Crop Production

The principal cereals in the study area are sorghum, maize and pearl millet. Sorghum and pearl millet, which are drought tolerant, grow on residual moisture and maize is grown when there are enough floods. Sorghum and pearl millet occupy the largest total area cultivated with 51 and 58% of the area, respectively. The overall grower's mean area in the three villages is sorghum (2 ha), Maize (0.93 ha) and pearl millet (0.76 ha). These cereals are used to make various types of traditional dishes. Moreover, beans, tomato, okra, and pepper are used to prepare sauce with sesame as a source of oil. The staple food in this area is sorghum and the average consumption per person is about 20 kg per month.

Ploughing is mainly performed using oxen, camels and in some instances donkeys and cows. Sorghum is planted with minimum tillage that is direct seeding after one time ploughing and then covering the seed with second ploughing. Seedbed preparation starts in April with the maintenance of diversion structures and bunds done by the help of oxen drawn scooping tools. Burying enormous amount of tree branches further enforces the diversion structures. The work is done manually each year, as machinery to be used for this purpose is not available. Sorghum is planted earlier in September as compared to other crops and thinning takes place in November. Maize is planted whenever there is enough water for irrigation mainly from late November to early December. In *Wodilo*, sorghum is planted in December and maize is planted either in September or from late November to early December (Table 19). Most of the farmers use their own seed for planting, which is either purchased from the market or from friends who have the required seed type for planting. Farmers also keep seed from their own stock for planting.

Different planting methods are practised for different crops. *Jeleb* is, a row planting method, where a wooden bar is attached to the plough and seed dropped in rows while ploughing. Crops planted in this manner are sorghum, maize and groundnuts. *Angesh* is a planting method where wider holes are made using hoes with seeds being dropped in the hole and covered. Pearl millet and watermelon are planted in this manner. In Sulukat, holes are made using sticks and seeds are dropped in the hole. Pearl millet is planted in this way. In *Nishih*, seeds are evenly broadcasted over the entire field. Sesame is a crop that is planted in this method. The study indicated that none of the farmers apply inorganic fertilizers. The reason is that the soil is alluvial and hence fertile. Organic manure is also not applied because the farmers think that it brings insect infestation with species such as *Pachnoda*.

Farmers use similar seeding rates for sorghum and maize ranging from 24 to 40 kg/ha. Pearl millet, watermelon and tomato have a seeding rate that ranges from 4 to 20 kg/ha. The seeding rate for crops like sorghum and pearl millet are more than the optimum in the three villages. This is in order to ensure proper emergence, and provide adequate crop stands and adequate fodder.

Table 19 Cropping calendar in Sheeb sub-zone

Crop	J	F	M	A	M	J	J	A	S	O	N	D
Sorghum	HH		SS	SS	SS	II	II	PP	PP			HH
Maize		HH	HH	SS	SS	SS	II	II	II	PP	PP	PP
Pearl millet		PP		PP		II	II	II				
Groundnuts	HH	HH	SS	SS						PP		
Watermelon		HH	HH							PP		

SS- Seed bed preparation; PP- Planting; HH- Harvesting; II- Irrigation

Various types of land races or genotypes of different crop species have been used for many years. Some of the varieties used are dwarf, high yielding and early with a certain degree of drought resistance. It is important to encourage farmers to grow those landraces with useful characters. Those landraces that have deficiency in some of the characters (low yielding and drought susceptibility) need to be improved through breeding programs. The landraces of sorghum are *Hijeri* (white seeded, tall, high yielding) and Dura (brown seeded, tall, low yielding and suitable for animal feed). Maize has three landraces namely *Wedilibab* (mixture of white and black seeded, high yielding, early), *Tsada* (white seeded, high yielding, susceptible to drought) and *Tenish* (red seeded, dwarf, early, low yielding, drought tolerant). Sesame has three landraces- *Tselim* (dark seeded, early, low yielding), *Lemus* (brown seeded, high yielding, early, high market demand) and *Gera* (brown seeded, red type, round with thick cover, not acceptable oil quality).

Broadleaves, grasses and parasitic weeds are common in the study area. The most prevalent grass is Bermuda *(Cyanodon dactylon)*. The proportion of farmers using higher seeding rate as a weed control measure is small (6.5%). The use of higher seeding rate for weed control has a consequence in terms of decreasing yield. Hand weeding usually starts 4 weeks after planting for maize and sorghum, whereas in pearl millet, tomato, okra and watermelon is 1-2 weeks after planting. In this area, the most important insects are ear head bugs, stem borer and locust.

Harvesting time varies with the type of crop used. Sorghum is harvested in December, and maize from late February to March. Harvesting of pearl millet takes place in February whereas groundnuts are picked between late March and early April. In general, majority of the farmers (63.4%) perform threshing 2 to 3 weeks after harvest so that the crop loses moisture. Few farmers (16%) do threshing immediately after harvest if the grain is fully dried. Ratooning is a common practice for sorghum in which the stem of sorghum is cut at ground level after the first planted crop reaches maturity. The plant regenerates again and a second harvest of the crop is possible even though the yield is not as high as the first crop. Ratooning for the second time is also possible and grain can be harvested if the moisture level is adequate. After the second or third ratooning, if the moisture level is not adequate, the plant is cut and used as feed for livestock. The cost of seed is reduced as planting is done once, labour is saved and the number of days taken to maturity is also reduced. The yield of sorghum ranges from 0.8 to 2.8 t/ha with a mean yield of 2.0 t/ha. Maize yield in good years is estimated at 1.2 t/ha and in poor years at 0.4 t/ha with a mean yield of 0.8 t/ha.

Livestock production

Livestock is an integral component of the spate-irrigated production system. Results of the survey indicated that 85% of the respondents own livestock. The major livestock are cattle, sheep, goats, camels and donkeys with few poultry in *Wekiro* and *Sheeb*. Camels and goats make up the majority of livestock in *Wodilo*. The indigenous livestock and their characteristics are shown in Table 20. The sources of livestock feed are green chop and dry stover for cattle. Goats and camels browse at the riverine areas and foothills. Grains are given to donkeys as supplementary feed.

The major livestock diseases are ecto- and endo-parasites, trypanosomiasis, mange, sheep pox and pasteurellosis. The main control measure is annual vaccination. Some farmers and pastoralists practice traditional medicine using herbs. They complain that there are shortages of supply of drugs and inadequate veterinary services.

The strategies implemented at times of feed shortages are moving animals to other areas (53.6%), reducing the quantity of livestock (9.3%) and purchasing additional feed (32.5%). The main constraints in livestock production in this area are feed shortage (26%), drought (22.3%), water shortage (17.4%), shortage of grazing areas (15.2%) and animal diseases (13.4%).

Table 20 Major types of livestock and their characteristics as described by the farmers and pastoralists

Type	Landrace	Characteristics
Cattle	Arado	Small body size, medium sized horns, low in milk production, adapted in all areas
	Begait (Barka)	Larger body size, short horned, good meat and milk production, adapted to low lands
	Bahri	Large body size, small horns, excellent milk and meat production, adapted to lowlands
Sheep	Bahria (Kirchie)	Flattened fatty and short tail, high milk yielding (3 lt/day), 2 lambing/year
	Tsaeda (Hamadi)	Long tailed, tall stature, high milk production, high market demand, low feeder
	Barka(Begait)	Tall, long tail, consume large amount of feed, good meat and milk production
	Kaieh	Short stature, low in milk, good meat producer
Goat	Zhe	White coloured, reproductive efficiency, preferred for meat, adapted to lowlands
	Ware	Black coloured, adapted to lowlands
	Tzaadit	Medium sized, high milk yielder, 2-3 lt/day, high market demand
Donkey	Riff	All, fast striding, used mainly for human transport mainly found in the lowlands
	Mekadi	Shorter than Riff, pack animal, used extensively in the lowlands and highlands
Camel	Barka	Tall and well built, high consumption of feed
	Cheaanit	Adopted to move in highlands, medium feeder
	Geiah(Gerej)	Good for milk, high reproductive potential
	Denkalia	Short stature, grey in colour

Farmers constraints and possible interventions

The main agricultural production constraints of the area are low moisture, food shortage and lack of animal feeds. The area receives less than 200 mm of rainfall, which is very low for crop production. To tackle this problem farmers use spate irrigation by diverting the rivers to their farm. A summary of the major constraints in agricultural production and a possible solution to be addressed by research and government are given in Table 21.

Table 21 Production constraints, coping mechanism and their possible solution in the study areas

Problem	Cause	Coping strategies	Opportunities
Drought	Low rainfall	Spate irrigation	Develop a permanent diversion of the rivers with their secondary canals
Animal feed	lack of rainfall	migration of animals and purchase of feed	cut & carry system; production of fodder
Deforestation	agriculture, construction, drought, fuel wood,agim	purchase of wood for construction	Grow multipurpose trees & shrubs
Lack of domestic energy	deforestation	kerosene for light	introduction of kerosene; planting trees
Decline of crop production	lack of improved seeds, lack of draft; pests, drought, weeds; lack of implements	Borrow seeds, hire oxen	credit system, machinery centre (tractors), sustainable diversion canal construction
Decline of livestock population	lack of feed, diseases, war	cut and carry system	develop ranches, spate irrigation, delineation of grazing area and better veterinary services

Conclusion and recommendations

The food production trends in the area could be improved if a combination of improved land management programs would be adopted. In this area, drought and salinity tolerant multipurpose trees should be identified and tested in multi-location trials. Tree planting should be promoted at individual household levels. These trees should include exotic and indigenous browse and fodder species. Besides, reclamation of degraded lands such as eroded gullies, sand dunes, and marginal lands should be initiated through construction of mechanical structures and planting trees. Introduction of soil and water management practices should be initiated based on the existing socio-economic and ecological setting of the area.

The area receives very low amout of rainfall which is not enough for crop and forage production. Because of this, the exisiting traditional irrigation system (gerif) need to be improved in various ways.To avoid frequent breakage of the main diversion canal as well as the secondary and teritiary canals, there is dire need for the construction of efficient permanent strutures using concrete. Furthermore, to ensure uniform distribution of water and silt at the farm level, further technical intervation is required to control the flow of water btewwn the upstrem and low stream farms. This would require the intervention of the government to assist the farmers for the constrution of the diversion.

It is very important to convince farmers so that they increase the area allotted for cash crops mainly horticultural crops. Effective means of transfer of technology (research and extension linkage) should be implemented in the area. Training in home economics, land management be given to farmers periodically. Emphasis should be given to the conservation and efficient utilisation of water resources. Focus should be given to spate irrigation and runoff harvesting not only for crop production but also to improve the quality of browse to the pastoral communities. Women are not engaged in income generating activities. They should be trained in weaving mats, making baskets, fishing nets and home.

Community veterinarians could play a role in disease control of livestock in the area upon intensive training. They can be paid certain % for the services rendered.

Specialised surveys on specific disciplines that need more attention could continue in the sub zone. For example studies on specific crops, specific crop management practices, type of livestock or vegetation types, spate irrigation, soil management etc. could be done.

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Downstream irrigation development of horticultural crops on selected dams: Socio-economic baseline survey

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Abstract

This paper deals with the study undertaken by the Central Highland Irrigation Development Project (CHIHDP), MoA, on 30 dams in zobas: *Debub, Maekel* and *Anseba.* The objective of the study was to assess and document socio-economic data related to the existing production systems, to set up a number of quantitative and qualitative indicators for measuring future changes in the intervention of the project, and to critically look at the farmers' perceptions on the dam situation. The main reason behind the need for this socio-economic baseline survey was to allow local community participation in order to promote effectiveness and sustainability of the proposed downstream irrigation development intervention of the Government. Local communities need to contribute to the development and sustainability of the programme in order to achieve its goals. The paper briefly highlights the historical perspective and background of the selected 30 central highland dams. The main particulars like dams' profile, number of beneficiaries, potential and existing downstream irrigable land, land tenure system under the down stream areas of the dams, farmers' perception and opinions are presented.

Key words: dams, downstream irrigation, Eritrea, horticulture

Introduction

Eritrea is a country in Northeast Africa bordering the Red Sea in the east, Djibouti and Ethiopia in the south, and The Sudan in the north and west. Eritrea is a relatively small country, which covers a total area of 124,324 km2. It has six agro-ecological zones based on agro-climate and soil parameters (FAO, 1994). Agriculture is the most dominant sector of the economy and employs more than 80% of the population. But its production has not been able to cover internal food demand in recent years. At present, most farmers cannot produce enough food to meet minimum nutritional requirements mainly because of the poor performance of the rainfed agriculture. The scarce and unpredictable rainfall has been the main problem for food crop production. The country is not self sufficient in food, even in the most productive years. The Government of Eritrea is making a substantial effort to secure production against the vagaries of climate. One of the strategies is the construction of small-scale water harvesting infrastructures, irrigation and drainage systems using rainfall, runoff, small streams and ground water development.

During the last four decades, the MoA and various NGOs in collaboration with the communities have built more than 190 micro-dams. Ninety five percent of these dams are located within the central highland zone. The extent of irrigation on downstream side is insignificant compared to the number of dams and the aggregate volume of stored water. It is also rare to see direct irrigation from reservoirs either due to the inexistence of direct outlet facilities or lack of community based organisations to manage and administer the infrastructure to benefit the community.

The aim of the study is to assess and document the socio-economic conditions related to the existing production systems, to set up a number of quantitative and qualitative indicators for measuring future changes due to the intervention of the project, and to critically look on the farmers' perception about such dams. Therefore, this paper, reports the findings of the study undertaken by the CHIHDP, MoA, on 30 dams from zoba *Debub, Maekel* and *Anseba*. The details of the selected dams for this study are given in Table 22.

Table 22 Reservoir capacity, inflow and available irrigation water of the selected dams

Dam Name	RSC (m^3)	EIF (m^3)	AWFI (m^3)	ICR (ha)	AIL (ha)
Adesfeda	233,000	240,537	138,560	15.6/11.7	16.1
Adi Keshi	222,000	51,000	19,086	2.6/1.7	6.8
Adi Nfas	1,070,000	443,784	356,135	43.2/35.5	11.8
Adi Sherefeto	44,100	74,750	23,331	2.9/2.1	11.5
Adi Shmagele	308,000	269,450	234,721	28.3/23.3	26.4
Adi Bahro	135,800	105,235	64,860	7.7/5.4	28.4
Ade Kolom	160,000	112,136	63,304	7.1/5.5	7.8
Afelba	53,700	60,480	24,509	3/2.4	20.5
Ametsi	49,785	68,382	22,255	2.5/1.9	11.2
Bihat	125,000	207,060	–	–	–
Chefa	737,340	280,500	214,169	24.5/16.7	89.0
Dekitsena	290,389	164,441	21,214	2.6/1.9	29.3
Durko	382,000	329,940	236,975	28.5/23.4	31.2
Embaderho	307,000	126,846	52,300	5.9/4.5	14.9
Adibagie	252,494	698,292	197,663	22.6/15.4	53.6
Gorbaiti	388,700	140,679	107,554	13.2/9.5	12.6
Harnet	1,316,972	1,038,700	826,405	99.7/81.9	40.0
Hawatsu	79,300	355,453	39,545	5.6/3.1	7.7
Himbirti Gomino	191,000	142,629	109,218	14.8/9.5	36.0
Himbirti Sheka	187,169	126,846	117,310	15.9/10.2	14.6
Kertse Kemte	316,915	185,976	159,141	21.5/12.6	12.4
Kodadu	1,269,923	80,388	48,118	6.5/4.2	6.0
Laguen	130,152	438,480	47,924	6.5/4.2	7.1
Maereba	24,283	157,920	62,966	7.6/6.3	35.6
Maereda	67,000	476,238	27,668	3.9/2.2	28.2
Shimangus Lailay	297,000	265,144	185,573	20.8/16	21.0
Shimangus Tahtay	84,000	369,944	42,226	4.7/3.6	7.0
Taereshi	145,000	318,592	94,445	10.6/8.1	5.3
Tseazega	290,822	1,546,738	166,873	18.8/14.1	27.3
Wara	106,826	69,462	27,392	3.8/2.9	2.6

Source: AFWEL and Yohannes (2003).Key: RSC- Reservoir Storage Capacity; EIF- Expected Inflow; AWFI- Available Water for Irrigation; ICR- Irrigation Capacity of Reservoir (figures separated with slash indicate 2 productions/year); AIL- Available Irrigable land

Materials and methods

In conducting the baseline survey various comparative data collection methods including participatory rural appraisal (PRA) techniques, secondary data, demographic census, interview with the farmers, and group discussion with the villagers have been conducted (Soenkel, 1995). The study employed both quantitative and qualitative methods of social inquiry and focused particularly on the perceptions of smallholder farmers regarding the dams in the selected villages. All available secondary data sources, that are appropriate to the study, have been reviewed and were used to derive relevant data from previous studies. As no population census has been undertaken in Eritrea, a house-to-house population survey with the help of structured questionnaire was employed to assess the exact population in the selected dam sites. Questionnaires were designed to acquire information on size and head of household, educational level of members, their general status and the number of livestock they own.

PRA tools, such as village mapping and direct matrix problem ranking based on Nebasa *et al.*, (1995) were considered during the baseline study. The participatory village mapping helped to build up an 'entry point activity' to establish rapport between the survey team and the local population. This produced information on rainfed and irrigated crop production and food security related problems and has explored the opinions and insights of the participants. The direct matrix problem ranking was used to instantly determine and prioritise the main problems of the study area. In addition, six to eight people were brought together for focus group discussions using semi-structured questionnaire in the respective selected sites. Topics covered during the discussion include: general background information, demographic characteristics, crop and vegetable production, food security issues, livestock production, land use pattern, community participation in development programs, nutrition, dam and down stream situation and development of agricultural wells.

The major data of this study were collected from individual interviews using semi-structured questionnaire. For each site, 30 individual farmers were interviewed and a total of 900 farmers contributed their opinion to the study. This generated quantitative data on household characteristics, vegetable and crop production, livestock production, food security situation, health, nutrition, water supply, household income and expenditure.

Results and discussion

Historical perspective of the dams

Out of the thirty dams selected for the study, 15 were constructed by the MoA, 9 by the Lutheran World Federation (LWF), 4 by the Relief and Rehabilitation Commission (RRC), 1 by the Eritrean Catholic Society (ECS), and 1 by the community (COM) (Table 23). The dams that were built before independence (1991) were small and less than 8 m high. The construction was mainly labour intensive and payment was effected by 'Food for Work Program'. After independence, however, construction of the dams involved machinery and the height increased up to 20 m. Payment during this time was through 'Cash for Work Program'.

Except for few, the dams constructed before independence were built with the idea of enhancing groundwater recharge downstream, as major soil and water conservation structures and as livestock water point. After independence the construction of the dams mainly aimed at downstream irrigation development purposes.

Table 23 Dams constructed by different agencies between 1961-1997

Institution	Dam Site	Year of Construction	Institution	Dam Site	Constructed in
MoA	Adi Nfas	1995	LWF	Cheffa	1988
	Bihat	1993		Adibagie	1984
	Kertse Kemte	1994		Adi Bahro	1987
	Gorbaiti	1996		Taereshi	1988
	(Adi Absha)	1995		Tseazega	1988
	Adi Shmagele	1996		Embaderho	1991
	Kodadu	1994		Afelba	1996
	Wara	1996		Dekitsena	1997
	Hawatsu	1983		Shimangus-T	1992
	Maereda	1983	RRC	Durko	1985
	Adi Sherefeto	1962		Adi Kolom	1989
	Shimanugus-L	1985		Himbirti-G	1987
	Adesfeda	1985		Adi Keshi	1990
	Himbirti-S	1984	ECS	Ametsi	1986
	Laguen	1987	COM	Maereba	1961

Source: AFWEL and Yohannes (2003)

It was difficult to get detailed information on the design of the dams. The only available information for the dams constructed by MoA was from micro-dam study (1994) and inventory report compiled by MoA (1999). The dams constructed after independence (*Adi Nfas, Kertsekemte, Adi Shmagle, Gorbati, Wara*, etc.) were planned to have hand-placed riprap on the upstream face of the dam, earth with grass cover on the downstream face and natural drainage blanket on downstream side. For those dams constructed before independence, no secondary data (technical data) were available.

