Small-scale Micro Irrigation in Eritrea

A feasibility study on the introduction of affordable micro irrigation technology in Eritrea

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2003

Funds
The study and the printing were funded by the Syngenta Foundation for Sustainable Agriculture, Basle

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Printed by
Cover: Kleiner AG, Monbijoustrasse 121, 3000 Bern 23
Content: Victor Hotz AG, Sennweidstrasse 35, 6312 Steinhausen

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ISBN
3-906151-72-7

Contents

1 Acknowledgements

This study was funded by the Syngenta Foundation for Sustainable Agriculture. During the past two years, Felix Nicolier, the Foundation's representative, gradually became more of a partner and supporter, with a personal interest in the study team's activities.

Pablo Loosli, a private consultant to CDE and a geographer by profession, was one of the initiators of this study. He has been connected with Eritrea in different ways for almost 20 years. The idea of introducing a new technology to increase agricultural productivity and hence the livelihoods of subsistence farmers took shape during several of his visits and discussions in Eritrea. Pablo was part of the study team on two field trips. The study also benefited from his extensive personal network.

For reasons explained in the report, IDE products were selected for the feasibility test. Sudarshan Suryawanshi, an Indian irrigation specialist and IDE consultant, introduced the team to the technology and helped during the first field visits to demonstrate the kits to farmers and technicians in a competent way. His commitment in formulating an initial mission report and in helping the team to understand technical topics later on was greatly appreciated.

Vision Eritrea, an Eritrean NGO in Asmara, supported the study with innumerable supporting activities, advice and infrastructure. Dr Tseggai Gherezghiher in particular showed continual interest in the progress of the study as well as personal commitment.

In many regions access to farmers was provided by the local offices of the Ministry of Agriculture (MoA). This was possible because of the personal and institutional interest of Semere Amlesom, Director of DARHRD (Department for Agricultural Research and Human Development), who supported the study from the beginning. A letter of recommendation from Mr Amlesom opened many doors at the local and regional administrative levels, and motivated employees to participate in demonstrations and support farmers with their knowledge.

The College of Agriculture, University of Asmara, and the Centre for Development and Environment (CDE), University of Berne, shared responsibility for the study. The following persons supported the study:

College of Agriculture: Dr. Abdulkadir Dawod (Dean of the Faculty), Dr. Woldeselassie Ogbazghi (evaluator) and Tedros (water analysis).

Discussions with experts helped increase the team's knowledge of many topics. Discussions were held with the following persons: Rainer Baudendistel (Swiss Honorary Consul), Redaegzy Gebremedhin (Director of RAM-Farm), Brother Amilcare Boccuccia (Director of Hagaz Agricultural School), Solomon Tesfahun (Director of Hamel Malo School for Agriculture), Semere Asmerom (Research Director of Halhale Research Centre), Dawit Woldu (Director, Polyplastics), Sium Fesehaye (Farm Manager), Robert Burtscher (Sustainable Land Managament Programme [SLM] Eritrea), Amanuel Negassi (Head of Irrigation and Soil and Water Conservation, MoA), Ghebrejesus Ghebreilul (Biselex Eritrea), Francis Hillman (Managing Director Phaesun Ltd), Fritz Leu (Aktion Lichtblick), John Weakliam (Country Director Refugee Trust International), Jon Naugle (Senior Programme Officer, Enterprise Work Worldwide), Josef Müller (Swiss Disaster Relief Unit), Yohannes Mezenghe (Managing Director, La Belle Flowers), and Christoph Studer (Schweizerische Hochschule für Landwirtschaft [SHL] Zollikofen).

Urs Heierli (Division Employment and Income, Swiss Agency for Development and Cooperation [SDC], Berne) and Elisabeth Katz (Landwirtschaftliche Beratungszentrale Lindau, Extension in Development Cooperation) supported the team by providing valuable knowledge and were involved in introducing a network for the promotion of small-scale irrigation. Many thanks for their support and friendship.

A great “thank you” also goes to Jürg Vogt, who carried out a material analysis of drip pipes for micro-irrigation systems. He focused mainly on the ecological qualities of the different types of plastic material used and on the durability of the material. His results influenced the team when they discussed and selected the provider of irrigation equipment.

A special word of thanks goes to all the farmers who took risks in agreeing to test the new technology and discuss their experience with the study team.

2 Preface

In current publications, affordable micro-irrigation technology for small-scale or subsistence farmers is one of the tools often mentioned as promising in the context of poverty alleviation. For individual farmers or small communities, the implementation of this new technology might help improve livelihoods, but only under distinct environmental, social and economic conditions. However, technical improvement of a local land use system can obviously not solve the structural or political problems of a globalised economy. Even when focusing on local subsistence farmers in Eritrea, we must bear in mind that the success or failure of a new technology is influenced by factors such as world market prices for agricultural products.

It is also well known and documented that successful introduction of a new technology is often a slow process that depends on more than only the technical performance of the products. Whether a farmer or a community accepts or rejects a new technology also depends greatly on the social context, the (local) market situation, the political environment, and the promotion and support farmers can get. Nevertheless, during fieldwork the temptation to focus on technical aspects is sometimes great because technical performance is normally visible, easy to access and easy to understand, and technical problems are often easy to solve (at least theoretically). The affordability of the tested irrigation equipment is not based mainly on "cheaper" prices, but more on the small size of single kits and the minimised input needed, allowing farmers to increase the area under irrigation slowly. Such small kits were developed recently in different enterprises in collaboration with international NGOs, technicians and farmers. The best-known products currently on offer are produced and installed by IDE, Netafim and Chapman.

For reasons explained in the report, we selected IDE products for the feasibility study. Sudarshan Suryawanshi, an Indian irrigation specialist and IDE consultant, introduced the team to the technology and helped to introduce it to farmers and technicians in a competent way during the first field visits. His commitment in formulating an initial mission report and in helping the team later on to understand technical issues was greatly appreciated.

In this report, the term "small-scale farmer" refers to farmers managing less than 2 hectares of land, with little or no external support. It is remarkable that these subsistence farmers are expected to earn their families' entire livelihood from their farm products, especially when we compare their situation with the highly subsidised farming in Europe or the United States.

In many publications the term "low-cost" is used. We replaced it with the term "affordable" because "low-cost" is often associated with low quality and low (or poor) support. On the other hand, affordability may create the illusion that even the poorest can afford something. Aside from the fact that the poorest members of a society can rarely be the target group for the introduction of a new technology, the affordability of selected hardware is mainly based on the small size of the single kits, and not on the price per hectare. Moreover, this "affordability" should be understood in relation to "traditional" large-scale irrigation schemes.

3 Summary

Eritrea is located in the eastern part of Africa, bordered by Sudan, Ethiopia, Djibouti and the Red Sea. About 80 % of the total population of about 3.5 million persons are small-scale farmers, most of them living in a semi-arid environment. Increasing pressure on natural resources, especially in the highlands, and aggravated problems of water scarcity were two of the driving forces for this study.

It is well known that micro irrigation technology helps save (irrigation) water. It also saves labour and time when optimally used. Because the irrigation units are small the initial capital requirement is lower than with conventional, pressurised irrigation equipment. Increased crop quality and human health are other positive effects of micro irrigation, especially of drip irrigation.

The environmental conditions for the introduction of micro irrigation technology as well as the potentials and constraints of this technology were evaluated by following a market-driven technology transfer approach.

In collaboration with different international organisations and local farmers in India, IDE India (International Development Enterprise) developed affordable micro irrigation equipment for small-scale farmers. Using this equipment, technical feasibility, agronomic and environmental implications, and social acceptance were assessed by a team of the University of Berne and the University of Asmara.

Main results:

- The quality and performance of the introduced irrigation equipment are absolutely essential. Problems with the material, lack of spare parts, and changes in design during the starting phase can jeopardize the success of implementation;
- The problem mentioned most often by farmers is clogging of the micro tubes. It is inherent to the system and can only be minimised through appropriate maintenance (e.g. frequent flushing of tubes, chemical or mechanical treatment of tubes, using a water filter, etc);
- In most cases optimal use of the technology requires adapting the agronomic system as well as changing land management practices. Therefore knowledge transfer, flow of information and backstopping of farmers for several years are essential preconditions for successful introduction;
- Often drip irrigation is expected to increase yields in comparison with traditional furrow irrigation. But the main goal with micro irrigation is to save water. If the two irrigation technologies are compared, results are positive when yield quantity and quality of one cropping cycle are similar. If water is available throughout the whole year and environmental conditions (e.g. temperature, radiation and wind) allow permanent crop growing, the technology can also be used to grow crops during the dry season and increase the total yield per year.
- Local water management, water pricing and the distance to the next well influence farmers interest fundamentally. As long as water is freely accessible during the whole year and there is no charge of water, farmers see no advantage in investing in a water saving technology;
- A topic very frequently discussed with farmers was the size of the kits. On one hand their small size allows farmers to start irrigating fields with a limited financial input. On the other, the standard area under irrigation (20 m^2 – 160 m^2 depending on the type of kit) is too small for commercial crop growing. In general the irrigation kits tested by the farmers were used by them to improve the nutritional status of the household;
- Urban and suburban areas with small backyard gardens are one of the target areas identified. Female headed households are also an important target group because of restricted land management rights for women.

4 ሰሌዳ ትሕዝቶ

4.1 መእተዊ

ኣብ ኤርትራ ከባቢ 28,000 ሄክታር ብመስኖ ዝለምዕ መሬት ኣሎ። ናይ ብመስኖ ክለምዕ ዝኽእል ስፍሓት መሬት ግምጋም ድማ ካብ 60,000 ክሳብ 90,000 ሄክታር ይበጽሕ።

ዳርጋ 50 ሚእታዊት ናይቲ 28,000 ሄክታር ብውሕጅ (spate) ዝለምዕ ክኸውን ከሎ፡ ናይቲ ዝተረፈ 50 ሚእታዊት ከባቢ 80 ሚእታዊት ድማ ብሓመዳዊ ካናለታት ኣብ ከባቢ ኣትክልትን ፍረታትን ጋብላታት ማይ ብምግባር ይለምዕ።

ካብ ግዜ መግዛእቲ ጥልያን ኣትሒዙ ኣብ ውሱን ከባቢታት፡ ከም ኣብ ዕላበርዕድ፡ ናይ ፌፍ (Sprinkler) መስኖ ተኣታትዩ ዓቢ ፍርያት የእቱ ከም ዝነበረ ብሰፊሑ ዝዝንቶ ታሪኽ ኣሎ። ካብ 1995 ኣትሒዙ ውን ነጠብጣባዊ (Drip) መስኖ ኣብ ብዙሕ ከባቢታት ኤርትራ መብዛሕትኡ ብደረጃ መንግስታዊ ዓቕሚ ተኣታትዩ።

ነጠብጣባዊ መስኖ ቀንዲ ዕላምኡ፡ ማይ ናብቲ ከባቢ ናይታ ተኽሊ እምበር ናብቲ ኣብ መንጎ ክልተ ተኽልታት ይኹን ኣብ መንጎ ክልተ መስመራት ናይ ኣትክልቲ ዘሎ ቦታታት ማይ ዘይምብኻን ዝብል ኣምር ኢዩ። እዚ ስለ ዝኾነ ድማ ካብቲ ልምዳዊ ናይ ሓመድ ካናለ መስኖኣዊ ሕርሻ፡ ክሳብ 50 ሚእታዊት ማይ፡ ጉልበት፡ ግዜ ናይ ምቑጣብ ተኽእሎ ኣለዎ።

እዚ ናብ ኤርትራ ዝተኣታተወ ምዕቡል ነጠብጣባዊ መስኖ ግና ብዙሕ ገንዘብ ዝሓትት ምስቲ ናይ መብዛሕትኦም ድኻታት ሓረስቶት ሃገርናን መብዛሕትኦም ሓረስቶት ኣብ ምምዕባል ዝርከባ ሃገራትን እኮኖምያዊ ዓቕምን ዝውንንዎ ስፍሓት መረትን ዘይሳነ ተክኖሎጂ ኢዩ።

እዚ ኣብ ላዕሊ ዝተሓበረ ሽግር ብምርዳእ፡ እዚ ነጠብጣባዊ መስኖ፡ ኣብ ብዙሕ ከባቢታት ዓለም ኣድማዕነቱ ኣብ ምስሳን እቶት ኣሕምልትን ፍረታትን ስለዝተኣመነሉን ዝተረጋገጸን፡ ነኣሽቱ ድኻታት ሓረስቶ ተኻፈልቲ ናይዚ ረብሓ ምእንቲ ክኾኑ፡ ንሶም ክጥቀምሉ ብዝኽእልሉ መንገዲ ብ IDE (International Development Enterprises) ተዳልዩ።

እዚ ንናኣሽቱ ሓረስቶት ከም ዘገልግል ኮይኑ ዝተዳለወ ትሑት ዝዋጋኡ ናይ ነጠብጣባዊ መስኖ መሳርሒ ንኣስታት ሓሙሽተ ዓመታት ኣብ ህንድን ካልኦት ብርክት ዝበላ ሃገራትን መጽናዕቲ ተኻይድሉ። እቲ መጽናዕቲ ከም ዝሕብሮ ድማ እቲ ናይ መስኖ መሳርሒ ናይ ብዙሓት ሓረስቶት መነባብሮ ከመሓይሽ ኪኢሉ ኢዩ።

ኣብ ኤርትራ ብዙሓት ድኻታት ሓሮስቶት ዳርጋ ሙሉእ መነባብርኦም ካብተን ካብ ነኣሽቱ ቓጽያታት ዝረኽብወን ጥረ እኽሊ እቶት ዝምርኮሰ ኣለው። ነዚ ሓቂ እዚ ብምርዳእ ድማ፡ ግብራዊ ጠቓምነት ናይዚ ንናኣሽቱ ሓረስቶት ዘገልግል ነጠብጠባዊ መስኖ ኣብ ኤርትራ መጽናዕቲ ይግበረሉ ኣሎ። እቲ መጽናዕቲ ብምትሕግጋዝ ኣብ መንጎ ዩኒቨርስቲ ኣስመራ (University of Asmara)፡ ኮለጅ ሕርሻን፡ በርን ዩኒቨርሲቲ (University of Bern) ማእከል ምዕባለን ኣከባብን (CDE: Center for Development and Environment) እዩ ዝግበር ዘሎ። እቲ መጽናዕቲ ገና ኣብ መደምደምታ ኣይብጻሕ እምበር ዓቢ ክፋሉ ተዛዚሙ ይርከብ።

እቲ ውጽኢት ናይ እቲ መጽናዕቲ ብሰፊሑ ኣብቲ ናይ እንግሊዝ ዓምዲ ሰፊሩ ኣሎ። እቶም ኣገደስቲ ዝበሃሉ ዝተረኽቡ ውጽኢታት ድማ ኣብዚ ናይ ትግርኛ ዓምዲ ተተርጒሞም ሰፊሮም ይርከቡ።

4.2 ዕላማታት ናይ መጽናዕቲ

ቀንዲ ዕላማታት ናይቲ ዝተገብረ መጽናዕቲ ኣብዞም ዝሰዕቡ ነጥብታት ክጠቓለሉ ይኽእሉ፦

ሀ. ንኣሽቱ መሬት ዝውንኑ ትሑት ዓቕሚ ዘለዎም ሓረስቶት ክጥቀምሉ ዝኽእሉ ዘመናዊ ናይ ነጠብጠባዊ መስኖ መሳርሒ ምትእትታው፡

ለ. እዚ ነጠብጠባዊ መስኖኣዊ ሕርሻ ምስ ተክኒካዊ ብስለት ሓረስቶት ኤርትራ ዝወሃሃደሉ መንገዲ ምንዳይ፡

ሐ. ብልጫታትን ድኽመታትን ናይዚ ነጠብጠባዊ መስኖኣዊ ሕርሻ ምስ ልምዳዊ መስኖኣዊ ሕርሻ ብምውድዳር ምጽናዕ፡

መ. ደረጃ ተቐባልነት ናይዚ ነጠብጠባዊ መስኖኣዊ ሕርሻ ኣብ ሓረስቶት ምጽናዕ፡

ሰ. ብኸፊል፡ ማዕረ ክንደይ እዚ ዘመናዊ ነጠብጠባዊ መስኖኣዊ ሕርሻ ተሳታፍነት ደቀንስትዮ ኤርትራ ኣብ እቶታዊ ሕርሻ ከዕዝዝ ከምዝኽእል ሓርፋፍ ሓበሬታ ምርካብ።

4.3 ኣገባብ መጽናዕቲ

ነዚ መጽናዕቲ እዚ ንምክያድን ነቶም ኣብ ላዕሊ ተዘርዚሮም ዘለዉ ዕላማታት ንምጭባጥን፣ እዚ ዝስዕብ ኣገባብ ተኸቲሉ፦

ሀ. ንኣሽቱ መሬት ዝውንኑ ሓረስቶት ብብዝሒ ዝርከቡሉ፣ ብቐሊሉ ክብጽሑ ዝኽእሉ ከባቢታትን፣ ከምኡ ውን ምስ ሓረስቶት ቀጥታዊ ርክብ ዘለወን ናይ ሕርሻ ኣብያተ ትምህርቲ ምልላይ። በዚ መሰረት ኣብ ዞባ ዓንሰባ፦ ቤት ትምህርቲ ሕርሻ ሓመልማሎን ቤት ትምህርቲ ሕርሻ ሓጋዝን፣ ኣብ ዞባ ጋሽ ባርካ፦ ባረንቱ፣ ኣብ ዞባ ደቡብ፦ ዓዲ ቐይሕ፣ ዓዲ ወገራ፣ ዓዲ ዛርና፣ መንደፈራ፣ ዓዲ መንጎንቲ፣ ኣብ ዞባ ሰመናዊ ቐይሕ ባሕሪ፦ ማይ ሓባር፣ ኣብ ዞባ ማእከል፦ ኣስመራን ከባቢኣን፣ ንመጽናዕቲ ከገልግላ ተመሪጸን፣

ለ. ኣብ ነፍሲ ወከፍ ዝተመርጸ ቦታ፣ ኣብ መጽናዕቲ ብወለንታኦም ንኽሳተፉ ቁሩብነት ዘለዎም ሓረስቶት ተመምዮም፣

ሐ. ቅድሚ እቲ ናይ ነጠብጠባዊ መስኖኣዊ ሕርሻ መሳርሒ ምዕዳሉ፣ ሓረስቶትን ተመሃሮን ብምእካብ፣ ሰፊሕ መብርሂ ብዛዕባ ኣብ መሬት ኣዘራጋግሓን ኣጠቓቕማን ናይ እቲ መሳርሒ ተዋሂቡ (ስእሊ ቁ.1ን 2ን) ፣

መ. ኣብቲ መጀመርታ ክፋል ናይቲ መጽናዕቲ: እቲ ናይ ነጠብጠባዊ መስኖ መሳርሒ ብነጻ ተዓዲሉ። ኣብቲ ካልኣይ ክፋል ናይ እቲ መጽናዕቲ ግና ሓረስቶት ብወለንታ ፍርቒ ዋጋ ከፊሎም ነቲ መሳርሒ ዓዲጎሞ። እቶም ሓረስቶት ነቲ መሳርሒ ድሕሪ ምፍታኖም ኣይጠቅምን እዩ ኢሎም ምስ ዝድምድሙ፣ ነቲ መሳርሒ ከየበላሸዉ ምስዝመልስዎ፣ ሰልዶም ብሙሉኡ ይምለሰሎም።

ስእሊ ቁ.1፡ ወለንተኛታት ሓረስቶት ጋሕተላይ ኣብ ምዝርጋሕ ናይታ ናይ መስኖ መሳርሒት እንዳተሳተፉ

ስእሊ ቑ. 2. ተማሃሮ ቤት ትምህርቲ ሕርሻ ሓጋዝ ኣብ ምዝርጋሕ ናይታ ናይ መስኖ መሳርሒት እንዳተሳተፉ

ሰ. ሓረስቶት እቲ መሳርሒ ድሕሪ ምግዝኦም ብጉቡእ ኣብ ባይታ ተኺሎሞ'ዶ ኣይተኸልዎን ንምርኣይ፡ ኣገዳሲ ምስኡ ዝኸይድ ምኽርታትን ንምልጋስ ድሕሪ ክልተ ወይ ሰለስተ ሰሙን ናብቲ ቦታታት ምብጻሕ ተገይሩ። ድሕሪ ከባቢ ወርሕን ፈረቓን ካልኣይ ምብጻሕ ኩነታት ቡቕሊ ንምዕዛብን ኣብ መስርሕ ንዘጋጥሙ ተክኒካዊ ጸገማት ብኣካል ተረኺብካ ግብራዊ ፍታሕ ክኾኑ ዝኽእሉ ነገራት ንምምይያጥ፡ ተኻይዱ። ሳልሳይ ምብጻሕ

