Smallholder Irrigation Market Initiative

Study on the Dissemination Potential of Affordable Drip and Other Irrigation Systems and the Concrete Strategies for their Promotion

Submitted to

The World Bank Group

by

Winrock International
Putting Ideas to Work

International Development Enterprises

Financial Support for the Study Provided by

JIID

The Japanese Institute for Irrigation and Drainage

March 31, 2001

Creating New Markets via Smallholder Irrigation

Creating New Markets via Smallholder Irrigation

Executive Summary

For the first quarter century of the new millenium, we are faced with an exponential escalation of two mutually reinforcing world problems: water scarcity and rural poverty. Despite the impressive gains in global food production over the last half century, an estimated 790 million people remain hungry. Meeting the crop demands projected for 2025, when the population is expected to reach 8 billion, will require an additional 192 cubic miles of water. 60% of current fresh water diverted for human use now goes to irrigation, and in many developing countries, irrigation's share is as high as 90%.

The crop per drop produced by irrigation must clearly increase. But improving irrigation productivity on large farms alone will not solve the continuing problems of rural poverty, which are getting worse instead of better in sub Saharan Africa and other parts of the world. Increasing the agricultural productivity and income of the majority of farmers in developing countries who cultivate less than two hectares is a relatively untapped opportunity for finding practical solutions to rural poverty. Opening smallholder access to affordable small plot irrigation is a critical first step to wealth creation for the rural poor. New affordable irrigation technologies like low cost drip systems not only open the door to a path out of poverty: they are also a path to saving water, and doubling irrigation productivity on small farms.

Smallholder Irrigation

Smallholder irrigation is an effective means for creating avenues for poor farmers to work their way out of poverty. About 600 million rural people are poor by country definitions. This study estimates that up to 30% of these rural poor could increase their incomes significantly through well designed and implemented country-specific smallholder irrigation programs. These farmers and their families are the targets of the Global Initiative for Smallholder Irrigation, an international effort to accelerate the commercial introduction of drip and other low cost irrigation technologies with the objective to bring 1 million hectares under cultivation each year for the next fifteen years.[1] This in turn will provide an opportunity for 2 million poor rural families each year to take a major step on the path out of poverty.

[1] The Global Initiative for Smallholder Irrigation is sponsored by the World Bank, Winrock International, International Development Enterprises and other organizations. This study is a component of the initiative and is supported by funding from the Japanese Institute for Irrigation and Drainage.

Scope of the Study

The scope of this study is to (a) determine under which conditions smallholder irrigation technologies can be successfully applied, (b) review case studies of smallholder irrigation programs including at least one case study from each of the six World Bank geographic regions, (c) evaluate prospective markets for the implementation of smallholder irrigation programs and (d) determine anticipated social and economic benefits. The World Bank commissioned Winrock International and International Development Enterprises to undertake this work, entitled "Study on the dissemination potential of affordable drip and other irrigation systems and the concrete strategies for their promotion" with financial support of the Japanese Institute for Irrigation and Drainage.

Hypothesis/Approach

- Water crisis is real
- Technologies for more efficient irrigation are available but need to be adapted
- Barriers to wealth creation exist and need to be overcome
  - Access to inputs, markets, credit,
- Market driven, private sector approach is key
- Process will involve understanding the barriers, developing pilot approaches, ramping-up
- Potential for Bank Group support

The World's Forgotten Farmers

A key factor in the disappointing performance of many poverty alleviation initiatives is their failure to address the fact that most of the farms in developing countries are less than two hectares in size. For example, more than 75% of the farms in Bangladesh and in Bihar, India are less than two hectares. The key to tripling the global harvest through modern seeds and inputs has been irrigation, but until recently commercial irrigation devices have been too large and too expensive for small farmers. This has left them on the outside, looking in on many of the accomplishments of modern agriculture. Yet because small farmers are themselves poor, and are disproportionately concentrated in food deficit rural areas, increased productivity and income is central to practical approaches to poverty alleviation. For most small farmers in developing countries, affordable small plot irrigation may be the first step to wealth creation.

New Markets that Serve Poor Rural Customers

A key first step in finding practical solutions to both the issues of water scarcity and poverty in developing countries is opening smallholder access to affordable small plot irrigation, followed by a shift from subsistence to wealth-creating high value market driven crops. This shift is made possible by improving smallholder access to fertilizer, high quality seeds, and integrated pest management, and opening access to smallholder-oriented microcredit.

A common approach has been to assume that smallholders deserve high quality equipment. When conventional high quality irrigation equipment turns out to be too expensive to be affordable to smallholders, the problem has been "solved" by donor and government subsidies in large government-led projects. The Global Initiative provides an alternative to this approach, focusing instead on creating new markets for commercially available low-cost systems that serve poor rural customers.

Opening Access to Affordable Small Plot Irrigation

The first step in creating new markets that serve smallholder customers is the design of irrigation devices inexpensive enough for small farmers, and small enough to fit their plots. This approach uses the private sector instead of the government as the key instrument for the marketing and distribution of irrigation equipment, and utilizes an initial subsidy not on the price of the equipment, but on the promotion and marketing effort required to build sales volume to the point that it becomes attractive for private sector investment. The private sector also becomes the key player in opening smallholder access to inputs, credit, and markets for crops.

Case Studies of the Market Creation Approach

This report summarizes the experience of nine different cases in which the principles of market creation, affordable small plot irrigation, rural mass marketing, and wealth creation for smallholders were applied across a remarkable variety of ecosystems, agricultural strategies, and smallholder conditions. Most of these cases represent many years of village level experience. For example, in the Gangetic Delta areas of Bangladesh, India, and Nepal, 1.5 million treadle pumps were installed over a fifteen-year period, increasing the income of 7.5 million poor rural people by more than $150 million (US) per year. Newer technology like low cost drip systems in Kenya, the Deccan plateau of India, and the Hill areas of Asia produced and marketed through the private sector show even greater potential.

Experience with smallholder irrigation over the past twenty years suggests that we have only begun to tap the potential of these technologies. The treadle pump, a simple manual pump developed in the 1980s and marketed for $25/set in Bangladesh, has generated over $100 per family in incremental income for 1.3 million farm families. This experience has now been documented by independent evaluation studies; development professionals worldwide acknowledge its value. New micro-irrigation technologies are starting to show the same types of impacts and could potentially reach millions more farmers than the treadle pump.

This study presents a model for smallholder irrigation based on the experience in Bangladesh as well as that in more than ten countries around the world where farmers have adopted new irrigation technologies and are working their way out of poverty.

The case studies document experience gained in smallholder irrigation in various regions around the world. These studies demonstrate the applicability of the model and highlight lessons that have been learned in various experiences with smallholder irrigation. The case studies also point to and assist in estimating potential demand for smallholder irrigation technologies. The approach was to identify experience with smallholder irrigation in various ecosystems in various regions around the world and then to extrapolate to the larger ecosystem to attempt to develop estimates of potential demand.

This study has identified the following steps necessary for the design and successful implementation of smallholder irrigation programs:

?? Carry out a feasibility study to identify opportunities and test potential technologies.
?? Adapt and develop the technology to the needs of the target customers.
?? Build the supply chain and rural mass marketing programs.
?? Develop a system of business development services that provides training and information to the target customers to enable them to take advantage of the new technologies.
?? Measure impact and feedback information to refine the program.

The Future Potential of the Smallholder Irrigation and Wealth Creation Approach

The goal of the global initiative is to place one million hectares a year under affordable small plot irrigation for smallholders over the next fifteen years, and to contribute to at least two million poor rural people moving out of poverty each year. Remarkably, the projections from the nine cases alone indicate potential for 4 million hectares of newly irrigated smallholder cultivation and a potential to alleviate poverty for 30 million poor rural families. If this potential can be realized, the new information gained from it can be applied much more widely to address rural water scarcity and poverty problems.

Key Barriers and Constraints

The study has determined key barriers and constraints to the promotion of commercial markets for smallholder irrigation systems. These constraints may be grouped as follows:

<u>Development Community</u>:

?? The resource-poor farmer has not been viewed as a potential entrepreneur, and therefore development investments have not been aimed at smallhold farmers in their role as customers of input markets, and suppliers of agricultural products;
?? Market forces have only partially been taken into consideration in smallholder development in general, and the dissemination of microirrigation specifically.

Smallholder Context:

?? Limited access to credit, communication, transportation, inputs, information;
?? In many cases, poorly developed markets for high-value agricultural outputs, and lack of linkages of the smallhold farmer to these markets.

Private Sector:

?? Rural markets, and particularly low-income customers, are relatively unattractive to the private sector.
?? Commercial availability of user-friendly kits is generally limited.

Social and Economic Benefits of Smallholder Irrigation Systems

The case studies reveal the principal advantages of smallholder irrigation systems as technologies that enable the production of high value crops:

?? Scalable, divisible technologies with low capital investment requirements;
?? Potential for poverty alleviation via wealth creation;
?? Reduced water consumption compared to traditional methodologies, especially when coupled with greenhouses;
?? Higher yields and quality;
?? Up to 50% less labor than that required for hand watering;
?? Potential benefits of tapping shallow aquifers and not mining deep water;
?? Low operation and maintenance costs.

Potential for Bank Group Involvement

As the result of this study and interviews with Bank staff, we have identified four priority avenues of exploration:

1. Follow up on specific Task Manager interest in integration of smallholder irrigation in Bank projects in the pipeline;
2. Lay the groundwork with the Bank and with donors for the establishment of a Smallholder Irrigation Focal Point that advises on policy and priorities in smallholder development, coordinates activities and investments, and serves as a clearinghouse and catalyst for smallholder irrigation initiatives;
3. Investigate with IFC the creation of a specialized Smallholder Irrigation Investment Fund coupling technical assistance with business development services and finance to invest in small enterprises along the supply chain for micro-irrigation, along the lines of the Solar Development Group model; and
4. Engage relevant Bank staff in donor funded RD&D activities and pilot programs in key countries.