The dams constructed by LWF have been observed to have standard and uniform design. All the dams built before independence have outlet facilities which include, an intake opening with metal sluice gate, an access bridge, an outlet concrete pipe cover, and discharge outlet with discharge basin controlled by sluice metal. Both upstream and downstream slopes of the earthwork of the dam are covered with a hand placed riprap. The farmers indicated that the main problems for the development of irrigation downstream are small size of the land holding, land tenure system, and lack of irrigation know-how.

Socio-economic profile of the dam sites

The semi-structured interviews in the 30 dams studied disclosed some interesting contrasts. Agriculture in all sites is based on rainfed crop production and livestock rearing. Irrigation is a common practice in the three zobas where the dams are located but almost 80 to 90 percent of the irrigation is done from existing wells. Farmers practice irrigation from dams or base flows in only few areas. The most common type of irrigation method practiced by small-scale farmers in the sites is surface irrigation (furrow and border).

Farming incomes are low and the average cultivated area per household ranges between 0.5 and 1 ha for cereal production and between 0.005 and 1 ha for growing vegetables. Yields are extremely low due to factors like drought, falling water table, poor seed quality, shortage of labour and incidence of pests and diseases. Discussions with the farmers revealed that most households could only feed themselves for about two to three months during bad years. In good years the households cannot feed themselves for more than 7 months. The survey showed that food shortage in the study area is covered by sale of livestock, wage labour, provision of food aid, participating in 'cash for work' activities, assistance from friends/neighbours/relatives, and through credit.

The income and expenditure analysis showed that in most villages the primary source of income for rich and middle level households is from sale of agricultural produce followed by sale of livestock and livestock products, wage labour, and remittance. The main source of income for the poor category is from wage labour, followed by sale of crop produce, remittance, sale of livestock, food aid and participating in 'cash for work' activities. A considerable share of yearly average income is spent on purchase of grain for food and essential consumption items like sugar, coffee, tealeaves, etc. Besides, relatively small share of the income is spent for cooking items, education, clothes, government tax and medication.

Households in all the sites studied except in *Wara* village acquire land through Diesa system (a communal form of land tenure where people have the right to cultivate the land, but do not own it). In *Diesa* system, a committee of elders selected by the *Baito* (village assembly), distributes the land. Arable land is distributed equally to households every seven years at village level. The farmers can also obtain additional farmland through a variety of tenancy arrangements known as *Nblhot. Nblhot* is a form of sharecropping, which represents a contract between two people - a landowner and an ox-owner, usually based on crop sharing agreement rather than renting the land. Most households rely on the available family labour for farming. Those who can afford also hire labour from the village. *Wara* village acquires land through patrilineal inheritance *(Tslmi)* where land is inherited from parents.

The survey confirmed that in almost all the selected dam sites social services are scarce, and health and education facilities are very poor. Since most of the sites do not have health centres, or hospitals farmers have to walk long distances to their respective zoba hospitals or to Asmara to seek medical services. Large number of the community goes to rural pharmacy or uses traditional medication. Similarly, most of the villages do not have middle and secondary schools. They have to walk to nearby villages or to schools in the sub-zoba, zoba or Asmara to study. Dropping out of schools and low attendance of classes were mentioned as main problems in most of the villages.

Farming problem and opportunities

Several problems hampering horticultural production under downstream irrigation schemes were mentioned in each dam site. The ranking of the problems in most villages are: silt and seepage of dams, lack of infrastructure (primary and secondary canals), erosion from the upper catchments, lack of labour, inadequate agricultural inputs (improved seed, fertilizers and chemicals), increasing frequency of plant pests and diseases, small size of the land holding, land tenure system and difficulties in the utilization of water.

The farmers have suggested some intervention measures in the following crucial issues in the downstream: land tenure system, water use management and lack of working force. The *Diesa* system, where people have the right to cultivate but do not privately own the land, operates as a disincentive. Periodic or regular redistribution does not encourage long-term investments and hampers the shift from subsistence farming to modern agriculture. Furthermore, the fragmentation of the rather small farms into even smaller parcels does not enable farmers to produce enough food. Water use management under the downstream of the dam sites for irrigation development is also a problem. The point is that no one can equally benefit from irrigation. Those, who are close to the water sources, derive more benefits from irrigation than those far from it. Farmers in most of the villages have stated that diverting water illegally for own use and inefficient management structures have a negative effect for irrigation development. The establishment of regulatory mechanism for water users is highly required in this respect. Most of the working force at present is deployed in the military service. Consequently, peak periods of horticultural activities, such as, land levelling and preparation, raising seedlings and transplanting, harvesting and storage are adversely affected in irrigation development in the downstream. Farmers recommended the return of some of the working force from military service. These are the most crucial problems that need to be addressed and solved directly by the intervention of relevant government offices.

Most of the opportunities proposed by the farmers call for the support of the government and/or NGOs. These include provision of agricultural inputs (e.g. improved seeds, fertilizers, motor pumps, farm tools, etc.) at reasonable price; construction of soil conservation structures, dam rehabilitation, and introduction of credit schemes with fair interest rates. These problems need collective action that involves all stakeholders – government, multilateral organisations, NGOs, and the community. Individual farmers or households can address problems like pest and disease control, and maintaining soil fertility in their fields provided that they have access to appropriate information and knowledge.

Farmers' opinions and perceptions of the dams

The data collected from the focus group discussions showed that some of the ideas for dam construction were initiated by the village(s) and with full participation of the community. Since the community basically took this initiative, the irrigation practices in the downstream were successful and cooperation among and within the villages was smooth. There were also cases where most of the idea for dam construction was initiated from the side of the developers without the participation and interest of the end users. As a result, unequal access to irrigation water and conflicts over the inequitable distribution of benefits arose between upstream and downstream farmers/villages. This has negatively affected the agricultural production and productivity as well as the livelihoods of the farming communities in these areas. The following boxes briefly explain some case studies of some of the dams.

Box 1: Harnet Dam *(Adi Absha)*

Adi Absha is a village located about 30 km west of *Emni Haili* and the dam is located 2 km west of the village. The focus group discussions verified that the villagers of Adi Absha initiated the construction of the dam. A group of experts from the MoA in collaboration with the farmers in the village selected the site and the MoA constructed the dam in 1995. Two villages, *Adi Absha* and *Abaebo*, are beneficiaries of the dam. However, *Abaebo* has not fully participated in the planning process. *Abaebo* owns the upstream area and about one-third of the reservoir while *Adi Absha* owns the downstream area and about two third of the reservoir. The water is fully utilized by *Adi Absha* for growing vegetables and for livestock consumption. This is a practical example that indicates an inequitable access to water for irrigation between the two villages. *Abaebo* has not yet received tangible benefits. Currently this village is requesting support from the government for the construction of a new reservoir and concrete irrigation canals in the upstream of the dam for growing vegetables.

There are a total of 197 beneficiaries in the downstream area. The total estimated irrigable land in the downstream is around 120 *Tsimdi* (30 ha), out of which 52 *Tsimdi* (13 ha) is under irrigation. Currently, the irrigable land under the downstream areas in *Adi Absha* is categorized into three as proposed by the MoA. The first category has around 13 ha, which is rented to 9 individuals; the second consists of 20 ha divided among 80 beneficiaries (0.25 ha each), and the third category embodies about 110 ha divided among 110 beneficiaries (1 ha each). Beneficiaries under the second and third category obtained the farm fields through *Diesa* system.

This study confirmed that the land use system practiced under the downstream, which was imposed by the MoA, is not to the interest of the community. It was revealed that only few well-off individuals are benefiting from the irrigation system and not the community as a whole. This example indicates that even within the same village, people do not benefit equally from irrigation. Farmers close to the water source are generally in a better position than those far away from it.

Box 2: *Afelba* Dam

Afelba is a village located about 8 km southwest of *Dekemhare*. The dam, which was constructed by LWF in 1996, is located 2 km south of the village. The group interviewed confirmed that the idea of the dam and its location was totally decided by the LWF. The village wanted to have the dam site at *Ruba Daero*. The villagers confirmed that the expected inflow, the irrigation capacity of the reservoir and the available irrigable land (3 ha) are small and cannot accommodate large number of beneficiaries. Currently, there is no vegetable farm in the downstream and the area is being used for cereal production. During the last 3 years, the dam was dry. The farmers identified high seepage (farmers' opinion is that the basement is sandy), and limited silt as the main problems. The group recommended that the only solution is to have another dam constructed at *Ruba Daero*. They believe that this site would accommodate more beneficiaries and provide more land for irrigation. This is a practical example of an unsuccessful intervention due to lack of proper users' participation.

Box 3: *Adi Kolom* Dam

Adi Kolom is a village located about 7 km northwest of *Serejeka*. The dam, which was constructed by RRC in 1989, is located 1 km southeast of the village. The focus group verified that the idea of constructing the dam was initiated by the village. However, the site where it is located now was not the choice of the community and two reasons were given for this during the discussion. (i) The land for irrigation in the downstream, according to the farmers' understanding, is not adequate (only 0.5 ha), and ii) the capacity of the reservoir is very small. Thus, the irrigation intervention by the RRC was not successful. Farmers believe that in the upstream there is around 30 ha of land that can potentially be irrigated.

Box 4: *Adi Bahro* Dam

Adi Bahro is a village located at about 6 km north of *Adi Quala*. The dam, which was constructed by LWF in 1987, is located 500 meters east of the village. The objectives of building the dam were to provide the beneficiaries, most of whom are small-scale farmers, with a better and more varied diet, as well as generating income to raise their standards of living. The farmers confirmed that the location of the dam and its construction was proposed by the governor of sub-zoba *Adi Quala* in collaboration with the LWF. The choice of the villagers was to construct the dam in the upper part of the site, but the donors did not accept this. Four villages namely *Adelges, Adi Ghenan, Adi Feyayu* and *Adi Sela'a*, in the downstream area, became beneficiaries of the irrigation water. Adi Bahro owns the reservoir (400,000 m^3) and the upstream resources. However, the village has not yet received tangible benefits. Thus, a conflict arose among the villages because of the absence of equitable distribution of water. The objective of developers did not take the practices, interdependence, and interrelationship among the villages into consideration.

Conclusion and recommendations

In general, the results of the study have shown that the socio-economic profiles of the villages where the dams are located are poor. The livelihoods of the farmers are based on agricultural production. Problems identified to hamper irrigated production include: inappropriate land tenure system, mismanagement of water and lack of labour. Yields are low mainly due to drought, falling water table, poor seed quality, and incidence of pests and diseases. Coping mechanisms to alleviate food shortage is met by sale of livestock, sale of labour, provision of food aid, assistance from friends/neighbours/relatives and through credit. The nutritional problems investigated in the households were unstable and inadequate food supply rather than dietary. The villages are characterized by low endowment of social services. Most of the villages do not have health and education services.

The preceding discussions have also shown that the construction of some of the dams was initiated by the village(s) and the full participation of the community. There were also cases where the donors alone without full participation and choice of the end users initiated most of the dams. Unequal access to irrigation water and conflicts over the inequitable distribution of benefits arose between upstream and downstream village(s). This has negatively affected the agricultural production and productivity and the livelihoods of the farming households of the proposed areas.

Based on the findings, the following recommendations are proposed for future irrigation project interventions.

- The success of an irrigation project in meeting the required objectives should depend not only on technical aspects but also on the social aspects of the end users themselves.
- If the objective is to help farmers benefit from a given intervention, farmers' practices, indigenous knowledge, interdependencies and interrelationships should be taken into account.

- In reality, the outcome of any intervention clearly depends upon farmers' needs and their participation. The best approach is to find means on how the needs of the beneficiaries could be incorporated through their participation to achieve project objectives.
- The study recommends an in-depth research on the pattern of social interaction prior to the initiation of an irrigation project, to achieve greater satisfaction and sustained cooperation among all groups benefiting from the development project.

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Shifting from conventional irrigation to drip irrigation: A socio-economic study of orange growers in Alla-Gaden Basin

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Abstract

Alla-Gaden basin is a potential agricultural area for fruit production, especially oranges and papaya. Nowadays, however, its potential to supply water is constrained by recurrent drought and continuous farming. Despite the acute shortage of water for irrigation, farmers in this area are generously irrigating their land with conventional way of irrigation that cannot keep pace with the increasingly shrinking capacity of the area to supply water for such purposes. Very few of the farmers have tried to practice drip irrigation. The aim of this paper is to examine the socio-economic factors and to understand the prospects and constraints accompanying the process of shifting to drip irrigation. To address these objectives, primary data was collected using a questionnaire and a sample of 30 orange growers in *Alla-Gaden* was selected by consulting the Ministry of Agriculture, *Dekemhare* branch. The sample included growers who never practised drip irrigation, and those who practised but later quit. In addition, secondary data was sought to support the primary data. The data was then analysed descriptively to address the research objectives. The study showed that the main constraints for the shift are high initial and running costs associated with drip irrigation and the system's incompatibility with the already established trees. However, the advantages of the area are the permanent ownership of the land, reasonable land size, positive perception, good awareness and consciousness of the growers towards the technology and its associated problems.

Key words: *Alla-Gaden*, drip irrigation, land ownership

Introduction

Eritrean agriculture is predominantly rainfed where the amount and timing of rainfall is not adequate to meet the moisture requirements of most crops. Such chronic failure often leads to acute shortage of water for sustained agricultural activities and it has been cited as a bottleneck for sustained crop and animal production in the country (MoA, 2002). The large dependency of agriculture on rainfall has only aggravated the problem and rainfed agriculture provides limited water management options to the farmer than irrigated agriculture (Stone and Willis, 1983). Searching for an alternative system of cultivation other than rainfed agriculture entails an implication for future commercial farming in the country. Michael (2002) states that irrigation is essential to raise crops in poor rainfall areas to meet the needs of food and fibre.

The *Alla-Gaden* basin, located in zoba *Debub*, sub-zoba *Dekemhare* 22 km east of the town of *Dekemhare*, is one of the pioneer areas with leading potential for commercial fruits, particularly orange production. Efforts to boost fruit production is primarily constrained by the recurrent shortage of water due to poor rainfall which has led to the ever diminishing underground water which is the chief source of water for irrigation. In a survey conducted among Alla-Gaden orange growers, Ghebreab *et al.*, (2003) have shown that water shortage is the main limiting factor and farmers have adopted different coping mechanisms to effectively utilise the already scarce water through different water management strategies. As part of this strategy, they practice ways to modify the conventional furrow and basin irrigation methods used in the area.

Surface irrigation via furrows or floods has long been used in many citrus growing regions in the world. Its relatively easy operation and demand on low capital and high availability of labour has made it a choice among subsistence and small-scale farmers. However, its uneconomical use of water has called for its critical evaluation particularly under arid and semi-arid areas where shortage of water is a common problem. Michael (2002) explains that in relative terms, furrow irrigation is suitable under conditions that render abundant rainfall and where water is less expensive.

An alternative to surface irrigation is drip irrigation where water is directly supplied to the root zone of the tree. Under such system, the growing tree economically utilises water by eliminating some of the possible forms of water losses. It provides an efficient method of supplying water to the tree on regular and consistent basis though they require more intensive management and capital than others (Davies and Albrigo, 1994). Several studies have clearly demonstrated that it is possible to produce comparable yields by using lesser amount of water through drip rather than through furrow or sprinkler irrigation. Davies and Albrigo (1994) state that micro-irrigation uses less water than other forms of irrigation without compromising tree growth and yield. Drip irrigation is particularly suitable for fruit production. Rice *et al.*, (1990) describe that drip irrigation is expensive to install but its maintenance costs are minimal and is more applicable to fruit production. In an experiment to show the efficient utilisation of water in drip irrigation, Roth *et al.*, (1974) found yields of orange varieties 'Campbell' and 'Valencia', to be comparable to furrow irrigation, yet drip irrigation used only 11% of the water applied through furrow irrigation.

Despite the drawbacks of the conventional irrigation and the clear merits of drip irrigation vis-à-vis the continually deteriorating underground water, *Alla-Gaden* orange growers continue to use the former to irrigate their orchard. This study aims at examining the socio-economic factors in order to understand the prospects and constraints accompanying the process of shifting to drip irrigation. Moreover, it assesses the factors that may explain why the farmers continue to use furrow irrigation.

Materials and methods

Primary data was collected by a structured questionnaire that included open and closed-ended questions on personal information of the respondents, the characteristics of their farm and their perception on drip irrigation. A sample of 30 orange growers from *Alla-Gaden* was selected by consulting the MoA, Dekemhare branch. *The sample included growers who never practised drip irrigation, and who pr*actised but quit it. In addition, secondary data was sought to support the primary data. The data was then analysed descriptively to address the research objectives.

Results and discussion

With the prevailing labour shortage, both the wife and husband make up the labour force required to run the enterprise. Although fruit production, particularly orange growing, dominates the farming activities in the study area, other crops like tomato, pepper, coffee etc. are also grown in small-scale mostly to fetch cash. The production of these crops, however, depends on the availability of water to minimise possible competition with the fruit trees. Few of them rear dairy animals for milk production.

The size of land holdings of the interviewed farmers ranges from 1 to 13 ha where the land is under permanent ownership under the land tenure system locally known as *Kahmahise* or 'Land of Brothers'. The geography of the area is dominated by plane topography with some land in a very gentle slope. Soil is conceived as good by all interviewees and according to them, it is in the range of sandy loam to loam.

All the interviewed farmers mentioned water scarcity to be the most critical limiting factor for increased production. Other constraints include diseases, pests and scarce labour. The failure of rainfall coupled with growing competition has led to acute shortage of water for irrigation. Over the years, availability of water for irrigation is becoming more problematic than ever before. Thus farmers embarked on digging more and very deep wells ranging between 17 and 46 m to ensure steady water supply. However, the situation is marked by low water supply, which does not generally go beyond two hours per day. The incidence of more unsuccessful wells is a common feature in the area.

Present irrigation system

During the dry season, irrigation is seen as a way to guarantee production in the area. Rainfed agriculture through the establishment of small ponds to supplement irrigation is also practiced during the rainy period. Surface irrigation through the use of canals and basins is the most common one. Water flowing through the long canals is directed towards the small holes (basins) around the tree where it is utilized. This is virtually the only irrigation system practiced in the area. According to the farmers interviewed, this system is characterized by high water loss owing to several factors like evapo-transpiration, seepage, and deep percolation. It greatly encourages weed growth along the canals and around the orchards, which would aggravate the water scarcity through competition.

In order to minimize the water loss in the canals, farmers use narrow and concrete canals instead of broad and earth bunds, which calls for continuous cleaning. This practice has not helped much, so they have employed a different strategy, which uses mobile pipes instead of canals. Sixty percent of the farmers are using this practice to cut some of the water losses. This modified irrigation system has greatly reduced the possible forms of water losses such as evaporation and deep percolation. All the farmers practicing this system conceive that this is more economical than the traditional one. Moreover, farmers prolong the frequency of irrigating their farms to once in three to four weeks instead of once a week, which is the case in good times. Even in very critical times, some farmers purchase water for 370-400 Nakfa per tanker that can water 25-39 trees of orange. However, the present system does not guarantee complete elimination of such losses, as there is inevitable outflow of water along the pipes and evapo-transpiration from the orchard. It also puts extra pressure on the already limited supply of labour in the area, as the pipe needs to be transported within the orchards. The continuous deterioration of available water for irrigation coupled with the inefficient nature of the existing irrigation system calls for better and efficient water management on top of better water harvesting techniques.