ድማ ኣብ መጨረሽታ ናይ ቡቕሊ ግዜ ተኻይዱ። ቀንዲ ናይዚ ዕላማ ድማ ብሙሉኡ እቲ ዝተኣከበ ሓበሬታታት ንምስናድን ንዝመጽእ ናይ ቡቕሊ ግዜ ክመሓየሹ ዝግበኦም ነገራት ንምዝታይን ኢዩ።

4.4 ሕጽር ዝበለ መግለጺ ናይቲ ዝተኣታተወ ናይ ነጠብጠባዊ መስኖኣዊ ሕርሻ መሳርሒ

ኣብቲ ዝተገብረ መጽናዕቲ፡ ኣርባዕተ ዓይነት ናይ መስኖ መሳርሒታት ተፈቲነን። ንሳተን ድማ፦ ሰለስተ ናይ ነጠብጠባዊ ሓንቲ ናይ ፊፍ እየን። እታ ናይ ፊፍ መሳርሒት ንዓኣ ዘድሊ ጸቕጢ ናይ ማይ ኣብ መብዛሕታኡ ቦታታት ስለ ዘይተረኽበ ግና፡ ክምቲ ዝድለ ኣብ ጥቕሚ ኣይወዓለትን። ዝርዝራዊ ሓበሬታ ብዛዕባ ናይተን ናይ ነጠብጠባዊ መሳርሒታት ማለት ብዛዕባ ዝተፈላለየ ክፍልታተን፡ ክፍርያኦ ዝኽእላ ዓይነትን ብዝሕን ኣትክልቲ ካልእን ኣብ ሰለዳ ቁ. 1 ሰፊሩ ይርከብ።

ሰለዳ ቁ.1፡ ሕጽር ዝበለ መብርሂ ናይ ነጠብጠባዊ መስኖ መሳርሒታት

ዓይነት መሳርሒ	ብሰንከሎ ማይ ትምገብ ንኣትክልቲ (Bucket kit)	ብፊስቶ ማይ ትምገብ ንኣትክልቲ (Vegetable kit)	ብፊስቶ ማይ ትምገብ ንፍረታት (Horticultural kit)	ብጸቕጢ ማይ ናይ ትቦ ትምገብ ፊፍ (Micro-sprinkler kit)
ተልምየ ስፍሓት መሬት	20 ትርብዒት ሜትሮ	100 ትርብዒት ሜትሮ	130 ትርብዒት ሜትሮ	160 ትርብዒት ሜትሮ
ቁጽሪ ነቑጣታት ነጥቢ ማይ	32	150	50	15
ኣብ ትሕቲኣ ክፈርዩ ዝኽእሉ ቁጽሪ ተኽልታት	32-128	150-600	50 ኣእዋም	ንተቖራሪቦም ዝቦቕሉ ኣሕምልቲ: ከም እኒ ጅርጅር፡ ሽጉርቲ ወዘተ...
ቁመት ናይ ማይ መቐመጢ	1 ሜትሮ ካብ መሬት	1-2 ሜትሮ ካብ መሬት	1-2 ሜትሮ ካብ መሬት	10 ሜትሮ ካብ መሬት
ካብ ሓንቲ ነቑጣ ዝወጽእ ዓቐን ማይ	2-3 ሊትሮ ኣብ ሰዓት	2-3 ሊትሮ ኣብ ሰዓት	2-3 ሊትሮ ኣብ ሰዓት	40-50 ሊትሮ ኣብ ሰዓት
ዘድሊ ናይ ማይ መቐመጢ	ሰንኬሎ ናይ 20 ሊትሮ	ፊስቶ ናይ 200 ሊትሮ	ፊስቶ ናይ 200 ሊትሮ	ፊስቶ ናይ 500 ሊትሮ ወይ ብቐጥታ ካብ ቡምባ
ኣብ ትሕቲኣ ዝቦቕሉ ዓይነት ኣትክልቲ	ኣሕምልቲ (ጉዕ፡ኮሚደረ፡ ወዘተ)	ኣሕምልቲ (ጉዕ፡ኮሚደረ፡ወዘተ)	ፍረታት (ፓፓዮ፡ዘይትሁን፡ ወዘተ)	ንተቖራሪቦም ዝቦቕሉ ኣሕምልቲ ከም እኒ ጅርጅር፡ሽጉርቲ ወዘተ...

4.5 ዝተረኽቡ ውጽኢታት

ካብ ውልቃውያን ሓረስቶትን ካብ ናይ ሕርሻ ኣብያተ ትምህርትን ዝተረኸበ ሓበሬታ መሰረት ብምግባር እዞም ዝስዕቡ ኣገደስቲ ውጽኢታት ክጥቀሱ ይኽእሉ፦

ኣብ ምብጋስ ናይቲ መጽናዕቲ ካብ ትጽቢት ንላዕሊ ብዙሓት ሓረስቶት ልዑል ተገዳስነት ኣሕዲሮም። ነዚ ተገዳስነት ዘጉለሐ ነገር ድማ ሕረስቶት ቅድሚ ጥቕሚ ናይተን መሳርሒታት ባዕሎም ፈቲኖም ምርግጋጾም፡ ፍርቂ ዋጋ እንዳ ከፈሉ ብዙሕ መሳርሒታት ዓዲጎም።

ዋላኳ ብዙሓት ሓረስቶት ነተን መሳርሒታት ብፍርቂ ዋጋ ሻማ ኢሎም እንተተገዝእወን፡ ብርክት ዝበሉ ሓረስቶት ነተን መሳርሒታት ብጉቡእ ኣየተጠቕመሉለንን። ናይ ዘይመጥቀሚኦም ምኽንያት እብ ዝተገብረ ዝርርብ፡ ሓረስቶት ብዙሕ ምኽንያታት ጠቒሶም። እቶም ቀንዲ ምኽንያታት ኣብዞም ዝስዕቡ ነጥብታት ክጠቓለሉ ይኽእሉ፦

- ብዙሓት ሓረስቶት እቲ መሳርሒ ኣዝዩ ንእሽተይ ስለ ዝኾነ፡ ካብኡ ዝርከብ እቶት ኣተባባዒ ኣይኮነን በሃልቲ ኢዮም። እዚ ብኽፊል ሓቅነት ኣለዎ። ሽሕ እኳ ሓረስቶት ኤርትራ ናኣሽቱ ቃጽያ መሬት እዮም ዝውንኑ እንተበልና፡ መብዛሕታኦም ካብ ርብዒ ሄክታር ንላዕሊ ኣለዎም። እታ ዝዓበየት ናይ መስኖ መሳርሒት ዝተዓደለት ግና 100 ትርብዒት ሜትሮ ጥራይ ኢያ ትሽፍን። ነተን ነናይ 100 ትርብዒት ሜትሮ ኣላጊብካ ክሳብ ሓደ ሄክታር ክትሽፍን ተኽእሎ ኣሎ። ይኹን ደኣ እምበር፡ ነዚ ኣብ ሓደ እዋን ንምግባር ኢቲ ዘድሊ መባእታዊ ዋጋ ኣዝዩ ዓቢ ስለ ዝኾነ፡ ነቶም ትሑት መነባብሮ ዘለዎም ሓረስቶት ኤርትራ ልዕሊ ዓቕሞም ኢዩ። ስለዚ እቶም ሓረስቶት በብደረጃ፡ ቕስ ኢሎም ጥራሕ እዮም ክልምዕዎ ዝደልዩ መሬት ከስፍሕዎ ዝኽእሉ። እዚ ድማ ካብታ ቐዳመይቲ ዝገዝእዋ መሳርሒት ብዝተኻእለ መጠን ብጉቡእ ተጠቒሞም፡ ፍርያምነታ ኣዕብዮም፡ በቲ ዝረኸብዎ መኽሰብ ካልኣይቲ ናይ መስኖ መሳርሒት ምግዛእ፡ ካብቲ መኽሰብ ናይታ ካልኣይቲ መሳርሒት ድማ፡ ሳልሰይቲ ምግዛእ ወዘተ.. ብምግባር እዩ። እዚ መስርሕ እዚ ብምኽታል ዝደልይዎ ስፍሓት መሬት ክልምዑ ተኽእሎ ኣለዎም።

- እቲ ካልኣይ ረቛሒ ናይተን መስርሒታት ናብ ዘይምቕባል ዘምርሐ፡ ናይ ሓረስቶት ምጥርጣር እዩ። እዘን ነጠብጠባዊ ናይ መስኖ መሳርሒታት ከም ስመን ዝሕብሮ፡ ጥብ፡ ጥብ እንዳኣበላ ኣብ ሓደ እዋን ኣዝዩ ውሑድ ማይ እንዳ ኣፍሰሳ እየን ዘስትያ። ሓረስቶት ኤርትራ፡ እቲ ልምዳዊ ናይ መስኖ መሳርሒ፡ ማለት ጋብላ ማይ መሊእካ ምስታይ ስለ

ዝለመዱ፡ እተን ጥብ፡ ጥብ ኣንዳበላ ዘስትያ ዝተዓደልኦም ናይ መስኖ መሳርሒታት ነትክልቶም ማይ ዘጽግባሎም ኮይነን ኣይተሰምዖምን፡ እንትርፎ ውሑዳት።

እተን ዝተኣታተዋ ናይ ነጠብጠባዊ ናይ መስኖ መሳርሒታት ምስቲ ልምዳዊ ናይ ሓመድ ካናለታት ናይ መስኖ ኣጠቓቕማ ክወዳደራ እንከለዋ፡ ዓቢ ናይ ማይ ምቑጣብ ተኽእሎ ኣለወን። እዚ ዝኾነሉ ምኽንያት ድማ፡ እተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት፡ ዘይከም እቲ ናይ ልምዳዊ መስኖ፡ ኣብ ካናለታት ዝጠፍእ ማይ ስለ ዘይብለን፡ ንብሃፋ ዝጠፍእ ማይውን ዕድል ስለ ዘይህባ፡ ከምኡ'ውን ኣብ ከባቢ እታ ትለምዕ ተኽሊ እንተዘይኮይኑ ኣብ ካልእ ቦታ ማይ ንኽባኽን ዕድል ስለ ዘይህባ እዩ። ኣብተን ናይ ሕርሻ ኣብያተ ትምህርቲ ዝተገብረ መጽናዕቲ ከም ዝሕብሮ (ወላኳ ሳይንሳዊ ብቕዕነቱ ብምድግጋም ኣይረጋገጽ እምበር)፡ እተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት ፍርቂ ናይቲ ልምዳዊ መስኖ ዝጥቀሞ ዓቐን ማይ ጥራሕ እዩ ዘድልየን። ብኣሃዝ ኣየስንይዎ እምበር፡ ብዙሓት ነተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት ዝተጠቐሙለን ሓረስቶት፡ ብዙሕ ማይ ከም ዝቑጥባ ኣዕርዮም ከም ተገንዘቡ ሓቢሮም።

ነጠብጠባዊ መስኖ ዘይከም እቲ ልምዳዊ ሓመዳዊ መስኖ፡ ብዙሕ ጻህያይ ስለ ዘየብቁል፡ መሬት ምድልዳል፡ ምኹስኳስን ካልኦት ከምኦም ዝኣመሰሉ ሕርሻዊ ንጥፈታትን ስለ ዘየድልዮ፡ ጉልበትን ግዜን ኣዝዩ እዩ ዝቑጥብ:: ሓንቲ ኣደ ኣብ ማይ ሓባር ነዚ ናይ ግዜን ጉልበትን ምቑጣብ ተኽእሎ ናይተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት፡ ብኸምዚ ኣገባብ እሕጽር እቢለን ገሊጸናኦ፥ "ገዛይ እንዳ ኾስተርኩ፡ ጸብሐይ እንዳሰራሕኩ፡ ጀርዲነይ ማይ ክስቲ ይኽእል"።

እቶት ናይ ገለ ኣሕምልቲ ከም ባምያ፡ ጉዕ፡ ኣብ ነጠብጠባዊ መስኖ ካብቲ ናይ ልምዳዊ መስኖ ኣዝዩ ዝተዓጻጸፈ ኮይኖ ተረኺቡ። በንጻሩ እቶት ናይቲ ብልምዳዊ መስኖ ዝተዘርአ ኮሚደረ ካብቲ ናይ እብ ትሕቲ ነጠብጠባዊ መስኖ ዝቦቐለ፡ ዳርጋ ብ 50 ሚእታዊት ዝዓቢ ኮይኑ ተረኺቡ።

ኣብ ትሕቲ እተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት ዝቦቐሉ ኣሕምልትን ፍረታትን፡ ምስቶም ኣብ ብልምዳዊ መስኖ ዝለምዑ ክወዳደሩ ከለዉ፡ ናይ ብሕማም ምጥቃዕ ተኽእሎኦም ኣዝዩ ድሩት ኮይኑ ተረኺቡ።

እተን ዝተኣታተዋ ናይ ነጠብጠባዊ መስኖ መሳርሒታት፡ ብፍላይ ድማ እታ ብሰንኬሎ ማይ እትምገብ መሳርሒት (ስእሊ ቁ.3) ንእሽተይ መሬት ስለ ትሽፍን፡ ከምኡ'ውን ምስ ዝተፈላለየ

ቅርጺ መሬት ንምስምማዓ ኣጸጋሚ ስለዘይኮነ፡ ኣብ ካንሸሎ፡ ድሕሪ ገዛውቲ ንዝድኮኑ ጀራዲን ኣዝያ ምችእቲ እያ። እዚ ብልጫ እዚ ድማ ንደቅንስትዮ ኣዝዩ ጠቓሚ ኮይኑ ተረኺቡ። ብዙሓት ደቅንስትዮ ኣብዛ ብሰንከሎ ማይ እትምግብ መሳርሒት ዓቢ ተገዳስነት ኣርእየን። ዳርጋ ኩለን ነታ መሳርሒት ክጥቀማላ ዕድል ዝረኸባ ደቅንስትዮ፡ እታ መሳርሒት ካብ ተጸጋዕነት ከተገላግለን ከም ትኽእል፡ ኣብ ምምሕያሽ መነባብሮ ናይ ስድራቤተን ድማ ዓቢ ተራ ክትጻወት ከምትኽእል ኣገንዚበን።

ስእሊ ቁ.3፡ በገባብ ዝተዘርግሐት ብሰንከሎ እትምግብ ናይ ነጠብጠባዊ መስኖ መሳርሒት

ሓደ ካብቲ ዝዓበየ ተክኒካዊ ጸገማት ናይ ነጠብጠባዊ መስኖ፡ ምዕባስ ናይተን ብቐጥታ ነትክልቲ ማይ ዝምግባ ናኣሽቱ ትቦታት እዩ ነይሩ። እዚ ጸገም እዚ ኣብ ብርክት ዝበሉ ቦታታት ተራእዩ ኣዝዩ ከቢድ ጸገም እዩ ድማ ነይሩ። ጠንቅታት ናይዚ ናይ ምዕባስ ጸገም ብዙሓት እኳ እንተኾኑ፡ ካብቶም ከም ቀንዲ ምኽንያታት ክጥቀሱ ዝኽእሉ፦ ጨዋምነት ናይቲ ናይ መስኖ ማይን ኣብቲ ናይ መስኖ ማይ ዝርከብ ዘይሓቐቕ ሓመድን እዮም። እተን ምስ እዘን መሳርሒታት ዝመጻ ፍልትሮታት (መጻረይቲ ማይ) እዝየን ናኣሽቱ ብምኧነን'ውን ነዚ ናይ ምዕባስ ጸገም ኣብኢስዎ እዩ።

ከምቲ ኣቐድም ኣቢሉ ዝተሓበረ፡ ቅድሚ እተን ናይ ነጠብጠባዊ መስኖ መሳርሒታት ንሓረስቶት ምዕዳለን፡ ብዛዕባ ኣጠቓቕመአን ሰፊሕ መብርሂ ተዋሂቡ ነሩ። እዚ ኮይኑ ከብቅዕ ግና፡ ኣብቲ

ዝሰዓበ ናይ ምክትታል ግዜታት ከም ዝተራእየ፡ ሓረስቶት ብዙሕ ናይ ኣተገባብራ ጸገማት ከምዘለዎም ምርዳእ ተኻኢሉ።

ካብቶም ዝተራእዩ ናይ ኣተገባብራ ጌጋታት እዞም ዝስዕቡ ምጥቃስ ይከኣል፦

- ኣብ ትሕቲ ሓንቲ ብነጠብጣብ እተሰቲ ቀጣን ናይ ማይ ቱቦ ክሳብ ኣርባዕተ ኣትክልቲ ምዝራእ እንዳተኻእለ እንከሎ፡ ብዙሓት ሓረስቶት እዛ ንእሽቶይ ትቦ ዝኣክል ማይ ኣይተፍስስን እያ ብዝብል ምጥርጣር፡ ሓንቲ ተኽሊ ጥራይ ኣብ ትሕቲኣ ዘሪኦም። ኣብ ስእሊ ቑ.4 ክርአ ከም ዝከኣል ግና፡ ሓንቲ ቀጣን ናይ ትቦ ማይ ነርባዕተ ኣትክልቲ ዝኣክል መሬት ከተጠልቂ ትኽእል እያ።

ስእሊ ቁ. 4፡ ካብ ሓንቲ ቀጣን ትቦ ዝወጽእ ማይ ከጠልቅዮ ዝኽእል ስፍሓት መሬት

- ብዙሓት ሓረስቶትን እቶም ኣብቲ ኣብያተ ትምህርቲ ሕርሻ ዝተገብረ መጽናዕቲ ዝተሳተፉ ተመሃሮን፡ እታ ትዝራእ ተኽሊ ብማዕረ ማይን ኣየርን መታን ክትረክብ ኣብ ከባቢ ናይታ ነጠብጣብ ማይ ትፈስላ ቦታ ኣክንዲ ምዝራእ፡ ነታ ተኽሊ ልክዕ ኣብ ትሕቲ እታ ጥብ፡ ጥብ ትብለላ ቦታ ዘሪኦማ። እዛ ቦታ እዚኣ ግና ብማይ ዝበስበሰት ቦታ ስለ ዝኾነት፡ ንኣየር ቦታ ኣይትገድፍን እያ። ሓንቲ ተኽሊ ኣየር ምስ ዘይትረክብ ድማ ክትመውት ትኽእል እያ።

- ኣብ ብዙሕ ካብተን ነጠብጠባዊ ናይ መስኖ መሳርሒታት ዝተዘርግሓሉ ቦታታት፡ ሓረስቶት ኣብ ክንዲ እቲ ዝሀብዎ ዓቕን ማይ ምስ ምዕባይ ናይታ ተኽሊ እንዳ ኣብዝሕዎ ዝኸዱ፡ እተን ኣብ መጀመርታ ዝሀብወን ዝነበሩ ዓቐን ማይ ጥራሕ ነታ ተኽሊ የስትይዋ ነይሮም። እዚ ድማ ኣብ ዕብየትን ፍርያምነትን ናይታ ተኽሊ ዓቢ ጽልዋ ኣስዒቡ።

4.6 መደምደምታ

እዚ ዝተገብረ መጽናዕቲ ሰፊሕ እኳ እንተዘይነበረ፡ እቲ ዝተረኽበ ውጽኢታት ግና ዘተባብዕ እዩ ነይሩ። ካብተን ዝተኣታተዋ መሳርሒታት እታ ናይ ሰንኬሎ መሳርሒት ተልምያ መሬት ንእሽተይ ብምዃኑ ንናይ ገጠር ሓረስቶት ኣይሰሓበትን። እንተኾነ፡ ንደቀንስትዮ ኣብ ከባቢ ገዛእን ዝፈተንኣ ግን ኣድላይትን ብዙሕ ጥቕምታት ክትህበን ከም ዝኸኣለት ተረጋጊጹ። እዚ ንደቀንስትዮ ተወሳኺ ኣታዊ ዝፈጥር ስራሕን ካብ ገዛእን ከይረሓቓ ክካይድኦ ዝኽእላ ንጥፈትን ብምዃኑ፡ ቀዳምነት ተዋሂብዎ ሰፊሕ መጽናዕቲ ክግበረሉ ዝግባእ ኣርእስቲ እዩ።

ከምቲ ኣብ ላዕሊ ዝተገልጸ፡ እታ ናይ ፊፍ ናይ መስኖ መሳርሒት ብጉቡእ ንኽትሰርሕ፡ ብውሑዱ ናይ ከባቢ 10 ሜትሮ ጸቕጢ ዘለዎ ማይ ስለእትደሊ፡ እዚ ድማ ኣብ መብዛሕትኡ ገጠራት ኤርትራ ስለ ዘይርከብ፡ ብዛዕባ እዛ መሳርሒት እዚኣ ከዛርብ ዝኽእል መጽናዕቲ ኣይተገብረን።