Next Steps

The following are priorities for follow-on activities to this initial study:

?? Conclude the Market Potential Study
?? Secure funding for and finalize Global Initiative Planning
?? Convene global network of donors and implementers (May 2001)
?? Explore mechanisms for Bank Group and donor support
?? Commercial ramp-up in key countries

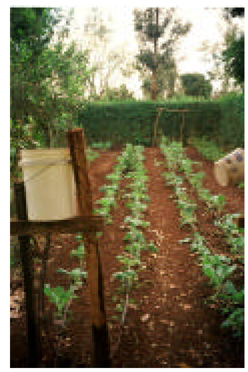
Creating New Markets via Smallholder Irrigation

I. Introduction. Over the next quarter century, water shortages will increasingly pose a fundamental obstacle to the further growth of productive agriculture. Water shortages are particularly acute in countries with large populations of rural poor reliant on smallholder agriculture. Although the problems involved in water management are complex, it appears that part of the solution may be to promote the introduction of new, small-scale, low-cost irrigation technologies and market access approaches where smallholders can improve yields of high value crops which can dramatically reduce water demand while improving their quality of life. (Polak, 1996, Postel, Polak, Gonzalez and Keller, 2001)

A growing body of literature documents the success of smallholder irrigation technologies (Barnes, Orr, and Islam, 1991; Downing and Polak, 2000; Hurdec, 2000; Mehta, 2000; Polak, Nanes, and Adhikari, 1997 and 1998; Polak, Morgan, and Saussier, 1999). The most widely known is the study by the International Water Management Institute (IWMI) (Shah, 2000), although other publications by independent evaluators provide a useful basis for comparing approaches to smallholder irrigation technology development and developing applicable models. They are referenced in various locations throughout the accompanying case studies.

What are Smallholder Irrigation Technologies?

- Micro Irrigation
- Treadle Pumps
- Low Head Sprinklers
- Mechanical Pumps



The problem addressed by this study is the low income level and (to date) limited investment opportunities for smallholder farmers throughout the developing world. These farmers have often exploited their limited resources to the best of their abilities. Small plot size and limited access to water are major constraints for these farmers. They need technologies that can (a) assist them to best use their limited resources, (b) are affordable and (c) can substantially improve their incomes. Such micro-technologies now exist and are starting to have macro impacts.

The United Nations medium growth projections indicate that global population will expand from the present 6 billion to nearly 8 billion in 2025. More than 80% of these people will live in developing countries. Presently there are 1.1 billion farmers in the world of whom 1.05 billion are in developing countries (World Water Forum, 2000). Of these an estimated 600 million are classified as poor by country definitions. These farmers and their families are the targets of this Global Initiative, to which this study contributes.

Smallholder irrigation technologies are the basis for a significant change in the approach to irrigation development in developing countries around the world (Heierli and Polak, 2000).

Through modest investments in irrigation equipment specifically designed for their conditions and proven to have the capacity to use their available water resources efficiently, smallholder farmers are working their way out of poverty (Postel, 2001; Polak and Sivinnappan, 1998).

Even when enabled with irrigation technologies, smallholders face barriers to wealth creation. Smallholders need access to inputs, markets and credit. In addition to access to technology, farmers need the skills that will enable them to successfully utilize that technology. Beyond that they need assistance to assure that markets for their produce expand in line with their increased production. Global markets for products ranging from asparagus to zucchini exist, though access to markets requires better transportation and communication infrastructure, better sources of credit, and better marketing facilities. This study describes the process of understanding the barriers, developing pilot approaches and gearing up to assure that smallholders have improved access to markets. Smallholder irrigation is a key entry point by which farmers can access avenues to wealth creation.

In this study we define smallholders as those primarily poor farmers, some of who are landless. Many of these farmers have some access to land, although they often do not have a land title or deed, necessary to easily obtain credit. In Latin America the definition of a smallholder may be different from that in Africa or in Asia. In general, though, we consider smallholders to be those poor farmers whose production is currently at or below the subsistence level. In most countries these farmers operate with less than two hectares (or five acres) of land.

The World Bank has always considered small-scale irrigation a promising option for developing countries. However, the Bank's past activities in smallholder irrigation have been minimal, and generally the Bank has focused on larger scale systems for larger plots. In addition, market-based technology diffusion via the private sector presents serious difficulties for governments as well as large international financial institutions, for neither are well-equipped to start, finance, and support very small enterprises.

The World Bank and other national and international bodies are now giving smallholder irrigation increased attention for five main reasons:

?? Technological advances, particularly in the area of developing affordable, small-scale water lifting devices and drip irrigation systems;
?? Shifts in the policy environment favoring private sector initiatives and increased smallholder participation;
?? Heightened environmental concerns--in particular, concern for increasingly severe water shortages and food security;
?? Increased focus on poverty alleviation, achievable by increasing smallholder productivity through affordable small plot irrigation;
?? The emergence of viable market creation approaches for smallholder development.

The objective of this study is to clarify the site-specific dissemination potential and promotion strategies of low cost smallholder irrigation technologies in developing countries.

The study will attempt to determine and classify site-specific requirements for smallholder irrigation development versus those factors, which are applicable across broad geographical regions.

Scope of this Study

The scope of this study (provided as **Annex 10**) is to conduct studies and limited field work to (a) determine under which conditions smallholder irrigation technologies can be successfully applied, (b) review at least six case studies of smallholder irrigation programs including at least one case study from each of the six World Bank geographic regions, and (c) evaluate prospective markets for the implementation of smallholder irrigation programs and determine anticipated social and economic benefits. A series of meetings is to be conducted with Bank staff and presentations during the course of the study. The draft study is due March 31, 2001.

Scope of the Current Study

- Determine conditions under which smallholder irrigation can be applied
- Prepare case studies
- Evaluate prospective markets

II. Background

The Smallholder Irrigation Market Initiative

The Smallholder Irrigation Market Initiative is a new effort by the World Bank to work with its member countries and the industry, research, foundation and NGO communities to provide financing and technical assistance for a global program to hasten the commercialization of low cost drip irrigation and other small scale irrigation technologies, and to expand their applications significantly in developing countries.

The initiative has four main thrusts:

?? Preparation and finance of commercial and near-commercial applications with a goal of 1 million new hectares under irrigation per year

?? Facilitation of international research, development, and demonstration (RD&D) and business development projects for expansion of commercial smallholder irrigation markets

?? Stimulation of high-volume global demand for smallholder irrigation technologies that, in turn, will stimulate agricultural intensification and ensure long-term participation of the private sector
?? Organization of interested stakeholders in smallholder irrigation as a thematic group (community of practitioners) to facilitate knowledge sharing.

The objective of this initiative is to accelerate the introduction of cost-effective new technologies by promoting dialogue, conducting pilot activities, and providing assistance and financing to support small enterprises and larger private sector elements in countries and regions where the technologies can make an important contribution. The end result is self-sustaining enterprises that, once formed, will continue to sell and maintain equipment in the future.

Relation to Global Initiative for the Promotion of Smallholder Irrigation

This study is part of a broader international effort to promote poverty alleviation via the acceleration of commercial markets for smallholder irrigation. A business plan for the global initiative for the promotion of smallholder irrigation is under development. The business plan will analyze market development requirements, the role of the World Bank Group, required support to the Bank's regional units for smallholder irrigation project identification and preparation, options for a coordinating, strategic, and catalytic role in removing barriers that impede the introduction of low cost irrigation technologies in developing countries, and all relevant issues pertaining to the establishment and operation of the Smallholder Irrigation Market Initiative. The plan will also define strategies for effective collaboration between the World Bank's initiative, and initiatives implemented by other organizations in the public, private, donor, and NGO communities.

The business plan will clearly identify opportunities and constraints for investment, whether by the Bank or other investors. This study is the first output of that process and the results will be incorporated in the detailed Business Plan. Subject to availability of funding, the entire business plan is expected to be completed by May 2001.

Experience Suggests Potential

The experience with smallholder irrigation over the past twenty years suggests that we have only begun to tap the potential of these technologies. The treadle pump, a simple manual pump developed in the 1980s and marketed for $25 per unit in Bangladesh, has generated over $100 per family in incremental income for 1.3 million farm families (Polak, 2000). This experience has been documented in several studies, including a major study by

Experience Suggests Potential

- Commercial smallholder market is emerging
- IWMI treadle pump evaluation
- Keller/Shah micro-irrigation evaluation
- Donor involvement: Swiss, Dutch, Japanese, Canada, DFID, etc.

an independent research organization (Shah, 2000). Over the past ten years, a range of low cost small plot drip irrigation systems have been developed and field tested by IDE (Polak, 2000) by Chapin Watermatics (Chapin, 1998, Adams and Chapin), and by the Yanshan Institute in Beijing. A team consisting of Jack Keller, a renowned irrigation expert, and Tushaar Shah of IWMI, is currently documenting experiences with micro-irrigation technologies in Kenya and Asia.

BangladeshTreadle Pump Program Investments and Returns

- Donor Investment $ 6.7 m
- Farmer Investment $33.4 m
- Number of Farm Families 1.3 m
- Annual Incremental Income/Family $100
- Annual Total Incremental Income $130 m

Markets for smallholder irrigation technologies are evolving rapidly. Large irrigation equipment firms, such as Netafim, which previously were not interested in the idea, are now seriously developing equipment specifically aimed at smallholders. Although the private sector is often understandably reluctant to target poor farmers, the efforts of the private sector can contribute to the solution. Finally, donors have increased their support for smallholder irrigation. Examples include bilateral donors in Switzerland, the Netherlands, the United States, Japan, Canada, and the United Kingdom and private foundations such as the Kellogg Foundation.

III. A Business Model for Smallholder Irrigation Development

Historical Approaches

Smallholder irrigation has a long history and includes a variety of approaches. During the 1970s and 1980s appropriate technology garnered a great deal of attention, led by proponents such as E. F. Schumacher (1974) and others. Although some equipment designed during this era such as fuel-efficient stoves succeeded to varying degrees, other equipment was never adopted other than by a pilot stage audience. Shelves are filled with the designs for such equipment. Numerous water harvesting technologies, for example, were developed to conserve water for smallholders, but the intended beneficiaries never adopted most of them. The promotion of many of these technologies lacked a business approach, which we assert is essential for programs aimed at convincing farmers to change their practices, even when the technologies are affordable and have demonstrable benefits.