The shift from conventional to drip irrigation

Despite the acute shortage of water for irrigation, farmers in the *Alla-Gaden* area are generously irrigating their land with the already indicated conventional way of irrigation. Such system cannot keep pace with the increasingly shrinking capacity of the area to supply water for irrigation. Hence, it is high time to shift to a better irrigation system such as drip irrigation. Farmers in the area have been struggling with different techniques to cope with the prevailing water problem but very insignificant numbers of them have opted for drip irrigation. This sparks an important caution to identify the reason.

The study has identified the potentials that can be the cornerstones for the introduction of drip irrigation systems. It also showed the main constraints towards this shift. Some of the main potentials grasped by this study are perception, willingness, consciousness and awareness of the farmers towards drip irrigation. The constraints are the initial and running costs of the system and its incompatibility with existing irrigation systems.

Constraints against the shift

The main constraint that was mentioned by all respondents to implement drip irrigation was the high initial and running cost of the system. This explains the low adoption of the system despite the good awareness prevailing in the area. Those farmers who tried drip irrigation (13%) got loans from some NGOs and relatives. All the rest remarked that they would shift to drip once this barrier is removed. Running cost is mainly related to the cost of fuel. All of the respondents think that irrigating a unit of land by drip irrigation takes longer time, which means more money. According to the MoA sub-zone *Dekemhare,* on average, drip irrigation takes 8-10 hrs/day to irrigate a hectare of land while furrow irrigation takes only 4 hrs. This may create an impression that more money is required to run drip irrigation and that is what all respondents perceived as compared to conventional irrigation.

Compatibility is the second important reason mentioned by all respondents for not using drip irrigation. This is mainly with those orange trees that have been already under conventional irrigation. According to the respondents, with the shift to drip irrigation, water for such orange trees becomes less that they start giving lower yields or completely fail. However, several studies have shown that it is possible to produce comparable yields by using lesser amount of water through drip than furrow and sprinkler irrigation (Davies and Albrigo, 1994). The trees, which have been under furrow irrigation, would certainly be stressed unless the timing of using drip irrigation is properly followed. In other words, drip irrigation would call for more frequent irrigation periods to satisfy the trees, a practice, which would increase the running cost.

Potentials towards the shift

The study showed that the promising aspect of the potentials to implement drip irrigation in the *Alla-Gaden* agricultural area is the land holding system. According to Albert and Makeham (1990), land holding system is important to economic development by influencing the application of labour, capital and entrepreneurship. Without some security of tenure, land users will apply only those inputs that bring immediate benefits and become less interested in long-term investments such as building up equipment, improving water supplies, drainage, terracing, maintenance of farm building etc. However, agricultural land in the study area is under permanent ownership that encourages long-term investment. This is reflected, for example, by the level of expenditure of a farmer in digging wells and the number of wells dug per farmer (successful or unsuccessful). In an effort to get steady water, for example, one farmer attempted to dig seven wells. In addition, another farmer drilled to a depth of 76 m costing him 120,000 Nakfa. Table 24 indicates the desperate endeavour of the farmers to get water and provides an insight of the level of investment incurred. With the exception of one of them, all the wells are manually dug.

Table 24 Level of effort by farmers in the Alla-Gaden area

	Farmer 1			Farmer 2	
Well	Depth (m)	Remark	Well	Depth (m)	Remark
1	23	No water	1	27	Water available
2	15	No water	2	16	No water
3	9	No water	3	14	No water
4	9	No water	4	76	No water
5	17	No water	5	10	No water
6	17	Water available	6	12	Water available
7	27	Water available	7	11	Water available

One cannot expect such level of expenditure if the land was not under permanent ownership. Therefore, one condition for long-term investment is met in the *Alla-Gaden* agricultural area. In addition to permanent ownership, agricultural land is dominantly located in a very gentle slope that is suitable for the intended irrigation system. Moreover, the average size of farm in the area is 3.5 ha which is suitable for fairly sized drip irrigation system.

Consciousness of farmers on certain problems and their awareness to technologies are among key entities in solving the problem of adoption. Valk and De Graf (1995) pointed out that in implementing certain technologies, increasing consciousness about the problem in question, is one an important step. All of the farmers interviewed, responded that shortage of water is the main problem in their farm. Their awareness to water conservation is reflected by the modifications they did to furrow irrigation. In addition, all of the interviewed orange growers are aware of drip irrigation. Their awareness was strengthened by their ability to describe the system in terms of its merits and technical know-how. Such information needed for the implementation of the system flows among the farmers via friends, relatives and local extension agents.

Willingness of farmers to adopt a particular technology is crucial for its implementation. All the respondents showed their willingness to use the system. The study also indicated that the farmers have positive attitude towards drip irrigation and perceived that it is more efficient in its water use than conventional irrigation. As a result, they point out that it can reasonably address the water problem in the area. Similarly, all farmers perceived that it is less labour intensive than the conventional irrigation system, a point worth considering now that steady labour supply is no more a guaranteed opportunity. Moreover, a dominant proportion of the respondents (86%) perceived that there are fewer incidences of disease and weed in drip irrigation than in conventional irrigation. The implication to weed control is notably important considering the wide spread of weeds booming due to the existing irrigation system.

Conclusion

Based on the findings of the research, the following suggestions and recommendations are forwarded to foster the implementation of drip irrigation in *Alla-Gaden*:

- The demand for initial cost should be alleviated through some mechanisms such as soft loans, cost sharing strategies, donations etc.
- Appropriate information on timing, water requirement, installation and maintenance of the technology should be disseminated to the farmers.
- Drip irrigation on already established trees should be accompanied by occasional flushing to compensate the water stress.

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Theme 5 General topics on irrigation

Potentials and constraints of drip irrigation system in the North-Western Lowland ecology: The case of Sawa Farm

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Abstract

The Sawa Farm, with an altitude of 540 m.a.s.l., is located in the *Gash-Barka* administrative zone, about 317 km from Asmara. The existing area under cultivation is 300 hectares. However, there is a potential of expanding the farm to 10,000 hectares. The farm produces different types of horticultural crops using drip-irrigation system along with other modern management techniques. The source of irrigation water is the underground supply of the *Sawa* River. The paper focuses on the potential of using drip irrigation system for vegetable production in the North-Western Lowland Agro-ecological Zone in general, and the *Sawa* Farm, in particular. It discusses the major constraints that the farm has been facing in using drip irrigation system in the last 4 years. The suitability, in terms of water quality, of the underground water of the *Sawa* River basin for use of drip irrigation will be discussed in depth. The paper will also give an insight on the status and dynamics of the underground water resource of the river basin. It concludes by giving some recommendations on the appropriate usage and management practices of the water resource of the basin.

Key words: Drip irrigation, horticultural production. North-Western Lowlands, *Sawa* River

Introduction

Eritrea is a country with a semi-arid climate. Rainfall is not only scarce but also very erratic. As the result, for decades, in most part of the country, rainfed agriculture has resulted in crop failures. Hence, the potential of the underground water resource needs to be exploited for crop and livestock production. Thus, a rapid development and expansion of drip-irrigation systems is essential and has a good opportunity of being adopted by commercial farmers. In this line, the *Sawa* Farm was established to utilize the farmland around *Sawa* area and the water resource of the *Sawa* River for horticultural production using drip-irrigation.

The *Sawa* Agro-Industry was established in 1998. The *Sawa* Farm, which is one of the farms of *Sawa* Agro-Industry, is located in the *Gash-Barka* administrative zone of the North-Western Lowland Agro-ecology of Eritrea. This agro-ecology, having an altitude range of 400-1500 meters, is characterized by hot arid climate with less than 300 mm of rainfall per annum. The potential evapo-transpiration is 1500-2000 mm. This area has a production system of nomadic pastoralists with irrigated horticultural commercial farms along the riverbeds. The farm, with an altitude of 540 m.a.s.l., is about 317 km from Asmara. The existing area under cultivation is 300 hectares. However, there is a potential of expanding the farm up to 10,000 hectares. The farm produces different types of horticultural crops destined for both local and export markets using drip-irrigation system along with other modern management techniques. Onion, tomato and hot pepper are produced for the local market, whereas watermelon, sweet melon and pumpkin are produced for the export market. Green beans, carrot, sunflower and ground nuts are grown for crop rotation purposes.

The source of irrigation water is the underground water resource of the *Sawa* River. The boreholes, with a depth ranging 20-40 meters, have dynamic and manometric water levels of 8 and 4 meters, respectively. The average output ranges between 13-18 l/sec, having capacities of irrigating 1 l/sec. In the last 4 years, as expected, drip-irrigation was observed to have a lot of advantages. However, with the existing level of management, there are also several constraints that have to be dealt with. The status of the water quality of the underground resource of the river is annually monitored to see the effect of utilizing drip-irrigation on the dynamics of the water quality.

The Sawa farm has been producing vegetables using drip irrigation system since 1999. Based on the experiences of the past 4 years, the potential benefits of drip irrigation system as compared to surface and sprinkler irrigation systems are assessed in this study. The major constraints that the farm has been facing in adopting the drip irrigation system have also been identified, and some recommendations are suggested.

Materials and methods

Since 1999, the hydro-chemistry of the water samples of the 17 boreholes of the Sawa Farm have been analysed annually at the laboratory of the Water Resources Department of the Ministry of the Land, Water and Environment. These samples were evaluated for their suitability for agriculture using the standard classification criteria as indicated in Table 25 after Lenka (1999). The major parameters taken are: total salt concentration or salinity measured as electrical conductivity (EC), sodium adsorption ratio (SAR), boron (B) concentration and the concentration of bicarbonates (HCO_3). The other parameters taken are: level of concentrations of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), manganese (Mn), sulfates (SO_4), nitrites (NO_2), nitrogen in ammonia form ($N-NH_3$), iron (Fe) and calcium carbonate ($CaCO_3$).

Table 25 Classification criteria of irrigation water

Parameters	Water quality classification criteria			
	Low	Medium	High	Very high
EC (mmhos/cm)	0-250	250-750	750-2250	2250-5000
SAR	0-10	10-18	18-26	> 26
HCO3 (mg/l)	< 91	91-518	> 518	
Boron (mg/l)	< 0.7	0.7-3.0	> 3.0	
Chloride mg/l	< 142	142-355	>355	

Source: Lenka (1999)

Results and discussion

The results of the quality of irrigation water of the boreholes in terms of its suitability to irrigation, and the benefits and constraints of using drip-irrigation system in *Sawa* Farm is discussed below.

Quality of irrigation water of the boreholes

The results of the hydro-chemistry of the water of the boreholes of the *Sawa* Farm are indicated in Table 27. The total concentration of soluble salts, expressed as electric conductivity (EC) is the most important single criterion of irrigation water quality because salinity of soil solution is usually related to and often determined by the salinity of irrigation water. Based on the standard classification criteria, twelve boreholes (SA-1, SA-2, SA-3, SA-4, SA-5, SA-6, SA-7, SA-9, SA-10, SA-12, SA-14 and BH-1) have a medium salinity that may require a moderate leaching and crops with moderate salt tolerance can be grown without a major damage. Five boreholes, namely, SA-11, BH-2, SA-13, SA-21 and SA-22 lie within the high salinity range and therefore are not suitable for soils with inadequate drainage and for salt-sensitive crops such as green beans. If they have to be used, crops with good salt tolerance should be selected. Relatively more saline water can be used with drip irrigation than with any other method (Reddi *et al.*, 2002). In the case of drip irrigation with saline water, depending on the discharge and quantity of water applied, a shallow pocket of salts, 30-80 cm radius, accumulate surrounding the transmission zone. As the distance from the plant increases, the salt concentration increases steadily either in lateral or vertical directions. Low salt concentration level is maintained in the root zone as the soil moisture is always kept close to field capacity.

Increased concentration of sodium (Na) in the solution increases sodium hazard. The most reliable index of sodium hazard, the tendency of irrigation water to form exchangeable sodium in the soil, is the sodium adsorption ratio (SAR). It is defined as:

$$SAR = \frac{Na^{\pm}}{\sqrt{\frac{Ca^{\pm\pm} + Mg^{\pm\pm}}{2}}} \text{ meq/1}$$

Based on the standard criteria, irrigation water in 2 boreholes (SA-12 and SA-13), has medium sodium hazard with SAR values of 17.63 and 13.58, respectively (Table 2). These levels may create moderate sodium (Na) problem in fine textured soils, but can safely be used in coarse textured soils. The water in the other 15 boreholes has low SAR values indicating that it can be used for irrigation in almost all soil types with little danger of developing harmful levels of exchangeable sodium.

The bicarbonate (HCO3) levels of the irrigation water in all the boreholes lie within the slight to moderate (91-518 mg/l) range (Table 26). The maximum level of 439 mg/l has been reported for water from borehole SA-13 which can have moderate effects on susceptible crops when irrigated by overhead sprinkling. It does not pose any problem for crops irrigated by drip irrigation.

Boron (B) concentration in irrigation water in semiarid and arid zones is more than in humid zones (Lenka, 1999). The water in all the boreholes is within the acceptable range (< 3.0). It can, thus, safely be used for irrigation for almost all crops. In the presence of organic matter, boron toxicity is not generally a problem and irrigation water containing high concentration of boron can be used. Since the soil in the *Sawa* Farm is very low in organic matter, should it have high level of boron, it could have created boron toxicity.

Table 26 Hydro-chemistry of the water of boreholes of Sawa Farm in 1999

Well No.	pH	EC (mmhos/cm)	HCO3 (mg/l)	Alkalinity as $CaCO_3$ (mg/l)	SAR	Boron (mg/l)
SA-1	7.51	463	220	180	1.72	0.3
SA-2	7.61	762	332	272	3.98	0.1
SA-3	7.64	506	264	216	3.56	0.3
SA-4	7.60	399	244	200	1.10	0.1
SA-5	7.64	501	220	180	1.62	0.2
SA-6	7.60	464	259	212	1.55	0.1
SA-7	7.57	438	229	188	1.13	0.1
SA-8	7.52	461	225	184	1.89	1.2
SA-9	7.58	595	288	236	3.62	0.1
SA-11	8.01	817	366	300	5.07	0.1
SA-12	8.26	674	312	256	13.58	0.1
SA-13	9.24	1,343	439	360	17.63	0.1
SA-14	7.87	635	312	256	2.95	0.6
SA-21	7.47	1,395	493	404	8.66	0.8
SA-22	7.83	911	405	332	6.25	0.2
BH-1	7.55	739	327	268	3.50	1.2
BH-2	7.70	789	342	280	4.21	0.6

SAR Sodium Adsorption RatioSource: Fikremariam (1999)

Benefits and constraints of using drip-irrigation system

Benefits of using drip-irrigation system

Drip irrigation has proved to be a success in terms of water saving and increased yield in a wide range of crops (Reddi *et al.*, 2002). At *Sawa* Farm, with the existing average output of 15.5 l/sec, one borehole can only irrigate 4 hectares of land per day using furrow irrigation, as compared to 15 hectares using drip irrigation system. In a hybrid cotton field, with the same quantity of water given, it was possible to irrigate 2 hectares with drip system against 0.6 hectares using surface irrigation, giving 2 fold increase in yield (Reddi *et al.*, 2002). Similarly, in India, studies on sugar cane have indicated that there was 32-46% saving in water, 25% saving in nitrogen fertilizer, and 23-31% increase in yield of sugar cane, with drip irrigation as compared to furrow irrigation (Chaudary, 1992). The increase in yield ranged from 20% in grapes to as high as 100% in bananas. The percentage saving of water mainly depends on crop and soil type, and environmental conditions. Under the *Sawa* Farm conditions, the main reasons for saving water are; absence of conveyance and runoff losses, reduced evaporation due to lesser wetted area and minimum or no deep percolation. Drip irrigation was able to provide the crops in the farm with sufficient amount of moisture throughout the growing season unlike other methods where soil moisture fluctuates from field capacity to different degrees of dryness between irrigation intervals.

Currently there is a trial going at *Afhimbol*, a comparable farm nearby, to compare drip and furrow irrigation methods on sugar cane yield. The growth of sugar cane was much more enhanced by using drip as compared to furrow irrigation. Preliminary results have also indicated that weed infestation was less with drip irrigation because not only a small area was wetted, but also the enhanced development of the cane canopy has suppressed the weeds at a very early stage resulting in an anticipated increase in yield.

Drip irrigation system is particularly advantageous when the water is saline (Mandal and Jana, 1995). Applying water frequently reduces the moisture tension and the salt concentration in the root zone. Thus, salt concentration in the soil water can be held below damaging levels and the unwanted salts move to the outer edge of the wetted zone. As a result, the osmotic potential of the dissolved salt does not impede water intake by the plant. At *Sawa* Farm, when compared to furrow irrigation, drip irrigation has shown reduced salinity damages to salt-sensitive crops such as green beans due to relatively low salt concentration because of the high and continuous availability of water to the crop.

Drip system is expected to increase the efficiency of fertilizer application in the farm. Several researchers (Besler *et al.*, 1974; Shani, 1974) have proposed various possible reasons for the increased efficiency of fertilization such as: a) decreased quantity of applied fertilizer only to the root zone, b) improved timing of fertilization, because of more frequent application at various crop growth stages, and c) improved distribution of fertilizers with minimum leaching beyond the root zone or runoff.

In short, applying fertilizer through drip system increases fertilizer use efficiency, because of the nutrients applied to that part of the soil in which water, solute and plant roots are located. It also improves the efficiency of fertilizer recovery (Miller *et al.*, 1976). It has also decreased labour and energy costs by making use of the water distribution system for distributing the nutrients, nematicides and herbicides.

As expected, at *Sawa* Farm, drip system has saved a lot of irrigation water as compared to the surface method. This was because direct evaporation from the soil surface and water uptake by weeds has been reduced by not wetting the entire soil surface between the vegetable rows. Water is also saved by irrigating a small portion of the soil volume, entirely avoiding deep percolation losses below the crop root zone, reducing runoff from the field and minimizing seepage. The water use efficiency of drip method is estimated to be over 90% higher than that of any other irrigation methods (Mandal and Jana, 1995). Thus, the system ensured results in saving of 40 to 50% water requirement as compared to furrow irrigation. Gustafson (1975) reported an estimated 30% saving of water by drip irrigation. Singh *et al.*, (1978) also reported that drip irrigation required 50% less water than furrow irrigation to obtain the same yield of potatoes. They further reported that double row planting of cabbage, cauliflower and tomato reduced water use by 50%. By virtue of utilizing the saved water over an additional cropped area, yield of vegetables, orchards and other plantation crops can also increase by up to 30% (Mandal and Jana, 1995).

In Australia, drip system, as compared to sprinkler and furrow irrigation, has reduced cost of production, improved efficiency and boosted profitability of grapes (Cole, 1985).

In drip irrigation system, only the root zone is saturated with water, and thus field levelling is not that important. There is no runoff in the system, and therefore soil erosion is not a problem.

Considering all the above advantages, with a reasonably good farm management, the initial expenditure on drip irrigation can be recovered quickly. The payback period of investment in drip irrigation could be one to four years depending on the type of the crop and the farm management level, vis-à-vis the life of the system, which is around 5-10 years.

Constraints of using drip-irrigation system

At *Sawa* Farm, with the current technical level of farm management, and the existing farm conditions with regard to climate, quality of irrigation water and financial capacity, there are few constraints that have to be dealt with in using drip irrigation system.