እታ ብፊስቶ እትምገብ ናይ ፍረታት መሳርሒት፡ ኣዝዩ ዘተባብዕ ውጽኢት፡ ብፍላይ ኣብ ፓፓዮ፡ ኣርእያ። ብወገን ፈተንቲ እውን፡ ተቐባልነት ረኺባ። ኩሎም ዝተጠቕሙላ ሓረስቶት ከም ዝሓበርዎ ግና፡ እቲ ትሽፍኖ ስፍሓት መሬት ኣዝዩ ንእሽተይ እዩ።

እታ ናይ ፊስቶ ናይ ኣትክልቲ ናይ ነጠብጠባዊ መስኖ መሳርሒት፡ ኣዝያ ተደላይትን ነቲ ጠለብ ዘሎ ተማልእን ትመስል። ነዚኣ'ውን እንተኾነ ሓረስቶት እትሽፍኖ ስፍሓት መሬት ካብ 100 ትርብዒት ሜትሮ ንላዕሊ ክኸውን ይመርጹ።

ብሓፈሻኡ ክርአ እንከሎ፡ እዘን መሳርሒታት ናይ ነጠብጠባዊ መስኖ ብዙሕ ብልጫታት ከምዘለወን እኳ እንተተራእየ፡ ክውንነታውያን ጸገማት ናብ ነተን መሳርሒታት ብሓረስቶት ናብ ዘይምቕባል ዝደረኹ እውን ነይሮም እዮም።

ካብቶም ዝተራእዩ ኣወንታዊ ውጽኢታት ንምጥቃስ፦

- ሓረስቶት ኣብ መሬት ምድልዳልን ምቕራብን፡ ከምኡ'ውን ኣብ ጻህያይ ዘጥፍእዎ ግዜን ጉልበትን ምስቲ ናይ ልምዳዊ መስኖ ክወዳደር እንከሎ ኣዝዩ ውሑን ነሩ፡

- ብኣስታት ፍርቂ ናይቲ ኣብ ልምዳዊ መስኖ ዝጠፍእ ማይ፡ በዚ ናይ ነጠብጠባዊ መስኖ (ብጉቡእ ምስ ዝተሓዝ) ማዕረ ወይ ውን ካብቲ ብልምዳዊ መስኖ ዝፈሪ እቶት ንላዕሊ ይህብ፡

- እዚ ናይ ነጠብጠባዊ መስኖ፡ ብፍላይ ንደቅንስትዮ፡ ብዙሕ ጉልበትን ድኻምን ስለዘይሓትት፡ ዘድልዮ መባእታዊ ወጻኢታት'ውን ትሑት ስለ ዝኾነ፡ ባዕለን ብዘይ ዝኾነ ይኹን ሓገዝ ነቲ መሳርሒ ተጠቒመን መነባብሮአን ከማሓይሻሉ ከምዝኽእላ።

ካብቶም ከም ጸገማት ክጥቀሱ ዝኽእሉ ቐንዲ ነጥብታት ድማ፦

- ኣብ ዝተፈላለየ ቦታታት ዝርከቡ ሓረስቶት ጥቕሚ ናይዚ ናይ መስኖ መሳርሒ ይረዳኣዮም እምበር፡ ነዞም ሓረስቶት ኣዝዩ ሓድሽ ተክኖሎጂ ብምዃኑ፡ ሓረስቶት ነዚ ሓደሽቲ ዝተኣታተወ መሳርሒታት ናይ ምቕባል ሸውሃቶም ከምቲ ዝድለ ኣይነበረን። ንኣብነት ብዙሓት ሓረስቶት፡ ነተን መሳርሒታት ብናጻን ብፍርቂ ዋጋን ወላ እኳ እንተወሰድወን፡ ከምቲ ዝድለ ክጥቀሙለን ግን ኣይተራእዩን።

- እዚ ናይ ነጠብጠባዊ ናይ መስኖ መሳርሒ፡ ብፍላይ ኣብ ማይ ዋሕዲ ዘሎዎ ከባቢታት፡ ኣዝዩ ዘድሊ ድኣ ይኹን እምበር፡ ኣብ ኤርትራ ማይ ብወግዒ ዋጋ ስለ ዘይክፈሎ (ኣብ ገጠራት) ማይ ምቑጣብ ዝብል ኣምር ብዙሕ ምስ ገንዘብ ተታሓሒዙ ኣይጥመትን።

ኣብ መወዳእታ ክበሃል ዝከኣል ብሓፈሽኡ፡ እዚ ናይ ነጠብጠባዊ መስኖ መሳርሒ፡ ምስ ቑጠባዊ ኩነታት ናይ ኤርትራ፡ ኤኮኖምያዊ ትሕዝቶ ናይ ሓረስቶትን፡ ባህርያዊ ናይ ማይ ዋሕዲ ኩነታትን ተራእዩ፡ ብዙሕ ጥቕሚ ክህብ ዓቕሚ ኣለዎ። እዚ ክዉን ንክኸውን ግን፡ ልዕል ዝበለ ጎስጓሳትን መርኣያታትን ብወገን ምኒስትሪ ሕርሻ ናይ ገጠር ልምዓትን፡ ከምኡ'ውን ናይ ምርምር ትካላትን ኣገዳሲ እዩ።

5 Eritrea – A brief introduction

Eritrea is located in the eastern part of Africa at 12°42'N to 18°20'N and 36°30'E to 43° 20'E. It is bordered by Sudan in the West and North, Djibouti to the Southeast, the Red Sea to the East and Ethiopia to the South. The estimated total area of the country is 124,300 km² with a Red Sea coastline of more than 1,000 km. Administratively, Eritrea is divided into six *Zobas* with 54 Sub-*Zobas* and about 2,685 villages. The population is estimated at 3.5 million with a rural/urban ratio of 80% : 20%. One-seventh of the whole population live in the Capital, Asmara. Roughly 50% of the total population is below 18 years of age (FAO, 1994).

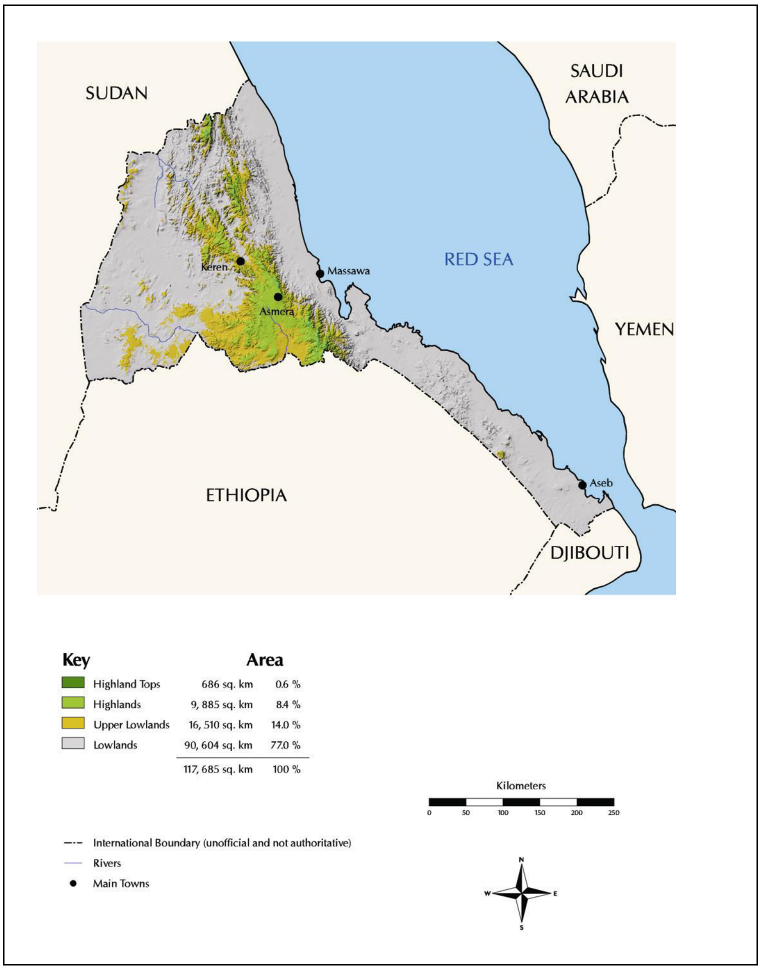

Figure 1: Map of Eritrea (Map by Andreas Heinimann, CDE)

The central area (indicated in green on the map) is known as the "Highlands" and its elevation is up to 2500 m. Fertile soils, moderate temperatures and the absence of malaria and other diseases make the Highlands an attractive settlement area for about 60% of the rural population. The central Highlands cover only 16% of the total area. Over-mining of natural resources, declining soil fertility, increasing erosion and enormous difficulties with the availability and quality of water are some of the current problems faced by the population due to this concentration in the highlands.

Erratic rainfall, frequent droughts and a growing population lead to a strong increase in the demand for water and the urgent need for more efficient use of this scarce resource. Mean temperatures vary with the agro-ecological zones, ranging from 25°C in the highlands to 40°C in the lowlands. Likewise, rainfall ranges from under 200 mm a year in the lowlands to 600-800 mm in the wet highlands.

The country is divided into six major agro-ecological zones. This classification is based on broad similarities of moisture and temperature regimes, natural vegetation cover, soils and land use. The major zones are divided into a number of agro-ecological units (AEU) on the basis of more specific differences in landform, soil type, land cover or land use. So far, about 55 agro-ecological units have been identified (FAO and MoA, 1998). Table 1 lists the major zones and their percentage cover in the country.

Agro-ecological zone	Coverage (%)
Moist highland zone	7.4
Arid highland zone	2.5
Moist lowland zone	16.2
Arid lowland zone	32.3
Sub-humid escarpment zone	0.8
Semi-desert zone	38.8
Total	100

Source : Agro-ecological Map of Eritrea, FAO and Ministry of Agriculture, Eritrea 1998

Table 1: Agro-ecological zones of Eritrea

5.1 Agricultural profile

Agriculture is the dominant sector of the Eritrean economy, engaging about 80% of the population. It contributes about 50% of the Gross Domestic Product (GDP), and accounts for 70% of the value of exports. Of the total population, 9% are pastoralists, 70% agro-pastoralists, while the rest are workers, traders and fishermen.

Of the total potential arable land of 12 million ha, the area presently under cultivation is estimated at 439,000 ha (3.6%), of which 95% is rainfed agriculture and 2% under irrigation (FAO, 1994). According to the World Bank (1994), there is a potential to increase the area under irrigation to 600,000 ha.

Horticultural production in Eritrea has a long history, starting with Italian colonisation and reaching a peak in the 1970s. During this time Eritrea had annual exports of horticultural goods. This was disrupted by the escalation of the struggle for independence. Since independence, the Ministry of Agriculture has constructed about 80 dams all over Eritrea to support and increase horticultural production.

Currently, landholdings of most farmers in areas where irrigation is possible are less than one hectare. Most small-scale irrigation farmers use furrow and basin irrigation systems for crops such as banana, citrus, papaya, mango, onion, tomato, pepper, potato and leafy vegetables.

As there are some fundamental ecological and social differences between the Highlands and the Lowlands that influence project procedures and effects, the two environments are briefly described below.

5.1.1 Highlands

The highlands, with an average elevation of 2100 m, are characterized by high temperature variation with nocturnal minimum values as low as 1 or 2°C in November, January and February, reaching about 35°C in September. Mean annual rainfall ranges from 500 to 700 mm. The farming system consists of rainfed cereal/pulse, irrigated horticultural crops, and semi-commercial peri-urban dairy/poultry production. The major staple crops are sorghum, wheat, millet, chick peas, lentils and a variety of vegetables and fruits. The soils in many regions are highly degraded and the average landholding per household is less than 2 hectares.

Figure 2: Eritrean highlands during the dry season.

The government of Eritrea, through its Land Proclamation No. 58 of 1994, has regulated the ownership of all kinds of land throughout the country. However, two distinct traditional land tenure systems are still widely practiced in the highlands: *diessa* and *meriet risty. Diessa* is a system where land use rights rest with the village. The land is classified as fertile, semi-fertile and poor, and each member of the village is entitled to plots in each category. Every 5 to 7 years, there is a redistribution of land. *Meriet risty* is family-owned land transferred from one generation to the next through inheritance. The owner is allowed to share the land with family members and even disinherit family members.

5.1.2 Lowlands

This is the largest agricultural region in Eritrea and is broadly classified into Eastern and Western Lowlands. Elevation ranges from 200 to 1500 m. The temperature varies from a monthly minimum of about 10°C in January to a maximum of nearly 50°C during the summer.

The Eastern Lowlands, with a mean annual rainfall of less than 200 mm, has flat or undulating fields with deep fertile soils. Crop production is mainly based on spate irrigation. This is a system where floods from the highlands are diverted to lower-lying fields by using simple soil, stone or brush-wood structures. The main crops are sorghum and maize, grown on residual soil moisture in spate-irrigated fields.

Figure 3: Western lowland area during the cropping season. This area is known as one of the breadbaskets of Eritrea, with high yields and fertile soils.

The Western Lowlands are considered the breadbasket of Eritrea, with an average annual rainfall of about 500 mm. The area is characterized by four main production systems:

1. nomadic pastoralism
2. semi-sedentary agro-pastoralism
3. settled farms with rainfed crop production and livestock breeding
4. large-scale fruit and vegetable production

The major rivers in Eritrea, the Setit, Anseba and Gash, flow through the Western Lowlands. Therefore water from open wells and bore holes along the riversides is available in a large area. The dominant land tenure system in the lowlands is *concessionaire farming*, where land ownership is for lifetime after having received the official recognition of land title. This includes also the right to bequeath a piece of land within the family.

6 The technology and the provider selected

Drip irrigation is generally not widely used on a global scale, and accounts for less than 0.1% of irrigated land worldwide. Affordable (low-cost) technology is even more recent, a response to the high initial costs of conventional drip irrigation systems. The new, affordable system attempts to retain the benefits of conventional systems while removing the factors that prevent their adoption by poor smallholders: purchase cost, the need for a pressurised supply, the associated pumping costs, and the complexity of operation and maintenance.

Micro (drip) irrigation technology leads to a slow and regular application of water close to the plants, wetting only the part of the soil in which the roots grow. Water can be applied on a daily basis, thus permitting retention of soil moisture content near field capacity, a condition very favourable for healthy growth of plants.

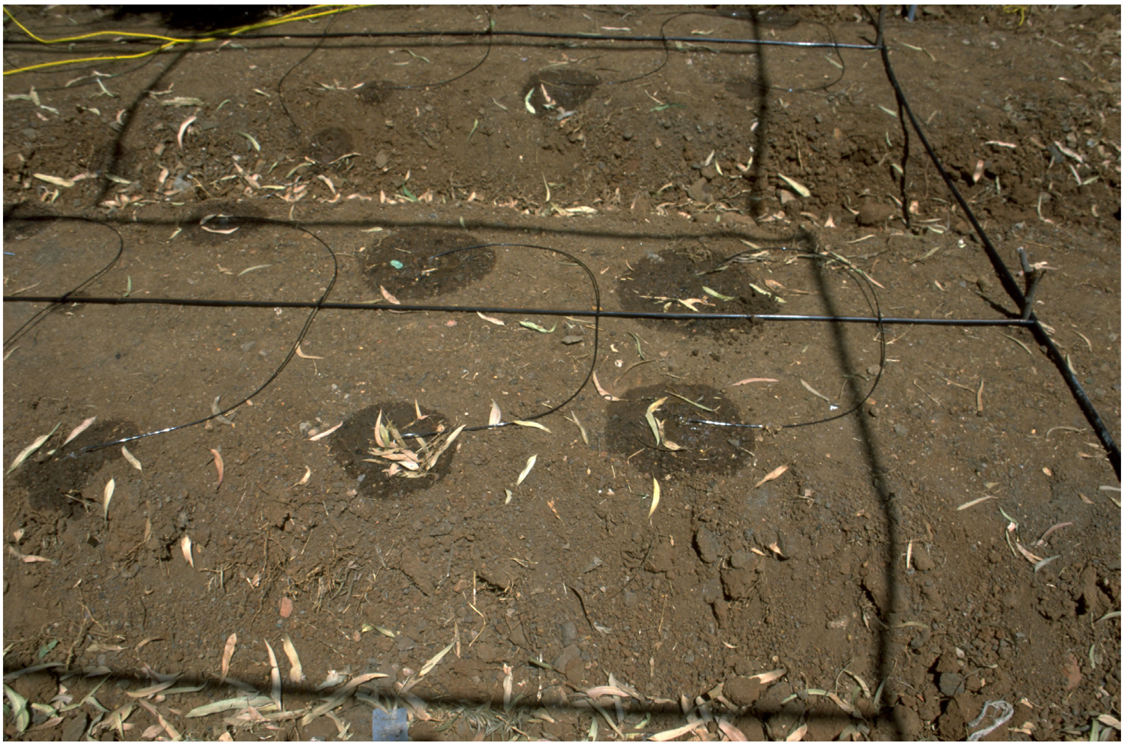

Figure 4: Typical elements of a micro drip kit, with main line, laterals, emitters and the wetting pattern on the soil.

Micro irrigation, despite its effectiveness in producing higher yields and high-value crops of good quality, has until recently been inaccessible to poor, rural smallholder farmers. This is mainly because of the high initial investment required (US$ 1000 to 3000 per ha), but is also due to non-adaptability to landholdings of less than one hectare. To overcome this problem, International Development Enterprises (IDE) played a leading role in developing a range of small, user friendly, "low-cost" micro irrigation kits. It is worth noting that "low-cost" does not imply low cost per ha, but rather refers to low initial capital outlay. The initial purchase of the number of irrigation kits required to cover one hectare is as costly as conventional drip irrigation systems. However, the kits are sold for areas ranging from 25 m² to 2500 m². This gives poor farmers the opportunity to start with a small piece of land and low initial investment, and gradually expand their irrigable area from the profits they make.

Several types of micro irrigation kits have been in use since 1995 in a number of countries, notably India, Nepal and Kenya. These include the Chapin bucket kit; Netafim family kits; and IDE bucket, drum and sprinkler kits. All these kits share several characteristics, i.e. a low-pressure head (0.5 to 4 m for drip and 10 m for sprinklers), movable low-cost pipes, easily adjustable micro tubes and sprinkler nozzles, low-cost filtration set-up with simple routine maintenance, and easily understandable installation procedures.

In summary, the major advantages of micro irrigation kits are: Low initial capital outlay; low water application rate (2 to 3 l/h with drip and 50 l/h with sprinklers), which permits maintenance of the soil near field capacity; water, nutrient and labour savings; high uniformity of water distribution (75 to 85%); increased yield and improved crop quality; applicability to a variety of vegetable, fruit, field and ornamental plants; suitability for irregular or undulating terrain; effectiveness on problem soils (slow water and frequent application minimize surface runoff and soil erosion in heavy soils, and reduce deep percolation losses in sandy soils); tolerance of salinity because the frequent application of water continuously washes the salts away from the effective root zone area; better control of diseases, as the stem and leaves of the plants are not wetted. The main disadvantage of the kits is the clogging of the micro tubes and the sprinkler nozzle.

6.1 International Development Enterprises (IDE)

IDE is an international NGO, established about 20 years ago in the United States. The overall goal of this organization is to alleviate rural poverty by developing and providing affordable technology to farmers. Its main geographical field of activity in recent years has been Asia, especially India and Nepal, and some African countries. One of the focal points of IDE's philosophy was the fact that water will become increasingly scarce for an increasing proportion of the world's population. Especially poor subsistence farmers – or smallholders with up to two hectares of land – will suffer in future from insufficient access to enough and safe water. To improve the situation of these farmers, IDE focuses primarily on poverty-level incomes, arguing that there is a fundamental connection to other aspects and causes of poverty.

IDE's approach can be described as follows: "Making effective use of technical knowledge and market information and developing stable linkages to output markets" by:

- Identifying **market opportunities** that can be exploited by poor people
- Developing **technologies** that the poor can use to generate income
- **Establishing supply chains** to deliver technologies to the poor at affordable prices
- Conducting **promotional campaigns** to convince smallholders to invest in income-generating technologies
- Ensuring that everyone in the market network, especially the smallholder, receives a fair **profit**.