The treadle pump, developed in the early 1980s in Bangladesh by Gunnar Barnes, a Norwegian development worker, and a number of others is an excellent example of a technology that could promote social equity but had little impact until it was marketed nationally. The pump is designed to lift water from shallow depths to the surface. Bangladesh is perfectly situated for this technology in that shallow groundwater is widespread and recharges annually. The treadle pump allows for growing a third dry season crop, usually a high value vegetable crop, thus essentially increasing family income by more than one third. A major evaluation (Shah et al, 2000) has now confirmed the estimates that the pump has generated an average of over $100 of annual income for the each of the 1.5 million purchasers.

The key to the success of the pump, as documented in the Bangladesh and other case studies, was the extensive promotion of the pump and its widespread availability through the private sector. This approach has now been successfully replicated elsewhere by other implementers and we feel confident we can now present a model of this approach.

Description of the Model for Smallholder Irrigation Development

What characterizes the present approach to smallholder irrigation development (as opposed to earlier approaches of appropriate technology) is the shift in emphasis from the technology development phase (although this phase is still important) to the phase of developing a private sector-led supply chain and rural mass marketing of the equipment (Edesess and Polak, 1997).

Based on the experience in a number of countries by a growing number of organizations, a framework that characterizes parameters for success can now be summarized. The overriding principle of all the successful approaches is that they *treat farmers as entrepreneurs* motivated by profit who make investment decisions based on information available to them. Successful technology transfer depends on finding farmers who fit this profile and using them as demonstrators who will influence their less entrepreneurial or more risk adverse neighbors.

Requirements of Successful Smallholder Irrigation

- Adequate water supply
- Training in all aspects of irrigated production
- Equipment and other inputs need to be readily available
- Marketing of produce is key

Components of the Model

The model has six components: feasibility, technology development, supply chain development, rural mass marketing, agricultural integration, and impact measurement and feedback. Each of these components is critical but each can be carried out by different actors.

Feasibility Study. A feasibility study is the initial step in making a decision to proceed with a national or regional-level program. Its objective is to determine the potential market for particular smallholder irrigation technologies. During the feasibility stage a team examines current smallholder irrigation practices, assesses water resource availability, reviews the experience with past technologies, identifies potential local partners and determines capability of local manufacturers. The team will set up several demonstrations of potential technologies and convene focus groups of farmers to evaluate the technology. The feasibility phase is not restricted to the market of micro irrigation technologies. Rather, this phase also looks at crops as currently produced, current production practices, and especially, market opportunities in high-value crops for which the smallhold sector may have a comparative advantage.

Business Model for Smallholder Irrigation Development

Develop the Technology:

- Conduct Feasibility Study
- Field Testing, Farmer Feedback
- Technology Adaptation

Technology Development. Once a decision is made to proceed with a program, the technology package is finalized. Decisions need to be made on importation or local production, manufacturing methods and materials, the size of kit, etc. Demonstrations are conducted on a wider scale and discussions are held with private sector producers to determine their capability. Definition of the specific product, its market and how it will be manufactured are determined at this stage. Feedback from farmers is needed at all stages, as well as analysis of characteristics of the target farmers, including affordability of the product. Successful programs market a product that is affordable to farmers and that can pay for itself in a season or, at maximum, a year. Also during this phase, research and adaptation is carried out on production technologies that the smallhold farmer can use, together with the water-related technologies, in his or her efforts to become a cost-effective supplier of high-value crops and agricultural outputs.

Keys to Technology Adaptation

- Appropriate sized kits
- Affordable kits
- Maintained by farmers
- Kits and spares available nationwide

Business Model for Smallholder Irrigation Development (2)

Develop the Market:

- Marketing Plan
- Supply Chain
- Rural Mass Marketing

Agricultural Integration

Impact Measurement & Feedback

Supply Chain. Once a product is identified it must be manufactured. Locally manufactured products are preferable, as demonstrated by the Kenya case study, in order to avoid supply problems. Although drip tape is not produced in many developing countries, PVC pipe and other plastic products are produced in many countries. Micro-irrigation kits can easily be produced using micro-tubes, which can be manufactured with a minimal upgrade at a PVC pipe factory. The method of manufacture is linked to the selection of technology and these decisions must be made in tandem. Also it is critical to determine how and by whom the products will be distributed. It is desirable to have as wide a distribution network as possible, not just to one target area within the country. Local agricultural outlets, hardware stores, etc. are logical candidates for retailers. The structure and relationship of manufacturer, wholesaler and retailer needs to be determined for each program. Questions of quality control, guarantees and other issues need to be resolved. Various types of supply chains have been developed, and it is essential that all parties in the chain make a profit to ensure sustainability.

In the development of supply chains, provisions are made for private sector enterprises to supply the associated inputs (seeds, fertilizers, soil amendments, plant protection agents, etc.) that the smallholder farming community will need to take maximum advantage of the water-related technologies. In addition, provisions are made for the private sector and/or government agencies and NGOs to provide necessary farmer training.

As availability of credit is a major factor in the successful mass dissemination of productivity-enhancing technologies for the smallholder, special consideration is given to building into the supply chain mechanisms for credit for the smallholder.

Rural Mass Marketing. In order to convince farmers to buy new technology major efforts must be put into marketing. The marketing effort will take different forms depending on the country. The Bangladesh experience with marketing included demonstrations, performances, leaflets, posters, calendars, etc. The Kenya Approtec experience involved national newspaper advertising including contact information on each local supplier in the country. In Latin America and elsewhere, radio has effectively been used as a marketing tool. Links with NGOs working at the field level have been effectively used to demonstrate and promote micro-irrigation technologies.

Agricultural Production: Adding Value to Product, and Output Marketing. With micro-irrigation farmers may be producing high value crops with which they are unfamiliar. They may need training on variety selection and management practices. Farmers may also need training in the use of postharvest practices and on-farm processing in order to add value to their products, and to gain access to profitable and stable markets. Promotion of high value crops may involve policy dialogue with the host government to facilitate relevant infrastructure development and the creation of new markets. Marketing may also involve improved storage and preserving (drying, pickling, cooling, freezing) of high value crops carried out on an industrial scale.

Impact Measurement and Feedback. In order for the program to work effectively, managers must be able to monitor impacts in order to continuously adapt the program to meet its objectives. Programs may need to adapt new technologies, tap new markets, or find new sources of donor funding. In order to respond to changing conditions, program staff members need to monitor sales, redefine the target smallholders and measure the impact that the technology is having on incomes, employment, and other factors. This data needs to be fed back to the program to enhance profitability, build sustainability, and ensure greater incomes for the target smallholders.

The process involves a number of actors with a variety of skills. For this reason the Global Initiative has placed high priority on the establishment of a network that would include a variety of organizations including donors, NGOs and other implementers, host governments and the private sector. There is a strong need for coordination of the program to assure that parties work together towards a common goal. A network secretariat would have a major objective of promoting coordination among all the actors involved in promoting smallholder irrigation.

IV. The Case Studies

The Approach

Review of Installed Systems: Case studies have been employed in this paper in several ways. The first is a straightforward approach to document experience that has been gained in smallholder irrigation in various regions around the world. Second, we use these studies to demonstrate the applicability of the model and to highlight lessons that have been learned in various experiences with smallholder irrigation. Third, and perhaps most significantly for this study, we make use of existing experience to point to and assist in estimating potential demand for smallholder irrigation technologies. Our approach was to identify experience with smallholder irrigation in various ecosystems in various regions

Approach of the Study

- Define ecosystems
- Identify experience in each ecosystem
- Determine lessons learned
- Extrapolate potential market demand based on experience

around the world. These experiences range from mature programs, such as the treadle pump program in Bangladesh, to the fledgling experience in China. From each of these we have extrapolated to the larger ecosystem to attempt to develop estimates of potential demand. We intend to use these cases as the basis for future programs and will expand upon these further in the next phase of the Business Plan. Annex 1 includes case studies of smallholder irrigation in various places around the world. The following sections on lessons learned and crosscutting issues serve to synthesize the information provided in the case studies.

Assessment of Past Approaches: Lessons Learned from the Case Studies

The case studies provide important information regarding model validation as well as insights into the design of future programs. The following is a summary of lessons learned based on the case studies.

Case Studies

- Africa
  - Kenya
  - Zambia
- Asia
  - Bangladesh
  - Maharastra
  - Nepal, Himalchal Pradesh
- Eastern Asia
  - China
- Latin America
  - Mexico
  - NE Brazil
  - Nicaragua
- Near East/North Africa

Need for Micro - Credit in the Supply Chain. In virtually all case studies, access to credit for the purchase of irrigation equipment and agricultural inputs was identified as the greatest single remaining constraint to smallholder adoption of improved irrigation and agricultural intensification; the poorer the farmer the greater the credit constraint. Netafim reported that access to credit would remove the greatest existing constraint to increased sales of their Netafim family drip systems in China, and treadle pump dealers in Bangladesh and India consistently predict a doubling of sales if credit were available.

Although existing microfinance organizations and equipment manufacturers occasionally make credit available, these cases are a distinct minority. Since smaller loans have relatively high transaction costs, loans for irrigation equipment in the range of $25-$75 are still very hard to come by in poor rural areas not well served by microfinance institutions. Even then, many existing microfinance organizations prefer not to specialize in agricultural equipment; others prefer densely populated areas where threshold loan volumes can more easily be reached, and still others prefer loan portfolios with larger average loan sizes. Since this affordable irrigation technology has repeatedly demonstrated the capacity of generating net cash returns of 300% on its purchase price in the first growing season, increasing the probability of 6-month payback, the absence of microfinance support is particularly unfortunate.

The business plan for the global initiative will include the development and field testing of economically sustainable models for increasing smallholder access to microfinance to purchase irrigation equipment and inputs. A collaborative effort with existing experienced microfinance organizations to develop and field test models of microfinance delivery through the private sector supply chain will be an important first step in this effort. This thrust should take advantage of the experiences of private sector companies like Singer that finance small household machinery and appliances.