The major problem with drip irrigation is clogging of system components by particulate, chemical and biological materials. The system has low flow rates and extremely small passages for water. These passages are easily clogged by organic debris and mineral particles carried in irrigation water, and by chemical precipitates and biological growths that develop within the system. When the dry season approaches, sometime in February, the water level of the boreholes, particularly SA-6 and SA-11, goes down. This usually results in siltation where water with a significant amount of silt is discharged by the pumps resulting in clogging of the entire system. Clogging adversely affects rate of water application and uniformity of water distribution and increases operating and maintenance costs, resulting in low plant population, crop damage and decreased yield. The major contributors to clogging in the drip irrigation system of the *Sawa* Farm include: suspended particles like sand, silt, clay, algae and other aquatic plants and chemical precipitates like phosphate fertilizer, calcium carbonate ($CaCO_3$), and calcium sulfate ($CaSO_4$).

Sand, silt, clay and debris are too large in size to pass through small openings of filter sand emitters (drippers). Precipitates are formed within the drip system and outer surface of the drippers due to soluble salts in irrigation water. Sodium and magnesium sulfates ($MgSO4$) are readily soluble in water while calcium sulfate is less soluble in water. In the presence of soluble calcium, sulfate precipitates as calcium sulfate. Precipitated salts caused by evaporation of water at the end of capillary tubes and deposition of carbonates can also cause clogging (Mandal and Jana, 1995). Precipitates are also formed with some type of fertilizers such as phosphorus. At *Sawa* Farm, phosphorus is applied as di-ammonium phosphate (DAP), which is believed to cause clogging in the drip irrigation system. On sandy soils, which have low exchange capacity, dissolved phosphates may combine with calcium and magnesium to form insoluble phosphates and can form complex precipitates, which clog the system. There is an effort to remove the organic and inorganic suspended particles by water filtration and periodic flushing of filters, main line, laterals and drippers. Filtration removes suspended particles and sand filters are used to remove suspended particles of size range >20-100 mm. Screen filters of 100-200 mesh size remove particles ranging between 100-150 mm. Filtered substances that have accumulated in the pores of the filter are removed by back flushing. Periodic injection of sulfuric acid (98%) into the system at the rate of 5 l/ha has been very useful at the farm.

The initial investment cost of drip system is high. Depending on the country of origin and types of accessories in the system, the cost may range between 2,500 and 3,000 USD per hectare. However, when there is a dire need for expanding agriculture and the use of irrigation as a major factor in boosting production, a search for more specialized way of applying and economizing the scarcely available water is very crucial. Thus, drip irrigation system becomes the best alternative when dealing with crop water consumption and stress. If drip system is used to produce high value and exportable crops, the payback on the initial investment can be recovered quickly provided that all other farm management practices are maintained at an optimum level.

At Sawa Farm, with the current available technique and level of farm management, drip system has posed a problem in the implementation of some cultural practices. It has impeded farm operations, mainly weeding and cultivation using machinery while the farm is being drip-irrigated. During cultivation, implements of a tractor damage the drip lines. Therefore, the rows between the drip lines are either manually cultivated, or if machinery is used, the dripper lines have to be removed before the operation starts. This makes the system not only inefficient, but also labour-intensive, and, thus costly. Initial assembling of drip system, and its routine operations and maintenance requires skilled technicians. There is a shortage of irrigation engineers and technicians, in terms of skill and number, in the farm.

Rodent damage of drip lines is also a problem. In search of water, rodents such as squirrels, mongoose and rats usually chew and damage the dripper lines as a result of which water is wasted, resulting in crop damage and decreased yield because the crop does not get the required amount of water. Rodents have also been a major problem in other farms such as the banana farm at *Mogoraib* where drip system is used.

Recommendations

Based on the information gathered and experiences gained in using drip irrigation system so far at the farm, the following recommendations are made for the North-Western Lowland Agro-ecology in general, and *Sawa* Farm in particular:

- The irrigation water of the boreholes should be analysed annually to monitor the dynamics and quality of the underground water resources of the river basin in terms of its suitability for irrigation.
- Chemical precipitation of calcium and magnesium carbonate are common in arid regions, and thus the irrigation water should be monitored for its Ca and Mg levels.
- Water-soluble fertilizers that do not normally react with water to form ions and relatively free from clogging problems should be applied. These include urea, potassium sulfate ($K2SO_4$), potassium nitrate (KNO_3), potassium chloride (KCl), and muriate of potash (52% K2O). Continuous or repeated application of potash in small quantities through drip irrigation was found very effective and economical.

- Phosphorous (P) has not been recommended for application in drip irrigation systems because of its low solubility in water, its tendency to cause clogging, and its limited movement in soil. Especially in sandy soils with low cation exchange capacity, dissolved phosphates may combine with calcium and magnesium to form insoluble phosphates and can form complex precipitates. Moreover, nitrogen inject in the form of ammo-phos can cause serious clogging in the irrigation system.
- Excessive application of any type of fertilizer at a time should be avoided so as to prevent clogging of the system. If more than one fertilizer, herbicide, or nematicide are used, they must be compatible and should not react adversely with the salts contained.
- Clogging of the drip irrigation system should be prevented using standard procedures.
- Borehole water with high salinity should be closely and periodically monitored. Salt tolerant crops should be selected for water with relatively high salinity levels.
- To promote and develop drip irrigation system in Eritrea, there is a need of advanced training of low level technicians and irrigation engineers within the country and/or overseas.

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Encroaching irrigation to hilly areas of the highlands with small scale investment

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Abstract

Agriculture is the main stay of the people of Eritrea. However, it is mainly rainfed, with low level of input and consequent low output. With proper water harvesting and management practices the amount of rainfall received can be enough for irrigated agriculture. However, it has been customary to irrigate the flat lands only even though it is possible to expand irrigation to the surrounding hills in the catchment area. This paper focuses on practical work of land preparation in the hillside of catchment areas for irrigation from a nearby dam or any water source. Primary data was collected using a questionnaire that included questions on farming characteristics, source of water, financial status and resources to grasp the farmers' attitude, readiness and capacity to irrigate hilly areas. Three villages, *Shimanegus-Laelay, Geremi* and *Dembe-Zawel*, were selected for the survey based on their background in practicing surface irrigation, time limits and access to transport. A sample of 20 households was randomly selected from the villages for the interview. Secondary data was also used to supplement the primary data for this study. The study reveals that the farmers have willingness to expand irrigation to hilly areas because their irrigable land in flat area is too small to motivate them to adapt better irrigation systems. Furthermore, the study identified that the main constraints that hinder farmers to encroach irrigation to hilly areas are lack of capital, land tenure system and shortage of water. In addition, the farmers lack economically and environmentally sound technical skill of land preparation in hilly areas. Hence, this paper gives technical approaches to improve farmers' skills.

Key words: Encroachment, hilly areas, irrigation, smallscale investment

Introduction

There is a great potential to improve the level of agricultural production using different techniques. However, as long as we depend on rainfed agriculture, the possibility of increasing agricultural production remains low whatever investment might be done. Therefore, agricultural activities should focus on irrigated agriculture for commercial purposes whenever possible. Irrigated agriculture can be implemented and be effective not only in flat lands but also in hilly catchment areas with proper land preparation activities. Thus, by decreasing the slope of the catchment and the use of proper soil conservation measures, it is possible to have cultivable land, which is suitable for irrigation (Schwab *et al.*, 1993). This can have advantages in that it minimizes soil erosion and gives additional land for cultivation and efficient consumption of the harvested water. Hence, such practices can play a role in increasing yield, diversifying products, and improving other sectors of agriculture such as livestock production, apiculture etc.

Materials and methods

The main source of data for this paper was the primary data that was collected using a questionnaire that included questions on personal information, farming characteristics, source of water, financial sources and status of the farmers etc. Three villages: *Shimanegus-Laelay, Geremi* and *Dembe-Zawel,* which are located in zoba *Maekel* sub-zoba *Serejaka* were selected based on their background in practicing surface irrigation. Time limit and access to transport were also taken into consideration in selecting these villages. A sample of 20 households was randomly selected from the three villages for interview. Moreover, secondary data was collected to supplement the primary data. For the technical aspects of land preparation in hilly areas (hilly area refers to an area with an average slope percentage of 5-15%), review of the steps listed below as presented by Doraisamy (1998) would be very important.

1. Survey the area and the water source to prepare the topomap of the hilly area.
2. Draw the profile of the area from the topomap: this helps to determine the slope percentage of the site.
3. Establish appropriate lines for the application of maximum land (the size of the cultivable land, space between inter-bunds), which help to determine the area to be cut and fill (Fig. 8).
4. Design the level bund or terracing for that area.
5. Calculate the volume of soil to be cut and fill. To determine the length of the level bund based on the lines established on ground, calculate the volume of soil and other materials used.
6. Propose appropriate agronomic practices, to support the physical measure of soil conservation.
7. Prepare a land use plan of the site to show the classification of the different activities.
8. Select the appropriate irrigation system (sprinkler or drip) suitable to the area.
9. Prepare the bill of quantity for the implementation of the conservation measure and the irrigation system.

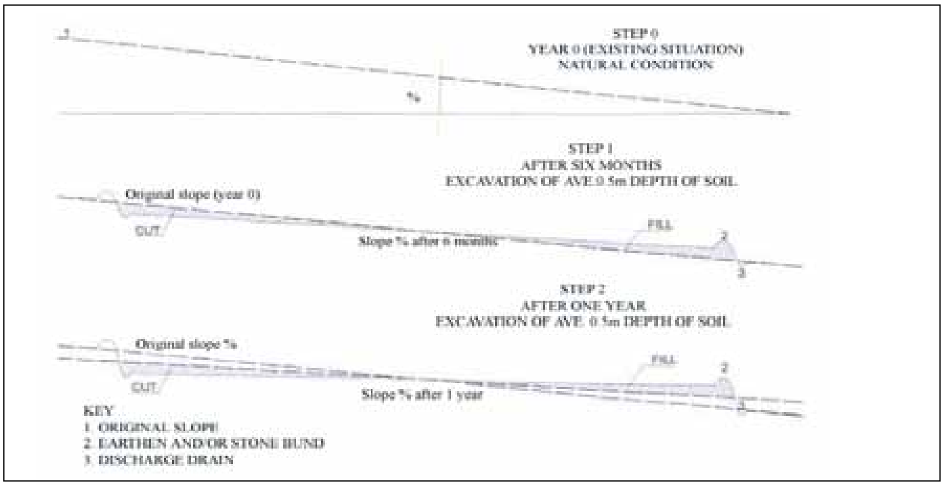

Figure 8 Typical drawing for the cut and fill method for the construction of bench terrace

To prepare hilly land for irrigation, bench terrace is the most common conservation structure. Bench terrace can be constructed by excavation or developed from level bund. The implementation of such measures may have negative impacts on the soil structure by compaction and disturbance. This, however, can be reclaimed with deep tillage, growing vegetation and vegetation residues where grasses are most effective. Moreover, improving the organic matter content of the soil with the application of manure and landfill compost is another means of improving the structure of the soil.

The following materials are required to accomplish the above-listed steps: surveying instruments for the preparation of the topomap, ordinary farming equipment, oxen or tractor for the preparation of the land, and pump, irrigation pipes and its accessories for the irrigation system.

Results and discussion

According to the data obtained from the interview, the average size of agricultural land in the study areas is 0.75 ha where half of it is in the hilly area and the remaining half in the flat area. The farmers irrigate only small part of the flat land by surface irrigation for vegetables, because the flat areas are far away from the water source. However, they also have land in the hilly area, which is near the water source and needs better land preparation to irrigate.

All of the interviewees responded that irrigation is possible in the hilly area by preparing land with appropriate conservation measures such as level bund or terrace through ordinary farming equipment and oxen. However, the respondents mentioned some common constraints, which include lack of land, capital and scientific approach to prepare land in hilly areas, shortage of water and land tenure system not conducive for investment. Almost all of the respondents indicated that getting loan from the bank could solve the problem of lack of capital. But they have reservation on the high interest rates. For this reason, they prefer to get loan from relatives with small or no interest. With regards to the loan from *Adawi Bank* (village bank) for small-scale investment, all respondents expressed that they prefer to get loan from such source individually so that they can get access to pumps, pipes and irrigation equipment. Small-scale investment refers to an investment, which can be done by farmers individually or in groups through investment or loans from government or NGOs. As to the loan for tractors, they prefer to get it in groups of 5-10. The farmers are confident that they can repay the loan they get from any source, provided that enough land and capital is available.

Lack of scientific approach for land preparation in hilly areas can be solved by strengthening (improving) the skill of farmers in preparing land in hilly areas by training and extension on scientific approach of land preparation. The following is the technical approach that can assist to achieve the objective:

Review of technical approach to land preparation

Generally, in selecting conservation measures, consideration should be given to the level or the scale of the measures that are taken. Conservation measure can be applied at farm level, slope level or catchment area level. This implies that conservation measures are level specific. However, this paper focused at farm or slope level. It is logical that before starting irrigation there is a need to prepare the land to be irrigated through contour farming or constructing level bunds, terracing, etc. But cost benefit analysis should be done to identify the kind of land preparation and the type of irrigation to apply on the hilly lands so that it is possible to come up with economically feasible and environmentally sound solutions.

Level bund is a slow process that takes longer time to prepare than excavated terraces. On the other hand, excavation of terrace is more expensive than constructing level bund in hilly areas. The time required for a level bund to develop itself to bench terrace, depends on the rate of sedimentation, which in turn depends on soil depth, organic matter content and other physico-chemical aspects of the soil (Hurni, 1995). In addition to the longer time taken for level bunds to develop into bench terraces, they are not as strong as bench terraces to resist unexpected high peak runoff. Moreover, until they develop into bench terrace, level bunds need very close supervision and incursion of some costs for their maintenance, such as raising the embankment annually.

Level bunds or bench terraces retain all runoff between two bunds (Huypers *et al.*, 1987). Soil that is eroded between two bunds is deposited in the basin behind the lower bund, whenever the basin is full of sediment. The bund must then be raised so that it results in a bench terrace in the course of years (Hurni, 1995). Level bunds or bench terraces should be convenient to practice agricultural activities and implement irrigation systems. The technical aspects of selecting the appropriate irrigation system and the type of crop to cultivate depend on the spacing between two bunds. The spacing between the bunds should be convenient to agricultural operations. The inter-bund spacing can mainly be determined in different ways based on the average slope of the land, soil characteristics (such as soil depth) and rainfall. The specification for inter-bund spacing is given in Table 27 as presented by Doraisamy (1998).

Table 27 Suitable inter-bund spacing for low rainfall areas (<750mm) as determined by the slope of the land

Average Slope of land (%)	Vertical drop to be adapted (cm)	Average inter-bund distance (m)
0.0 - 1.0	105	105
1.0 - 1.5	120	96
1.5 - 2.0	135	75
2.0 - 3.0	150	60
3.0 - 4.0	165	51
4.0 - 5.0	180	39
5.0 - 6.0	195	36
6.0 - 7.0	210	33
7.0 - 8.0	240	33
8.0 - 10.0	270	30
10.0 - 12.0	360	30

After the preparation of the hilly area, there should be proper water harvesting mechanism and management of irrigated agriculture (Michael, 2002). This can be done through efficient integration of the crop-water relationship and selecting appropriate irrigation system.

Conclusion

In conclusion, contour farming is not advisable for irrigation because it enhances soil erosion and loss of water. Nevertheless, as it is mentioned above, both the level (contour) bund and bench terrace have their own drawbacks. Therefore, instead of direct construction of bench terraces, it is more economical to construct level bunds, which ultimately develop into bench terraces in the course of time. It is practical and efficient to minimize the time span to develop the bench terrace from level bund through mechanical practice that is, by cut and fill method. The terraced land will be suitable for agricultural activities and irrigation systems and as a result there will be efficient utilization of water.

This is a review paper, and it may shed light to conduct research on introducing irrigation systems in the hilly areas of the highlands of Eritrea with small-scale investment or integrated long-term investment. Such studies can provide information that could be used by farmers to farm additional land and generate more income.

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Agricultural water use in Anseba Basin, Eritrea: A preliminary assessment

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Abstract

Eritrea is one of the developing countries located in the horn of Africa along the Sahel region. It has six administrative zones and covers an area of about 124,000 km^2 with a total population of about 3.5 million. It has arid and semi-arid climatic conditions. The Water Resources Department carried out water point inventory survey in 1995-1997 and 2000-2002. However, these surveys did not cover the agricultural wells and hence lack data on water quality and other management aspects. The present study was mainly conducted to identify the type of wells used for irrigation, to study the types of pumps, their efficiencies and the range of horsepower used. The study also aimed at getting general information on the agricultural areas, irrigation systems used and application practices. The present study based on a detailed questionnaire covered the above aspects in *Anseba* region. In this paper, the methodology of collection of data, the water use parameters in agriculture and the preliminary assessment of the study are presented.

Key words: agricultural water use, irrigation, water lifting devices, water resources.

Introduction

Water sector is a lifeline for economic and social development for any country. Water development programmes and projects are usually formulated and implemented to cope up with the demand of various sectors of the economy. Therefore, the presence of ample water resources is an asset, which boosts the development processes, and the economy of the country while its absence is a detrimental factor in the growth process.

Eritrea's economy is basically dependent on agriculture and about 80% of the population depends on it. Rainfed agriculture and animal husbandry are the main activities. Low and erratic rainfall adversely affect rural population. Drying up of wells and lack of water cause migration of people along with the cattle. Agriculture and drinking water supplies are the sectors most affected by the recurring droughts.

As it is located in the Sahelian region, Eritrea has shortage of surface and ground water resources. The major part of Eritrea is characterized by hard rock and poor aquifer and the landform of the country is mainly mountainous that encourages land degradation due to erosion. Recharge of groundwater is less due to undulating topography and quick runoff. Most of the irrigation agriculture depends on ground water resources. Spate and furrow irrigation are the common irrigation systems that lose a lot of water on the channel.

Irrigation in Eritrea

Of the total area of Eritrea, 26% is suitable for agriculture. According to reports of the Ministry of Agriculture, little over 500,000 ha is cultivated and 95% of this area is under rainfed agriculture. The area under irrigation is estimated at 22,000 ha only, which is very meagre. In Eritrea, there are several types of irrigation namely: furrow, spate, drip and sprinkler. As the population pressure is increasing in Eritrea, more food needs to be produced and this can be done through intensification of agriculture and extending the cultivable area. Since rainfed agriculture is dependent on the vagaries of the monsoon, efforts have to be made to improve the irrigation systems and to increase their efficiencies.

The WRD is interested in conserving and managing water resources giving priority to domestic water use and agriculture. In light of this, the present study envisages addressing the problems of the nature of aquifers in agricultural and domestic wells by studying the preliminary quality of water (EC and pH), the type and status of pumps, the qualitative type of soils, the crops and their water requirements. Special presentation of the agricultural wells associated with GIS software is being attempted.

Materials and methods

There is no recorded data or information concerning agricultural water resources in the country. The Ministry of Agriculture has collected some information on agricultural wells for its own use. Most of the agricultural wells are located in *Alla* Plains, along the *Anseba-Barka* Rivers, *Mereb-Gash* River and *Tsilma* Plains.

The Water Resource Department (WRD) in collaboration with the MoA has surveyed about 1310 ha of farmland and more than 2000 wells with all their parameters and pump situations. The survey was primarily set to study in detail basin by basin. To achieve this, the two line ministries agreed to commence with *Anseba* and *Mereb-Gash* basins, which are the two major basins where intensive agricultural activities take place. However, due to the rainy season in the highlands, the survey was forced to shift its priority to the Red Sea basin.