IDE was a pioneer in developing affordable irrigation technology for small-scale farmers in developing countries. Since 1995 IDE has worked with farmers and irrigation specialists to develop systems fulfilling the requirements of small-scale farmers in India and Nepal. The fact that the construction of the kits is based on different stakeholders' experience was important in the selection of IDE as a hardware provider. The irrigation kits are produced locally in India by small-scale manufacturers. In addition to this we also benefited from the experience of an IDE consultant who joined the two first missions to Eritrea; he introduced the system and the changes in land use practices that are necessary to the team and to the farmers and institutions involved.

Table 2: Estimated market prices for different irrigation tools accessible in Eritrea. Only the Chapin kit is available on the market; both other kits are available only on project level.

Type of drip irrigation kit	Area under irrigation	Price per unit in Nakfa*	Price per 0.1 hectare in Nakfa
IDE bucket kit*	20 m^2	135 Nakfa	6750 Nakfa
IDE vegetable kit*	100 m^2	445 Nakfa	4450 Nakfa
Netafim family drip system*	500 m^2	3726 Nakfa	7450 Nakfa
(Chapin Watermatics) (selling price in offer)	500 m^2	3500 Nakfa	7000 Nakfa

* Price ex factory x 2 (for service charge, shipment costs, customs clearing) plus 15% retailer's margin)
All prices are partially based on estimations and approaches.
Exchange rate Nakfa : US$ = 13.5 : 1 in October 2001
Additional equipment (like buckets or barrels) is not included in the calculation

Ecologically the main advantage of the IDE equipment is that all parts of the kits are made of linear low density polyethylene (LLDP), a plastic that is harmless when it is burned. Most other systems are partly or completely made of PVC, which is very poisonous when burnt. Further technical information can be found in the article in Annex 2.

Since one of the goals of IDE is to provide quality equipment at affordable prices, the decision to select IDE irrigation equipment for the feasibility study was easy. But it is important to bear in mind that affordability is mainly a product of the size of the kit. An overview about what products were available in 2001 in Eritrea at what price is given in the rough estimation in Table 2.

An overview of the details of the kits used during the feasibility study is given in Table 3

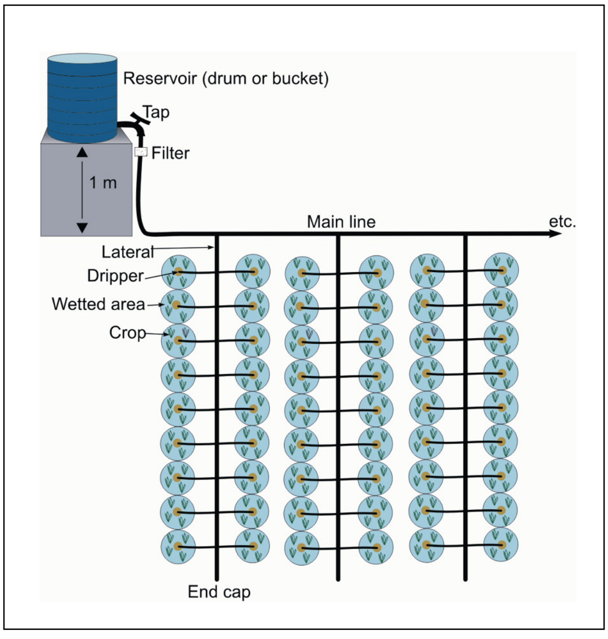

Figure 5: Main components of an affordable drip irrigation kit as developed by IDE. Source: IDE, modified by Ulla Gämperli, CDE

Table 3: Overview of the characteristics of the different types of IDE-kits distributed to farmers and institutions for the feasibility study.

Features	Kitchen garden kit (bucket kit)	Vegetable garden kit (drum kit)	Horticulture garden kit (drum kit)	Micro-sprinkler kit
Major components	Main line, lateral lines, micro-tubes, filter, pegs, fittings etc.	Main line, lateral lines, micro-tubes, filter, pegs, fittings etc.	Main line, lateral lines, micro-tubes, filter, pegs, fittings etc.	Main line, lateral lines, micro-sprinkler, filter, fittings etc.
Area under irrigation	20 m^2	100 m^2	130 m^2	160 m^2
Number of emitters	32	150	50	15
Approximate number of plants	32 to 128 for spaced crops; also used for row crops	150 to 600 for spaced crops; also used for row crops	50 for horticulture / orchard crops.	Mainly used for closely spaced crops
Required height of water source (minimum)	1 meter	1 meter	1 meter	10 meters
Discharge per emitter	2 l/h	2 l/h	2 l/h	50 l/h
Required content of water storage bin	Bucket with 20 l	Barrel with 200 l	Barrel with 200 l	Barrel with 500 l or connect to tap
Type of crops	Vegetable crops	Vegetable crops	Perennial fruit crops	Vegetables, flowers, pulses, cereals etc.

Resources were concentrated on the drip kits for the study project because sprinkler technology is different from drip technology and has a different field of application. Sprinklers also require higher pressure than the drip kits (10 meters (=1 bar) instead of 1 meter (=0.1 bar)). The general design of the kits and the most important components are shown in Figure 5.

7 The study

7.1 Aim and goals

The overall, long-term aim of this study (and its planned continuation) is:

To improve the livelihoods of Eritrean small-scale farmers by increasing agricultural productivity with an appropriate, feasible and affordable irrigation technology.

The goals of the study were:

- To assess technical feasibility and the need for change in the selected drip irrigation equipment.
- To assess the degree of acceptance of the technology by small-scale subsistence farmers and other users.
- To investigate the agricultural, ecological and environmental implications of adoption of the technology.
- To study social acceptance and affordability.
- To build up a network of stakeholders involved to promote irrigation technology in Eritrea.

7.1.1 Constraints

As the war between Eritrea and Ethiopia blocked personnel and financial resources at all levels in the country, it was often impossible to find resource persons.

Moreover, several project team members from the University of Asmara were offered opportunities to attend Masters or PhD courses abroad and had to be replaced. This always led to a loss of detailed knowledge.

7.2 Methodology and methods

The purpose of the initial mission in spring 2001 was mainly to identify stakeholders at all levels and to determine their interest and the possibility of their becoming involved in the project itself or at least in information exchange. This mission, known as a pre-feasibility test, was carried out jointly by CDE, CAAS and IDE India. Competent introduction to the technology and information about advantages and performance were the main topics. Initial alliances with partners, testing institutions and farmers were formed, and preliminary findings on the performance of the system and ways of addressing and instructing farmers were made. Dissemination of information, knowledge transfer and open interviews were the main activities. A brief, photocopied report on this mission is available at CDE on request.

In September 2001 the field test was initiated with the distribution of about 200 irrigation kits. The following selection criteria were used for the persons and institutions approached to test the kits:

- Different agro-ecological zones
- Male and female-headed farms
- Small- and medium-scale farmers (as defined in Eritrea)
- Availability of a local resource person to support the farmers
- Different income levels
- Urban and rural environments

As a methodological tool, an approach called "Poverty alleviation through market creation for the poor" was used. Support was given by Dr. Urs Heierli, of the imployment and income section of SDC. A detailed description of the approach can be found in: *Poverty Alleviation as a Business* (SDC, 2000). Since the time horizon of this approach is several years and many basic conditions must be fulfilled, it was impossible to follow the approach strictly.

Parallel to the distribution and introduction of the irrigation kits, the process of discussion and network building continued and an initial evaluation of local and regional markets was begun on the basis of interviews with farmers.

7.3 Field research

The different irrigation kits were thoroughly introduced to the farmers by a team of specialists, including one to two irrigation specialists and a horticulturalist. After the demonstration of the kits, farmers were encouraged to experiment with them and ask questions. In many cases, especially when farmers needed a customisation of the kit, or when farmers were uncertain how to install the kit, team members helped them to properly install the equipment on their fields. At least two follow-up visits took place by the end of the test and farmers were interviewed about the technical performance, the advantages and disadvantages, economic profitability, and growth performance of different crops. Thereafter a questionnaire was prepared and filled out by the team members.

A number of detailed questions and field experiments have been formulated for schools and were presented to the teachers in charge and the students testing the kits in two agricultural schools, and partly also to the Halhale Research Station.

7.3.1 Distribution points

The main focus was on the Highland areas where the population density is the highest and the size of landholdings per household the smallest. In addition, it was also important to have test sites in other agro-ecological zones to compare the results. Focusing on the differences in access and adaptation of the new technology between urban and rural environments was another important criterion for selection of the different study sites. The main places where kits were demonstrated are shown in Figure 6.

Figure 6: Map of Eritrea with sites where irrigation kits were distributed and tested. The sites are indicated on the map with a red X. Most of the sites are in the Highlands because the mean landholding size per household is smaller and population pressure in the highland areas is much higher.

7.3.2 Costs and pricing

As mentioned above, the terms “low-cost” and “affordable” refer mainly to the size of the kit and focus on the fact that farmers need less initial capital when introducing the new technology. Until now so-called low-cost systems are not widely reported in the literature, but FAO / IPTRID synthesised current knowledge in a report in 2001. The report concludes: “Low-cost systems attempt to retain the benefits of conventional systems whilst removing the factors preventing their uptake by poor smallholders: purchase cost, the requirement of a pressurised supply, the associated pumping costs and complexity of operation and maintenance.”

Importing kits in small numbers and by plain increases remarkably the trading costs per unit. In addition farmers take over a risk of failure when testing the new technology. Therefore most kits were distributed at a subsidised price of half the total paid costs. In detail the price was fixed as follows:

Table 4: Sale prices for the kits sold during the feasibility test to farmers. Farmers not willing or able to pay the required amount could hire kits for the duration of the test. The kits were then re-collected by the team.

	Bucket Kit	Drum Kit (vegetable and horticulture)	Sprinkler Kit
Price (in $) at manufacturer's door	5	16	21
Plus service charge in India, 10% of net price	0.5	1.6	2.1
Plus shipment costs (in this case with air freight) 60% of net price	3	9.6	12.6
Plus customs clearing in Eritrea, including transport costs etc., 10% of net price	0.5	1.6	2.1
Total cost per set (in $)	9	28.6	37.6
Full cost per set in Nakfa (exchange rate = 1 : 13.5 in October 2001)	121.5	386.1	507.6
Subsidised price per set in Nakfa (higher initial risk = +/- half price)	60	200	250

8 Assessment by study areas

The presentation of results is divided into two parts, one part discussing the results of the tests made by institutions, the other part discussing the experience farmers made on their private fields when testing the different irrigation kits. A more detailed assessment was possible with institutions, especially when it came to more scientific questions.

8.1 Assessment of kits in institutions

8.1.1 Halhale research station

The Halhale Research Station belongs to the Ministry of Agriculture (MoA). It is located in Zoba Debub, Sub-Zoba Dbarwa, about 35 km south of the capital, Asmara, on the road to Mendefera, at an altitude of 2100 m. Annual rainfall ranges from 500 to 700 mm and the temperature varies from 0°C on the coldest days in January to days with up to 35°C in July and August. The soil in the area is sandy loam.

A comparative performance assessment of drip and furrow irrigation was done in the Research Station. Potato (variety from Togo), green pepper, and lettuce were tested with drip irrigation as well as with furrow irrigation. Field size and plant density for both irrigation techniques was similar. The growing period for all crops except lettuce was approximately three months. Just before harvest, heavy rainfall destroyed the tomato and green pepper fields. Due to the failure of the water pump, the lettuce trial could not be finished. Therefore a comparison between the total yields from fields irrigated with drip and furrow irrigation was not possible.

In the successfully completed potato trial, the indicators measured were yield per plant, yield per plot, and water use efficiency. In this report, the term "plot" refers to the areas covered by the respective kits, which are 20 m^2 for the bucket kit and 130 m^2 for the horticultural drum kit. Water consumption on the potato plots is given in Table 5, where it is visible that the total amount of water applied with the irrigation kit is less than half of the water used for furrow irrigation.

Table 5: Comparison of total water consumption on two 20 m^2 potato fields, one with furrow irrigation and one with drip irrigation.

Irrigation system	Litres of water/day			Total amount of water (litres)/ growing period
	1st month	2nd month	3rd month	
Drip irrigation by bucket kit	60	60	80	6,000
Furrow irrigation	174	174	174	15,660

*Table 6: Comparison of yields on two 20 m² potato fields, with drip irrigation. Soil was loosened up on one field and untreated on the other field. *One plant is grown per micro tube outlet. The bucket kit has two lateral pipes, each with 16 micro tubes, 8 on either side.*

With loosening of the soil				Without loosening of the soil			
Microtube outlets*	№ of tubers per plant	Total wt of tubers in g	Average wt /tuber in g	Microtube outlets*	№ of tubers per plant	Total wt of tubers in g	Average wt /tuber in g
1	4	150	37.5	1	9	200	22.2
2	5	200	40.0	2	4	100	25.0
3	6	250	41.7	3	6	100	16.7
4	5	200	40.0	4	9	200	22.2
5	4	200	50.0	5	12	150	12.5
6	11	200	18.2	6	8	400	25.0
7	3	100	33.3	7	15	250	16.7
8	5	100	20.0	8	10	200	20.0
9	5	200	40.0	9	6	100	16.7
10	3	150	30.0	10	7	150	21.4
11	7	250	35.7	11	10	150	15.0
12	5	100	20.0	12	6	100	16.7
13	6	200	33.3	13	8	200	25.0
14	5	100	20.0	14	6	100	16.7
15	3	200	66.7	15	–	–	–
16	8	200	25.0	16	10	200	20
Total	70	2800	34.5	Total	126	2600	19.5

The following can be concluded from Tables 6 and 7:

- Under drip irrigation, soil treatment (loosening up) does not significantly influence the total yield, but it decreases the number of tubers and increases the tuber size by about 40%.
- Loosening the soil under furrow irrigation increases the total yield as well as the tuber size by about one-third.
- When the soil is not loosened up, the total yield under drip irritation is about 40% higher than that under furrow irrigation.

Table 7: Comparison of yields on two 20 m^2 potato fields, with furrow irrigation. Soil was loosened up on one field and untreated on the other field.

With loosening of the soil				Without loosening of the soil			
Plant №*	№ of tubers per plant	Total wt of tubers in g	Average wt /tuber in g	Plant №*	№ of tubers per plant	Total wt of tubers in g	Average wt /tuber in g
1	3	100	33.3	1	7	150	21.43
2	2	50	25.0	2	9	50	5.56
3	5	300	60.0	3	7	200	28.57
4	4	50	12.5	4	4	100	25.00
5	9	650	72.2	5	5	150	30.00
6	10	100	10.0	6	6	150	25.00
7	6	100	16.7	7	–	–	–
8	2	25	12.5	8	–	–	–
9	6	300	50.0	9	5	150	30.00
10	3	200	66.7	10	5	100	20.00
11	7	100	14.3	11	4	150	37.50
12	8	200	25.0	12	3	50	16.67
13	–	–	–	13	8	200	25.00
14	4	100	25.0	14	–	–	–
15	2	25	12.5	15	–	–	–
16	–	–	–	16	–		–
Total	71	2300	31.1	Total	63	1450	24.1

* The numbers indicate the location of the plants in the four furrows, with the numbers "1" and "9" indicating the upstream plants. Each number refers to a single plant. The spacing between the plants is exactly the same as that in the bucket drip kit.

Observations made by the research station

- There was a severe clogging problem due to suspended sediment and salty water. The time needed to clean the micro tubes was almost the same as the time spent weeding the furrow-irrigated plots.
- Although the same varieties were used on both fields, tomato sizes were much smaller under the drip system, while green peppers were much bigger.
- The potato tubers were small (Tables 1 and 2) under both the drip and furrow irrigation systems. It was suggested that this could be due to the variety, as the potato used was under a variety trial.
- There were no diseases and/or insect infections.
- The sprinkler kit was not tested due to lack of pressurized water supply. The available ¾- and 1-inch diameter taps that fit the main line of the sprinkler could not generate the required pressure to make the sprinklers fully operational.

8.1.2 Hamelmalo agricultural school

Figure 7: Students at the agricultural school in Hamelmalo during a demonstration of the bucket kit.

Hamelmalo Agricultural School is situated about 20 km northeast of Keren in the Anseba *Zoba*, Halhal Sub-*Zoba*, at an attitude of 1360 m. Mean annual rainfall ranges from 300 to 500 mm. The temperature fluctuates between 20 and 35°C. The soil texture is sandy loam with a slightly alkaline pH of 7.4.

The school tested and compared the performance of drip and furrow irrigation systems. Eggplant and sweet pepper were tested with the bucket kit, papaya with the horticultural kit, and tomatoes were grown with the vegetable kit. The criterion for comparison was the yield per plot (see Table 8). The school also tried to evaluate the performance of a sprinkler irrigation kit by growing *girgir* (*Eruca sativa*), but due to lack of permanent pressurized water supply, the trial failed.

Table 8: Comparison of the total yield [in kg per field] from similar sized fields with drip- and furrow irrigation

Crop and field size	Furrow irrigation	Drip irrigation
Eggplant (field size: 20 m² each)	3.1 kg	5.5 kg (bucket kit)
Sweet pepper (field size: 20 m² each)	7.0 kg	4.4 kg (bucket kit)
Tomato (field size: 100 m² each)	23.2 kg	29.4 kg (vegetable kit)

From the table above it can be deduced that:

- The eggplant yield was 45% higher under drip irrigation than under furrow irrigation.
- Compared to the yield under furrow irrigation, the yield of tomato under drip irrigation was about 20% higher.

- About 40% more sweet pepper was harvested from the field under furrow irrigation.

Papaya trees were tested, and although the vegetative growth of the trees was good in the beginning, they showed poor development during the later stages, resulting in a smaller size compared to the same variety of papaya irrigated by surface (micro-basin) irrigation. The increased demand for water with increasing papaya plant size was not taken into consideration, as the amount of water applied was held constant with the drip irrigation kit. This may explain the poor plant development.

Observations made by the school

- There was a severe clogging problem, which required almost daily follow up.
- The wetted areas of the micro tubes overlapped, forming a continuous wet bund.
- The water distribution uniformity was good.
- The T-joints broke frequently and easily.
- The major disease observed was a worm attack on tomatoes. Unfortunately, there is no information about the frequency observed under the different irrigation technologies.
- Sheep and cattle damaged crops because the fields were not fenced.
- A sprinkler irrigation trial was discontinued because pressurized water was not permanently available.
- Weed control was easier with the drip system and cut the labour requirement to almost one third.

Recommendations made by the school

- The size of the bucket filter should be enlarged to help minimize clogging.
- The micro tubes should be directly connected to the laterals, instead of being fitted via T-joints.

8.1.3 Hagaz agro-technical school

The Agro-Technical School is located in Hagaz, the Capital of the Hagaz sub-*zoba*. It belongs to the Anseba *Zoba* and is 29 km from Keren on the main road to Aqordat. It is at an altitude of 880 m. The minimum temperature is around 10°C, the maximum temperature around 47°C. The average annual rainfall is 300 to 500 mm. The soil type is sandy loam.

As part of their fieldwork the students compared the drip and furrow irrigation systems mainly to study yield and water efficiency (see Tables 9 and 10). The crops planted were tomato, eggplant and okra under drip irrigation and alfalfa using the micro sprinkler kit. Due to lack of sufficient pressurized water supply in the area allocated for the trial, not all of the 15 sprinklers could be operated simultaneously. This led to the running of only 9 sprinklers at a time. The frequent malfunctioning of the sprinklers (not making full circle rotations with the optimum of 1.5 m radial coverage) and later, a complete operational failure of three sprinkler nozzles, led to the discontinuation of the trial.

Figure 8: Hagaz Agricultural School students during the on-field experiments.

Table 9: Yield comparison between drip and furrow irrigation (field size for all crops was 20 m² each). This Table reveals that the yield of all crops was better under furrow irrigation.

Crop	Yield on furrow irrigated plot	Yield on drip irrigated plot
Tomato	1.4 kg	0.9 kg
Egg-plant	1.6 kg	1.5 kg
Okra	6.0 kg	3.6 kg

Table 10: Rough comparison of water use efficiency between drip and furrow irrigation; tomato trial.

Application period	Applied water (litres)		Percolated water (litres)		Water used by crops (litres)		Water use efficiency (%)	
	Drip irrigation	Furrow irrigation	Drip irrigation	Furrow irrigation	Drip irrigation	Furrow irrigation	Drip irrigation	Furrow irrigation
1st – 38th day	1,400	26,000	600	18,000	800	8,000	60	30
39th–75th day	2,700	50,000	1,200	42,000	1,500	8,000	55	16

The students were able to calculate roughly the water use efficiency of tomatoes under drip and under furrow irrigation (see Table 10). The calculation does not include different terms of losses like operational losses (amount of water used for flushing of the main and lateral pipes and micro tubes; cleaning of the filters), leakage of tap and filter, evaporation losses. Evaporation loss from drip-irrigated field, when compared to that under surface irrigation, is negligible. However, it still deserves consideration, particularly in places like Hagaz, where humidity is low, strong winds are frequent and the temperatures are hot.