Local Production and National Distribution. The **Kenya** case study of the Chapin bucket kits distributed by the Kenya Agricultural Research Institute (KARI) provides two important insights into problems associated with production and distribution. The bucket kit is manufactured in the U.S. and shipped to Kenya in container-lot quantities. Although the shipping costs per kit are relatively low, delays hinder the availability of kits. An entire container is expensive, so the program must depend on a large influx of funding to import the kits. This means that the program is not run as a sustainable business. Second, the kits have been distributed only at the national headquarters of KARI and several other outlets. They are not available through the private sector at local outlets. Although the program has conducted a good demonstration program both at the national headquarters and at local agricultural field days, it lacks a consistent advertising campaign. Only sporadic advertisements and newspaper articles have announced the availability of the kits. This has resulted in uncertainty and reliance on distribution through NGOs, which buy a number of kits for their target farmers. Finally, spare parts are not readily available as there is no national supply chain of kit retailers.

Existing Irrigators are a Natural Target. The case study from **China** examines a potential program to promote smallholder irrigation in China, targeting poor farmers in Guizhou. Although it is not yet clear which technologies would be most beneficial to these farmers in terms of increasing incomes, farmers have shown keen interest in micro-irrigation and other technologies which save labor, increase yields and increase quality of produce. In comparison to some experiences in Africa where farmers are being introduced to irrigation for the first time, in the China case, the transition is much easier because farmers are already producing high value irrigated crops. Wealth generation, however, may come as much from efforts to expand their opportunities to enter export markets as from the introduction of new irrigation technologies.

Market Linkages. The Zambia Dambo[2] development case study provides a number of interesting lessons learned. First, the program emphasized local production of treadle pumps, which lowered costs from $200 to between $60 and $70 per pump. IDE has operated the project in 4 areas of Zambia with 18 retailers, with emphasis on demonstrations to reach farmers. Farmers have been linked to micro-credit. The dispersed nature of the population and poor transportation and other infrastructure has hindered adoption. The most significant lesson is from the socio-economic study, which shows that those farmers who are linked to established horticulture markets realize the highest incomes. Generally, limited access to markets has prevented many farmers from full adoption of the technology. Zambian farmers

[2] *Dambo* is a term locally used in Eastern and Southern Africa referring to seasonal wetlands which are usually located in the headwater areas of river plateaus and are typically grass-covered flood plains or valley bottoms.

tend to be dispersed, and although access to land and water in dambo areas is good, farmers are generally located far from markets, and are constrained by poor road infrastructure.

The Poor as Target Customers. The experience in Nepal reported in the Poor Hill Agriculture Case Study illustrates the techniques used when extremely poor farmers, including women, are targeted as major potential users of micro-irrigation technologies. This experience is repeated in Kenya and elsewhere where poor women are not only producers of household gardens, but can also be involved in commercial agriculture. More emphasis on training is needed for farmers who lack experience producing high value crops. On the other hand, IDE found that hill areas often had climates suitable for off-season crop production with possibilities for good returns for crops produced during certain seasons.

Advantages of Micro-Irrigation

- A Scaleable Technology
- $5 entry level investment
- Potential for Wealth Building
- Improve household nutrition levels

Quality vs. Affordability. The Bangladesh case is classic in its approach to mass marketing: the program used a variety of methods, including demonstrations, plays, a movie, leaflets, and songs to reach the target audience. As the Bangladesh market for treadle pumps matured, growing competition developed among treadle pump manufacturers, some of whom produced inferior quality pumps. IDE educated customers to differentiate between high and low quality products and to make informed decisions. IDE produced three levels of pump quality and advertised the expected life of each pump, finding that customers preferred the lower cost pumps. The main lesson is that suppliers need to be ready to face competition in a maturing market. Other lessons from this case include the importance of endorsement from key decision makers in the country. Also, in one interesting micro-credit example, a bank has taken the lead in promoting and selling treadle pumps as part of a credit package.

Working with NGOs. The case study on the Deccan Plateau in India illustrates several principles in line with the model just presented. This is a case where micro-irrigation technologies have been introduced and are now rapidly being adopted by smallholders due in large part to promotion by over 200 NGOs working at the grassroots level. This demonstrates an important lesson: working with NGOs can provide important benefits. In this case the partner organizations handle the whole task of demonstration and promotion. Also, in working with the NGOs, new business opportunities have opened up for crop input packages and the opportunity to facilitate the marketing of pre-packaged seed, pesticide and fertilizer as well as seedlings and saplings. Another important lesson that is clear in this case is the scalability of the micro-irrigation technology. IDE is marketing four levels of kits to the target farmers, each one providing an annual profit potential which allows moving up to the next larger kit with an increased wealth building potential. This program is still at an early stage, with IDE serving a supplier. Sustainable businesses need to be developed which can provide desired products to NGOs as well as to private customers.

Crosscutting Issues
A number of crosscutting themes have been identified during the course of the study. Some of these are discussed in more detail in the case studies.

Role of Women. Irrigation schemes have often been developed with scant attention to the important role played by women in agriculture and commerce. Particularly in Africa, women play the predominant role in choice and use of such technologies as low-head drip irrigation. Equipment design must carefully consider women's concerns, such as the need to be close to home, the need to devote time to multiple activities such as child care and the role women play in economic decisions in the household.

Hybrid Approach. In the hills of Nepal, limited access to irrigation water was identified as a key constraint to the expansion of smallholder irrigation using low cost drip systems. Water from village drinking water systems was commonly available, but in limited quantities. Householders in Kenya often used extra water from their drinking water source for the 50-70 liters of water a day required by a bucket kit. Hybrid drinking water/irrigation systems at the village level make it possible for village drinking water systems to turn a profit, and at the same time expand access to irrigation water for smallholders. The marginal cost of building a three-inch pipe to a spring instead of a two-inch pipe is slight, but the irrigation water it brings to village drip systems can generate enough income to pay for two thirds of the total cost. Six households with access to credit can pay off the loan to build a shared tubewell with the income from six-bucket kits installed along with it. The design of hybrid drinking water/irrigation systems can be incorporated as a planned element of community water supply schemes. Making drinking water profitable through hybrid systems can significantly leverage the impact of the finite resources available for drinking water programs, as well as making a large contribution to opening smallholder access to irrigation water

Peri-Urban Irrigation. Although not often regarded as significant by irrigation officials, peri-urban irrigation plays an important role in contributing to income generation among lower income groups in most developing countries. Peri-urban irrigation can enhance the nutrition of urban dwellers, although health concerns are often raised about irrigating with polluted water. Recent studies of peri-urban irrigation in Africa (Cornish and Aidoo, 2000; Hide and Kimai, 2000) identify opportunities and constraints of peri-urban irrigation in two cities in sub-Saharan Africa: Kumasi in Ghana and Nairobi in Kenya. Lack of land tenure and the uncertain nature of the enterprises limit the scope of working with these entrepreneurs. Smallholder irrigation technologies in peri-urban areas have high potential, particularly where vegetable producers irrigate with sprinkler cans and immediately see savings in labor. Other benefits include water conservation; improved quality of produce; portability and low investment cost and are well suited to peri-urban irrigators.

Commercial Irrigation. Commercial farmers generally have higher incomes, better access to credit and other resources and better access to markets in comparison to smallholders. Although we hesitate to draw a fine line between "smallholders" and "commercial" farmers we generally consider commercial farmers to have sufficient income earning opportunities, distinguishing them from our target farmers. In the case of China, for example, private sector companies should work with greenhouse producers to improve production methods since in most cases those farmers are not considered poor by Chinese standards. Elsewhere, however, partners of the Global Initiative will reach the rural poor, who will pay for irrigation equipment but not necessarily the full cost of delivering that equipment at the early stages of market development. Commercial irrigation can benefit smallholders in that drip irrigation products tend to be readily available where there is a substantial market for commercial irrigation. On the other hand, larger commercial irrigators may dominate the local market, as is the case in South Africa, making it difficult for smallholders to gain access to markets to sell their products.

Irrigation by Landless. Even landless farmers may have some access to land, perhaps through illegal occupation or by paying rent. These landless farmers may benefit from micro-irrigation technologies, which are affordable, portable, and water efficient.

Water Resource Issues. From the individual farmer's perspective smallholder irrigation technologies make sense if they can improve family income. From a national water management perspective, though, do these technologies make as much sense? The question is whether drip irrigation results in water savings in comparison to other irrigation methods. (Seckler, 1996; Keller, Keller and Seckler, 1996; Postel, 1999; Suryawanshi, 1995). As discussed by Gleick (2000), drip irrigation can reduce water consumption by up to 60% in comparison to furrow irrigation. This results from decreased on-farm losses since water is delivered directly to the root zone of the beneficial crops. Drip irrigation reduces non-beneficial water consumption such as through transpiration by weeds and evaporation from bare soil, resulting in "real" water savings – more water available for other uses. Many developing countries in Africa, for example, have only developed a fraction of their irrigation potential according to published figures (IMPIM, 2001), yet are still facing at least localized water shortages. Under this scenario, micro-irrigation technologies make sense to increase food production while having minimal impact on already scarce water resources. Gleick (2000) also includes tables that quantify increased yields (up to 50%) for various crops and decreased labor requirements (up to 90% savings) in comparison to various other irrigation methods. Thus drip irrigation has many advantages in addition to its water saving characteristics.

Advantages of Micro-Irrigation

- Reduces water consumption up to 60%
- Higher yields and higher quality produce
- Good water uniformity
- Up to 50% less labor compared to hand watering

Environmental Concerns. Smallholder irrigation technologies generally have relatively minor impacts on the environment in comparison to other irrigation methods. Farmers using treadle pumps in Bangladesh and elsewhere use shallow groundwater, which is recharged annually. Drip irrigation systems require less water than other irrigation methods; hence less water is pumped from aquifers in comparison to other irrigation methods. One concern about micro-irrigation is the discarded plastic waste from abandoned drip tape and tubing. In India, an industry has emerged to recycle drip tape, obviating this problem. Generally when farmers convert from surface to drip irrigation or add a small area of irrigation to their dryland farms there are few concerns. However, greater concerns arise where individual or groups of farmers initiate irrigation on new land adjacent to water sources, such as is the case with the dambos of southern Africa. In this case there may be concerns for preservation of ecosystems and endangered species. Countries should have regulations for allocating these types of lands and may need to restrict such development.