The survey has used the following methods to collect data:

- Selected farmers were interviewed using a questionnaire with regard to location of water sources, and parameters of wells, pumps, geology, crop and soil, farmland and irrigation systems.
- On site preliminarily water analysis (using pH-meter and EC-meter) was conducted.
- Direct observation and measurement of well parameters.
- Review of relevant literature on domestic and agricultural wells and some preliminary study documents on Eritrean wells and pumps
- Record the primary and secondary data concerning water points, management systems, pump condition and type, type of soils and crops, etc.

– Wherever possible, logging analysis was implemented, and then database was created using MS-Access 2000. The data was analysed with appropriate tools and where applicable, qualitative and spatial analysis of the data was done using GIS.

Results and discussion

Primary studies on agricultural activities around the urban areas showed that many wells are becoming non-functional and yielding low discharges due to excessive water use from the ground water and utilization of improper irrigation systems.

Irrigation well parameters

Boreholes for irrigation are mainly in Keren with depth range of 45 to 70 m and yielding between 0.77 and 4.13 l/s. The the shallow hand-dug wells with depth ranging from 3 to 12 m constructed in the alluvial plains along the *Anseba* River constitute the major source of water for irrigation. In some places, however, the wells penetrate the weakened and jointed granitoid rocks. The details of the depth range of hand-dug wells in different sub-zobas are presented in Table 28.

Table 28 Depth range of hand-dug wells in different zobas

Sub-zoba	Depth range				
	< 1m	1 - 3m	3 - 6m	6 - 9m	9 - 12m
Keren	0	2	26	35	39
Hamelmalo	0	38	122	49	2
Elabered	0	21	114	74	17
Adi Tekelezan	0	3	4	0	0
Berak	0	0	1	0	0
Mekerka	0	4	31	1	0
Total	**0**	**68**	**298**	**159**	**58**

The minimum static water level of 0.5m below ground was found in sub-zobas *Elabered* and *Hamelmalo*, while a maximum level of 18m below ground was observed in sub-zoba *Keren*.

The actual yield of the hand-dug wells, ranged between 0.733 and 19.35 l/s. The rated pumping capacity as per the pump installed ranges from 2 to 35 l/s.

Well spacing

The distance between the irrigation wells was so close in a number of cases, which has caused interference while pumping. Therefore, there is a need to maintain a minimum distance of 200 m between two irrigation wells. This temporary spacing could be revised based on actual pumping tests, which have to be conducted as part of the regular surveys of the Water Resources Department.

Anseba irrigation

The total area under irrigation so far surveyed is in zoba *Anseba* (*Keren, Hamelmalo, Elabered* sub-zobas) and in some part of sub-zoba *Berike* is 1141 hectares (plus 300 ha in *Elabered*) and covers the bulk of the irrigated area.

Basin and furrow irrigation is the common practice in zoba *Anseba* and drip irrigation is still not very popular except in *Keren* and *Elabered*. In very few farms, drip and sprinkler irrigation are practiced. The crops under irrigation are mainly horticultural crops covering varieties of fruits and vegetables. Farmers were applying 30-40% more water as compared to drip irrigation for the horticulture crops. For fully matured citrus trees, the computed value for water requirement is 44 liters per day per tree (l/d/t) during December while currently they are applying 74 l/d/t. *Elabered* farm is using drip irrigation for citrus plants and providing 88 liters per plant (spaced at 6 x 6m) on alternate days.

Water quality

The water quality in zoba *Anseba* is suitable for irrigation purposes. The salinity ranges from 420 S/cm, at sub-zoba *Adi Tekelezan*, to 1511 S/cm at sub-zoba *Hagaz*. However, there are very few sources, which have extreme cases of salinity. The mean value of chloride and sulphate concentrations was 52 mg/l and 86.5 mg/l respectively. The sodium (Na) concentration in *Adi Tekelezan* was 18.5 mg/l while the value in *Hagaz* was 162 mg/l (Fikremariam, 1998).

Water lifting devices

Out of the total of 757 wells surveyed: 2 wells in sub-zoba *Berike*, use manual water lifting devices for small-scale irrigation, 64 wells use shadoof, 647 use diesel engines, 40 wells benzene engines, and in 4 wells use electrical motors. The majority of the pumps in use have a capacity, which ranges between 5 to 10 horsepower. Lombardini, Lister, Mercury, Honda, Anil, Slanzy, Yanmar are some of the popular engines /motors installed on the wells. As there are numerous types of pumps, there is a need for standardization of pumping systems.

The studies revealed that most of the pumps set are operating at a low efficiency. Therefore, there is a need for the concept of complete pumping system for which the five components viz., the prime mover which could be diesel engine or electric motor; the pump; foot valve; suction pipe and delivery pipe have to be considered (Nabard, 1984). The last three constitute what could be called piping subsystem of the entire pumping system. The installations in most parts of the country are not under optimum level. Unless the individual components are selected as per the recommended standards, the overall efficiency will be very low because of the mismatch between various elements of the pumping system. The question is not which motor or pump meets specifications but what is the most efficient pumping system when measured by the ratio of net output to the energy supplied through electricity or diesel given the discharge required and the head over which water is to be raised. Therefore, farmers should be advised on the use of the most efficient pumping system in their farms.

Conclusion

The existing irrigation system in the study area was found to be highly water consuming while drip irrigation may save 30–40% of irrigation water. In addition, the existing spacing creates interference among the wells.

Due to lack of awareness farmers were observed to overuse their water resources. Wells located along *Anseba* basin have shown negative influence on the domestic wells of Keren quantitatively and qualitatively. Thus, there is a need for introducing the concept of complete pumping system (CPS).

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Annex 1 Workshop programme

“Irrigation Development in Eritrea: Potentials and Constraints”

August 14-15, 2003, NCEW hall, Asmara Eritrea

Workshop Rapporteurs:

Abraham Mehari, Simon Abay, and Sirak Mehari

Day1: August 14, 2003

08:00-09:00	Registration of participants
	Chair: Dr. Bissrat Ghebru
09:00-09:10	Remarks by the Organising committee
09:10-09:20	Opening speech, *Dr. Tadesse Mehari, Chairman of AEAS.*
09:20-09:30	Opening of workshop, *H. E. Mr. Arefaine Berhe, Minister, Ministry of Agriculture*
09:30-10:00	Review of Irrigation Development in Eritrea *Semere Amlesom, DARHRD, Ministry of Agriculture.*
10:00-10:30	COFFEE BREAK
	Chair: Dr. Woldeselassie Ogbazghi
10:30-10:50	Rainfall Input to irrigation Development in Eritrea: potentials and constraints *Zeneb Habte, WFP.*
10:50-11:10	Application of Seasonal Climate Forecasts to Water Resources Management *Michael Negash, Ministry of Land water and Environment (MLWE).*
11:10-11:30	Performance Measurement in Canal-fed Surface Irrigation Systems *Abraham Mehari, CA, University of Asmara (UoA).*
11:30-11:50	Gender and Irrigation Development, *Solome Haile, MoA*
11:50-12.30	Discussion
12:30-02:00	LUNCH
	Chair: Ms. Zeneb Habte
02:00-02.20	Introducing smallscale irrigation technology in Eritrea: lessons and experiences. *Bissrat Ghebru and Abraham Mehari, College of Agriculture, UoA.*
02:20-02:40	Socio-economic and institutional aspects influencing the acceptance of AMIT by farmers, *Brigitta Stillhardt (CDE), B. Ghebru and A. Mehari (CA, UoA).*
02:40-03:00	Potentials and Constraints of drip irrigation systems in the North Western lowland Ecology: the case of *Sawa* Farm. *Bereke-Tsehai Tukue (Sawa Agro Industry) and Mebrat Gebreab*
03:00-03:30	Discussion
03:30-04:00	COFFEE BREAK
	Chair: Mr. Michael Negash
04:00-04:20	Encroaching Irrigation to hilly areas of the Highlands with small-scale investment. *Michael Andom, College of Agriculture, UoA.*
04:20-04:40	Agricultural water use in Anseba basin, Eritrea: a preliminary assessment. *Vishwanathan, K. S, Yohannes Michael and Yonas Hadgu, MLWE.*
04:40-05:00	Agronomic considerations of low cost micro-irrigation systems. *Samuel Asghedom, College of Agriculture, UoA.*
05:00-06:00	Discussion

Day 2: August 15, 2003

	Chair: Mr. Semere Amlesom
08:00-08:20	Farming System Survey under Agro-pastoral Spate Irrigation in the Coastal Plain Zone (CPZ) of Eritrea: a case of Sheeb, Wekiro and Wodilo. *Adugna H., Woldeamlak A., Woldeselassie O., Dagnew G., Bissrat G. and Mohammed Kheir O., College of Agriculture, UoA.*
08.20-08:40	Downstream Irrigation development on horticultural crops on selected thirty dams: socio-economic baseline survey, *Asghedom Tewelde and Fitsum Gebreyohannes, Ministry of Agriculture*.
08:40-09:00	Shifting from Conventional Irrigation to drip Irrigation: A socio-economic study of orange growers in Ala *Tsehaye Woldemichael and Sirak Mehari, College of Agriculture, UoA.*
09:00-09:20	Runoff irrigation systems in western lowlands of Eritrea: Potentials and constraints *Abraham Mehari and Mehretab Tesfai, College of Agriculture, UoA.*
09:30-10:00	COFFEE BREAK
	Chair: Mr. Amanuel Negasi
10:00-10.20	The challenge of spate Irrigation development in Eritrea: the case of the eastern lowlands *Berhane Haile, Ministry of Agriculture.*
10:20-11:00	Options to speed up adaptation and dissemination of AMIT kits in Eritrea. Ermias Beyene and Viveca Nidecker
11:00-12:00	Discussions
	Chair: Brigitta Stillhardt and Dr. Mehretab Tesfai
12:00-12:15	Formation of working groups and briefing
12:15-12:45	Working group discussions
12:45-02:00	LUNCH
02:00-03:30	Group discussions continue
03:30-04:30	Working group presentations and discussion
04:30-05:00	COFFEE BREAK
05:00-05:15	Wrap up, *Organising committee*
05:15-05:30	Closing remarks, *Chairman of AEAS*

Annex 2 List of participants

No.	Name	Institution
1.	Abdela Mohammed Ali (Dr)	MoA
2.	Ablelom Asfaha	Zoba Debub
3.	Abraham Ghebre	ERIPA
4.	Abraham Mehari	UOA
5.	Abraham Tzegay	Hagaz Agro-tech School
6.	Adugna Haile (Dr)	UOA
7.	Afewerki Solomon	Norwegian Church Aid
8.	Alga Tewolde	Elabered Farm
9.	Amanuel Negasi	Land Resource, MLWE
10.	Amanuel Negasi	NCEW
11.	Andemariam Tsegay	Student, UOA
12.	Andom Kiflemariam	DARHRD, MoA
13.	Asghedom Tewolde	CHIHDP, MoA
14.	Asmerom Kidane	DARHRD, MoA
15.	Babiker Tahar	Zoba Anseba
16.	Bahta Tedros	Zoba Debub
17.	Belainesh Sium	NUEW
18.	Belay Habtegaber	Development, MoA
19.	Bereket Mebrahtu	UOA
20.	Bereke-Tsehai Tukue (Dr)	Sawa Agro-Industry
21.	Berhan Khiar	DARHRD, Halhale
22.	Berhane Ghirmai (Dr)	Chemical Society
23.	Berhane Haile	ELWDP, MoA
24.	Biniam Abraham	UOA
25.	Biniam Tsehaye	UOA
26.	Biniam Zerayakob	UOA
27.	Bissrat Ghebru (Dr)	UOA
28.	Dagnew Ghebreslassie (Dr)	UOA
29.	Dawit Mebrahtu	DARHRD, Sheeb
30.	Ephrem Abebe	Sawa Agro-Industry
31.	Ermias Asmelash	MoA
32.	Ermias Beyene	NGO
33.	Ermias Bokretsion	MLWE
34.	Esayas Negash	Hamelmalo Agro-Tech School
35.	Estifanos Bein	Regulatory, MoA
36.	Eyob Tekleab	NCEW
37.	Fikreyesus Ghilai	NRS, MoA
38.	Filmon Yohannes	Zoba Debub
39.	Fitsum Tewoldebrhan	Zoba Debub
40.	Fitsumbrhan G/Yohannes	CHIHDP, MoA
41.	Francis Hillman	PHAESUN Enterprise
42.	Gebreamlak Aregay	Ministry of Information
43.	Gebremeskel Habteyonas	UOA
44.	Gebremeskel Tewolde	Zoba Anseba
45.	Ghebremichael Habteab	MoA
46.	Ghezae Kibreab	Regulatory, MoA
47.	Ghirmai Abraham (Dr)	Macro-policy
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49.	Goitom Zewongel	Afdeyu, MoA

No.	Name	Institution
50.	Haddish Mogos	NLDP, Livestock Production
51.	Hagos Yohannes	MoA
52.	Haile Ghidei	Promotion, MoA
53.	Haileab Ghebrezgabher	MoA
54.	Hayelom Debesay	NRS, MoA
55.	Helen Habte	MoA
56.	Huruy Abraha	Seawater Farm
57.	Ibrahim Mohammed Osman	Promotion, MoA
58.	Ibrahim Saleh	Zoba Anseba
59.	Ilan Ronen	Private
60.	Isayas Haile	M Sc Student, SA
61.	Kaleab Negash	UOA
62.	Kebra Gebremeskel	Zoba Anseba
63.	Kesete Ghebregergis	NRS, MoA
64.	Kidanemariam Teclemariam	Support, MoA
65.	Kifle Negash	DARHRD, MoA
66.	Legese Kefle	Afhimbol Agro-Industry
67.	Letegergish Habtemichael	NRS, MoA
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70.	Mebrat Gebreab	WRD, MLWE
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72.	Melake Ghebrekristos	NRS, MoA
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74.	Mengisteab Ghebreselassie	DARHRD, MoA
75.	Michael Haile	NRS, MoA
76.	Michael Hailemariam	MOF
77.	Michael Negash	WRD, MLWE
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79.	Micheal Araya	AliGhider Agro-industry
80.	Micheal Tekie	MoA
81.	Milak Araya	Zoba Debub
82.	Mogos Woldeyohannes	WRD, MLWE
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84.	Nigisty Seyoum (Dr)	ARD, MoA
85.	Nitsihty Abay	DARHRD, MoA
86.	Ogbazghi Kifle (Dr)	Zoba Debub
87.	Paul Roden	DCG
88.	Redaegzhi Ghebremedhin	MoA
89.	Refone Paulos	Zoba Maekel
90.	Rezene Habte	UOA
91.	Robert Burtscher	CDE/UOA
92.	Samson Tesfalidet	DARHRD, MoA
93.	Samuel Asgedom	UOA
94.	Samuel Musazghi	MoA
95.	Semere Amlesom	DARHRD, MoA
96.	Semere Zaid	UOA
97.	Senait Haile	Promotion, MoA
98.	Simon Abay	UOA
99.	Sirak Mehari	UOA
100.	Solome Haile	DARHRD, MoA
101.	Solomon Fisseha	LWF
102.	Solomon Tareke	MoA
103.	Tadesse Mehari (Dr)	UOA
104.	Tecleab Mesghena	Regulatory, MoA

No.	Name	Institution
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107.	Tedros Kibrom	UOA
108.	Tedros Mekonnen	Hagaz Agro-tech School
109.	Teklezghi Tekie	Gash Barka, MoA
110.	Teklu Seyuom	Zoba Debub
111.	Tesfalem Tekeste	Vision Eritrea
112.	Tesfalidet Mehari	Support, MoA
113.	Tesfom Beraki	Zoba Debub
114.	Tewoldemedhin Debru	UOA
115.	Thegaz Teclemariam	Sheeb Wadi Project
116.	Tim Vaessen	UNHCR
117.	Tsehaye Woldemichael	UOA
118.	Weakliam, John	Refugee Trust
119.	Woldeamlak Araia (Dr)	UOA
120.	Woldeslasei Ogbazghi (Dr)	UOA
121.	Woldetensae Tewolde (Dr)	UOA
122.	Yebiyo Ghebregziabiher	DARHRD, Sheeb
123.	Yemane Andemariam	Promotion, MoA
124.	Yohannes Beyene	Promotion, MoA
125.	Yohannes Micheal	WRD, MLWE
126.	Yonas Hadgu	WRD, MLWE
127.	Yonas Haile	UOA
128.	Yosief Asgedom	Zoba Anseba
129.	Yosief Nega	CARE International
130.	Zekarias Andemariam	NUEYS
131.	Zemenfes Tsighe (Dr)	UOA
132.	Zeneb Habte	WFP
133.	Zerai Haile	Afhimbol Agro-Industry
134.	Zufan Mekonnen	ARD, MoA

Annex 3 Tigrigna translation of abstracts

ጽሟቕ ናይቶም ኣብ'ቲ

“ምዕባለ መስኖኣዊ ሕርሻ ኣብ ኤርትራ፥ ተኽሎታትን ማሕንቖታትን”

ብዝብል ቴማ ካብ 14-15 ነሓሰ 2003 ዝተኻየደ ዓውደ መጽናዕቲ ዝቐረቡ ጽሑፋት።

ኣገባብ ምዕቃን ደረጃ ብቕዓት ብካናለ ዝስተዩ ስርዓተ መስኖታት ኣብ ኤርትራ

ኣብርሃም መሓሪ

ኮለጅ ሕርሻ ፡ ዩኒቨርሲቲ ኣስመራ፡ ቁ .ሳ. ፖ. 1220 ኣስመራ፡ ኤርትራ

ኤርትራ ዘይምዕሩይ ዝርጋሔ ዝናብ እምበር ፡ ዋሕዲ ዝናብ ዘለዋ ሃገር ኣይኮነትን። ሓደ ካብቶም ከም ቀንዲ ሽግራት ናይዛ ሃገር ክጥቀሱ ዝኽእሉ፡ ነቲ ዝርካቡ ማይ ብግቡእ ንምዕቃቡን ናብቲ ሓንቲ ተኽሊ እትደልዮ ቦታ ብውጽኢታዊ መንገዲ ምብጽሑን ዘኽእል ቴክኖሎጂካዊ ብቕዓት ዘይምህላዉ እዩ። ኣብዚ ጊዜ'ዚ፡ ኤርትራ ካብቲ ዓመታዊ እትረኽቦ ማይ፡ 4% ጥራሕ እያ እትጥቀም። ውሕስነት መግቢ ናይቲ ኣብ 2025፡ 8.5 ሚሊዮን ክበጽሕ ትጽቢት ዝግበረሉ ሕዝቢ ኤርትራ ክረጋገጽ እንተደኣ ኮይኑ፡ እዚ ዝተጠቕሰ ኣሃዝ ናብ 25% ክብ ክብል ኣለዎ። ሓደ ካብቶም ነዚ ክውን ኣብ ምግባር ክሕግዙ ዝኽእሉ ስራሓት፡ ምዕቡላትን ዉሑድ ማይ ዘጥኽኡ መእለዪ ዉሑጃት፡ ዝካየዱ ዝነበሩ ናይ መስኖ ሕርሻታት ኣማዕቢሉን ኣብ ምምዕባል ይርከብን። እዚ ይኹን እምበር፡ ክሳብ ሕጂ ንደረጃ ብቕዓት ናይቶም ምዕቡል መእለዪ ውሕጃት ዝወገኑ ስርዓተ-መስኖታት ንምግምጋም ዝተገብረ መጽናዕቲ የለን። እዚ ዓይነት መጽናዕቲ ሓጋዝን ወጺኢታውን ክኸውን እንድሕር ኮይኑ፡ ኣብ ሃገርና ዝርከቡ ናይ መስኖኣዊ ሕርሻ ክኢላታት፡ ሓንጸጽቲ ሕርሻዊ ፖሊሲታት ከምኡዉን ኣብቲ መዳይ ዝተዋፈሩ ተመራመርቲ ዝሰማምዑሎም መምዘኒታት ምስ ዝህልዉ ጥራሕ'ዩ። እዞም መምዘኒታት እዚኣቶም ንናይ መስኖ ክኢላታት ንዕላማታቶምን ቀዳምነታቶምን ብጉቡእ ንምስራዕን ዕብየት ናይቶም ኣብ ትሕቲኦም ዝተዋፈሩ ሰራሕተኛታት በቶም ዝሰርዕዎም መምዘኒታት ንምውሳንን ሓገዝቲ እዮም። ከምኡውን ነቶም ኣብ ዝተፈላለየ ቦታታት ኤርትራ ብዛዕባ ተመሳሰልቲ ስርዓተ መስኖታት ዝመራመሩ፡ ሓንቲ ናይ መስኖ ሕርሻ ካብታ ካልእ ትሓይሽ ወይ ትሓምቕ ኢሎም ንምውሳን ናይ ሓባር መረዳእታ ንኽህልዎም ይሕግዙ። ብተወሳኺ ሓንጸጽቲ ፖሊሲ ሕርሻ መብዛሕትኦም ብዝሰማምዕሉ መንገዲ ገምጋም ናይ ዝተፈላለዩ ናይ ፖሊሲ ኣማራጺታት ክገብሩ የኽእልዎም። ዕላማ ናይዛ ጽሕፍቲ እዚኣ እምበእርከስ ነዞም ዝስዕቡ ሕቶታት ንምምምላስ እዩ። ሓንቲ ናይ መስኖ ሕርሻ ጽቡቕ ደረጃ ብቕዓት ኣለዋ ክንብል ከለና እንታይ ማለትና እዩ፡ እቶም ንደረጃ ብቕዓት ናይ መስኖ ሕርሻ ንምጽናዕ ዘገልግሉ ቀንዲ መምዘኒታት ኸመይ ክንዕቅኖም ንኽእል።