Observations made by the school

- There was frequent clogging in almost all the drip kits during the first two to three weeks after the installation, calling for continuous inspection and cleaning, but later the problem was less serious.
- The sprinkler nozzles were also frequently clogged and three sprinklers completely stopped functioning.
- The maximum depth of water percolation was 80 cm under the drip kit but 150 cm in the field under furrow irrigation.
- The diameter of the wetting pattern of the micro tubes was about 26 cm during the first month, increasing later to nearly 38 cm; towards the end of the growth stage (90 days and later) the wetted areas of the micro tubes overlapped, resulting in a permanently wet strip of land.
- The size of the bucket kits was too small for almost all the irrigated fields and even for the backyard plots.
- The spacing between the lateral lines was too big, resulting in a large unproductive area. (This is because only one crop per outlet was planted instead of up to four plants per outlet as recommended).
- The major diseases and insect pests were tomato blight, aphid, leaf miner, leaf curl, white flies, termites and stalk borers. Their impact was severe under furrow irrigation, but caused only minor damage under drip irrigation with the bucket kit.
- During the whole growing period, the bucket kit plots needed to be weeded twice only, as compared to six times on the furrow-irrigated plots.
- The labour and time needed for land preparation for drip irrigation was negligible compared to that for furrow irrigation.
- The drip-irrigated fruit were smaller in size, with the exception of okra.
- Given the windy and hot climate of Hagaz, sprinklers are not recommended. A greater portion of the sprayed water is lost due to evaporation before it reaches the soil surface. Four bucket kits were also blown away by strong winds.

Recommendations made by the school

- As there is strong wind in Hagaz, additional support is needed to hold the kits firmly on the ground.
- A vegetable kit is preferable to a bucket kit merely due to its bigger area coverage.

8.2 Assessment of kits in farmers' fields

For a description of the environment at the first site, please see the respective section in the chapter entitled "Assessment of Kits in Institutions"

8.2.1 Hagaz

Besides the school trials, the study team organised with the help of the sub-*zoba* Ministry of Agriculture staff also two demonstrations for farmers. The interest of farmers was so great that seven sprinkler kits and two bucket kits were sold on the spot. The farmers wanted to use the sprinkler kit for onion seedling production. However, during the follow-up visits, most of the sprinkler kits were not installed and some of the farmers indicated that they bought the kit to make extension workers at the Ministry of Agriculture happy.

They also explained that their fields are bigger (mean land holding size per family in the area: 2-3 ha) and the kits were identified as too small. An NGO is currently testing Netafim family kits in the area, covering an area of 500 m^2. It will be interesting to study the performance of these kits and the argumentation concerning the size of the kits.

8.2.2 Aqordat

Figure 9: Typical farm environment in Aqordat

Aqordat is one of the main towns in Eritrea, located about 172 km west of the Capital Asmara at about 600 m. The climate is hot and dry, with temperatures reaching up to 50°C. The rainy season is from July to September, with a mean annual rainfall of 300-500 mm. The surroundings of Aqordat are well known for fruit and vegetable production. Land tenure is different from the *dessa* system in the Highlands (*concessionaires,* see description of Lowlands*)* and mean landholding size is bigger. Because of the high temperatures and the frequent winds, evapo-transpiration is very high and therefore flood and furrow irrigation practices are common among farmers. In spring temperatures are too high for most agricultural activities, even under irrigation.

In spring 2001, a farmer who grew mainly fruits was visited and given an introduction to the handling of drip irrigation and sprinkler systems. The farm has a well and the water is pumped up with a motor pump and distributed through a pressurised tube system to the fields. The demonstration kits were too small because of the large fields. Nonetheless, the farmer was interested in the sprinkler kit for forage production. He connected it to a tap to get enough pressure. During the follow up visit, the team reported that dogs and birds were bathing in the irrigation canals and lying in the sprinkled forage area. According to the farmer’s son, the sprinkler provides a cool micro-climate for the animals lying in the wetted area. This caused physical damage to the sprouting seedlings. In a second attempt, the farmer used the kit to raise tomato seedlings in a different place and was successful.

8.2.3 Barentu

Barentu is the main town in Gash-Barka Province. It is located about 230 km west of the capital of Asmara and lies at about 1000 m. The climate is hot and dry with temperatures reaching 40°C. The rainy season is from July to September, with a mean annual rainfall of 400-700 mm. During the months of April and May, water is scarce and temperatures are high; almost all agricultural activities cease.

Traditionally the area is better known for livestock breeding than for fruit and vegetable production. Recently, some farmers rehabilitated and enlarged some old farms and established irrigation systems to boost fruit and vegetable production. One of these innovative farmers was visited and the horticultural kit was demonstrated. The farmer grows vegetables and fruits in basins, with papaya trees along the borders of the terraces. Therefore the team suggested intensifying papaya production by using the irrigation kits. A horticulture kit was customised and adapted to the field. The length of the laterals was doubled but the total area covered by the kit remained the same.

Figure 10: Barentu has suffered increasingly from water scarcity in recent years. Therefore vegetable and crop farming is along the (ephemeral) riverbeds.

The papaya plants performed well and vegetative growth was excellent during the follow up periods. The farmer was impressed to see the plants growing successfully at that time of the year. However, after re-organisation of the farm (periodic removal and reconstruction of terraces), the kit was not re-installed (also because parts of the kit were removed by floods in the previous rainy season) when the last follow up took place. The farmer mentioned lack of knowledge about how to customise the kit and lack of professional support as factors. In the meantime, the kit was re-installed by team members and information about agronomic practices and maintenance was offered. The flourishing papaya trees also caused some interest among neighbouring farmers.

In addition, one bucket kit and one vegetable kit were installed in the eye clinic of the Barentu Hospital. The vegetable kit was customised to fit the existing garden so that patients and visitors at the hospital had a chance to observe the new technology. Both kits were successfully used to grow flowers. The garden of the new eye clinic has now been offered as a demonstration site to grow flowers, vegetables and fruits. Since patients often wait for hours it is possible to demonstrate the new technology to many different farmers.

8.2.4 Adi Keih and surroundings

Adi Keih is a town in the south-eastern highlands of Eritrea, at about 2400 m. Since the Italians introduced intensive vegetable growing in the area, furrow and basin irrigation are widely used along riverbeds. The vegetable growing areas are 200-300 m lower than the town and benefit from moderate temperatures and a mean annual rainfall of 500-700 mm.

Figure 11: The vegetable fields under traditional irrigation are situated along the riverbeds and often lie 200-300 m lower than the town of Adi Keih itself.

Mean landholding size per household for vegetable growing is about 2-3 ha. For most of the year, the fields along the riversides are irrigated. During the rainy season vegetable production stops because of low market prices and colder temperatures, and the season is used to help the soil recover during the short fallow period. The limiting climatic conditions force farmers to grow salad, cabbage and carrots during the colder season. During the warm season tomatoes, peppers and potatoes are the main crops. Local market saturation with the respective vegetables is often high and in good years market prices are low.

Traditional staple food (cereals and peas) are grown further away from the waterways during the rainy season, when the vegetable growing area is under fallow.

During two visits all types of kits were demonstrated to individual farmers and extension workers from the Ministry of Agriculture. A sprinkler kit was demonstrated and installed on Meri Gida Farm, which belongs to the Eritrean Disabled Association. The farmers were very interested in the kit. A new tap was installed especially for the kit and the pressure was high enough to run the sprinkler. The sprinkler was used in a nursery where different types of vegetable seedlings were raised. A follow-up visit showed that all sprinklers were working properly and the vegetables were growing perfectly. During the rainy season the kit was dismantled and correctly stored for use in the next season. This group of farmers is very interested in learning more about the technology and the agronomical practices needed to grow vegetables and alfalfa successfully.

In Adi Uegera two vegetable kits were installed on furrow-irrigated fields and used mainly for demonstration purposes, as the field is bigger and motor pumps distribute the water to the fields. For the two farmers, it was an additional effort to maintain the drip irrigation kits. Both farmers installed the kit in May and replaced part of the area under furrow irrigation with drip irrigation. Tomatoes, peppers, salad and cabbage were grown on the two fields. The follow up discussion with the two farmers revealed the following:

- More vegetables per outlet could have been grown on both fields.
- Once installed, both kits worked properly and water distribution was uniform.
- Barrels are rather expensive and one broke where the tap is located (barrels are produced locally and the quality is not entirely satisfactory).
- Both farmers did not understand the manual and installation was difficult for them.
- The drippers were installed in such a way that the tubes were too tightly stretched, thus creating a source of problems. Outlets were placed directly above the plants; this should be avoided because it causes insufficient oxygen availability for the plants.

Neither farmer customised the kit or used the cloth enclosed to pre-filter the water. In one kit clogging with soil particles occurred, but cleaning was easy; the particles were removed by blowing out the drippers. Farmers expect increasing problems with clogging in future because the water is salty (two irrigation water samples from Adi Uegera and Adi Keih were analysed in Eritrea. Results: groundwater in Adi Keih = 11.8 mS/cm and a pH of 7.6; open well in Adi Uegera: EC = 16.5 mS/cm, pH = 7.1. According to the FAO classification both samples must be classified as slightly saline).

Cabbage production failed because of water scarcity during the growing period. This was not limited to the fields under drip irrigation as the whole area was affected.

The local extension worker from the Ministry of Agriculture who introduced the farmers to the technology had many questions about the handling of the kit and the changes necessary in agronomic practices. He was one of the few employees from the Ministry of Agriculture who promoted the technology and supported the two farmers intensively.

Two bucket kits were installed in backyards in Adi Keih. One was used for flower production, the other to grow maize. No follow up of the one with flowers was carried out because the family was absent at the time of the survey.

The bucket kit used to grow maize was customised to fit the house garden. Every time water was applied, part of the micro tubes was moved in order to water all the plants in the garden. A first visit revealed that the maize plants were very uneven in size but since the owner did not know how much water was applied, it is not clear whether this was the effect of water stress because of insufficient application or whether it was caused by irregular movement of part of the micro tubes. After instructions were given about checking how much water is needed, the maize plants grew well and developed large cobs. The farmer also mentioned changing soil qualities within the field because part of the area was once a chicken farm. No fertilizer was applied and only one plant per outlet was planted. Water was bought for 2.5 Nakfa per barrel every three days from a water tank. The water is not salty and no clogging has occurred so far (the kit had been installed for one year when the follow up took place). The owner is not a farmer and his backyard is the only area where he can grow vegetables. The area covered by the kit (20 m^2) was thought to be too small for real subsistence production.

8.2.5 Shiketi

Shiketi is located about 20 km south of Asmara. The very first kit distributed in Shiketi was installed in a farmer's house garden (*gedena*). The area was protected by an expensive fence, including a good structure to fix the bucket. The woman of the house managed the garden and the children were responsible for fetching water by donkey from a well more than 1 km away. Lettuce was grown, which performed very well. Only few plants had to be replaced later on. The woman said she liked the kit very much as it increased food diversity and food security, and that most of the yield she got was used for home consumption.

The fence was installed because the garden was in the middle of the village and chickens picked the seedlings. But material and construction costs in cash and kind are much too high to recommend such protection.

The distance to the watering place and the time needed for fetching additional water were among the constraints mentioned. During the first rainy season, the kit was removed and later on it was not re-installed. The reason given was that it is more than one hour of additional work for children to fetch water, which is too great a workload for them during school-time.

8.2.6 Dbarwa

Dbarwa is one of the large villages on the road from Asmara to Mendefera. In Dbarwa, none of the kits have been installed so far. The local office of the Ministry of Agriculture, responsible for demonstrating and installating the kits argued as follows:

- The kits are too small. Mean landholding size in the area is between 0.5 and 2 ha and minimum size required is said to be 0.25 ha (2500 m^2).
- The demonstration site of the MoA was closed last year.
- Many farmers own a water pump and are therefore only interested in pressurised irrigation.
- There is a shortage of water.
- Farmers do not want to invest time and labour in a new technology.
- Because a representative of the MoA accompanied the team during the presentation of the kits, some farmers bought the set to make officials happy.

The discussion following this list of reasons brought the following results:

- Can the additional labour be paid by the local office and is the MoA willing to demonstrate the kits on a demonstration field within the compound of the office building?
- Lack of knowledge is most probably the main reason why extension workers did not demonstrate the kits and farmers did not test the kits.
- The risk of investing time and labour in an unknown technology was too high for farmers (which is not logical in relation to the arguments of mean landholding size and larger size needed because of pumps).

8.2.7 Mendefera and surroundings

Mendefera is located 56 km south of Asmara on the Highland plateau and is one of the better known areas for crop production. Climatic conditions are similar to those in Halhale.

Figure 12: Experts in Adi Mongonti: Two scientists, a farmer's wife and the leader of a women's self-help group discuss the technology in a drip-irrigated backyard garden. For security reasons the kit is stored in the house and installed only for the time of irrigation.

One bucket kit was demonstrated and installed in a gardener's compound. At the beginning, he feared that there wouldn't be enough water from such kits for his vegetables but he was very keen to see how the kit worked. The kit was properly installed and the gardener grew peppers. After transplanting the pepper plants the gardener was sceptical that the seedlings planted at a certain distance from the outlet of the micro tubes could get enough water. However, he observed that these seedlings performed better than those he planted close to the micro-tubes. The peppers grew very well and he reaped a considerable amount of pods from the irrigated plot. The yield as compared to the pepper plots in the backyard with furrow irrigation was almost double. The gardener liked the system very much and is now keen on getting larger kits for vegetables. So far he has used the kit for three cropping cycles and reported that time saving compared to traditional furrow irrigation was about 50 % (less labour, less weeding, less water to carry).

Because of the strategic position of the town this farmer profited from more visits by the research team. This was probably also a main reason for the good results he got. In turn, these repeated visits were of course also influenced by the gardener's interest and responsibility.

A local women's self-help group took the initiative of encouraging some of the women in the area to test the new technology. This led to two bucket kits being installed in Adi Mongonti, approximately 6 km from Mendefera. Instructions and follow up was also done by the group. One of the women who tested the technology was very successful even though it was her first contact with irrigation. After a short time she customised the design by planting a second field with additional crops and shifting the kit every day. The lady however had to remove the kit every evening and re-install it in the morning, because of security problems. The yield is used for home consumption and surplus will be sold on the market.

Water is carried from a nearby well by donkey, but during part of the year additional water must be bought for 4 Nakfa per barrel. This might influence the perception of water as a limited resource and increase the motivation to evaluate water-saving technologies.

In Adi Zarna one vegetable kit for seedling production and one bucket kit for peppers were installed successfully. The woman from Adi Mongonti instructed the newcomer on her own initiative. Since this was an unexpected follow up reaction of a satisfied tester, kits were properly introduced. Due to recent installation of the kit, a follow up is not yet possible.

In Maado, a village near Mendefera, the kits were demonstrated to the local office of the Ministry of Agriculture and some model farmers. One of these farmers, who also has a demonstration site for trials introduced through the Ministry, bought one vegetable kit but never installed it. Asked for the reasons he mentioned lack of agricultural knowledge and wrong size of the kit.

Two water samples were analysed. The sample from Mendefera has an electrical conductivity of 25.5 mS/cm, and the sample from Adi Mongonti a conductivity of 25.3 mS/cm. Interestingly there was no complaint about clogging, even when the results allow to expect that sooner or later such problems could occur.

Some kits demonstrated in Adi Quala and left with the responsibility of the Ministry of Agriculture were not distributed. The extension workers felt there were not enough additional incentives.

8.2.8 Adi Jemel

Adi Jemel is a remote village situated on the southern escarpment. In this area only one farmer is familiar with irrigation at all, using a motor pump and furrow irrigation. He gaines the necessary knowledge when he went to the market; no followers were found in the village until now.

A bucket drip irrigation kit was demonstrated to farmers. The interest was high and farmers asked many questions, mainly about the technical performance of the kits and about land management practices. After demonstration the kit was left in the village for a test, but the remoteness of the village made a follow up impossible until now.

8.2.9 Afdeyu

Afdeyu is about 20 km north of Asmara, not far from the main road to Keren. Since 1984, the University of Berne has been supporting a soil and water conservation research station managed by the Ministry of Agriculture. Therefore, access to farmers for a demonstration through the local research assistants was easy.

Figure 13: In the few past years, farmers in Afdeyu started to irrigate small plots to sell vegetables on the roadside along the main road from Asmara to the north.

Land use pressure in this area is very high and mean landholding size for most farmers is less than one hectare. Therefore, during and after the presentation farmers had intense discussions about the income they may get from the kit. Immediately after the presentation many farmers expressed the wish to test one kit (either the bucket kit or the vegetable kit). About 10 kits were left with the assistants of the research station for testing. It was therefore surprising for the follow up team that none of the kits was installed. Reasons given by the research assistant were that the quality is not good enough, that the size of the kits did not fit farmers fields, that buckets or barrels were not provided (but even the two barrels left in Afdeyu at the research station were not used), etc. Since the names of the farmers originally interested in testing the kits were not known to the team a direct interview with these farmers was not possible.

8.2.10 Gaden, Ala Valley and Maihabar

Gaden is located 17 km from Dekemhare and connected with an asphalted road to the Highlands. It lies at about 1400 – 1600 m asl, normally benefits from sufficient rainfall and is one of the major citrus production areas in Eritrea. Farmers are also involved in vegetable production, mainly tomato and pepper.

Figure 14: Discussion in a drip-irrigated field where tomatoes are grown in Ala Valley. The area is well known for intensive agricultural production.

During the first visit, a horticulture kit was demonstrated on a farm that belongs to five brothers. They were more interested in the vegetable kit instead of the horticulture kit (designed for fruit trees) because of landholding problems (*dessa*). A vegetable kit was left with the farmers, but when they unpacked it they noticed that the main line was missing and could not install the kit.

One bucket and one sprinkler kit were installed on a farm that belongs to Catholic Brothers. The kits work very well. Onions and tomatoes were grown successfully with the sprinkler kit and the bucket kit was used for garden flowers. The woman who takes care of the kits told the team that the kits save both labour and time. In simple terms she mentioned “I can do other household activities while irrigating my vegetables and flowers.” The farmer responsible intends to use the kit for seedling production because there is a high demand (and a good price) for citrus seedlings.

During the follow-up some farmers objected: “just leave us with what we have. Introducing a new technology might increase the attractiveness of our region and we have water problems”. Arguments that this is a water-saving technology didn’t convince them because they feared that the new technology would not only replace traditional furrow irrigation but cover new areas and enlarge the size of the total irrigated area.

The high initial costs hinders many farmers from producing citrus fruit. Field visits also showed that the horticulture kit can only be introduced with freshly planted trees, because the distance between the outlets normally does not fit the distance between the trees. It is therefore recommended that a horticulture kit be designed with which the installation can easily be done to suit the spacing between trees.

In Maihabar, a bucket kit and a vegetable kit are used to grow orange seedlings. Since this happened recently evaluation was not yet possible. A short visit revealed that the plants are growing well, but that only one seedling per outlet was planted.

8.2.11 Gahtelay and Mensheb

Gahtelay is located in the footzone of the Escarpment on the road from Asmara to Massawa and is permanently settled. A collective farm partly equipped with a pressurised drip irrigation system was used as a demonstration site. When the last land re-distribution began, problems arose with the irrigation system that had been installed because the new shape of fields did not fit the layout of the installation. Moreover, some of the farmers lost direct access to distribution nodes and thus also their freedom of choice in agricultural questions.

Mensheb is situated in the Eastern Lowlands near the Red Sea coast. The annual rainfall amount and high temperatures make it impossible to grow rainfed crops; water shortage is a common problem in the region. Since it is too hot during part of the year in this region, temporary settlers grow crops under spate irrigation. In spate irrigation water comes from the Highlands and is diverted to the fields where it infiltrates into the deep soils. Sorghum is then grown on the fields with the residual water.

The presentation and demonstration of a drip irrigation kit showed that for the time being, the area and the current land use system are not suitable for the introduction of micro irrigation technology. First, during part of the year the population lives in the Highlands or along the Escarpment, and permanent installations are not required. Second, the land use system (spate irrigation) has been known for over 100 years in the region and is well adapted to environmental conditions. If the Eritrean resettlement programme is successful in Mensheb, there might be an interest in kits for vegetable production in backyard gardens.

8.2.12 Urban areas

Some 20 bucket kits were sold in urban areas. Since most of the owners were friends or relatives only little data are available. However, some bucket kits were installed and properly used, and allow to conclude that they are suitable to urban backyards.