V. Constraints and Opportunities: The Market for Smallholder Irrigation Technologies

Prospective Markets: Approaches to Estimating Market Potential

There are a number of factors that must be considered when estimating the market for smallholder irrigation technologies. Among these are factors related to land and water resources, socio-economic factors related to numbers of potential poor farmers likely to adopt the technology, and, finally (but important), factors related to markets for irrigated crops. This section will briefly describe these factors. This analysis is similar to a linear programming model in which we attempt to maximize sales subject to constraints represented by functions of various variables. This study reviewed experience to estimate the limits imposed by each set of variables.

Land and water play a critical role in estimating potential markets for smallholder irrigation technologies. The FAO and others have published estimates of existing and potential irrigable land by country. A recent compilation for Africa (IPTRID, 2001) includes a list of countries by their rate of irrigation development. These statistics can serve as a good first sort on countries where irrigation is important and where the potential for additional irrigation is high. Zambia is a case with a high potential for irrigation development (3.5 million hectares) but a very low percentage of developed irrigation. Whether it has a high potential for smallholder irrigation technologies needs to be determined by examining other factors as well. In the case of treadle pumps it would be most important to know about the availability of shallow groundwater and irrigable land adjacent to surface water. Unfortunately most countries do not publish statistics on shallow groundwater, and only general conclusions can be drawn from the existence of broad alluvial valleys and plains, or dambos in the case of Zambia. A detailed review of groundwater data would be important once a country is selected for investigation.

The second set of constraints deal with socio-economic aspects of smallholder agriculture. Our assumption here is that a certain percentage of smallholders will adopt a particular technology in any given country and that number may or may not be related to the amount of irrigable area. Experience in other countries may be a guide for estimating the percentage of adopters. Thus the number of potential adopters of drip technology in Country X may be estimated based on the number of adopters in Country Y, which has had a longer history with drip irrigation but similar conditions otherwise. Estimates for potential treadle pumps sales in India are thus based on previous experience with treadle pumps in Bangladesh. This method is limited by the assumption that experience in one country is applicable and transferable to that in another. An important factor is the entrepreneurial spirit of smallholders versus their conservative nature. Smallholder farmers, particularly poor subsistence farmers who are concerned about meeting their basic food requirements, are conservative. The entrepreneurial aspect of farmers needs to be developed in order to speed adoption. Through the use of demonstrations and growing farmer awareness based on personal observation of the technology used by their neighbors, the potential number of adopters will grow over time. Since micro-irrigation technologies are aimed at poor farmers, we can expect that as farmers gain more wealth they graduate from our target group and become more commercial farmers.

The third set of constraints is based on consumers' demand for crops commonly grown by smallholder irrigators. There have been many examples of glutted local markets for crops that are typically irrigated such as tomatoes, cabbage etc. We need to be able to forecast these markets and make sure that smallholders do not flood the market, thus lowering prices and reducing returns. Farmers need to be aware of the limited absorptive capacity of local markets, and be prepared to grow alternative crops and time the market for windows of opportunity when supply is low and demand high. Part of the agriculture integration program is to expand markets for irrigated crops through measures such as processing, expanding use, and promoting exports. When farmers can meet quality and other demands of export markets there is less concern about market oversupply. Although we generally assume that farmers using smallholder irrigation technologies will irrigate high value horticulture crops, in some countries farmers have obtained satisfactory returns from what are generally considered lower value crops, including maize, sugarcane, and wheat. A further point is that estimates of per capita consumption for high value crops may vary tremendously from country to country and these values are likely to increase as incomes increase. For example, in China vegetable production is quoted as 350 kg per capita per year whereas Africans would be shocked to see this quantity of vegetables on their plates.

Although resource and socio-economic constraints are important, market constraints are likely to be most important in terms of hindering the sales of smallholder irrigation technologies. Work to expand crop markets is necessary if significant numbers of farmers are to be brought out of poverty.

In this study we have used our best estimates and estimates of colleagues around the world to assist in the projection process. For example the Indian National Committee on Irrigation and Drainage has estimated the potential for drip irrigation in India to be 10.5 million ha (INCHED, 1994) based on adoption of drip irrigation technologies to that date. The committee suggests as a target for India to convert at least 1% of the irrigable land to drip irrigation over the next 8 to 10 years. We have used these and other data as the basis for our estimates of potential acreage and numbers of potential target farmers.

Evaluation of Potential: Extrapolating from the Case Studies

Each of the case studies gives an indication of the potential for smallholder irrigation within the larger ecosystem. These results are summarized in the table below. Although the results are not complete, they indicate that over 40 million poor farmers are potential customers for irrigation technologies that will bring them out of poverty. With an average family size of five, this represents a potential population of 200 million, or over 30% of the world's rural poor. The projection represents almost 7 million hectares of newly irrigated land, which could be productively and efficiently used for producing high value vegetables and other crops.

Table 1. Potential areas and numbers of farmers adopting smallholder irrigation technologies by ecological areas

Ecosystem	Case Study Country/ Region	Current Area (ha)	Current Number of Farm Families	Projected Area (ha)	Projected Number of Farm Families
Water Scarce Tropics SSA	Kenya	32	5,000	300,000	3 million
Dambo area of SSA	Zambia	1,000	2,000	400,000	1 million
Gangetic Delta	Bangladesh, Eastern India, Nepal Terai	300,000	1.5 million	1.5 million	8 million
Deccan Plateau, India	Maharastra and Gujarat	150	10,000	500,000	7 million
Hill Areas of Asia	Nepal Hills, Himachal Pradesh India	500	7,000	500,000	7 million
Semi-arid areas of Latin America	Mexico		Field test stage	300,000	600,000
Winter Vegetables in China	Greenhouses in North China, Natural Greenhouses in South China				
Natural Greenhouse River Valleys	a. Guizhou Province	13,000	100,000	80,000	600.000
Natural Greenhouse River Valleys	b. Guizhou, Yunnan, and Guanxi Autonomous Region	40,000	300,000	250,000	2 million
Greenhouses	c. Northern China	15,000	200,000	150,000	2 million
Central and West Asia and North Africa					
	Totals	**369,682**	**2,124,000 families (10.5 million individuals)**	**4 million**	**31.2 million families (200 million individuals)**

VI. Findings/Conclusions/Next Steps

The conditions for successful smallholder irrigation relate to implementation of the model set out above. Clearly poor smallholder farmers all over the world could benefit from these technologies, which they currently lack access to. The conditions under which they will adopt these technologies need to be carefully studied and developed. Lessons learned from Bangladesh and a growing list of other countries have assisted us in defining a model for delivering appropriate technologies to smallholders and developing their understanding and willingness to adopt the technologies. Adoption rates are dependent on many factors. The model attempts to systematize these and serves as the basis for developing effective programs worldwide.

Specifically, the conditions for successful implementation of smallholder irrigation programs include:

?? Carrying out a feasibility study that identifies opportunities and tests potential technologies
?? Developing the technology
?? Building the supply chain and rural mass marketing
?? Integrating agriculture and work to expand the market for agricultural produce
?? Measuring impact and feeding back information to redesign programs

The case studies have served to verify the model and provide insights into new methods of implementation.

Estimating the market potential for smallholder irrigation technologies is an inexact science. Three important factors have been identified (resource constraints, socio-economic constraints and output market constraints). Experience has shown that smallholder irrigation technologies will expand to a certain percentage of the overall irrigated acreage. Marketing constraints, while often cited as a major limitation, have proven less important than initially thought since farmers can produce a wide variety of crops with micro-irrigation.

Overall we see a huge untapped potential for smallholder irrigation technologies. This demand is well beyond that which can be satisfied by a single donor or single implementing agency. The experience of the treadle pump in Bangladesh, which has enabled over 1.3 million farm families to move out of poverty, provides the model for future programs, with the private sector playing an important role once the initial market is established. Start-up programs need to emphasize technology, rural mass marketing and other factors. The demand for smallholder irrigation technologies needs to be addressed on a global scale, with intensive country level programs by a number of implementers and coordination at a central level. The Global Initiative on Smallholder Irrigation has tackled an ambitious goal and should move quickly toward the next step of preparing a detailed business plan to target at least one million poor farmers per year.

Potential Mechanisms for Bank Group Support

The World Bank considers small-scale irrigation to have great potential for enabling commercial markets for high value, sustainably produced crops, thereby creating wealth and expanding jobs. The Global Initiative for Smallholder Irrigation reflects this vision. However, defining approaches to aggregating these small, distributed technologies into technical assistance and financing packages suitable for development bank action is difficult.

The increasing focus of the Bank on poverty alleviation, coupled with Bank policy to work more closely with NGOs and the private sector and looming water shortages has encouraged more innovative approaches to including small-scale irrigation activities in financing and technical assistance packages[3].

Traditionally, the major development banks[4] faced several obstacles in packaging small-scale irrigation activities into a loan package:

- Minimum loan size to justify the bank's investment in the entire project cycle is often too large for the needs of a national small-scale irrigation initiative.[5]
- Small-scale irrigation is essentially a dispersed, local activity where bank funding tends to support centralized, large-scale investments or investments targeted at large institutions (e.g. national research and extension systems) capable of absorbing large tranches of funds.
- Traditionally, small-scale irrigation has depended on NGOs or Community Based Organizations to jumpstart the process with training, demonstrations, loans, and mass communication campaigns. Banks have traditionally focused on public sector institutions.

However, recent innovations in funding and country agreements have reduced significantly these barriers to funding small-scale irrigation initiatives.

- Governments, as the borrowing agencies, have been more amenable to passing on responsibilities and funding to NGOs or other local organizations to plan and implement activities.
- Targeted microfinance projects have been able to provide a package (training, funds, marketing assistance, etc.) to promote small-scale irrigation.
- Small-scale irrigation, where feasible, can be part of a larger loan package such as a larger water development or rural development project. Such projects often include investments to support other parts of the small-scale irrigation project business model such as rural roads and marketing infrastructure.