ስርዓተ መስኖ-ጀሪፍ ኣብ ምዕራባዊ መታሕት ኤርትራ፡ ተኽእሎታትን መሓንቖታትን

ኣብርሃም መሓሪን ምሕረትኣብ ተስፋይን

ኮለጅ ሕርሻ፡ ዩኒቨርሲቲ ኣስመራ፡ ቁ. ሳ. ፖ. 1220 ኣስመራ፡ ኤርትራ
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እዚ ወረቐት'ዚ መትከላትን ትግባረ ስርዓተ-መስኖ ጀሪፍ (ኣብ ምዕራባዊ መታሕት ኤርትራ) ዝገልጽ ኮይኑ ብዛዕባ ተኽእሎታት፡ መሓንቖታት፡ ክተኣታቶ ዘሎዎ ምምሕያሽን የጠቓልል። መስኖ-ጀሪፍ ሓደ ካብ ኣገባባት መስኖ ኮይኑ ኣብ

በረኽቲ ቦታታት ዘኒቡ ካብ ዝተረኽበ ናይ ዝባን ባይታ ማይ ብምእላይ ዝካየድ መስኖ እዩ፣ ኣብ መታሕት ከኣ ይዝውተር።ኣብ ምሩጻት ፕሮጀክትታት ናይ መስኖ-ጀሪፍ ማለት ብልቱብያይ፣ ኣረደ፣ ፋልኮን መጎራይብን ዳህሳስ ብምግባር ከም ኣርእስቲ ናይ መጽናዕቲ ኮይኖይ ተወሲዶም። ኣብዚ እዋን'ዚ ኣብ ምዕራባዊ መታሕት ኤርትራ ኣስታት 1,750 ሄክታር መሬት ብመስኖ-ጀሪፍ ለሚዑ ይርከብ፣ 50,000 ሄክታር ዝግምገም ስፍሓት መሬት ንምልማዕ ተኽእሎ ከምዘሎ ከኣ ይፍለጥ። ኣብ ዝተጠቕሰ ናይ መስኖ ፕሮጀክትታት ሕጽረት ሓበሬታ ብዛዕባ ዓቐን ዝናብ፣ ተጸይሩ ዝኸይድ ጽዕነት ድበት፣ ስልጠት መስኖ፣ ባህርያት ሓመድ ከምኡ'ውን ተደላዪ መጠን ማይ ዘራእቲ ስልዘሎ ቀንዲ ማሕንቐ ምድላው ዲዛይን/ንድፊ መእለዪ ወሓዚ/ ዓግምን ቅርጽታት መትረባትን ኮይኑ ኣሎ። ስለዚ ትሕተ ቅርጺ ስርዓተ መስኖ ብቕዓት ዝጎደሎም ስለዝኾኑ ከም ቀንዲ መሓንቖ ምኺኖም ንምዕዛብ ተኻኢሉ። ብተወሳኺ ፍጥነት ወሓዚ ዘዝሕሉን ጽዋር ሓመድ ንምሓዝ ዘኽእሉን ግድባት ይኹን ዛላታት ኣብ ውሽጢ ግራት ዝተሰርሑ የለዉን። ካብዚ ዝተወስደ ትምህርቲ ይኹን ኣቲ መጽናዕቲ ዘብርሆ ባህርያት ዝናብ ማይ-ኮፆ፣ ዋሕዚ ማይ፣ ጻዕቂ ጽበት/ጽዋር ሓመድ፣ ስልጠት መስኖ፣ ሓመድን ማሕበረ-ቁጠባዊ ኩነታትን፣ ምቹእ ቦታ ናይ መስኖ-ጀሪፍ ንምምራጽን ብቑዕ ንድፊ ትሕተ ቅርጺ መስኖ ንምድላውን መጽናዕቲ ክካየድ ከምዘድሊ እዩ። ኣብ ርእሲ እዚ ክእለት ናይቶም ኣብ ምዕራባዊ መታሕት ኤርትራ ዝርከቡ ሓረስቶት ነቲ ኣብ ምብራቓዊ መታሕት ዘሎ ተመሳሳሊ ስርዓተ መስኖ ክርእይዎን ካብኡ ክመሃሩን ከም ዘለዎም ምግባር እዩ።

ብድሆታት ልምዓት መስኖ-ጀሪፍ ምብራቓዊ መታሕት ኤርትራ

ብርሃነ ሃይለ
ሚኒስትሪ ሕርሻ ኣስመራ፣ ኤርትራ E-mail:berha@eol.com.er

እዚ ወረቐት'ዚ ሕጽር ብዝበለ ኣገባብ ብዛዕባ ምዕባለን ምሕደራን መስኖ-ጀሪፍ ብፍላይ ድማ ኣብቲ ያታውን ዘመናውን መስኖ ጀሪፍ ኣብ ምብራቓዊ መታሕት ኤርትራ ኣተኩሩ ይግለጽ። እቲ መጽናዕቲ ከምእኒ ባዳ፣ ገድገድ፣ ኣፍታዙላ፣ ላብካ፣ ሽዕብ ዝኣመሰሉ ዓበይቲ መስኖ-ጀሪፍ ዝካየደሎም ቦታታት ካብ ዝተረኽበ ሓበሬታ ምርኩስ ብምግባር'ዩ ዝትንትን። እዚ መጽናዕቲ'ዚ ኣብ ክልተ ዓበይቲ ጉዳያት የተኩር። እቲ ቀዳማይ ኣብ ያታዊ ኣገባብ መስኖ-ጀሪፍ ኮይኑ፣ ከም እኒ ኣሰራርሓ ዓግም፣ ኣቃውማ ማሕበር ሓረስቶት፣ ኣጠቓቕማን ምሕደራን ማይ ከምኡውን ጠቕምን ጉድኣትን ናይ'ዚ ኣገባብ'ዚ ዝኣመሰሉ ማሕበረ ተክኒካዊ ጉዳያት የተኩር። እቲ ካልእይ፣ ኣብ ዋዲ ላባን ማይ ኡለን ዝተገብረ መጽናዕቲ ምርኩስ ብምግባር ነቲ ዝተመሓየሸ መስኖ-ጀሪፍ ምስቲ ያታዊ መስኖ-ጀሪፍ የወዳድር። ሓረስቶት ኣብዚ ሓዲሽ/ዝተመሓየሸ ኣገባብ መስኖ ጀሪፍ ዘለዎም ኣረኣእያን ንምምምዕባሉ ዘጋጥሙ ብድሆታትን ከኣ የጉልሕ። እዚ ወረቐት'ዚ መስኖ-ጀሪፍ ኣብ ምብራቓዊ መታሕት ኤርትራ ብኸመይ ኣገባብ ክምዕብል ከምዝግብእ ፣ እማመታት ብምቕራብ ይድምድም።

ምትእትታው ንነኣሽቱ ቓጽዖታት መሬት ዘልምዕ ነጠብጣባዊ ስርዓተ መስኖ ኣብ ኤርትራ፣ ዝተቐሰመ ትምህርትን ተመክሮታትን

ብስራት ገብሩን ኣብርሃም መሓሪን
ኮለጅ ሕርሻ ዩኒቨርሲቲ ኣስመራ ቊ. ሳ. ፖ. 1220 ኣስመራ፣ ኤርትራ

ዓቐን ዝናብ ኣብ ኤርትራ ዉሑድ እኳ እንተዘይኮነ፣ ዝርጋሐኡ ኣዝዩ ዘይተመጣነ ስለ ዝኾነ ኣብቲ ነትክልቲ ዘድልየሉ ግዜን ቦታን ዘይምህራሙ፣ ሓደ ካብቲ ናይ ደርቂ ምኽንያት ኮይኑ ይርከብ። ቀንዲ ቁጠባዊ ፖሊሲ ኤርትራ ምርግጋጽ ዉሕስነት መግቢ እዩ። እዚ ክውን ንምግባር ሕርሻ ዝናብ እኹል ስለዘይኮነ፣ ብመስኖኣዊ ሕርሻ ክድገፍ ይግበኦ። ብሃገር ደረጃ ዉሕስነት መግቢ ክረጋገጽ እንተኾይኑ፣ እቲ ቀዳማይ ስጉምቲ ንሓንቲ ስድራቤት እኹል መግቢ ኩተፍሪ ዘኽእላ ቴክኖሎጂ ምትእትታው እዩ። ካብቶም ሓገዝቲ ክኾኑ ዝኽእሉ ቴክኖሎጂታት፣ ንናእሽቱ ቓጽዖታት መሬት (ኣስታት ክልተ ጽምዲ) ዘልምዕ፣ ምስ ድሩት ቁጠባዊ ትሕዝቶ ሓረስቶት ሃገርና ዝሳነ ስርዓተ ነጠብጣባዊ መስኖ እዩ። ብዙሓት ክምዚኦም ዓይነት ቴክኖሎጂታት ኣለዉ። ንኣብነት ቻፒን (Chapin) ፣ ነታፊም (Netafim)፣ ብዋኒን ኣህጉራዊ ልምዓት ዝፈሪ (IDE, International Development Enterprrise) ዝኣመሰሉ ስርዓተ ነጠብጣባዊ መስኖ ክጥቀሱ ይኽእሉ። እዚ ድሒሩ ዝተጠቕሰ ስርዓተ መስኖ-ጠብታ ናብ ኤርትራ ብ2000 ዓ. ም. ተኣታትዩ። ብዛዕባ ክህቦ ዝኽእል ጥቕሚ ንምፍላጥን ምስ ዉድዓዊ ኩነታት ሓረስቶት ሃገርና ዝሳነየሉ ኣገባባት ንምንዳይን ሓበራዊ መፅጽናዕቲ ብኮለጅ ሕርሻ ዩኒቨርሲቲ ኣስመራን ብማእከል ምዕባለን ስልጠናን ኣከባብን ዩኒቨርሲቲ በርንን ተኻይዱ። እዚ ወረቐት'ዚ እምበእር፣ ቀንዲ ኣድህቦኡ ኣብቲ መስርሕ መጽናዕቲ ዝተዋህለለ ተመክሮን ዝተቀሰመ ትምህርትን ምብራህ እዩ። ኣብ ግብሪ ማዕረ ክንደይ እቲ ብዛዕባ ናይ'ዚ ቴክኖሎጂ'ዚ ልዑል ናይ ማይ ጉልበትን ግዜን ተኽእሎ ክምዘለዎ ዘረድእ ክልሰሓሳባዊ ኣምር፣ ክውን ክም ዝኾነ ንምርዳእ'ውን ሓበሬታታት ተኣኪቡ። ዕሙቕ ዝበለ መጽናዕቲ ደኣ ኣይኹን እምበር፣ ደረጃ ተኽእሎ ናይ'ዚ ናይ መስኖ ቴክኖሎጂ ምስ ማሕበረ ቁጠባዊ ክውንነት ደቀንስትዮ ሃገርና ዘለዎ ስኒት ኣብቲ መጽናዕቲ ኣተኩሮ ተዋሂብዎ እዩ። እዚ ወረቐት'ዚ ኣብ መፈጸምታ ለበዋታትን ምኽርታትን ብዛዕባ እቶም ቀንዲ ማሕንቆታት ንምትእትታውን ምዝርጋሕን ናይ'ዚ ቴክኖሎጂ ክእለይሉ ዝኽእሉ መንገድታት ብምልጋስ ይድምድም።

ስኑ-ማሕረስ ኣብ ትሑት ዋጋ ዘለዎም ስርዓተ መጠነ -ንኡስ መስኖ።

ሳሙኤል ኣስገዶም
ኮሌጅ ሕርሻ፣ ዩኒቨርሲቲ፣ ኣስመራ ቊ. ሳ. ፖ. 1220፣ ኣስመራ፣ ኤርትራ

ብዙሓት ሃገራት ኣብ ዘመነ ሕጽረት ማይ ይኣትዉ ምህላዎም ብሰፊሑ ፍሉጥ ኮይኑ ኣሎ። ናይ ቀረባ ኣዋን ምዕባለ ትሑት ዋጋ መጠነ-ንኡስ ስርዓተ መስኖ ቴክኖሎጂ፣ ሕጽረት ማይ ኣብ ዘለዎ ቦታታት፣ ንናይ ሚልዮናት ድኻታት ሓረስቶት ዓለም ኣብ ሂወቶም ኣገዳሲ ዝኾነ ጥቕምታት ሂብዎም ኣሎ። መጠነ-ንኡስ ስርዓተ መስኖ ኣብ ኤርትራ ተኣታትዩ፣ ምስ ገለ ገለ ሕጽረታት ኣወንታዊ ውጽኢት ሂቡ ኣሎ።

መጠነ-ንኡስ ስርዓተ መስኖ ብዙሕ ስነ ማሕረሳዊ ጥቕምታት እኳ እንተሃለዎ ሓረስቶት መታን ብግቡእ ክጥቀምሉ ስነ ማሕረሳውን ቴክኒካውን መምርሒታትን ግቡእ ስልጠናን ክወሃቦም ይግባእ። ግቡእ ስነ-ማሕረሳዊ ስልጠና ኣዝዩ ኣድላዩ እዩ፣ ብፍላይ ከኣ ኣብ ምምራጽ ዓይነት ዘራእቲ፣ ኣጠቓቕማ ድኹዒ፣ ኣብ ዝተፈላለየ ደረጃ ዕድመ ዘራእቲ ጠለብ ተደላዩ መጠን ማይ፣ ምርሕሓቕ ተኽሊ፣ ብባሴቲ ምድጋፍ፣ ምቕምቃም፣ ምጥቃም መድሃኒት ጸረ ሕማማት ፋንጋስ፣ ካብ ንቡር ወቕቲ ወጻኢ ምፍራይ፣ ኣብ ጨዋም መሬት ምፍራይ፣ ምቁጽጻር ሕማማትን ሓሻኹን፣ ኩነታት ክሊማ፣ ዓይነት ሓመድ፣ ምጽሃይ፣ ግዜ ምእካብ ምህርቲ ምቁጽጻር፣ ፍርያትን ዓይነትን ካብቶም ኣገደስቲ ዝበሃሉ እዮም። ካብ መደብ ፈልሲ ኣሰጋጊርካ ንዝትከሉ ኣሕምልቲ፣ ብግቡእ መታን ክዓብዩ ብመስኖ ክሰትዮ ይግባእ፣ ከምእኒ ብሮኮሊ፣ ካውሎ ፍዮሪ፣ ሰላጣ ዝኣመሰሉ ኣሕምልቲ ብዙሕ ማይ ብምስሓብን ዘድልዩ መኣዛታት ብምውሳድን ቀልጢፎም ይዓብዩ። ከም በዓል ማንጎ ዝኣመሰሉ ኣእዋም ግን ኣብቲ ዝዓብይሉ ግዜ (ዕምባባን ፍረን ቅድሚ ምውጻእም) ዉሑድ ማይ ይደልዩ። መጠነ-ንኡስ ስርዓተ መስኖ ብተዛማዲ ሓዲሽ ከም ምዃኑ መጠን፣ ዘራእቲ ዘድልዮም ነገራት ብምንጻር ክትግበር ዝግቦእ ኣገባብ ስነ-ማሕረስ ምእማም ኣገዳሲ ይኸውን። እዚ ወረቐት'ዚ እምበኣርከስ ዘሎ ናይ ማሕረስ ፍልጠት ምስ መስርሕ ምትእትታው መጠነ-ንኡስ ኣገባባት መስኖ ማለት ህሉው ተክኒካዊ ፍልጠት ብምዝማድ ኣወሃሂዱ ዝዝቲ እዩ።

ተራ ማሕበራት ልምዓት ኣብ ምትኣትታውን ምዝርጋሕን ንናኣሽቱ ቃጽዖታት ዘልምዕ ስርዓተ መስኖ-ጠብታ ኣብ ኤርትራ

እርምያስ በየነን ቪሸካ ኒደክርን

ሕርሻ ኣብ ኤርትራ ዘየተኣማምን ምዕሩይ ዝርጋሐ ኣብ ዘይብሉ ዝናብ ዝተሞርከሰ እዩ፣ እቶም ቀንዲ ንመግቢ ዘገልግሉ ኣእካል፣ መብዛሕትኡ ግዜ ንዘቤታዊ ሃልኪ ጥራሕ ተባሂሎም ካብ ዝናብ ተጸቢኻ ዝፈርዩ እዮም። ዋላ እኳ ዋሕዲ ማይ ኣብ ኤርትራ ሓደ ካብቶም ኣዓበዩ ጸገማት እንተኾነ፡፡ ኣብዚ እዋን እዚ ንጥቀመሎም ዘለና መብዛሕትኦም ስርዓተ መስኖታት ጀሪፍ፣ ለምን/ ትልሚን፣ ጋብላን እዮም። እዚኣቶም ድማ ብዙሕ ማይ ብሃፋን ብምዝዓግን ከምኡ'ውን ካብ ደረት ግራት ወጻኢ ብምፍሳስን ዝባኽኑ እዮም። ማይ ንምቑጣብን ምህርቲ ንምስሳንን፣ ምትእትታው ስርዓተ መስኖ ጠብታ ኣዝዩ ሓጋዚ እዩ። ምስ ቁጠባዊ ዓቕምን ናይቶም ናኣሽቱ ቃጽዖ መሬት ዝውንኑ ድኻታት ሓረስቶት ዝሳነ ስርዓተ-መስኖ ጠብታ ብዘይምንባሩን፣ ንዝርጋሐ ልምዓት መስኖኣዊ ሕርሻ ኣብ ኤርትራን ኣብ ካልኦት ሓውሲ ምድረበዳ ሃገራትን ደሪትዎ ጸኒሑ'ዩ። መብዛሕታኡ መሳርሒታት ልሙድ ኣገባባት መስኖ ኣዝዩ ክቡርን ኣብ ወጻኢ ሃገር ዝፈርን እዩ። ነዚም ሽግራት እዚኣቶም ንምፍታሕ እምበኣር፣ ምስ ቁጠባዊ ዓቕምን ትሕዝቶን መሬት ድኻታት ሓረስቶት ሃገርና ናይ ምስናይ ተኽእሎን ልዑል ፍርያምነትን ዘሎዎም ናይ መስኖ ቴክኖሎጂታት ናብ ኤርትራ ምትእትታውን ምዝርጋሕን ኣዝዩ ኣገዳሲ እዩ። ተኽእሎታት ናይ'ዞም ኣብ ላዕሊ ድሒሮም ዝተጠቐሱ ኣገባባት መስኖ ክሳብ ሕጂ ከምቲ ዝድለ ኣብ ጥቕሚ ኣይወዓለን ዘሎ። ካብቶም ቀንዲ ምኽንያታት ከኣ ካብ መጠን ንላዕሊ ድኽነት፣ እኹል ሓበሬታ ዘይምህላው፣ ደገፍ ናይ ኣህጉራውያን ዘይመንግስታውያን ማሕበራት ዘይምንባሩን ክጥቀሱ ይኽእሉ። እዚ ይኹን እምበር እቲ ክሳብ ሕጂ