Most of the bucket kits were used to grow herbs, spices, flowers or vegetables. Often customisation of the kits took place to fit the installation to the shape of the home garden. Two sprinklers were sold and used to irrigate grass in gardens. Both are connected to taps and are working perfectly. One of the persons reported the following observations and problems:

- Saves time and energy in gardening;
- Frequent problems with breaking T-joints;
- Leakage; during cold weather, leakage was less acute;
- Filter too small;
- Additional tubes and connectors should be provided to allow customisation.

Initially a commercial nursery owner also purchased three vegetable kits and used them to irrigate transplanted rose cuttings. As the distance between the outlets was too big, additional micro tubes were fitted to adapt the kits to the distance between plants. The kits were successfully used for a while until the grower opted for a bigger, pressurised irrigation kit to cover the whole area of production.

Figure 15: Customising a kit to the needs of an urban flower farm. The shape of house gardens often demands a certain flexibility during installation.

Although so far the distribution of kits and the study have focussed mainly on rural small-scale farming areas, the results in Asmara provide evidence that urban areas should also become a focus area for future dissemination of the technology.

9 Synthesis of results

Some of the differences between the results collected in the different study areas are due to environmental variations in these areas, as described below. But many other findings are valid for most environments. Therefore, in the first sub-chapter, environment-specific results are summarised, followed by general results concerning technical, agronomic, socio-cultural and economic aspects.

9.1 Specific environmental aspects

9.1.1 Lowlands and escarpment

Aqordat, Barentu, Sheeb and Gahtelay are the study sites in the lowlands (see Figure 6, map of Eritrea).

The mean field size per farm is larger in the lowlands than in the highlands, and water is applied to fields most often by flood or furrow irrigation; in Sheeb and other areas spate irrigation is used where environmental conditions are favourable. In the lowlands, agricultural production is either limited by the availability of water itself, or by high temperatures and wind even where water is available. From March to May/June it is generally too hot and windy to grow plants. Seed production is from August to October and field production starts in November and lasts until February. With the exception of the south-western lowlands, the climatic conditions often make rainfed crop production impossible. This is why most farmers need to have access to wells operated by diesel pumps.

Most often, the size of the kits did not fit the size of fields, and since traditional irrigation technology is used on most farms, additional labour was caused when part of the farmland was irrigated with drip kits. Using the newly introduced irrigation technology could not be included into the daily working steps and had to be done in addition to normal tasks (e.g. for most farmers, filling the barrel meant carrying the water to the barrel in buckets instead of just turning on the motor pump and letting the water run to the furrows by gravity).

In some areas the sprinkler kit was used by farmers for seedling production, provided it was not too windy. Indeed, strong winds cause unequal water distribution; in extreme cases they can even destroy the irrigation equipment.

In the Sheeb area transhumance is still frequent. During the hot season people migrate to the cooler mountain areas with their animals. Permanent irrigation installations in this area are therefore not necessary. If people start settling in the area there might be a demand for backyard garden kits to grow vegetables. Traditionally in this area field crops are grown with spate irrigation on a large scale, and substitution of this traditional irrigation technique is not necessary.

The sites studied in the transitional zone between the lowlands and the highlands and along the escarpment are fairly different from each other. Therefore it is often not possible to directly compare results and make valid overall conclusions. Land use systems, farming practices, and environmental conditions vary a great deal. Only the comparatively small but nevertheless important areas known for citrus fruit production are an exception. In these areas the size of all kits was reported to be too small, as one farmer normally owns more trees than can be irrigated with a non-pressurised system. In some cases it was reported that the vegetable kit was used for citrus seedling production in pots. Another frequent observation made by the team in citrus growing areas was that the design of the horticultural kits did not coincide with the spacing between trees. Therefore new irrigation equipment can only be installed with new plantations or with the necessary knowledge and material for customisation. For horticultural crops it is recommended that the kits be made individually customisable to fit the spacing between trees as well as the shape of gardens.

9.1.2 Highlands

In the highlands, agricultural production is limited either by the availability of water or by low temperatures during part of the year. Road access to the market centres is often better from the highland villages than from the villages in the lowlands. On the other hand population pressure in many regions of the highlands is high and permanently increases the pressure on natural resources. Additionally the area has also been settled for a long time, and in some areas excessive mining of soils occurs because fertilizer is not available or cannot be afforded by farmers.

Discussions with highland farmers revealed that many of them know about environmental problems and increasing population pressure. Some farmers even expressed their fear that the introduction of a new irrigation technology might lead to an increase in the size of the permanently irrigated area instead of replacing traditional irrigation techniques, thus leading to an increased demand for water. Therefore they feared that acceptance of the new technology would aggravate the problem of water scarcity even faster.

9.2 Technical aspects

Figure 16: The plastic sticks are made of LLDP (linear low density polyethylene) and are not strong enough to resist dry and hard soil conditions.

Between the first and the second shipment of irrigation kits from India, IDE changed the design of the kits. It was no longer possible to use the new parts as spares for the older kits because there was no compatibility. In addition farmers had no time to get familiar with the system. Such changes during a first contact with a new technology are absolutely fatal and must be avoided.

It was observed that for all kits in all study areas installation and maintenance were the main difficulties. Problems started with the English manual packed with the kits. For most farmers it was not understandable. Moreover, the follow-up visits clearly showed that a single day of instructions (independently of the quality of training) about how to install the kits is not enough. At least two follow-up visits are necessary until farmers' knowledge of the technology and its handling is sufficient. The main problems observed were: micro tubes installed too tightly, filter installed the wrong way, tap not correctly connected to the barrel or bucket, micro-tubes not properly fixed to sticks, laterals wrongly connected, etc. On the other hand, sometimes the material itself was low quality. Despite expensive prices the buckets and plastic barrels were of minor quality and in some cases broke during installation. The weak T-joints are discussed below, in a separate section; but the quality of the sticks to fix the micro-tubes in the soil was also insufficient, with sticks often breaking in hard soil. Sometimes the pre-drilled holes along the laterals (to enter the T-joints) were too small and in other cases it was almost impossible to connect the micro sprinkler to the tubes. For the last problem there is a simple solution: one should install the material during the hot time of the day. Since it is black it heats up, which makes it softer and therefore easier to handle.

In the case of micro sprinklers, the study team learned that fitting the micro tubes to the laterals and to the sprinkler heads was very difficult (sometimes impossible), and that the sprinkler was very fragile. Since higher pressure is needed to run the sprinkler (10 meters instead of 1 meter for the drip kits, which generally means that a tap connection or a motor pump must be available) and since the field of possible application is much smaller, we propose to concentrate in the near future on the performance of micro irrigation kits. Apart from the experience in Hagaz from where it was reported that three sprinkler nozzles malfunctioned, the technical performance of the micro sprinkler kits was not properly assessed because the number of farmers testing the technology was too small to be representative. Therefore further discussions about micro-sprinklers are in general not included in this report.

9.2.1 Clogging

In Hagaz and Hamelmalo schools, and at Halhale Research Station, serious clogging of micro tubes was reported, mainly due to salty water and/or suspended sediments. This problem is inevitable as the kits are supplied with a simple small mesh filter. Even in conventional drip systems, where an expensive graded filter network is furnished, clogging remains a central problem, making flushing or cleaning with acids a routine operational practice. Keller and Bliesner (1990) mentioned in their useful overview of sprinkle and trickle irrigation that "long flow path emitters (also called 'spaghetti tubes') are slightly less likely than other emitters to become blocked, as the minimum flow path dimension for a given discharge is greater".

No filter prevents the system from clogging through dissolved salts. The only solution is to apply acid chemicals, added to the irrigation water. The frequency of treatment depends on the salt concentration. Usually sulphuric acid is used. It is very efficient but expensive and hard to get in Eritrea. Hence, an attempt should be made to explore the efficiency of locally available chemicals.

The frequency of clogging with suspended sediments can be minimized by pre-filtering the water, e.g. with a cloth filter. It is also recommended to flush the system at least twice weekly and clean the mesh filter at the end of each irrigation procedure.

A piece of cloth was included in the pre-packed kits after first negative experiences. Neither the schools nor the farmers used the cloth filter, probably because they found it difficult to fit the cloth to the bucket or barrel. Since it was a nice piece of new cotton some farmers used it for other purposes. Perhaps sowing a thread into a cloth filter to enable tying it up would encourage use of the filter.

Hagaz Agricultural School reported that clogging became less frequent with time. This is a rather peculiar observation because it is obvious that clogging through both dissolved salts and suspended sediments becomes more serious over time because the accumulation of salts and sediments increases inside the tubes. It is therefore difficult to comment on the observation reported by the students from Hagaz School. Possibly, a lot of soil entered the pipes and micro tubes during the installation, leading to clogging in the beginning, or the water source was shifted from one well to a less salty one at a later stage.

9.2.2 Water use efficiency

Figure 17: Saving water (and labour for weeding) is one of the benefits of the micro irrigation systems, since only the area where plants are grown is wetted, not the whole soil surface.

Only Hagaz School made an attempt to estimate water use efficiency and concluded that drip irrigation is at least twice as efficient as furrow irrigation. Water use efficiency is one of the most difficult parameters to measure accurately. Exact measurement requires field instruments such as Trime Domain Reflectrometry (TDR) to measure soil moisture. Apart from this, specific local data such as climatic parameters, soil and crop data are needed for the computation of crop water requirement. In Hagaz operational losses and net and gross crop water requirements were not calculated. Furthermore, figures given on percolation loss should be treated with caution as they are probably measured by a gravimetric method, since the school laboratory lacks accurate scales for weighing. Nonetheless, the values reported are sufficient for rough comparisons (see Table 10). Even if the results are only a rough calculation, they show that water use efficiency was doubled in Hagaz.

According to the literature water use efficiency can reach the very high level of 90%. But such a high result can only be reached when the kit is really properly installed, optimised water application and land use practices are used, and there is absolutely no leaking. But even if the amount of water can be cut by half compared with furrow or flood irrigation, as reported from Hagaz, this method is a full success with regard to saving water.

9.2.3 Water distribution uniformity

Water distribution uniformity is defined as the measure of the variability of discharge among the micro tubes. All testers (schools, farmers, research station) reported that the uniformity was good.

9.2.4 System management

As mentioned many times it is essential that more knowledge about how to handle the kits be made available to farmers. Another problem frequently mentioned by farmers and schools is that it is rather difficult to fill the barrel: The minimum height required for the outlet position is 1 m above ground. The height of the 200 litre barrel is almost 1.5 m. So every jerrycan must be lifted at least to a total height of 2.5 m, which is hard to manage.

9.2.5 Wetting pattern

The wetting pattern (or wetting bulb) is the vertical and horizontal dimension of the water body under each micro tube. Both schools found that the surface wetted areas of the micro tubes overlapped, making a continuous wet strip. Assuming that the wetted areas form a perfect circle, this implies that a single micro tube wetted an area with a diameter of at least 60 cm. Compared to the maximum value of 50 cm found in the literature this seems high, particularly with the dominant soil texture (sandy loam) analysed in both schools.

In Hagaz school, a maximum vertical water depth of 80 cm was recorded, which exceeds the rooting depth of annual vegetables and indicates that the technology can be used for almost all corps with regard to this aspect of water availability.

9.2.6 T-joints

With the first kits distributed in Eritrea the micro tubes were directly connected to the laterals. This is a simple way of connecting them; the only disadvantage is that it is hard to clean the micro tubes if they are clogged. In the kits ordered later the micro tubes were connected to the laterals with a T-joint. The advantage of T-joints is that clogged micro tubes very easily be cleaned by taking off the T-joints and blowing through them. T-joints also make it easy to pack away the system (e.g. during the rainy season).

T- joints connect the lateral lines to the micro tubes, as shown in Figure 18. These parts were supplied with the second order of drip kits only. Hamelmalo School as well as many farmers complained that these joints are of minor quality and break easily. The study team shares this opinion and proposes to eliminate the T-joints by connecting the micro tubes again directly to the laterals.

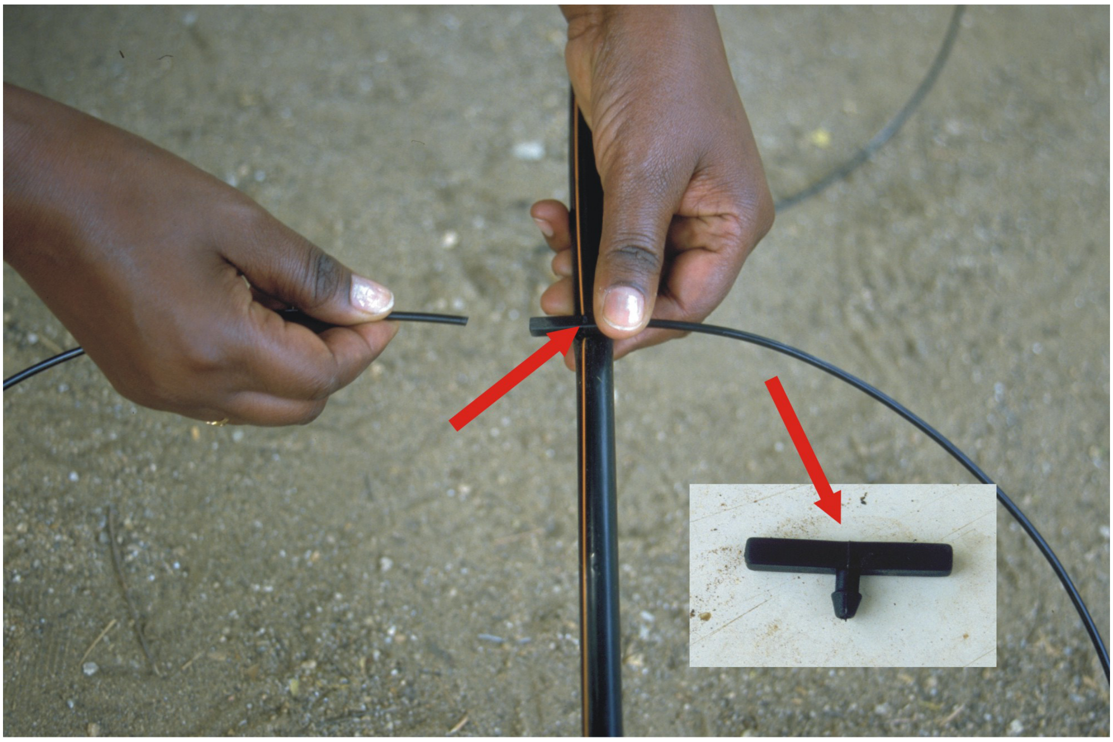

Figure 18: T-joints connect the micro tubes to the laterals. The red arrows point to the weak part of the piece.

9.2.7 Size and shape of kits

In all discussions during the follow up process, the size and shape of the kits were important topics. In many cases it was easy to understand why farmers wanted to discuss this point (e.g. when used for backyard gardens with a complex shape, for fruit trees with different spacing, or when used in areas where furrow irrigation is common and field size too big, therefore creating additional workload, etc). In other cases the team suspected that there might be other (political or social) reasons behind the critique of size and shape of kits. Until now it has not been possible to assess this discussion in greater detail, but a Masters thesis focusing on the social and economic framework needed for the successful implementation of micro irrigation[1] will hopefully discover new facts and figures.

Again it has to be mentioned that the affordability of irrigation kits is mainly based on the small units available and not on the lower price per area (for details see Table 4). If larger units are required farmers must be aware of the higher price.

[1] Masters thesis by a student of the University of Berne, started in February 2003. Results can be expected in 2004.

Packing problem and lack of spare parts

Some kits were not complete when they were unpacked for the first time. In other cases minor-quality parts were found. Such problems have very serious consequences during the implementation phase because spare parts are not easily accessible and farmers rightly consider the quality of the technology to be low. A small stock of spare parts must always be ready for all type of kits, and installation must be controlled by the supervisor to make sure that all components are present and properly working or fitting.

Bucket kit

Experience until now clearly shows that the size of the bucket kit (20 m^2) is appropriate mainly for backyards or house gardens. All the farmers who were testing a bucket kit on the field mentioned this when consulted. For house gardens it is often necessary to customise the kit because of the shape of the field. To customise a kit, knowledge and a certain degree of practical experience is needed. Neither can be expected from newcomers. It is therefore essential to build a community of supporters with sound knowledge.

Most testers mentioned that additional yields were mainly used to upgrade the quality of nutrition or the situation of their family. Only when there happened to be some surplus this was sold on the market. But the market for high-value cash crops is too small in Eritrea to broadly promote production of herbs and spices with a bucket kit.

To promote the bucket kit the team proposes to focus on urban and sub-urban areas and to address mainly women because the responsibility for house gardens is with them. Success depends greatly on the quality and availability of information and support. Therefore promotion must take place at a professional level.

Vegetable kit

The argument heard most frequently against installing the vegetable irrigation kit was that either the size, or the shape, or both did not meet the farmers' needs. Interestingly non-testers were not the only ones who mentioned this topic: farmers who tested one or more kits also highlighted this point as a problem.

For further evaluation it is necessary to divide the farmers who answered into two groups: those who had been irrigating their fields with another (introduced or traditional) technology before the introduction of micro irrigation, and so-called "newcomers".

Farmers who had already been using an irrigation scheme for a longer period made an investment in labour and/or in money to adapt their land use system to the needs of the system. The newly introduced kits sometimes simply did not fit the shape of their fields. Changing the design of irrigation channels or basins creates additional work and because only part of the area under irrigation is substituted there is no noticeable benefit. Especially in cases where farmers use a motor pump, the area traditionally under irrigation might be too large for the small kits and the introduction of a new low-pressure system might create additional work, e.g. for filling the bucket or barrel. Statements made by the schools, the research station and farmers traditionally involved in vegetable production in the area of Adi Keih are examples of this difficulty. The "Netafim family kit", which covers 500 m^2, might be more suitable in size for some farmers, but a customisation of IDE equipment to this size should also be possible. Since the market is small it might be better (especially in the beginning) not to introduce too many different products but instead to offer more flexibility in customisation.

The vegetable kit can be used in larger house gardens and on fields for vegetable production. For further promotion the concentration on farmers without experience in other irrigation practices like furrow irrigation with motor pumps seems to be most promising. To ensure the success of promotion among farmers with experience of other irrigation technologies, it is necessary to be able to offer the possibility of, and the necessary knowledge for customising the kit to their needs. A basic prerequisite for customisation is the availability of the components and a manual with technical guidelines on how to customise a kit (e.g. maximum length of laterals with a given pressure). Support, supervision and sound knowledge are absolutely essential for successful implementation, both at the technical and the agronomic level.

Horticulture kit

Horticultural crops are produced mainly in the lowlands and the escarpment. The farm size and landholding system here are different from the highlands and climatic conditions are more favourable for fruit production. Fruit farms normally cover an area of at least 1 ha and motor pumps are used to irrigate the trees during the dry season (furrow irrigation). In most cases the spacing between the trees is different from the spacing between the micro-tubes of the kit. Implementing a new irrigation technology on such a farm would mean changing the system for the whole area and adapting it to the spacing between the trees. Since most of the fruit farmers use a motor pump the precondition for pressurised irrigation is given and often the large size of fields requires a higher pressure anyway.

The team proposes not to focus on the promotion of the horticultural kits. In special cases such as field border tree irrigation, as seen in Barentu, some kits should be made available, but only when time and knowledge for customisation and follow up can be guaranteed.

9.3 Agronomic practices

Many farmers did not believe that with drip irrigation 3-4 harvests per year are possible if the system is properly managed. Management must also include measures to maintain soil fertility, otherwise the higher demand for soil nutrients resulting from the more intensive growing practices will lead to decreased soil fertility within a short time.

9.3.1 Water application

The amount of water and the time needed for its application were the main problems observed by farmers as well as by the schools. Most farmers and some institutions hold the amount of water applied during plant growing constant. In the beginning this amount of water was sufficient, but later on, especially at times with increased demand, plants were under permanent water stress and plant growing was slowed down. Even when the surface of the wetted soil exposed to evapo-transpiration is minimised thanks to drip irrigation, water should not be applied during the hottest time of the day because of the plants' internal water management.

If the total amount of water applied is correct the frequency of application is not a major problem. But instead of applying water twice a day in small amounts, one large application every second or third day could save a lot of labour.

In some regions the access to water was restricted to about two days per week towards the end of the dry season. Though drip irrigation usually requires daily water application, applying water only twice a week does generally not lead to a water deficit, as the soil stores the water were the emitter is installed. However, this does not remain visible for long and farmers feel that the plants may suffer from water stress. In many cases, the farmers therefore removed the kits because flood irrigation with one application per week enabled them to fill the soil profile in a visible manner.