The Niger Private Irrigation Project, currently in the World Bank project cycle for 2001, represents many of these innovations in practice. The Government has decentralized management of water resources to local communities and encouraged greater private sector participation. The project combines tube wells with manual pumps, thus increasing project size, and includes funds for training, technical assistance and finance. An umbrella NGO will implement the project. Advice will include study tours, workshops, demonstrations, field trials, field days, and techniques to improve crop yield and quality. This work will be

---

[3] A good example is the proposed Niger-Private Irrigation Promotion project proposed for 2001 funding. This is discussed below.

[4] The section refers to development banks in general, including the World Bank, Asian Development Bank, Interamerican Development Bank and African Development Bank. These are collectively referred to as banks or development banks.

[5] The projections provided in the paper for India illustrate this point. The potential for drip irrigation was stated as 10.5 million ha and if 1/10 of that could be converted to drip irrigation per year using low-cost small scale irrigation technology, and assuming this would require development bank funding for only a small proportion of total funding, then the amount required would probably be about the minimum loan size.

contracted out to the Niger Association for Private Irrigation Promotion ANPIP). The program will also create savings associations; provide land-titling assistance for project beneficiaries; and assist local irrigation service providers. Total project cost is programmed at $33 million.

As the result of this study and interviews with Bank staff, we have identified four priority avenues of exploration:

1. Follow-up on specific Task Manager interest in integration of smallholder irrigation in Bank projects in the pipeline;
2. Explore with the Bank and with donors placement of a Smallholder Irrigation Specialist in the Rural Development Group of the Bank dedicated to preparing subproject components in Bank projects;
3. Investigate with IFC the creation of a specialized Smallholder Irrigation Investment Fund coupling technical assistance with business development services and finance to invest in small enterprises along the supply chain for micro-irrigation, along the lines of the Solar Development Group model;
4. Engage relevant Bank staff in donor funded RD&D activities and pilot programs in key countries.

Next Steps

The following are priorities for follow-on activities to this initial study:

?? Conclude the Market Potential Study
?? Secure funding for and finalize Global Initiative Planning
?? Convene global network of donors and implementers (May 2001)
?? Explore mechanisms for Bank Group and donor support
?? Commercial ramp-up in key countries

VII. References

Gleick, P 2000, "The World's Water 2000 - 2001 Island Press, Washington DC

INCHED, 1994, Drip Irrigation in India, New Delhi

IPTRID, 2001 International Programme for Technology and Research in Irrigation and Drainage, FAO, Rome.

Schumacher, E. F. 1974. Small is Beautiful: Economics as if People Mattered, Harper Collins, New York

Adams, Elizabeth, and Chapin, Richard. Bucket Kits Watering Vs Hand Watering. Chapin Third World Products, 368 N Colorado Blvd, Watertown, NY.

Barnes, Gunnar, Orr, Alistair, and Islam, Nazrul, 1991. The Treadle Pump: Manual Irrigation for Small Farmers in Bangladesh. Dhaka, Bangladesh. Rangpur Dinajpur Rural Service.

Cornish, G. A. and J. B. Aidoo, 2000. Informal Irrigation in the Peri-urban Zone of Kumasi, Ghana: Findings from an Initial Questionnaire Survey, H.R. Wallingford, Wallingford, Great Britain.

Chapin, Richard, 1998. Bucket Kits for Vegetable Gardens. Chapin Watermatics, 368 N Colorado Ave, Watertown NY 13601

Downing, Jeanne, and Polak, Paul. The Development and Commercialization of the Treadle Pump in Bangladesh: A Case Study of Product Marketing on a Mass Scale. Proceedings of the conference on Business Development Services, Hanoi, April 2000.

Edesess, M. and Polak, P. 1997. Paul Market Driven Product Development as a Model for Aid-Assisted International Development. International Development Enterprises Publications, 10403 W. Colfax, Lakewood Colo.

Heierli, Urs, and Polak, Paul. Poverty Alleviation as a Business. The Market Creation Approach to Development. Swiss Agency for Development and Co-operation, Freiburgstrasse 130, CH-3003 Berne Switzerland, March 2000.

Hide, J. M. and K. Kimani, 2000. Informal Irrigation in the Peri-Urban Zone of Nairobi, Kenya: Findings from an Initial Questionnaire Survey, H. R. Wallingford, Wallingford, Great Britain.

HURDEC, n.d. Report on socio-economic impact assessment of treadle pump program in Siraha and Saptari districts (Nepal) Kathmandu, Nepal: Human Rsource Development Center (mimeo)

Keller, Andrew, Keller, Jack, and Seckler, David., 1996. Integrated Water Resource Systems, Theory and Policy Implications. IWMI Rport # 3, Colombo, Sri Lanka, 1996.

Leslie, Jacques. 2000. Running Dry. What happens when the world no longer has enough freshwater? Harper's Magazine, July 2000.

Mehta, Rohda. 2000. IDE's approach to development. Draft Report presented at the IDE-SDC Workshop held at Dhaka, April 26-27, 2000.

Polak, Paul R. 1996. Dismantling the Barriers to the Green Revolution for Small Farmers. International Development Enterprises Publications, 10403 W. Colfax, 1995Lakewood Colo. USA 80215

Polak, Paul, and Sivanappan, R.K, 1998.. The Potential Contribution of Low Cost Drip Irrigation to the Improvement of Irrigation Productivity in India. In Water Resources Management Sector Review, the World Bank and the Ministry of Water Resources, India, p 121-123. 1998. World Bank Publications, 1818 H St, Washington, D.C.

Polak, Paul How IDE Installed 1.3 Million Treadle Pumps in Bangladesh by Activating the Private Sector: The Practical Steps. P 101-108. SDC, Swiss Agency for Development and Co-operation, Berne Switzerland, March 2000.

Polak, Paul R, Nanes, R, and Adhikari, D. A Low Cost Drip Irrigation System for Small Farmers in Developing Countries. Water Resources Bulletin, February 1997, V 33, No1,, P 119-124.

Polak, Paul R, Nanes, R, and Adhikari, D. The IDE Low Cost Drip Irrigation system. Zeitschrift fuer Bewasserungswirtschaft, Frankfurt. 1998.

Polak, Paul, Morgan, Will and Saussier, Jeff. Increasing the Productivity of the World's Micro-farmers. In Sustainable Agricultural Solutions, Novello Press Ltd, London, UK, 1999.

Polak, Paul. The Design Process for the IDE Low Cost Drip Irrigation System. In Poverty Alleviation as a Business. The Market Creation Approach to Development. Pp 95-100 Swiss Agency for Development and Co-operation, Berne Switzerland, March 2000.

Postel, Sandra, 2001. Growing More Food with Less Water. Scientific American, February, 2001.

Postel, Sandra. 1999. Pillar of Sand: Can the Irrigation Miracle Last? W.W. Norton, 1999.

Postel, Sandra, Polak, Paul, Gonzales, Fernando, and Keller, Jack. Drip Irrigation for Small Farmers: A New Initiative to Alleviate Hunger and Poverty. Water International, March, 2001

Surywanshi, 1995. Success of Drip in India: an Example to the Third World. In Microirrigation for a Changing World, Proceeding of the Fifth International Microirrigation, Conference, Orlando, Florida, 1995. American Society of Ag Engineers, 1995, P347

Seckler, David, 1996. The New Era of Water Resources Management., from “Dry” to “Wet” Water Savings. IWMI Report # 1, Colombo, Sri Lanka, 1996.

World Water Forum, 2000, "A Vision of Water for Food and Rural Development," The Hague.

Annex 1. Water-Scarce Tropical Regions of Sub-Saharan Africa: Kenya Case Study

The Case: With an estimated four million potential users of smallholder irrigation technologies, Kenya is a natural target for initial work in Sub-Saharan Africa. Experience has been gained over the past three years with over 5,000 farmers who have adopted small scale drip irrigation technologies. This work has been evaluated and it has been confirmed that there is a vast untapped potential for these technologies in water - scarce areas in tropical regions of Sub-Saharan Africa. The case describes initial efforts by Chapin Watermatics and local Kenyan partners to introduce bucket kits and eighth acre kits to smallholders in Kenya.

Project Period	1997 – present
Farmers Served	5,000
Water-related Technologies	ApproTec treadle pump, rope and washer kit and various local versions of the bucket kit developed by local entrepreneurs stemming from initial work by Chapin.
Irrigated Crops	Tomatoes, kale, cabbage, beans, squash, passion fruit and other fruits
Most Important Lessons Learned	1. Drip kits have proven popular with users who produce vegetable crops for home consumption and the market. Users can improvise to solve problems of drip kits such as clogging, breaking of tape, etc. 2. Alternative kits can be fabricated locally using readily available components including drip tape and performance is not significantly reduced. 3. Whereas the ApproTec treadle pump has been distributed through a wide network of stockists throughout Kenya, the drip kits have only been distributed through a small number of outlets, thus limiting the reach to a very few adopters. 4. Use of NGOs as vehicles for demonstration and sales is a good initial approach but a national promotion program is needed to reach the maximum number of potential adopters. 5. Approximately 10 per cent of sales have been for larger kits which have much greater impact in terms of income generation. Farmers adopting the larger kits need to have entrepreneurial skills and access to markets for their produce.
Key Constraints to Scaling up:	1. Absence of private sector rural supply chain 2. Access to credit 3. Access to inputs 4. Access to markets for crops 5. Access to transport
Potential Impact:	Increased net income in Kenya from 1.5 million adopters x $100 - $200 per family = $150 - $300 million annually. In similar regions in other areas of SSA the estimated potential number of adopters is conservatively estimated at 3 million farm families for an annual additional income generation of $300 - $600 million.
Potential New Areas Under Microirrigation	Potential additional area under irrigation in by smallholders using micro-irrigation technologies Kenya is estimated at 35,000 hectares. For the region the estimate is 300,000 acres.

Water-Scarce Tropical Regions of Sub-Saharan Africa: Kenya Case Study

Characterization of Water-Scarce Regions in Sub-Saharan Africa

With 11 percent of the world's people (622 million), Sub-Saharan Africa (SSA) produces just 1 percent of its goods and services. Currently about 40 percent of Africa's 242 million people live on less than $1 per day. Poverty is most severe in rural areas where 7 of 10 Africans live. Agricultural practices such as slash and burn cultivation and nomadic livestock raising originated in an era when per capita availability of land was much higher than today. The traditional style of agriculture is now working against farmers who have not been able to adapt production techniques quickly enough to these challenges. The pressure to grow more on less productive land has strained scarce and fragile natural resources to the point where smallholders can no longer easily raise crop yields.