ኣብ ምትእትታው ናይዞም ናኣሽቱ ቃጽያታት መሬት ከልምዑ ተኽእሎ ዘለዎም ስርዓተ መስኖ ጠብታ ዝዓለመ፡ ብዉሑዳት ማሕበራት ዝተኻየደ መጽናዕቲ ዘተባብዕ ውጽኢት ኣርእዩ እዩ። ስለዚ፡ እቲ ዘድሊ መደባት እንዳወጠንካ ነዚ ቴክኖሎጂ እዚ ንምትእትታው፡ ምስ ክውንነት ሃገርና ንምውህሃዱን ንሓረስቶት ሃገርና ብዛዕባ ኣጠቓቕማኡ ኣስተምህሮ ንምሃብን፡ ናይ ኣህጉራውያን ዘይመንግስታውያን ማሕበራት ደገፍን ምታትታውን ኣድላዪ እዩ። ኣድህቦ ናይ'ዚ ወረቐት እዚ ኣብ ምድንፋዕ ተሳታፍነትን ተራን ናይ ኣህጉራውያን ዘይመንግስታውያን ናይ ልምዓት ማሕበራት፡ ኣብ ምትእትታው ስርዓተ መስኖ ጠብታን ምስ ክውንነት ናይ ኤርትራ ምውህሃድን እዩ። ቀንዲ ኣተኩሮ ናይ'ዚ ወረቀት እዚ መጠነ-ንኡሳን ናይ ፋይናንስ ትካላት ምስ ስርዓተ-መስኖ ጠበታ ብምትእስሳር ኣብ ገጠር ዝነብር ትሑት ዝመነባብሮኡ ህዝቢ ናይ ንግዲ ባይታ ንምፍጣርን፡ ቀጻልነት ዘለዎ ዉሑስ ቀረብ ምእንቲ ክህሉ ዓቕምን ብቕዓትን ናይ ብሕታዊ ክፋል ንምምሕያሽን ዝከኣለሉ ጉዳያት ብምንጻር እዩ።

ኣበርክቶ ዝናብ ኣብ ልምዓት መስኖ ኤርትራ ፣ ተኽእሎታትን ማሕንቖታትን

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ዕዉት ውጥንን ልምዓት ፕሮጀክትታትን መስኖ ኣብ ጥንቁቕ ምርዳእ ግምገማን ክጸልዉ ዝኽእሉ ነገራትን (ንኣብነት ዝናብ) ዝተመስረተ ክኸውን ይግባእ። ካብ ዝናብ ዝርከብ ማይ ቀንድን ወሳንን ረቛሒ ህላወ ናይ ልዕለን ትሕተን ባይታ ማይ እዩ። ብምኽንያት ሕጽረት ብጽቡቕ ዝተወደበ ኣሃዛዊ ሓብሬታ ክሊማ፡ ኣብ ኣስመራ ዝርከብ ሓደ መደበር ሜትሮሎጂ ጥራይ (ብተዛማዲ ካብ 1914-2002 እኹልን ምሉእን ኣሃዛዊ ሓበሬታ ስለዘሎዎ) ነቲ ኣብ ላዕሊ ዝተጠቕሰ ኣርእስትታት ንምዝታይ ክዝውተር'ዩ። ዝተፈላለዩ ስታትስቲካዊ ኣገባባት ኣብ ትንተና ኣሃዛዊ ሓበሬታ ኣብ ጥቕሚ ውዒሎም'ዮም። ውጽኢት ናይ'ዚ መጽናዕቲ'ዚ ከም ዝሕብሮ ከኣ፡ እቲ ክትንበዮ ዘጸግም ዝናብን ያታዊ ኣተሓሳስባን ሓረስቶት ኣብ ዝናብ ዝምርኮስ ሕርሻን ነቲ ካብ ዝናብ ክርከብ ዝኽእል ጠሊን ኣቋናጺብዎ ይርከብ። እንተኾነ ካብ ዝናብ ዝርከብ እኹል ማይ ከምዘሎን ጽቡቕ ምሕደራ እንተ ተገይሩሉ ከኣ፡ ንመስኖኣዊ ልምዓት ክውዕል ከምዝኽእልን ተረጋጊጹ እዩ። ኣብ ክረምቲ ዝረአ ተለዋዋጢ ዓቐን ዝናብ ንመጻኢ ዝግበር ትንቢት ዓቕን ዝናብ ሓጋዚ እይኮነን ። እንዳ ጎደለ ዝመጽእ ዓቐን ዝናብ ከኣ፡ ነቲ ኣብ ዝናብ ዝተመርኮሰ ሕርሻ ኣስጋኢ እዩ። ነዞም ሽግራት እዚኣቶም ንምቅላል ከእ፡ ኣፍልጦን ተሳታፍነትን ሕብረተሰብ ምዕባይ፡ ኩሉ መዳያዊ ምርምር ምግባር፡ ዘመናዊ ምሕደራ ሓበሬታ ምትእትታው፡ ከምኡውን ዝተመሓየሹ ኣገባባት ምዕቃብ ማይን ሓመድን ምጥቃም ኣገደስቲ ኮይኖም ይርከቡ። ቀንዲ ዕላማ ናይ'ዚ ጽሑፍ'ዚ እምበኣርከስ ተኽእሎታትን ማሕንቖታትን ዝናብ ንመስኖእዊ ልምዓት ኣብ ኤርትራ ንምትንታንን ንምዝታይን'ዩ።

ምጥቃም ትንቢታት ክፍለ-ዓመታዊ ክሊማ ንምሕደራ ሃብቲ ማይ

ሚኪኤል ነጋሽ
ሚኒስትሪ መሬት ማይን ኣከባብን፡ ክፍሊ ሃብቲ ማይ፡ ኣስመራ፡ ኤርትራ

ምዕባለ ሃብቲ ማያት ንባህርያዊ ዋሕዚ ናይቶም ኣብ ዓለምና ዝርከቡ ሩባታት ቀይርዎ ይርከብ። ነቲ ቀንዲ ኩነታት ውሽጣዊ ክፋል ሩባታትን ብማይ ዘዕ ለቕልቑ ጎላጉልን ስለ ዝቆጻጸር ፍልልይ ኣብ ባህርያዊ ምንቅስቓስ ማያት፡ ኣብ ወሓይዝን ሩባታትን ንዘሎ ሂወታዊ ብዙሕነት ቅርጺ ኣብ ምትሓዝ ሓጋዚ ተራ ኣለዎ። ኣብ ወሽጢ ሓደ ዓመትን ካብ ዓመት ናብ ዓመት ዝረአዩ ዝተፈላለዩ ምንቅስቓሳት ማያዊ ክፋል ናይ ዓለምናን፡ ከምኡ'ውን ምስኡ ዝተኣሳሰሩ ባህርያት ናይ ግዜ፡ ዕድመ፡ ምድግጋምን መጠን ምቅይያርን፡ ኣብ ምውሓስ ቀጻልነት ናይ መበቆላዊ ብዙሕነት ፍጥረትን ምሉእነት ናይ ማያዊ ግዝኣትን ኣዝዮም ኣገደስቲ እዮም። ቀንዲ ኣድህቦ ናይዚ ፕሮጀክት ኣብ ምግምጋም ብቕዓት ትንቢት ክፍለ-ዓመታዊ ክሊማ ንምምሕያሽ ምሕደራ ሃብቲ ማይ ክኸውን እዩ። እቲ ሓፈሻዊ ዕ ላማ፡ ናብ ዝሓሸ ውጽኢታውነትን ምምቕራሕ ሃብቲ ማይ ኣብ መንጎ ኣከባብን ተጠቀምትን ዘምርሕ ትንቢት ክሊማ ተኸቲልካ ብዛዕባ ብዝሕን ህላውነትን ማይ ሓበሬታ ምሃብ እዩ። ቐጻልነት ዘለዎ ምዕባለ ናይ ሕርሻን ሃብቲ እንስሳን ክረጋገጽ ዝኽእል ናይ ክሊማ ሓበሬታ ኣብ ማሕበረ-ቁጠባዊ ንድፍን ትግባረን ተራ ምስ ዝህልዎ ጥራሕ እዩ። እዚ ድማ ብቐጥታ ኣብ ምርግጋጽ ዉሕስነት መግቢ ኣበርክቶ ይህልዎ። እዚ ወረቐት'ዚ ኣብ ጠቓምነት ሓበሬታ ክሊማዊ ኩነታት ክፍለ-ዓመታዊ ዝናብ ጽልውኡ ንዓመታዊ ሚዛን ማይን ከድህብ እዩ። ከምኡ'ውን ትንቢታት ክፍለ-ዓመታዊ ዋሕዚ ሩባትታት ፍርያምነት ንምዕባይን ኣጠቓቕማ ማይ ኣብ መስኖኣዊ ሕርሻ ንምምሕያሽን፡ ዘኽእሉ ቑንዓት ምሕደራዊ ዉሳነታት ንምግባር ዝህልዎም ጥቕሚ ኣብ ምብራህ ከድህብ እዩ።

መስኖኣዊ ልምዓትን ጉዳይ ጾታን

ሶሎሜ ሃይለ

ሚኒስትሪ ሕርሻ፡ ክፍሊ ምርምርን ምምዕባል ዓቕሚሰብን፡ ኣሃዱ ሕርሻዊ ምህንድስና ቁ. ሳ. ፖ. 4627 ኣስመራ፡ ኤርትራ E-mail: merhawihh@yahoo.com

ኣብ ኤርትራ ደቀንስትዮ ኣብ ሕርሻዊ ንጥፈታት መሪሕ ተራ ኣለወን። መብዛሕትኡ ኣብ እዋን ዘርኢ። ጸህያይ ኮነ ምእካብ ምህርትን ድሕሪኡን ዘድሊ ናይ ጉልበት ቀረብ ኣብ ልዕሊ ልሙድ ናይ ገዛ ስርሔን የማልኣ። ኣብ ገለ ከባቢታት ናይ ኤርትራ ንኣረስቶት ደቀንስትዮ ብጉጅለኣዊ ኣገባብ ዘሳትፉ ብECD (ትካል ምምዕባል ማሕበረሰብ ኤርትራ) ከምኡውን UNICEF (ዓለማዊ ዉድብ ህጻናት) ዝተመወሉ መደባት ንምምዕባል ኣብ ሕብረተሰብ ዝተመርኮሰ መስኖኣዊ ሕርሻ ኣብ ምንጥጣፍ ይርከቡ።ኣብ ምስልሳል እዞም መደባት ተራ ደቀንስትዮ ኣዝዩ ዕዉት ምዃኑ ድማ ይግምገም። ኣብ'ዚ መጽናዕታዊ ጽሑፍ ካብ ዝተፈላለያ ብሃውሪ ዝተሓርያ ኣብ ሰለስተ ዞባታት ማለት ዞባ ማእከል ደቡብን ዓንሰባን ዝርከባ ሸውዓተ ዓድታት (ምምሕዳር ከባቢታት) ተኻይዱ። ኣብዘን ዓድታት ንዝተፈላለያ ሓረስቶት ዝተዳለወ መሕተቲ ተሳትፎ ደቀንስትዮ

ኣብ ሕርሻ ብፍላይ ድማ ኣብ መስኖኣዊ ኣገባብ ዘለወን ጸገማት ንምልላይ ብሓፈሻ ከኣ ተርኣን ኣብ ሕርሻዊ ንጥፈታት ንምድህሳስ ዝዓለመ ኔሩ። ገለ ካብቶም ንተሳትፎን ንጥፈታትን ደቀንስትዮ (ብፍላይ ኣብተን ዝተሓርያ ዓድታት ንዘለዋ) ኣብቶም ዝተጠቕሱ መደባት ብኣሉታ ዝጸለዉ ቀንዲ ምኽንያታት እዞም ዝስዕቡ ክጥቀሱ ይኽእሉ፣ ሕጽረት ጉልበት፣ ተወሳኺ ናይ ገዛ ስራሕ፣ ሕጽረት ገንዘብን ድሩት ኣፍልጦን ብፍላይ ኣብ ኣገባብ ኣጠቓቕማ ማይ። ብመንጽር እዞም ዝተገልጹ ጸገማት እዘን ደቀንስትዮ ገንዘባዊ ዓቕመን ተመሓይሹ ደረጃ መነባብሮ ስድራቤተን ከደላድላ ምኽኣለን ከምኡውን ብቕዓተን ኣብ ምስልሳል መስኖኣዊ ናይ ሕርሻ መደባት ዝያዳ ክብ ምባሉን ብእዎንታ ክጥቀሱ ዝኽእሉ መኽሰባት እዮም።ከም ቅድመ ኩነት ንምዕዋት እዞም መደባት ብዉሑድ ጉልበታዊ ሃልኪ ክዕየ ዝኽእል መስኖኣዊ ኣገባብ ምታእትታውን ንሓረስቶት ዝያዳ ኣተባባዒ ዝኾነ ናይ ገንዘባዊ ለቓሕ መደባት ምስራዕን ኣገዳሲ ተራ ክጻወቱ ይኽእሉ እዮም። ብተወሳኺ ብሰንኪ ኣገባብ ኣተዓዳድላ ዝሕረስ መሬትን ሕጽረት ንዋታዊ ቀረብን ዘጋጥሙ ዕንቅፋታት ንምእላይ ሓገዝቲ እዮም። ሓያል ዝኾነ ናይ ኤክስተንሽን ወይ ግብራዊ መርኣያን ትምህርትን ድማ ንዘሎ ድሩት ኣፍልጦ ሓረስቶት ኣብ ዘመናዊ ተክኖሎጂ ንምምሕያሽ ብፍላይ ድማ ኣድማዒ መስኖኣዊ ኣገባብ ንምስራሕ ኣድላዪ እዩ።

ማሕበረ-ቁጠባዊን ትካላዊን ጽልዋታት ኣብ ምትእትታው ምዕቡል ናይ መስኖ ቴክኖሎጂ ኣብ ኤርትራ

ብርጊታ ስቲልሃርት
ማእከል ንምምዕባልን ኣከባብን፣ ዩኒቨርሲቲ በርን፣ ስዊዘርላንድ
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ሓደ ሓዲሽ ተክኖሎጂ ወይ ኣገባብ ካብቲ ተጠቃሚ ተገዳስነት ንኽረክብ ነቲ ዘሎ ከባቢ ብቴክኒካዊ መዳይ ኮነ ብዓይነት ምቹእ ክኸውን የድሊ። ብቐንዱ ዝኾነ ሓዲሽ ቴክኖሎጂ ወይ ኣገባብ ነቲ ዝተመርጸ ኣከባቢ ብዝተፈላለየ መለክዒ ምስ ዝሰማማዕ ዕዉት ኮይኑ ክተኣታቶን ተቐባልነት ክረክብን ይኽእል። ኣብ ምትእትታው ምዕቡል መስኖኣዊ ቴክኖሎጂ ንንኣሽቱ ሓረስቶት ደሓን ዝኾነ ተቐባልነት'ውን እንተ ረኸበ ዝያዳ ኣቓልቦ ክግበረሎም ዝነበሮም ጉዳያት ግን ኣለዉ። ንማሕበራውን ቁጠባውን ትካላዊ መሳርዕ ወይ ኣምራት ትሑት ግምት ኣዩ ተዋሂቡዎም ጸኒሑ። ንብቕዓት ሓደ ኣገባብ መስኖኣዊ ቴክኖሎጂ ዝምልከት ኣብ 2002-2003 ዓ.ም. ኣብ ዝቐረበ መጽናዕቲ ከም ዘመልክቶ ገለ ካብቶም ንተበግሶን ኣድህቦን ሓረስቶት ኣብ ሓደሽቲ ኣገባባት ካብ ዝጸለዉ ቀንዲ ረቛሕቲ ኣዞም ዝስዕቡ እዮም። ልሙድ ኣገባባት እጠቓቕማ ማይ፣ ተመክሮን ብቕዓትን፣ ትሕዝቶ ዝሕረስ መሬት፣ ንመስኖ ዝኸውን ማይን ንዋትን፣ ዋጋን ሃልኪን ብመንጽር እቶት፣ ጾታዊ ኣተሓሳስባ ኣብ ሕርሻዊ ንጥፈት፣ ዓቕንን ቅርጽን ንመስኖኣዊ ሕርሻ እንጥቀመሎም ንብረት ከምኡውን ምትሕልላፍ ኣፍልጦ መስኖኣዊ ሕርሻ ኣብ ኩሎም ክፋላት ሕብረተሰብ።