9.3.2 Quantity and quality of yield

Only institutions had the possibility of directly comparing the yield of fields under micro-irrigation with the yield from fields under furrow irrigation. Most of the results below are therefore based on the experience of these institutions.

With the exception of okra in Hagaz and green pepper in Halhale, the size of fruit in the drip-irrigated crops was small, in some cases so small that the fruit became unmarketable. Moreover, the yield of most crops under drip irrigation, (with the exception of eggplant and tomato in Hamelmalo and potato in Halhale), was smaller compared to the yield of surface-irrigated fields. A number of factors influence the quantity and quality of crops, but without permanent observation it is not possible to analyse what happened. In many cases it was observed that application of constant amounts of water was at least one factor leading to a yield reduction. In the schools and the research station, a constant 2 to 3 buckets/barrels of water were applied daily to almost all crops. To a large extent, this is because during demonstration of the kits, no special attention was given to the irrigation schedule, and to the amount of water proposed in the manual (two to three buckets/barrels per day). It is a well-known fact, however, that crops have four distinct growth stages, each demanding different amounts and intervals of water application.

In Hamelmalo eggplants and tomato performed rather well under drip irrigation and the harvest was about 35 - 40% higher compared to the harvest form a similar sized field irrigated with furrow irrigation (see Table 8). The retarded and poor development of the papaya trees after healthy and vigorous growth during the initial two months is most probably attributable to the fixed amount and schedule of water application.

When seedlings are raised under surface irrigation and later transferred without proper pre-flooding to a drip irrigated field they suffer from transplantation shock. This usually results in far-reaching negative impacts on the plants' development and fruit setting stages. The lower yields and small size of fruit in Hagaz was most probably caused by such transplantation shock. The basis for this assumption is the healthy vegetative growth and big size of okra fruit. Indeed, the okra plot under drip irrigation was accidentally flooded during irrigation of the adjacent surface-irrigated plots.

Spacing between plants undoubtedly affects crop yield and quality. The peppers in Halhale are a good example. The normal spacing for green peppers is 25 to 30 cm between plants, and the surface-irrigated plots were planted accordingly. With the drip kit however, only one pepper plant per micro tube was planted, which means that the spacing between the plants was 60 cm and hence the stand percentage was half of that in the surface irrigated plot. Less stand percentage correlates with lower total harvest. But a smaller number of plants also creates less competition for water and nutrients, which is a possible explanation for the larger peppers harvested from the field under drip irrigation.

A frequently observed practice was to place the plants directly under the micro tubes. This definitively causes yield reduction as it deprives the plants of sufficient air part of the time. Farmers who only look at the small spot of humidity at the soil surface cannot imagine how the water is distributed underground.

The new technology also demands a change in agronomic practices. Soil and crop management must be adapted to the new situation. This urgently requires that available agronomic knowledge be transferred to farmers and that farmers be intensively backstopped by an expert at least at the beginning. As a first step the team proposes to support a few model farmers willing to introduce other, newly interested farmers to the technology as well as to support them. These model farmers also need permanent monitoring and backstopping.

Land preparation and weeding

Most of the traditional irrigation practices need intensive field preparation such as adjustment of channels or levelling of the surface of micro basins, etc. For the irrigation with a drip kit field preparation is not necessary because drip irrigation works also on uneven terrain. The students of the agricultural school in Hagaz remarked that land preparation is negligible in drip irrigation, whereas the furrow and ridge constructions of the surface irrigation systems are labour intensive.

It is also unnecessary to loosen up the soil when working with drip irrigation, as the example described in Table 7 shows. Loosening the soil is necessary under traditional irrigation because with flood or furrow irrigation, a large amount of water is distributed within a short period, often leading to the development of a crust at the surface of the soil, thus reducing the infiltration rate. Loosening up the soil is also necessary for rainfed crops since the infiltration of water into the soil must be maximised in a semi-arid environment.

Drip irrigation wets only part of the soil; it is clear that infestation of fields by weeds is restricted to the area where water is available. Both Hamelmalo and Hagaz schools reported that the amount of labour and time needed for weeding a field under drip irrigation is only one third of the time needed for a field of the same size under surface irrigation.

Diseases and pests

Wetting of stems and leaves increases the susceptibility of plants to a number of diseases and insect infections. This was observed by Hagaz students who recorded a large number of diseases under surface irrigation, resulting in severe damage of the crops. By comparison the drip-irrigated crops showed only a minor infection rate. This suggests that drip irrigation helps to control diseases and pests.

9.3.3 Types of crops

The most important vegetables in the Highlands of Eritrea are tomato, onion, pepper, potato, Swiss chard and cabbage. The results show that there is no general problem in growing these vegetables with drip irrigation. All vegetables can be a good source of additional income when produced off-season. But most farmers used the additional yield for home consumption. Crops were sold on the market only if there was a surplus. Success or failure of a specific crop is mainly connected to the handling of the equipment, the schedules for water application and agronomic practices. The literature shows that best successes can normally be reached when high value crops are promoted. Apart from a market analysis, this requires above all better knowledge and easier access to information for farmers.

To focus on off-season production (proposed later in this report as one possible strategy) also requires better access to seedlings throughout the year. When asked what they grew under drip irrigation, farmers sometimes reported that the choice of vegetable produced was not due to rational selection but because it was the only type available on the market at the time they started irrigating. In some cases it was also observed that the selected crop was not suitable for the season. Especially in the lowlands it is sometimes too hot to grow vegetables and the harsh winds can cause additional damage.

It was possible for model farmers with demonstration sites to take over the function of local or regional promotion and help other farmers to properly introduce the technology. They also provided help with agronomic questions. To facilitate knowledge transfer and access to information the team proposes to promote a local Eritrean network of stakeholders with strong participation of the above-mentioned model farmers.

The team proposes to create about 3-4 local nodes with well-instructed irrigation farmers from whom other farmers can learn how to apply the technology. In the beginning support must be provided from outside, but as soon as it comes to marketing, this system must become self-sufficient. A national network of stakeholders should be initiated with the goal of facilitating knowledge exchange and creating local competence. A nationwide workshop in August 2003 will help launch such an initiative.

9.4 Social and institutional framework

Within the given time frame and budget, a proper assessment of the social, economic and institutional framework needed for the successful implementation of a new technology is impossible.

9.4.1 Land ownership

As described in the introduction there are different land ownership systems in Eritrea. In the Highlands the *dessa* system is widespread; this system is one of the very important arguments used in assessing the possibility of implementing a new technology. As long as every 7 to 10 years farmers’ fields are re-distributed, farmers’ planning horizon is very restricted. Investments in conservation, land or yield improvement, technology, etc. must pay back within one or two years. The *dessa* system is the reason for the almost total absence of fruit trees in the Highlands of Eritrea.

Especially when it comes to fixed installations such as concrete water storage or a system of distributing pipes, farmers demand security of land tenure before investing. Gez Cornish (1998) states that “Security of land ownership is often a prerequisite for farmers to secure loans or grants for the purchase of irrigation equipment”.

The increasing pressure on land resources leads to an extension of cropland in marginal areas, as well as to a decreasing farm size per family in the Highlands. This trend will not change in the coming years. Therefore, ways of intensifying production must be found to fulfil the increasing demand for food. Implementing irrigation technology can help increase crop production if the institutional, economic and social framework allows farmers to invest in a new technology and to adapt it to their farming system.

For the time being we propose to concentrate promotion of bucket and vegetable kits on the Highlands. These kits are designed for annual crops / vegetables and are easy to remove. If used for growing high-value crops the return on investment is rapid; the system can easily be moved when land is re-distributed.

9.4.2 Access to information

As often mentioned above it is absolutely essential that farmers, traders, producers etc. have access to better and more sound information. This starts with promotion of the irrigation equipment. If no understandable manual is available, how can farmers be informed? Then come all the technical questions. An English manual is not helpful for most farmers. And a manual alone is insufficient. Farmers need competent information about how to install the kit, and a proper follow up must be available. Local experts must become familiar with customisation of kits and have enough knowledge of the changes needed in crop management practices (such as how much water must be applied to a certain crop in a certain place at a certain season). Also, information about market development and market prices must be accessible.

It will take time for all of this to be realised. Eventually, trading and merchandising must fulfil many functions such as providing information and knowledge, as well as bearing part of the costs of promotion. However, first steps must be initiated and subsidised from outside (one should have in mind that it is often expected from African farmers to be self-sufficient, while millions are spent in northern countries to support agriculture!).

A nationwide network of stakeholders must be initiated with the goal of increasing local knowledge of all questions related to smallholder micro irrigation. It should also serve the functions of promotion, knowledge exchange, marketing etc.

A video in local languages based on farmers' experience and problems with the new technology could substantially help to spread information about micro irrigation technology and about how to use it in a sustainable way.

9.4.3 Infrastructure

Some farmers - especially those living in remote areas - complained about access to markets and information. For the distribution of irrigation kits in such areas marketing facilities must be offered, such as, for example, a network of local traders bringing the crops to market and fetching spare parts and information for the farmers. The initiative for such improvements must come from the user community and should not lie within the responsibility of a project. The improvement of local or regional infrastructure such as wells, telephone connections, access to radio, television and other mass media are also essential in satisfying farmers' need for information. But providing such facilities is within the responsibility of the local, regional or national administration.

9.4.4 Economy

Market situation

A great number of farmers have still not been demobilised, therefore human labour is scarce, income low and prices high. The study team expects that the economic situation will fundamentally change when demobilisation of the army is completed. To assess the market situation under the actual circumstances is difficult, because it is known that market prices are one of the key factors influencing farmers attitudes towards the new technology.

Costs of the irrigation equipment

When it came to distributing the kits during the test phase, the team experienced a long expert discussion with different stakeholders on pricing of the irrigation equipment used for the study. Details of the compromise found are described in the chapter “Costs and pricing”. As mentioned there, the price the farmers were charged took into account that they took over a higher risk of failure by testing a new technology.

The price of the kit is not the only expense for farmers. Depending on the environment and the kit, farmers must also buy a bucket or a barrel; moreover, sometimes the irrigated field must be fenced off. Off-season production also requires access to seedlings, which is often difficult and sometimes also rather expensive.

The short planning horizon (discussed in the chapter on “Land ownership”) requires that within one or two years all costs must be recovered. Only the first two farmers who started testing the drip irrigation equipment at the very beginning of the project gained experience covering almost two years by the time the follow up took place, but only one of them used the kit permanently. This farmer reported that costs were recovered after 3 harvests and that he started to make a profit in the second year.

Credit loans and soft loans

As mentioned above the initial investments are considerable, even when farmers start with only one kit. Access to small commercial credits would increase the capacity of farmers to buy a kit. All the literature consulted mentions that one of the preconditions for successful implementation of a technology is that farmers have access to credits.

Some farmers proposed to introduce a soft loan system (loans with generous repayment conditions) instead of commercial credits. Such a system must be integrated in the marketing procedure and lie within the responsibility of traders or retailers. Conditions must be clearly defined among the stakeholders involved. Farmers imagine that the hardware and some support is provided for free during the first season and a certain percentage of the yield (in kind or cash) is defined as the rate to be paid back.

Marketing of products

A first rough market evaluation started in spring 2003 and will provide some basic information about price fluctuations and market saturation of some local markets, as well as of the national market in Asmara. Even if local differences in seasonal prices are to be expected because of different climatic conditions, it is not realistic for small-scale farmers to plan their strategy on a national scale because exchange between the local markets and the centre is limited.

The present study began in 2001 and the community of testers is far too small to provide figures on market behaviour. First it must be clear that with a total population of slightly less than 4 million people, market opportunities are limited and changes in offer or demand can occur rapidly because of the limited market size. Past experience has shown that nationwide promotion of products (such as tomatoes or bananas) ended in a dramatic fluctuations in prices. A farmer in Ala Valley reported that he even destroyed bananas because bringing them to market was more expensive than leaving them to rot. Three strategies can be used by farmers when they want to produce cash crops with the drip kit. They can either produce off-season products or focus on niche products. For these two strategies it is crucial that farmers have access to market information so that they can adjust their production at the right time. Another possibility could be that farmers start processing food locally (e.g. drying, conservation with sugar, salt or vinegar, jam production, etc). This third strategy depends on access to the national (or international) market and therefore requires a good infrastructure.

9.4.5 Gender

The amount of information sampled until now is much too small to really analyse the situation from a gender perspective. In many places male farmers said that the bucket kit is too small for a “real” farmer and it should be sold to ladies. In other places this was not the case. Until now no clear patterns have been identified but some indicative conclusions can be given: When the kit is installed in the home garden, responsibility for running it lies mainly with women. If it is on a field men are (also) involved in managing irrigation.

Since women are traditionally not allowed to plough fields, widows are (not only) economically in a very difficult situation. There is no social security and many women are compelled to search for other ways of getting some income. Experience gained by the women of the self-help group in Mendefera shows it is important to address these women. Often alternatives are lacking and the willingness (or pressure) to invest in new ideas is high. Eritrea has just been through two long-lasting wars that took a heavy toll on human life; according to studies (Tronvoll 1995, Stillhardt et al 2002), the number of female-headed households is as high as 25%.

The study team proposes that special attention be given to female-headed households. This segment of the rural population is often at the lower end of wealth statistics; offering alternatives to generate some income can considerably enhance the economic situation of these households.

9.4.6 Water

In most regions water is a common good that does not have to be paid. Also, wells are freely accessible and every farmer takes as much water as he needs, without thinking about the future. Users are charged for the water they abstract when water is brought by tank during part of the year, or when tap water is available. In the villages around Mendefera, for example, consumers are currently charged 4 Nakfa per barrel. This increases the attractiveness of water-saving technologies, as shown by the examples in Adi Mongonti, Adi Keih and Mendefera.

The distance to the well where the water for irrigation has to be fetched is a crucial factor, especially for families with low labour capacity. Introducing drip irrigation during the dry season can create one to two hours of additional work per day if the well is far away.

The increasing population leads in many areas to increasingly scarce water resources; therefore a national water management plan with water saving strategies was proposed in 1995 but not yet realised. The team proposes to include a discussion about how to increase the population's awareness of water scarcity and possible ways of managing it efficiently when discussions begin on how to implement this water management plan.

9.4.7 Institutional problems

The institutional links between researchers from various institutions and NGOs are weak and often unclear. In this case, initial work on the project was hampered by a confusing distribution of responsibilities: while for the study the College of Agriculture was the Eritrean partner of CDE, there was a misconception that a technology transfer project should be Ministry job.

Moreover, there was no possibility of attracting local partners at *Zoba* and sub-*Zoba* level willing and able to introduce the kits to the farmers and to instruct them. This was often left to extension workers of the Ministry of Agriculture who were keen to participate in the initial demonstration of kits only. Further follow up and continued support of the kits was however not guaranteed, primarily because this was an additional load for extension workers and had not been streamlined through the Ministry.

9.4.8 Time of distribution

In the lowland villages, such as Hagaz, Hamelmalo, Sheeb and Gahtelay, the kits were distributed during the hottest and windiest months, during which vegetable production is traditionally stopped. It was interesting to see that even under such a harsh environment, use of the kits led to successful support of vegetative growth in certain areas, leading to good results with some vegetables. However, as there was not much vegetable production under conventional surface irrigation systems in these areas, it was not possible to make sound comparisons between furrow irrigated crops and drip irrigated crops.

In the Highlands, the rainy season started before the vegetables grown with the help of the kits could be harvested. This made it difficult to achieve proper yield comparison between the micro-drip and the respective surface irrigation systems.

To avoid the above-mentioned difficulties, the team suggested that both in the highlands and the lowlands, the distribution of the kits should be done in the months of October and November.

10 Concluding critical remarks

Technology

From a technical point of view micro irrigation technology is promising. But it requires a careful assessment of local circumstances and a **thorough selection** of the appropriate product. Selecting and distributing components that are not fully appropriate is one of the main reasons for rejection of the new technology.

Moreover, changing the technical details of a system during farmers' first contact with the new technology creates a lot of confusion and can lead to their refusing it. A thorough technical pre-evaluation conducted with local specialists would help to avoid having to change something later.

Water

If water is available and the next well not too far from the fields, micro irrigation kits can either be used for deficit irrigation during the rainy season or to grow additional crops during the dry season. The assessment showed that the amount of water used is much lower compared to surface irrigation practices. The **cost of water influences farmers' perception** of the new technology considerably. As an additional effect of the application of water directly in the root zone, drip irrigation also **helps to avoid water-born human diseases** such as hepatitis or some parasites, because plants themselves (especially salads, tomatoes and other vegetables that are usually consumed raw) are not in contact with the water that may be contaminated. In this sense the technology is also a contribution to enhancing human health.

Land tenure

The land tenure situation, farmers' planning horizon and the often long period before economic **return on investments** is available are key elements that influence farmers' willingness to evaluate the new technology. Frequent land re-distributions encourage farmers' perception of land as a resource to be used intensively for a number of years, in order to get out of it as much as possible with comparably low (financial) input. In such a case comparatively high investments that require a long-term perspective are not attractive.

Rate of implementation

For several reasons many of the kits introduced by the study team have still not been installed in Eritrea. Either kits were not properly introduced, people felt forced to buy kits without being convinced, or installation failed because of technical or agronomic problems, etc. As a result it was observed that all in all, not more than about 15% of the imported kits were used for more than one cropping season. The evaluation team often heard that with such an adoption rate implementation of a new technology can be considered a failure. This is too quick a conclusion, however: appropriate **technology transfer requires more than just marketing structures and demonstration sites.** It is well known from other studies that introducing a technology to a new environment, including the process of spreading its use, can require periods running as long as several decades, depending on local circumstances.

Nevertheless, immediate action is worth taking: in a report, IPTRID underlines: *"If the current rate [of irrigation development in 40 countries in the sub-Saharan African region] continues over the next 25 years then an extra million ha of irrigation could be brought into production – increasing the total area presently under irrigation by 50 percent."* But IPTRID also warns: *"Even at the most optimistic rate, the contribution that irrigation can* *make to increase food production in the region will be modest unless some of the key constraints are removed."* A double effort is thus needed.

It is obvious that micro irrigation equipment is not spreading like a wildfire in Eritrea. Interpreting the above quotation, two factors underline this observation:

- **The time factor**: the mean annual growth rate of the area under irrigation (not only drip irrigation) in sub-Saharan-Africa is around 2%. Under the given circumstances the introduction of a new technology will take several decades!
- **Key constraints**: besides the often-cited and well-known economic and ecological constraints, there are also many social factors that influence the perception and acceptance of a new technology[1].

Costs

It is essential to keep in mind that the affordability of the material tested (and of unpressurised micro irrigation equipment in general) **depends mainly on the small size** of the units offered. If prices are calculated per hectare, the cost of so called "affordable micro irrigation technology" (AMIT) kits is almost as high as the cost of conventional irrigation technology.

Marketing approach

To follow a pure marketing approach requires high initial economic **input**, intensive and on-going training of farmers, a critical mass of potential early buyers, access to the necessary resources (seedlings, water, fertiliser, knowledge, etc), access to markets and information, a very careful handling of subsidies, etc. Under the circumstances of the project on the one hand and of the country on the other, it was only partly possible to follow such an approach.
The project's own experience as well as other relevant studies (e.g. Mackay H. 2003) show that with a marketing approach **the poorest are not necessarily reached.** Therefore a detailed discussion must take place to find out whether the approach is successful with regard to the goals of "poverty alleviation" and "enhancing rural livelihoods" in general.

Increasing the nutritional status of the household

Farmers used bucket kits in particular, and sometimes also drum (barrel) kits, mainly to diversify crop and vegetable production for **home consumption.** Only the surplus was sold on the market. If the goal is not only to support family nutrition but to generate additional income, the focus must be on high-value (or cash-) crops. This requires a careful market evaluation, especially if the market is small.

Access to knowledge and information

Micro irrigation technology requires that farmers have adequate **technical knowledge**; but it also requires a change in agronomic practices as well as a **profound understanding of (invisible) processes** of irrigation. Often the land use system must be adapted or changed. This requires intensive external support over several years. Training, knowledge transfer and follow up are therefore essential key parameters for the adoption rate. In the beginning, further work should focus only on a few places and support should be given to developing user communities. By also supporting exchange of information among farmers, these communities will be strengthened and the technology will be more efficiently disseminated.

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[1] A diploma student at the University of Berne is currently conducting research on this topic; she is comparing a group of farmers using the new technology with a group of similarly introduced farmers who decided **not** to use the new technology.

Possible synergies

A final remark ought to be made at this stage: the construction of micro-dams is currently heavily promoted in Eritrea as a means to enhance rural livelihoods. The potential for the implementation of micro-irrigation technology in areas where micro-dams are foreseen is considered to be high, though it was not possible to fully assess it during this study. Indeed, small-scale farmers living below newly constructed dams will have to modify their land use system anyway if they intend to include irrigation practices in their farm management. Therefore introduction of micro irrigation technology could usefully be combined with the distribution of irrigation land.