The deterioration of land quality, in combination with poor agricultural policies has left much of SSA less able to feed itself than ever before. Food output per person has dropped by 16 percent since the early 1960s, with SSA lagging far behind the increases shown elsewhere in the world. Future prospects for food security in Africa are grim. African farmers would have to increase production five-fold just to meet the region's basic food needs by 2050. To do so would require increasing farm yields to levels close to those of countries adopting the Green Revolution in Asia. While not impossible this goal will be difficult to reach without major investments in fertilizers and concomitant increases in education, infrastructure and communication levels, areas where Africa lags far behind other developing regions. A rapid decline in population growth rates would make it much easier for the continent to achieve food self-sufficiency. Ironically, the high incidence of AIDS, which has decimated the productive workforce in many countries, has further exacerbated SSA's food production situation.

Table 1 shows the distribution of irrigated land in Sub-Saharan Africa (Hydrosult, 1993). We estimate about 3,000 million hectares is located in semi-arid and arid areas.

Table 1
DISTRIBUTION OF IRRIGATED AREA IN SUB-SAHARAN AFRICA

Region	Irrigation area in 000's ha	% of total irrigated area in SSA
Sudano-Sahelian Africa	2302	47
Humid and sub-humid West Africa	1030	21
Humid Central Africa	35	1
Sub-humid and mountainous East Africa	1137	23
Sub-humid and semi-arid South Africa	402	8
Total	4906	100

Countries with the largest areas of irrigated lands are shown in Table 2. Of these we could classify Sudan, Mali, Ethiopia and Somalia as semi-arid. These account for 2.3 million hectares of the irrigated area of Sub-Saharan Africa. We estimate over 90 percent of this area is farmed by smallholders, although many of these farmers are located in formal irrigation schemes, particularly in Sudan.

Table 2
SUB-SAHARAN COUNTRIES WITH THE LARGEST IRRIGATION AREAS

Country	Irrigation area in 000's ha	% of total irrigated area in SSA	Cumulative percentage
Sudan	1848	19	48
Nigeria	846	9	70
Madagascar	826	9	79
Mali	187	2	87
Ethiopia	162	2	89
Somalia	160	2	91

Table 3 shows the area under traditional irrigation in Sub-Saharan Africa. It can be seen that 45% of irrigation in this region is by traditional means.

Table 3
TRADITIONAL IRRIGATION BY REGION IN SSA

Region	Area under traditional irrigation (in 000's ha)	% of traditional irrigated area in SSA
Sudano-Sahelian Africa	380	17
Humid and sub-humid West Africa	894	87
Humid Central Africa	6	17
Sub-humid and mountainous East Africa	820	72
Sub-humid and semi-arid South Africa	108	27
Total	2208	45

Throughout the region formal irrigation schemes have been problematic, with performance, in terms of agricultural production, often not meeting expectations. In most SSA countries area under irrigation is much less than irrigable area. Despite the availability of water, investments in formal irrigation schemes in SSA have slowed significantly over the past ten years due to a number of factors.

Characterization of Kenya

Kenya, situated on the east coast of Africa has a population of 28 million and a total area of 58 million hectares of which 10 million is cultivable. An estimated 6.9 million hectares is actually cultivated, primarily by smallholders with an average farm size of one hectare (Abbott, 2000). Annual rainfall averages 572 mm with a large variation in seasonal and annual amounts resulting in frequent droughts affecting agricultural production in regions of the country. The potential yield from groundwater has been estimated to be 0.6 km^3/year with some 68% of this yield from shallow wells (FAO 1995).

Irrigation potential is estimated at 352,400 ha with full or partial irrigation of approximately 67,000 ha of which 99% is reported from surface sources. While irrigation has been declining in certain areas of the country, other areas have shown large demands for new irrigation to produce high valued crops including tomatoes, green beans and cabbage. A growing urban market has increased demand for these crops while exports of horticulture crops have increased markedly over the past 10 years led by commercial cut flower exports to Europe.

Competition for water has resulted in conflicts and has placed stress on surface water resources in downstream areas (Gichuki 2001). This is most pronounced in Likipia region where commercial and smallholder irrigation on the slopes of Mt. Kenya have resulted in serious depletions of flows of the Ewaso Nyiro River which is an important wildlife habitat and tourism site.

One significant factor currently contributing to growth of irrigation in Kenya is the treadle pump marketed by Approtec, a Kenyan NGO. Sales of their pressure treadle pump, which has the capability to irrigate up to an acre and costs about $60, soared in late 2000. Pump sales went from 300 per month to 400 per month, causing Approtec to scale up its manufacturing process to produce 1500 pumps per month. At this level, the treadle pump may add on the order of 8,000 ha of irrigated land to Kenya per year, whereas government development of irrigation has stagnated for at least the past five years.

Chapin Drip Kits in Kenya

Several pilot programs have been carried out in Sub-Saharan Africa involving drip irrigation kits. The best known of these is probably the Chapin bucket kit experience in Kenya. The Chapin bucket kit makes use of drip tape produced by Chapin Watermatics in New York, USA. The kit consists of a 20 liter bucket with an outlet in the bottom fitted with a mesh filter and tubing attached to 2 strips of drip tape each 15 meters long. The kit has been modified to serve a rectangular household garden with 4 lengths of tape. It also has been expanded to serve a 1/8 acre plot utilizing a 200 liter drum serving 10 lengths of drip tape each 15 meters long.

The Chapin bucket kit was originally distributed through missionaries and religious organizations in Malawi and was subsequently introduced in Kenya. The kit was aimed at farmers growing vegetables, with training provided to users in producing vegetables. A brief manual was distributed with the drip kit.

The first attempt to distribute the kit on a commercial basis was in 1996 in a project sponsored by the Kenya Agricultural Research Institute (KARI) as a collaborative project between KARI and Chapin Watermatics with initial support from USAID. The project's overall objective was to improve the economic and nutrition levels of small-scale rural farmers through increased production. The project targeted small-scale farmers with low economic resources such as women's groups, community-based organizations and youth groups. Under this project, kits were imported in container lots and marketed through KARI at the headquarters office for the equivalent of \$15 for the bucket kit and \$110 for the 1/8th acre kit (not including the bucket or drum).

Since 1997, the project has undertaken the following activities:

- Establishment of the testing and demonstration site at the National Agricultural Research Laboratories. Here the technology is tested and adapted for various crops and farmer needs. Problems being experienced in the field are researched and solutions identified and disseminated to the farmers. The water use efficiency with different cropping systems is also determined.
- Establishment of six pilot projects in seven areas in the dry area of Kenya. Each of these involved a group of more than fifty farmers.
- Training of extension officers and farmers. Over 60 extension officers, *jua-kali* practitioners and farmers have been trained on the fabrication, installation and management of the drip kits. Jua-kali practitioners are local technology developers whose products often work but are less refined that similar ones produced at a factory level.

Other efforts include those of Winrock International, through its African Women Leaders in Agriculture and Environment (AWLAE) program, working with over 15 groups in 5 districts of Kiambu, Nyeri, Embu, Mbeere and Machakos and the ITDG in Kitui, Garissa and Tharaka.

The bucket drip system requires between 50 and 75 liters per family per day. From the workshop and from research it appeared that under certain conditions farmers are willing to carry water (usually by donkey) over long distances or to buy water to produce crops. Beyond a certain threshold cost of water, though, the value of the produce is less than the cost of its production. In the most arid areas of Kenya, therefore, lack of water and exorbitant prices for water appeared to be a major constraint for using the bucket drip systems.

As the quantities of water used for low-head drip irrigation are minimal, it is even possible to incorporate an allocation for household garden irrigation in domestic water supplies, which are typically sized for a minimum of 20 liters per capita per day. Including a family allowance for household gardens, based on the bucket kit requirement, this capacity is well within the realm of possibility for many domestic water systems in Kenya and in other developing countries. As discussed in a recent study by Catholic Relief Services, opportunities of synergism between domestic water supplies and irrigation should be investigated at every opportunity. Further, since income can be generated from the garden, there is a recurring source of capital for meeting the maintenance and operational costs of the water supply.

A further concern is the quality of water. Saline water cannot be used, although some crops, such as tomatoes, are more tolerant of brackish water. Heavily silted water requires special handling because the Chapin filter mesh size does not trap fine sediment, which may then be trapped in the emitters. Letting the water stand for sometime to settle out the sediment may be required. Alternatively, filtering the water with a cloth before pouring it into the bucket was suggested as well. Farmers have developed means of unclogging emitters by rubbing them.

Currently 4500 bucket kits have been sold in Kenya while the number of 1/8 acre kits sold has been 500. These sales, it should be kept in mind, are based on very limited distribution without the benefit of an intensive mass marketing campaign.

Lessons Learned:

A number of technical issues were discussed at the workshop. These included wearing out and cracking of the tapes; limited range of dripper spacing; breakage of the filter housing; clogging of the filter and of drip tape; damage to drip tape by rodents; cracking of the tape under strong exposure to the sun; difficulties in drilling the hole in the bottom of the bucket; improper installation; lack of skills in operating, maintaining and repair of bucket kits; lack of spare parts; and the need for an albeit and relatively clean water supply. A number of solutions were mentioned. Farmers have developed means of repairing or substituting parts with locally available materials such as nylon stockings to replace filters, Bic pens to replace worn connectors, and bicycle inner tubes to reinforce filter housings. Farmers have improvised using a hot metal bicycle pump casing to drill the hole in the bottom of buckets. Research has shown (Ngigi, 2000) that other commercially available drip tapes (including a locally manufactured tape) have adequate uniformity and could replace the imported tape.