ኣስታፌ ዳህሳስ ስርዓተ ሕርሻ ኣብ ሕርሻዊ-መጎሰን መስኖ-ጀሪፍን፣ ኣብ ዞባታት ጎላጉል ገማግም ባሕሪ ኤርትራ።

ፍሉይ መጽናዕቲ ሽዕብ፣ ወቒሮን ዋደሎ*

[1]ኣዱኛ ሃይለ፣ ወልደኣምላኽ ኣርኣያ፣ ወልድስላሴ ዑቕባዝጊ፣ ዳኘው ገብረስላስ፣
ብስራት ገብሩን፣ መሓመድ ክያር ዑመርን

[1]ሕርሻ ኮሌጅ፣ ዩኒቨርሲቲ ኣስመራ፣ ቁ. ሳ. ፖ. 1220 ኣስመራ፣ ኤርትራ

ኣብ ጎላጉል ኤርትራ ማለት ኣብ ሽዕብ (መንሸብ፤ ደምነት፤ ድገ፤ ቢሰስ፤ ቲሉክ፤ ገለብን ሽዕብ ቀጢንን) ወቒሮን ዋደሎን ካብ ታሕሳስ 1995 ክሳብ መስከረም 1996 መጽናዕታዊ ዳሕሳስ ስርዓተ ሕርሻ ተኻይዱ። እዚ ዝተሓዋወሰ ስርዓተ መስኖኣዊ ሕርሻን ምርባሕ እንስሳታትን ብምኽያድ ዓቕሚ ፍርያት ሕርሻ ዘሎዎ ቦታ እዩ። ሕርሻዊ እቶት ኣብ መስኖ-ጀሪፍ ዝተመስረተ ኮይኑ፣ ፍሉይ ብመስመር ምዝራእ፣ ውሑድ ማሕረስ ዘድልዮ ስርዓተ-መስኖን ናይ ደምበ ሞጎሰን ዝዝውተረሉ እዩ። ዕላማ ናይ'ዚ ዳህሳስ ስርዓተ ማእቶት መስኖ ጀሪፍ ንምግላጽን ንምርዳእን ኮይኑ፣ ሓረስቶት ንምሕጋዝን ፍታሕ ንምርካብ ቀዳምነት ዝወሃቦም ቀንዲ ማሕንቖታት ማእቶት ንምልላይ እዩ። እዚ ዳህሳስ'ዚ ዝተፈላለየ ዓቕሚ ሰብ ናይ ስነ-ማሕረስ፣ ምክልኻል ቡቕሊ፣ ስነ-ኣከባቢ ናይ እንስሳን ናይ ጾታዊ ጉዳይ ክኢላታት ዘሳተፈ እዩ ኔሩ። ብቑዕ ናይ ሕርሻ ትዕዝብትን ክምኡ እዉን ናይ ጉጅለ (ምስ 10-15 ሓረስቶት ካብ ነብሲ ወከፍ ዓዲ) ዘተ ተኻይዱ። ስለዚ ኣሳታፊ ገጠራዊ ገምጋም ብደረጃ ስድራ ቤት ክኣ መሕትት ምምላእ ተዘውቲሩ፣ ኣብዚ ብድምር 195 ሓረስቶት (ሽዕብ 84፣ ወቒሮ 81፣ ዋደሎ 30) ብሃውሪ ተመሪጾምን ቃለ መጠይቕ ጌሮምን። ቀጥታዊ ትዕዝብትን ቆጸራን ኣታኽልቲ፣ ኩነታት ኣከባብን ባህርያዊ ሃብትን ተኻይዱ። ኣብ ዝተኻየደ መጽናዕቲ ቀንዲ ዓይነት ባሕርያዊ ኣትክልቲ፣ መስኖ (መስኖ-ጀሪፍ) ኣታሓሕዛ ዘራእቲን ምርባሕ እንስሳታትን፣ መሓንቖታት ማእቶት ተለልዮምን ተግሊጾምን። ሓረስቶት ብዝሃብዎ ተርታ ቀዳምነት መሰረት፣ ቀንዲ መሓንቖታት ሕጽረት ምጋሃጫ መሬትን ማይን፣ ድኹም ትሕተ ቅርጺ መስኖ፣ ትሑት ኩነታት ጥዕና፣ ትሑት ፍርያምነት ዘራእትን ምርባሕ እንስሳታትን እዮም። ክም ፍታሕ ክኣ ዝተፈላለዩ ግቡእ ኣጠቓቕማ መሬት ምዝዉታር፣ ምህናጽ መኽዘን ማይ፣ ተወሰኽቲ ዓላታት፣ ትሕተ ቅርጺ መስኖ፣ ኣድማዒ ምቁጽጻር ተጻባእቲ ብቑልን ግቡእ ኣገልግሎት ሕክምና እንስሳን ተለልዮምን ርእይቶ ቀሪብሎምን፣ ስርዓተ-ሕርሻ፣ መሓንቖ ማእቶትን ፍታሕን ናይ ሰለስቲኡ ዓድታት (ሽዕብ ወቒሮን ዋደሎን) ኣብቲ ዝተዳለወ ሰነድ ናይ ስርዓተ መስኖ-ጀሪፍ መጽናዕቲ እኹል መግለጺ ተዋሂብዎ ኣሎ።

*ኣብ ፕሮጀክት ኣታሓሕዛ ነቕጺ-መሬት ዝተኻየደ መጽናዕቲ

ምልማዕ ትሕተ-ዲጋዊ ናይ መስኖ ጀራዲን፡ ጻህሳስ ኣብ ማሕበረ-ቁጠባዊ ስረት

ኣስገዶም ተወልደን ፋጹምብርሃን ገብረዮሃንስን
ፕሮጀክት ምልማዕ መስኖኣዊ ጀራዲን ኣብ ማእከላይ ክፋል ከበሳ ኤርትራ
ሚኒስትሪ ሕርሻ ቁ. ሳ. ፖ. 1048 ኣስመራ ኤርትራ E-mail: asghedom@tse.com.er

ፕሮጀክት ምምዕባል መስኖኣዊ ጀራዲን ኣብ ማእከላይ ክፋል ከበሳታት ኤርትራ፡ ኣብ ዞባታት ደቡብ፡ ማእከልን ዓንሰባን ኣብ ዝርከቡ ሰላሳ (30) ዲጋታት መጽናዕቲ ኣካይዱ ኔሩ። ከም ዕላማ ንዘሎ ኣገባብት ዝምልከት ማሕበረ ቁጠባዊ ሃዋህው ንምድህሳስን ንምስናድን ኮይኑ ሓረስቶት ኣብ ኩነታት እዘን ዲጋታት ዘለዎም ትኩርነት ንምግምጋምን ብዛዕባ እዚ ፕሮጀክት ኣብ መጻኢ ክህልዎ ዝድለ ኣድማዕነት ንምሕያል ዘኽእሉ መለከዒታት ንምርቋሕን ሓጋዚ ኣበርክቶ ኣለዎ። ዕላማ ናይዚ ፕሮጀክት ንምውቃዕ ኣብ ከባቢ እዘን ዲጋታት ዝርከብ ሕብረተሰብ ኣበርክቶኡ ኣብ ምድንፋዕን ቀጻልነት ናይዚ መደብን ኣገዳሲ እዩ። በዚ ምክንያት ድማ ጻህሳስ ኣብ ማሕበረ-ቁጠባዊ ስረት ናይቲ ሕብረተሰብ ተሳትፎኡ ኣብቲ ፕሮጀክት ከም ዝሕይል ብምግባር፡ ኣድማዕነትን ቀጻልነትን ብመንግስቲ ናይ ዝተወጠነ መደብ ምምዕባል ትሕተ-ዲጋዊ መስኖኣዊ ሕርሻ ክብ ከምዝብል ይገብር። ኣብዚ ዝቐረበ ወረቐት ታሪኻዊ ኣመጻጽኣን ድሕረባይታን ናይቶም ዝተመርጹ ኣብ ማእከላይ ክፋል ከበሰታት ኤርትራ ዝርከቡ 30 ዲጋታት ጠቒሱ ኩነታት እቶም ዲጋታት፡ ብዝሒ ተጠቀምቲ፡ ህሉውን መጻኢን እዘን ዲጋታት ክለምያኦ ዝኽእላ መሬት፡ ኣገባብ ኣተዓዳድላ መሬት ናይቲ ከባቢን፡ ግንዛቤን ርእይቶን ሓረስቶት ይገልጽ። ኣብ መወዳእታ ድማ ነቶም ቀንዲ ስነ-ሓሳባዊን ተግባራዊን ውጽኢታት መጽናዕቲ ብምትንታን ለበዋታት ብምስፋርን ይድምድም።

ምልዋጥ ኣገባብ መስኖኣዊ ሕርሻ ናብ ነጠብጣባዊ መስኖ፡ ማሕበረ-ቁጠባዊ መጽናዕቲ ኣብ ከባቢ ዓላ-ጋዴን ኣብ ዝርከቡ ኣፍረይቲ ኣራንሺ

ጸሃየ ወልደሚካኤልን ሲራክ መሓሪን
ኮለጅ ሕርሻ፡ ዩኒቨርሲቲ ኣስመራ ቁ. ሳ. ፖ. 1220 ኣስመራ፡ ኤርትራ

ከባቢታት ዓላ-ጋዴን ብምህርቲ ፍረታት ብፍላይ ከኣ ኣራንሺን ፓፓዮን ዝተፈልጠ ሰጣሕ ቦታታት የጠቓልል። ኣብዚ ሕጂ እዋን ብሰንኪ ተደጋጋሚ ደርቅን ቀጻሊ ማሕረስን ዓቕምን ተኽእሎን ንመስኖ ዝኸውን ማይ ናይቲ ከባቢ ኣንቆልቍሉ ይርከብ። ሓረስቶት እቲ ከባቢ ግን ዝርካቦም ማይ ብልምዳዊ ኣገባብ ተጠቒሞም ምህርቲ ፍረታት ንዕዳጋታት ኣብ ምቕራብ ይርከቡ። እዚ ዘሎ ኣገባብ መስኖ ግን ምስ ኩነታት ማይ ናይቲ ከባቢ ዘይከይድ ኣብ ርእሲ ምዃኑ ነዚ ዘሎ ጸገም ማይ ከመቓርሕ ተክእሎ ንዘለዎ ነጥብጣባዊ ኣገባብ ዝጥቀሙ ሓረስቶት ከኣ ዳርጋ የለዉን። ኣብዚ ዝቐረበ ወረቐት ኣብ ሰላሳ ዝኾኑ ኣብቲ ከባቢ ዝረከቡ ኣፍረይቲ ኣራንሺ ንዝተዳልወ መሕተት መሰረት ብምግባር ማሕበረ-ቁጠባዊ ጽልዋታት ንምምርማርን ካልእ ምስ ምልዋጥ ኣገባብ መስኖኣዊ ማሕረስ ናብ ነጠብጣባዊ ቴክኖሎጂ ክቕልቀሉ ዝኽእሉ ጸገማት ንምርዳእን ተፈቲኑ ኣሎ። ካብ ሞንጎ እዞም ኣብቲ መጽናዕቲ ዝተሳተፉ ብሚኒስትሪ ሕርሻ ጨንፈር ደቀምሓረ

ዝተሓርዩ ሓረስቶት ቅድሚ ሕጂ ነጠብጣባዊ ኣገባብ መስኖ ፈጺሞም ዘይተጠቐሙን ፈቲኖም ዝገደፍዎን ይርከብዎም። እዚ መፅናዕቲ ከም ዘረድኦ ኣብቲ ከባቢ ዘሎ ኣገባብ ዋንነት ዝሕረስ መሬት ንቀጻሊ ዋንነት ዝህብ ብምዃኑ፣ ስፍሓትን ዓቐን ቦታ እኩል ምዃኑ ከምኡውን ተገዳስነትን ቅሩብነትን ሓረስቶት ንቲ ቴክኖሎጂ ምስ ናይ ተተሓሒዞም ክስዕቡ ዝኽእሉ ጸገማቱ ገለ ካብ ክጥቀሱ ዝኽእሉ ኣዎንታዊ ጎድንታት እዮም። ብኻልእ ወገን ቀንዲ ጸገማት ናይዚ ለውጢ ክኾኑ ዝኽእሉ መበገሲ ርእሰማልን መካየዲ ገንዘብን ልዑል ምስ ምዃኑን እቲ ኣገባብ ምስቲ ድሮ ተተኺሉ ዝፈሪ ዘሎ ተኽሊ ፍረታት ናይ ምስናይ ተኽእሎ ዘለዎም ስክፍታን ይርከብዎም።

ተኽእሎታትን መሓንቖታትን ኣገባብ ነጠብጣባዊ መስኖ ኣብ ሰሜናዊ ምዕራብ መታሕት ኤርትራ፣ ኩነታት ሕርሻ ሳዋ

በረቀጸሓይ ቱኩእን[1] መብራት ገብረኣብን፣[2]

[1]ሳዋ ኣግሮ ኢንዱስትሪ ቁ. ሳ. ፖ. 6530 ኣስመራ፣ ኤርትራ
[2]ሚኒስትሪ መሬት ማይን ኣከባብን ቁ. ሳ. ፖ. 1488 ኣስመራ፣ ኤርትራ

ካብ ኣስመራ ንወገን ሰሜናዊ ምዕራብ ኤርትራ ኣስታት 317 ኪ.ሜ. ርሒቑ ኣብ ዝርከብ ሕርሻ ሳዋ 300 ሄክታር መሬት ብነጠብጣባዊ መስኖ ለሚዑ ይርከብ። ኣብ'ዚ ካብ ጽፍሒ ባሕሪ 540 ሚትሮ ብራኽ ዘለዎ ቦታ፣ ዝተፈላለዩ ኣሕምልቲ ይፈርዩ፡፡ ንመጻኢ ድማ ናብ 10,000 ሄክታር ናይ ምስፍሑ መደብ ተታሒዝዎ ይርከብ። ምንጪ ናይቲ ንመስኖ ዘገልግል ማይ ካብ ትሕተ ባይታዊ ቀረብ ሩባ ሳዋ እዩ። እዚ ዝቐርብ መጽናዕታዊ ጽሑፍ ኣብቲ ናይ ሕርሻ ቦታ ኣብ ዝሓለፉ ኣርባዕተ ዓመታት ከጋጥሙ ዝጸንሑ ጸገማት ምርኩስ ብምግባር ተኽእሎ ነጠብጣባዊ መስኖ ኣብ ምልማዕ ኣሕምልቲ ኣብ ሰሜናዊ ምዕራብ መታሕት ዝርከብ ሕርሻዊ ኣከባቢ ብፍላይ ከኣ ኣብ ከባቢ ሕርሻ ሳዋ ዘተኮረ እዩ። ኣብ ኩነታትን ተኽእሎን ተለዋዋጥነት ባህርን ትሕዝቶን ትሕተ-ባይታዊ ቀረብ ማይ ሩባ ሳዋ ኣቓልቦ ብምግባር ብመንጽር ዓይነት ማይን ምስ ነጠብጣባዊ ኣገባብ ዘለዎ ኣዎንታዊ ጠባያትን ብዕምቆት የረድእ። ንግቡእ እጠቓቕማን ኣተሓሕዛን ምንጪ ናይዚ ማይ ዝምልከት ለበዋታት ብምሃብ ድማ ይድምድም።

ምትእትታው መስኖኣዊ ሕርሻ ኣብ ኣጻድፍ ከበሳታት ኤርትራ ብትሑት ወፍሪ

ሚኪኤል ዓንዶም
ኮለጅ ሕርሻ፣ ዩኒቨርሲቲ ኣስመራ ቁ. ሳ. ፖ. 1220 ኣስመራ ኤርትራ
E-mail: micand95348@yahoo.com

ብቑዕ ዝኾነ ኣተዓቓቕባ ማይ ተጠቒምካ ኣብ ኣጠቓቕምኡ ከኣ ማዕሪኡ ግቡእ ጥንቃቐ እንዳገበርካ ኣብቲ ናይ ዝናብ ማይ እናተጸበየ ዓመታዊ ምህርቲ ዘማዕዱ ከባቢ ኣጻድፍ ከበሳ መስኖኣዊ ልምዓት ኣሕምልቲ ክካየድ ይኽእል እዩ። እዚ ኣገባብ እዚ ድማ ነዚ ዘሎ ካብ ዲጋታትን ራህያታትን ዝርከብ ማያት ተጠቒምካ ኣብ ሰጥ ዝበለ መሬት ጥራይ ዘልምዕ ኣገባብ ናብ ኣጻድፍ ዝበዝሐ ከባቢ

ክተኣታቶ ተኽእሎ ኣሎ። ብመሰረት ኣብ ሰለስተ ዓድታት ማለት፡ ሽማንጉስ ላዕላይ፡ ገረሚን ደምበ-ዛውልን ካብ ዝርከቡ ብመስኖ ዘልምዑ ሓረስቶት ዝተኣከበ ሓበሬታ ፡ ባህርያት ዝጥቀምሎም ኣገባብ ማሕረስ፡ ምንጪ ማይ፡ ገንዘባዊ ዓቕሚ፡ ከምኡውን ኣብ ከባቢኦም ዘለዉ ኣጻድፍ ናይ ምልማዕ ቅሩብነት መምዘኒ ብምግባር ካብ ዲጋታት ኮነ ካልእ ዝርከብ ማይ ተጠቒምካ ብኸመይ መሬት ኣዳሊኻ ከምተልምዕ ኣብዚ መፅናዕታዊ ጽሑፍ ሰፊሩ ኣሎ። ነዚ ንምግባር ከኣ ኣብ 20 ሓረስቶት ናይተን ዓድታት ዘለዎም ድሕረባይታ ናይ መስኖኣዊ ማሕረስ፡ ጊዜን ቅርበት ቦታ ሕርሻ ካብ መንበሪኦምን፡ኣብ ግምት ዘእተወ መሕተት ተዳልዩ ሓበሬታ ድማ ተኣኪብሉ። እዚ መጽናዕቲ ከምዘረድኦ፡ ቀንዲ ጸገማት ናይ'ዞም ሓረስቶት ኣብ ምልማዕ እጻድፍ ድሩት ገንዘባዊ ዓቕሚ፡ ኣገባብ ኣተዓዳድላ (ዋንነት) ዝሕረሰ መሬትን ሕጽረት ማይን ይርከብዎም። ብቕንዱ ግን እቲ ብመስኖ ዘልምዕዎ መሬት ንኡስ ዓቐንን ስፍሓትን ዘለዎ ብምዃኑ ዝሓሸ ኣገባብ መስኖ ተጠቒሞም ዝሰፍሐ መሬት ናይ ምልማዕ ድሌትን ባህግን ኣለዎም። ብመንጽር ቁጠባን ኣከባብን ዝሓሸን ዝማዕበለን ኣገባብ ምድላው መሬት ተጠቒሞም ንኽይሰርሑ ዓቕሞምን ኣፍልጥኦምን ድሩት ብምዃኑ ኣብ ኣጻድፍ ከስርሖም ዝኽእል ኣፍልጠ ምድላብ የድልዮም። ነዚ ንምምዕባል ድማ ኣብዚ ጽሑፍ ገለ ተክኒካዊ ኣገባባት ቀሪቦም ኣለዉ።

ኣፈናዊ ገምጋም ኣብ ኣጠቓቕማ ንሕርሻ ዝውዕል ማይ ኣብ ዞባ ዓንሰባ

ኬ.ኤስ. ቪስዋንታምን፡ ዮሃንስ ሚካኤልን ዮናስ ሓድጉን

ሚኒስትሪ መሬትን ማይን ኣከባብን ክፍሊ ሃብቲ ማይ ቁ. ሳ. ፖ. 1488
ኣስመራ ኤርትራ E-mail: wrd@cts.com.er

ሚኒስትሪ መሬትን ማይን ኣከባብን ኤርትራ፡ ክፍሊ ሃብቲ ማይ ንዓይኒ ማያት ዝምልከት ዳህሳስ ካብ 1995-1997 ከምኡውን ካብ 2000-2002 ኣካይዱ ኔሩ። ንኣገልግሎት ሕርሻ ዝውዕሉ ዓይኒ ማያት ብዝምልከት ሓበሬታ ብዘይምምዝጋቦም ግን ንዘሎ ዓይነት ማይን ኣጠቓቕምኡን ዘድሊ መረዳእታ ኣየስፈሩን። ኣብዚ መጽናዕታዊ ጽሑፍ፡ ንሕርሻ ኣብ እንጥቀመሎም ቦታታት ዘሎ መስኖኣዊ ኣገባባትን ኣጠቓቕምኦምን ዘተኮረ ሓፈሻዊ ሓበሬታ ንምእካብ፡ ዓይነት ንመስኖ ኣንጥቀመሎም ሳዳጉዲን፡ ብቕዓትን ሓይልን መስመራት ማይን ንምልላይ ተፈቲኑ ኣሎ። ነዚ ንምስላጥ ዝርዝራዊ መሕተት ተዳልዩ ኣብ ከባቢ ዞባ ዓንሰባ ብምዝርጋሕ መምዘኒታት ኣጠቓቕማ ማይ ኣብ ሕርሻዊ መዓላ ዝምልከት ኣፈናዊ መረዳእታ ተሰሪሑ። ብመሰረት እዚ ዘሎ ህሉው ኣጠቓቕማ መስኖኣዊ ማይ ንምንጪ ማይ ዘህልኽ ኣብ ርእሲ ምዃኑ ብነጥብጣባዊ ኣገባብ ካብ 30-40% ናይዚ ሃልኪ ክድሕን ምኽኣለ። ብተወሳኺ ኣብ ከባቢ ሩባ ዓንሰባ ዝርከቡ ሳዳጉዲ ንትሕዝቶን ብዝሕን ዘቤታዊ ሳዳጉዲ ከተማ ከረን ብኣሉታ ጸልዮሞ ይርከቡ።

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