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12 Figures and Tables

13 Annex

13.1 Implementation of affordable micro irrigation technology in Eritrea – a presentation and discussion workshop in December 2002

Workshop programme

Topic	Presentation by
Why introduction of micro-irrigation technology and why in Eritrea?	Pablo Loosli
Presentation of results (what have we done until now)	Abraham Mehari, Bissrat Ghebru
Presentation and installation of a bucket kit with practical discussion on advantages and disadvantages of the selected hardware.	Abraham Mehari, Brigitta Stillhardt
Poverty alleviation through market creation Presentation of the approach	Urs Heierli, Senior Advisor, Division Employment and Income, SDC
More than a donor: The Syngenta Foundation and its efforts and goals.	Felix Nicolier, Syngenta Foundation
How to transfer knowledge to new users? Presentation of parts of a new digital manual drawn up by IDE	Brigitta Stillhardt
Presentation of project recommendations and key questions	Brigitta Stillhardt
Round table discussion with stakeholders and other people involved or interested	Plenary-discussion on open key questions and controversial topics of the day, discussion on follow-up, etc.

Workshop participants

Name	Institution
Abraham Mehari	College of Agricultural Sciences (CAS), University of Asmara
Bissrat Ghebru	College of Agricultural Sciences (CAS), University of Asmara
Brigitta Stillhardt	Centre for Development and Environment, University of Berne, SLM Eritrea
Christoph Studer	Landwirtschaftliche Fachhochschule Zollikofen
Daniel Maselli	Centre for Development and Environment, University of Berne, NCCR
Elisabeth Katz	Landwirtschaftliche Beratungszentrale Lindau
Felix Nicolier	Syngenta Foundation for Sustainable Agriculture
Fritz Leu	Aktion Lichtblick
Hans Hurni	Centre for Development and Environment, University of Berne, Director
PabloLoosli	Privat Consultant
Ruedi Gsell	Landwirtschaftliche Beratungszentrale Lindau
Semere Zaid	College of Agricultural Sciences (CAS), University of Asmara
Thomas Kohler	Centre for Development and Environment, University of Berne, Director
Urs Heirli	SDC, Division Employment and Income
Viveca Nidecker	Masters student CDE

Main topics discussed during workshop

The role of CAAS and CDE (as research institutions) needs to be defined. It can be restricted to backstopping and monitoring of distributed kits. While seen as important, continued distribution must be left to traders. However, the research team should have access to interested individuals as well as to institutions in order to complete the study. Also, spare parts and customisable parts are needed. Support must be available to farmers for any technical problem that may arise while the kits are under study. The continuous need for extension even when kits are sold by traders is crucial and needs to be addressed.

Currently, the possibility that kits be sold by commercial investors seems to be remote. First, a wider acceptance of the technology must take place and the demand must be higher. A mid-term perspective seems to be to start with local assemblage of kits including all the information needed for customisation. Bulk import of the products will be necessary and must be taken up by traders. The research team's function can include assistance in making information available (e.g. in the form of a manual for local kit assemblage or as knowledge of how to modify farming practices).

In future the exchange of ideas and knowledge on national level and access to international information networks should be facilitated. Especially also the small-scale farmers must have access to such information. This can be done in the form of stakeholder workshops. Such workshops should also focus on water management and usage issues. Farmers do not yet properly understand why it is necessary to introduce water saving technologies. Indeed, until now no water management policy has been implemented and water is still freely accessible and can be fetched without payment (water as common good).

An important experience gained during the study is that there is an information gap between the technical and the agronomic part. There are several good studies comparing the technical performance of different irrigation products available on the market, but not much on changing agronomic practices needed for the successful implementation. What specialists and scientists produce as output is not understandable for most of the involved stakeholders, especially not for farmers.

Training is needed at different levels including among the extension services. This is one of the crucial points for a successful implementation. Training of trainers may be the first step. The institution that is responsible for training must be properly equipped and needs to be funded for its activity. Some of the innovative and motivated farmers could be trained as trainers. This would support communication among the community of users.

Even a marketing approach requires external support in the initial phase. Information and knowledge transfer, backstopping, monitoring etc can not be provided by a small local or regional entrepreneur. A certain demand must exist until local promotion becomes attractive.

Until now there are not many analysis available concerning the economic performance of micro irrigation kits. On the other hand return on investments it has been recognised as one of the key factors for success or failure of the introduction of a new technology. A student working on her Masters thesis is currently assessing the social and economic framework needed for the successful adaptation of the newly introduced technology. Results will be available end of 2003.

It is recommendable to focus on key-areas and/or key groups knowing and using IDE kits and to offer farmers there better access to information and knowledge as well as better support and to help them building up a network of users to strengthen the user community. Hopefully a spreading effect will happen when the supported users of micro irrigation technology make positive experience.

13.2 Material analysis of drip pipes for micro-irrigation systems

by Jürg Vogt,

September 2001 / June 2003

with contributions from Jean-Luc Schläpfer, Anthony Mayr, Matthias Villiger, R. Odermatt, Walter Lüthi, Urs Bachmann, Roland Trösch

Content

1. Summary

This report summarizes the results of a material analysis of drip pipes from three different producers (IDE India, IDE Nepal and a commercial product from Israel).

The systems from IDE India and the Israeli product make use of almost similar grades of LLDPE (linear low density Polyethylene). They both use commodity grades with a rather high density and stiffness. Both products, but especially the Indian drip pipes, are well stabilized against degradation due to UV-radiation. Quite a long service life can be expected in both cases if early failure is not caused by mechanical damage.

The Nepal drip kit is made of a green, softer PVC-compound and a harder, black PVC-compound. These materials are more susceptible to attack by UV, heat aging or attack by micro-organisms. Therefore, it is to be expected that the service life of the Nepal drip kit is shorter than the service life of the LLDPE products.

The costs of the pipes are similar to prices in Western countries. However, it can be assumed that the share of costs for materials and processing are different.

Theoretically, it should be possible to produce pipes made of special Polyethylene grades with PVC-like handling properties. However, this might negatively affect costs and heat resistance of the pipes.

2. Goals

This investigation was made in order to develop a knowledge base on the raw materials for drip pipes. The main goals were:

- to gain some basic information about the materials used;
- to assess and compare the service life of different systems;
- to compare costs for raw materials, processing and finished parts;
- to evaluate the potential for optimisation (technically, economically and ecologically):

3. Samples analysed

Samples of the following drip pipes were analysed:

IDE India sprinkler kit

Code:	IDE Ø12
Colour:	black with orange stripe
Diameter:	12 mm
Wall thickness:	1.1 mm

Code:	IDE Ø16
Colour:	black with orange stripe
Diameter:	16 mm
Wall thickness:	1.2 mm

Nepal drip kit

Code: NDK Ø8
Colour: green
Diameter: 8 mm
Wall thickness: 0.8 mm

Code: NDK Ø14
Colour: black
Diameter: 14 mm
Wall thickness: 1.8 mm

Commercial drip kit from Israel

Code: NFS Ø8
Colour: black
Diameter: 8 mm
Wall thickness: 1.0 mm

Code: NFS Ø25
Colour: black
Diameter: 25 mm
Wall thickness: 1.7 mm

4. Tests

The following tests were carried out:

Test	Conditions	Comment
DSC	25–250°C, 20 K/min, 2 runs	only LLDPE
TGA	50–855°C, 50 K/min	only LLDPE
DMA	–50 to 200°C, 2 K/min, 10 Hz, tension	
MFI	190°C, 8.7 kg	only LLDPE
FT-IR		
Tensile test	DIN, 23 °C, 50% rel. humidity	
Density	Pycnometer, Ethanol, 25 °C	
Extraction	Soxhlet extraction with diethyleter	only PVC
Lead test	NH_4S	only PVC
Weatherability	QUV, UVB 60°C 8 h / water 50°C 2 h	

5. Results of material analysis

5.1 LLDPE pipes

Both IDE India and the Israeli producer are using LLDPE for their pipes. Both use only one grade of material to make pipes with different diameters.

The tests carried out showed that there is virtually no difference between the quality of material produced by IDE India and the Israeli company. With a storage modulus of about 620 MPa at 30°C, both have chosen quite a stiff material. Also, the mechanical properties are quite similar.

The analysis cannot provide results on the kind and amount of stabilizers that are used. Special equipment and test procedures would be required to conduct such an analysis. However, it is known that a black masterbatch including a stabilizer package especially developed for drip pipes is widely used in Israel (Producer: Cabot, Grade: Plasblak PE2668).

For detailed results please refer to the table in the Appendix.

5.2 PVC pipes

The green pipes of the Nepal drip kit are made of a softer PVC compound than the black ones. Based on the detected amount of plasticizer, it can be expected that the initial content of plasticizer was 20 - 25% (NDK Ø8) and 10 - 13% (NDK Ø14). The plasticizer detected is DOP (Dioctylphthalate), which is the most commonly used type. The black material also contains a larger amount of fillers (most probably $CaCO_3$) to reduce the cost of the material.

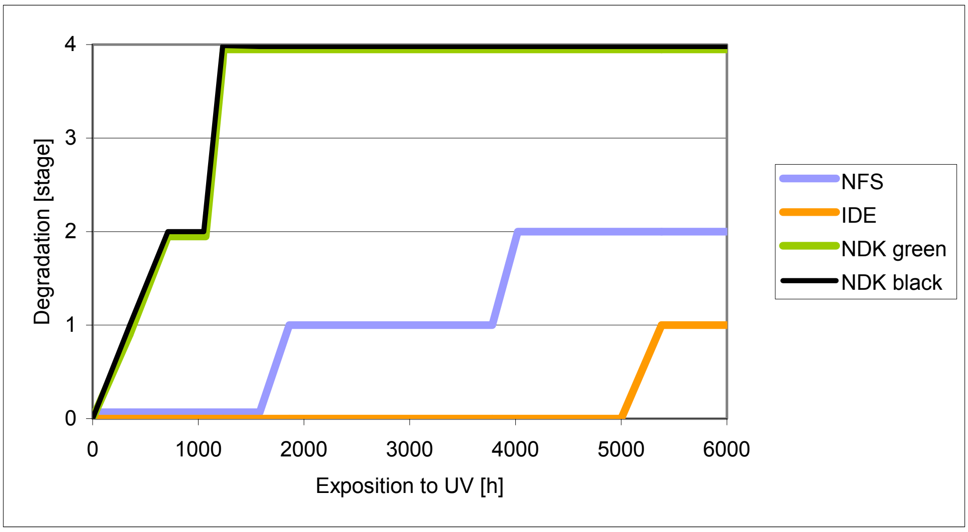
The test to indicate the presence of a lead-containing stabilizer was negative. However, small amounts of Cadmium were detected (46 ppm in the black material, 89 in the green one). If Cadmium stabilizers were used, the amount would be in the range of about 600 ppm. Therefore, the Cadmium detected here most probably comes from the use of a limited amount of recycled PVC. As a consequence, the main stabilizers used seem to be Ba-Zn- or Ca-Zn-types. However, no specific test was carried out to confirm this conclusion.

6. Durability

6.1 UV resistance

QUV tests on all materials were carried out in order to get an idea of the service life of the different pipes. However, expectations based on such results should not be exaggerated: they may allow to make a ranking of the different samples, but it is generally not possible to predict the service life exactly. There are many other parameters that greatly influence the longevity of the material and it is far from possible to simulate them all in the lab (e.g. use of pesticides, microorganisms, rain, temperature, colour of sample).

Degradation of drip pipes in accelerated weathering



Stage 1: Small cracks visible when magnified 10x
Stage 2: Visible cracks and continuous net of cracks visible when magnified 10x
Stage 3: When sample is bent, cracks are visible at reading distance without magnification
Stage 4: Cracks visible at reading distance without magnification

PVC and LLDPE are different kinds of plastic and therefore they react in a different way in an accelerated weathering test. Thus, the degree to which degradation is accelerated in the QUV-test can be different for the two materials. Nevertheless, the following conclusions can be drawn:

- The IDE drip kit is very well stabilized; it can be assumed that this material will have a service life of 10 years and more, unless it is mechanically damaged.
- The Israeli product is also well stabilized, but not as good as the IDE material.
- The PVC grades from Nepal are quite susceptible to UV (degradation) and heat (loss of plasticizer). It is very hard to predict a service life in this case.
- It is likely that the service life of the LLDPE kits will be limited by mechanical damage, whereas the service life of the PVC kits is limited by ageing of the material.

6.2 Heat ageing

Ageing due to heat will mainly be an issue for the PVC-products. Due to the higher volatility of the plasticizer at elevated temperature, the loss of plasticizer over time is a function of temperature.

LLDPE will also suffer to a certain extent from heat ageing. However, this effect is not expected to be the one that finally limits the service life. Since the weathering test takes place at 60°C, heat ageing is (partially) also included in the longevity prediction.

6.3 Attack by microorganisms and animals

Under certain conditions, PVC is susceptible to attacks by microorganisms: Microorganisms can extract plasticizer. This results in dimensional change (shrinkage), increasing stiffness and embrittlement. The danger of attacks by microorganisms mainly exists when the material is surrounded by mud for an extended period of time. LLDPE doesn't suffer from a similar effect: This plastic is free of any plasticizer that could be extracted.

It is hard to judge the possible risk of attacks by insects (e.g. termites) or rodents. It can be assumed that here, too, LLDPE is better protected due to the chemical nature and the hardness of the material.

6.4 Environmental stress cracking resistance (ESCR)

Some Polyethylene grades (especially hard grades such as HDPE) are susceptible to mechanical stress in the presence of aqueous solutions of detergents. No ESCR-tests were carried out since such tests are quite complicated and labour-intensive. Based on experience, it is difficult to make the link between such tests and performance in the field. Furthermore, it is very unlikely that environmental stress cracking will be a limiting factor in the service life of a low-pressure drip system.

7. Cost comparison

7.1 Costs of raw material

Estimated costs of raw material for LLDPE, based on European prices[1]

Price of raw material		
LLDPE[2], density 0.927 g/cm³	1.29 CHF/kg	(0.77 US$/kg)
Carbon / stabilizer masterbatch[3] 40%	3.10 CHF/kg	(1.86 US$/kg)
Cost of complete formulation:		
LLDPE	93.75%	1.21 CHF
Carbon / stabilizer masterbatch	6.25%	0.19 CHF
Total	100%	1.40 CHF/kg
Total costs per kg	1.40 CHF	0.84 US$
Total costs per litre	1.30 CHF	0.78 US$

1 All calculations are based on the following exchange rates :1 US$ = 1.095 EURO = 1.67 CHF
2 KI Information, Nr. 1548, June 2001
3 Cabot Plasblak PE2668. This masterbatch is specially developed for drip irrigation pipes; according to my source of information it is used in large quantities by an Israeli company.

7.2 Costs for finished pipes

	IDE Ø12	IDE Ø16	NDK Ø8	NDK Ø14
Material consumption cm^3/m	37.6	55.8	18.1	69.0
Total costs CHF/m [1]	0.084	0.15	0.10	0.22
Total costs CHF/kg	2.39	2.91	4.53	2.37
Estimated material costs CHF/kg	1.40	1.40	1.80[2]	1.50
Remaining costs (processing, overhead, profit) CHF/kg	-.99	1.51	2.73	-.87

Based on the cost calculations presented in the table above, the following conclusions can be drawn:

- It is quite obvious that there is something peculiar about the costs of NDK Ø8 and NDK Ø14. It seems that the cost of the green pipes is too high while the cost of the black pipes is acceptable.
- The costs are similar to pipes produced in Western countries.
- It seems that in India and Nepal, the cost of raw materials tend to be somewhat higher than in the calculation above, but the processing costs would be accordingly lower.

8. Potential for optimisation

As far as the situation is understood, there is a wish (or a need) to optimise the following properties:

- Costs;
- Longevity;
- Flexibility of LLDPE-pipes;
- Ecological profile of the entire product.

8.1 Optimisation of the IDE sprinkler kit

The following thoughts and calculations are based on the assumption that the pipes analysed are also used for low-pressure drip irrigations systems.

8.1.1 Design

The wall thickness of 1.1 mm for the 12 mm pipe is quite sufficient to withstand mechanical stress: If a PVC pipe with a wall thickness of 0.8 mm can do the same job, there is no reason why an LLDPE pipe should be designed with a strength almost 40%

[1] E-mail from Sudarshan Suryawanshi, June 17. 2001
[2] Estimated costs

higher. However, there is one exception, i.e. if the criteria for designing the pipes in such a way is resistance not against water pressure but against buckling.

Pipes with a lower tendency to buckle could be designed as follows:

- more flexible material;
- smaller outer diameter;
- bigger ratio between wall thickness and pipe diameter.

Unfortunately, most of the measures to reduce buckling listed here will increase the cost of pipes. The only exception would be if the inner diameter of the pipes was reduced without affecting their functionality (if possible).

8.1.2 Alternative materials

Basically, the following materials can be taken into consideration as alternatives to LLDPE

Material	Estimated costs [CHF/litre]	Melting temperature [°C]	Modulus of elasticity [MPa]
LLDPE (reference)	*1.40*	*122*	*620*
PVC green (reference)	*2.20*	*-*	*54*
PVC black (reference)	*2.-*	*-*	*114*
mLLDPE, density 0.918	1.80	118	270
LDPE, density 0.923	1.54	109	390
VLDPE, density 0.900	2.-	100	130
EVA 5%	2.-	105	270
mPE, density 0.900	2.20	100	110
PP/EPDM blend	2.50	141	90

- All materials listed above are pure hydrocarbons[1] and have the same basic properties from the ecological point of view.
- All materials will have approximately the same resistance to UV radiation.
- It seems that LDPE is also used for irrigation pipes[2].
- None of the suggested materials are as flexible as the green PVC used in Nepal. However, some are close to the flexibility of the black PVC compound.
- Except for LDPE and EVA, all other materials are non-commodity plastics, meaning that it might be quite difficult to purchase them. For example it appears that mPE is not currently marketed in Africa.
- Except for PP/EPDM all materials have a lower melting point than LLDPE (there is a rule of thumb: the more flexible, the lower the melting point). In some cases, thermal resistance may be crucial. However this problem could be solved by using an

[1] EVA also contains a small amount of oxygen. This has no impact on the ecological profile of the product.
[2] Brochure produced by Polimeri Europa, Riblene PC 47

alternative colour to black (but this has consequences on the stabilizer systems used and will increase the cost).

- LLDPE is the cheapest of the materials suggested. The difference with LDPE, however, is small and can even change, making LLDPE become more expensive than LDPE.
- The LLDPE grade used in India is quite stiff[1]. By choosing a different LLDPE grade it may be possible to make the pipes more flexible.
- There are significant differences between the mechanical strength of the different grades of material, but these are not shown in the table.

It is obvious that possibilities of improving the handling of the pipes exist. But it will be more difficult to reduce costs (especially if at the same time the flexibility should be improved).

8.1.3 Longevity

The IDE drip kit seems to be very well stabilized. As an alternative, one could check whether the special stabilizer masterbatch developed for the Israeli irrigation industry offers some cost advantage. The product is called Plasblak PE2668, it is produced by Cabot. This masterbatch includes carbon black (40%) and an optimised package of heat and UV stabilizers. The amount of masterbatch that has to be added is 6.25%.

8.1.4 Ecology

Ecologically, the current drip kit is at a suitable level. Given the plastic chosen for it, disposal is possible by burning the components[2]. Moreover, the energy resulting from the heat could also be utilized. Landfill is also possible. The materials are relatively inert and will not degrade for a very long time.

8.2 Optimisation of the Nepal drip kit

It seems that the Nepal drip kit has the following weak points:

- Its service life will presumably not be very long. After some time the pipes become increasingly stiff and brittle. The surface gets cracks.
- Correct disposal of old pipes is quite difficult. Neither burning[3] nor landfill[4] is a solution. Recycling, in this case, is neither practical nor reasonable.

To improve the longevity of the kit and to reduce disposal problems, the best solution would be to switch to pipes made of LLDPE or to one of the previously listed polymers.

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[1] There is a possibility that carbon black also contributes to a certain degree to the relative stiffness of the LLDPE grades that were analysed.
[2] Although the burning of LLDPE will result in the formation of water and carbon dioxide, carbon monoxide may also be produced under certain conditions. Furthermore it must be ensured that LLDPE is not mixed with other plastics (e.g. PVC) during the combustion process.
[3] Chloric acid, heavy metals and potentially even dioxins are released.
[4] Plasticizer contaminates the soil, and heavy metals containing stabilizers will be washed out.