As discussed in a workshop in 2000, the bucket kit has proven popular with the users. Its benefits are easily recognizable and have the potential for growing high value crops. For many families use of drip kits has availed fresh vegetables for own consumption during the dry season for the first time ever. For those farmers having access to adequate water and markets for their produce, the bucket kit can easily repay its costs in one season. The use of the bucket kit also leads to a process of expanding production through the purchase of more kits or the jump to the larger scale 1/8 acre farm kit. Examples of viability filled the workshop discussions. For example, the ITDG-supported Tharaka, Garissa and Kitui projects have recorded per season profits of US$ 60 for tomatoes (excluding what the family consumed), $ 35 for kale and $70 for tomatoes and kale. A widow from Embu, who struggled to purchase a kit, makes a profit of $6 per month.

Limited availability and accessibility of the technology to farmers at the local level was found to be a major constraint for more widespread use of low-head drip irrigation. It was suggested to improve this by decentralizing the distribution and by facilitating local production. The bucket kits should be stocked at local levels. An aggressive awareness and marketing campaign is to be launched countrywide to raise the adoption levels. Demonstrations and training of potential users, actual users and trainers in proper installation, operation, maintenance and repair should be part of the campaign package.

The bucket kit has proven especially suited for women's needs and potentials in Kenya. Between 70 and 80 per cent of the users of the bucket kits are women. Male kin may support women to purchase the kit, but women do all the rest. The kit is well designed for intensive cultivation of small pieces of land, such as homesteads. Women have easier access to small portions of land, especially around the house, but limited rights to larger plots. It also emerged during the workshop that men seemed less interested in the bucket kit because of the small size of the enterprise with limited commercial value.

As shown in the workshop, the bucket kit clearly enables primarily women to produce adequate food from their household gardens to meet their family's vegetable needs as well as produce excess for sale. It provides an opportunity to create employment in the rural areas. Moreover, the bucket kit provides an entry into a process whereby poor farm families can pull themselves from poverty and develop into larger-scale producers of high value crops for marketing. Better preservation, processing and marketing facilities stimulate such a process.

Potential

In order for the technology to significantly expand and have an impact on the poor of Sub-Saharan Africa, a well-designed program needs to be undertaken. This program would be according to the model described in the text with initial work in Kenya and eventual expansion to countries in the region. Specifically the steps would consist of the following:

1. Establish local manufacturing of all components
2. Expand the range of sizes of low cost drip systems, from two types (bucket and quarter acre) to a whole range from bucket to one acre- for example
    a. 15 sq meter bucket kit
    b. 50 sq meter drum kit
    c. 125 ‘ ‘ ‘ ‘
    d. 250 ‘ ‘ ‘ ‘
    e. 1,000 and multiples of 1,000 square meter

3. Introduce and field test and adapt to Kenyan conditions the range of sizes and possibly other types of low cost drip equipment.

4. Establish a private sector supply chain through retailers in agricultural towns throughout the country.

5. Implement marketing and promotion activities aimed at ramping up sales volume in the private sector marketplace of local producers, distributors and dealers as well as through NGOs working specifically with poor farmers in irrigated areas.

6. Scale up adoption of low cost drip in Kenya to perhaps 10,000 units a year and include an agricultural integration program which will involve farmer training and expansion of markets for smallholder produced crops.

7. Based on the Kenyan experience, initiate the process of creating new markets for low cost drip in Zimbabwe; peri urban areas of South Africa, Tanzania, Malawi, Zambia, and initial work in West African countries such as Ghana and Niger.

Based on experience in Asia, a reasonable estimate of total potential acreage of low-cost drip systems in Kenya is 10% of the irrigable area or 35,000 ha. Alternatively, from the estimated 4 million rural households in Kenya who are potential adopters of the technology we estimate a potential of 3 million bucket kits serving 15 square meters each for a total of 4,500 ha, 1 million drum kits serving 50 square meters each for a total of 5,000 ha, and 500,000 households larger eighth acre kits for a total of 25,000 ha. This coincides with the total potential of about 35,000 ha.

Although the small bucket kit irrigating 15 square meters is ideal for families becoming self-sufficient in producing vegetables for home consumption, it is not seen as having the potential for lifting farmers out of poverty. Farmers need to move up to a larger size operation in order for this to occur. For this reason we consider only those farmers who have adopted the larger size kits as having the potential to move out of poverty. Thus the potential number of Kenyan farmers moving out of poverty is estimated at 1.5 million.

Extrapolating this to semi-arid and arid areas of Sub-Saharan Africa where conditions are likely to be similar to Kenya, we estimate the potential acreage for micro-irrigation at 300,000 hectares. If we make similar assumptions regarding adoption in these countries we conservatively estimate the potential demand at 3 million drum kits or larger kits.

Of course there are many factors which may limit the market for irrigation equipment in SSA countries. Among these is the availability of markets for irrigated produce. Not all farmers adopting drip kits could produce tomatoes, but given the need for intensified food production we foresee farmers producing not only high-valued vegetable crops under drip irrigation, but many will find that other crops such as bananas, sugar, soybeans and off-season green maize will produce income and food with which to meet local demands without oversupplying markets. At the same time, a well designed program will include efforts to expand markets, including efforts to include smallholders in the export of horticultural crops.

References:

Abbott, D. 2000. How to Boost Crop Yields in Nairobi. Daily Nation Newspaper, Nairobi, Feb. 29, 2000.

Blank, H., C. Kabutha, and B. van Koppen. 2000. Drip Irrigation Kits for Small-holder Farmers in Kenya: Experience and a Way Forward, paper presented at Micro 2000, Capetown, South Africa.

FAO. 1995. Irrigation in Africa in Figures, ISSN 1020-1203, FAO, Rome.

Gichuki, F. 2001 (forthcoming). Water Scarcity and Conflicts: A Case Study for the Upper Ewaso Ngiro North Basin, IWMI paper for forthcoming SWIM publication entitled "The Changing Face of Irrigation in Kenya."

Hydrosult, Inc. 1993. Overview of Irrigation Potentialities in Africa. Canadian International Development Agency, Ottawa.

Ngigi, S.N., J.N. Thome, D.W. Waweru and H.G. Blank (2000). Technical Evaluation of Low-Head Drip Irrigation Technologies in Kenya. Collaborative Research Project between Department of Agricultural Engineering, University of Nairobi and International Water Management Institute (IWMI).

Winrock, KARI and IWMI (2000). Report on the Low-head Drip Irrigation. Review Workshop at the National Agricultural Research Laboratories, 17-18 February, 2000. Winrock, Nairobi.

Annex 2. Dambo Horticulture in Sub-Saharan Africa

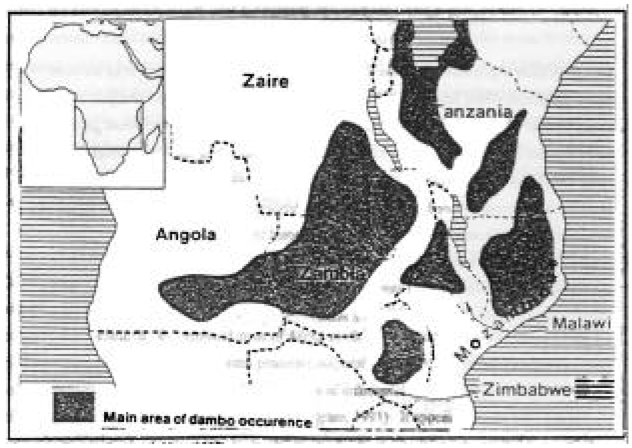
The Case: A project in the Zambian dambos, started in 1997, for the development of local supply chains for treadle pumps and drip irrigation for smallhold farmers.

Project Period	Started in 1997
Farmers Served	2,000
Water-related Technologies	Treadle pumps, pressure pumps, low-cost drip irrigation, low-cost micro sprinkler irrigation.
Aggregate Annual Income Generated	$500,000
Irrigated Crops	Vegetables (cabbage, tomato, onions, green beans, carrots, green maize)
Most Important Lessons Learned	1. The successful introduction of microirrigation technologies must be based on the availability of profitable output markets for the smallholder farmer; 2. Local manufacture and private sector distribution of microirrigation technologies is key. 3. Affordability of input technologies is the essence of success. 4. Smallholder credit is a basic necessity. 5. Marketing and promotion of the microirrigation technologies play an important role in the dissemination process. 6. The technology must be such that the farmer can obtain annual net additional income from its use amounting at least to double his investment.
Key Constraints to Scaling up:	1. Lack of credit facilities for the smallholder. 2. Large distances and scattered population, and underdeveloped roads and infrastructure contain effective supply chain distribution systems. 3. Constrained access to inputs. 4. Limited access to regional, national, and export markets for crops.
Potential Impact:	1 million smallholders in dambo areas of Sub-Saharan Africa. The annual net additional income is estimated at $250 million.
Potential New Areas Under Microirrigation	400,000 hectares

Dambo Horticulture in Sub-Saharan Africa

Characterization of Dambos

Description



Dambos are perennial or seasonal wetlands with a wide variety of plants, soils and hydrologic characteristics. Dambos are characterized generally as geologic basin-like depressions or concavities with underlying layers of clayey organic soils of low permeability that retain water at shallow levels.

There are several different types of dambos, but they share two common characteristics. In their natural state, they tend to grow grass rather than trees, and at least for part of the year, they are a source of relatively easy access to a critical resource that is often in short supply in Sub-Saharan Africa- water.[1]

Dambos absorb water during the rainy season and release water gradually during the dry season. Water filtration rates vary depending on sediments and soil types of the dambo. The water level within each dambo drops at a slow, gradual rate according to the transmission characteristics of the soils. Organic soils found in dambos act as the main sponges by which water is retained.[1] Dambos also serve as rainfall catchment basins supplying streams at lower elevations of the catchment network. Dambos can also be independent or outside the main drainage system. Monitoring of water levels becomes more critical as usage increases.

Size of the Area Covered by Dambos in South Africa. Scoones[2] suggests that dambos comprise 5-10% of the total land area of Africa's savannas. Balek[3] estimates a total of 8.5 million hectares of dambos in Africa. There are an estimated 1.28 million hectares of dambos in Zimbabwe representing 3.6% of the country's land area, 259,000 hectares in Malawi, and 3.5 to 4 million hectares of dambos in Zambia.

Potential Acreage of Dambos for Smallholder Irrigation. Dambos are potentially some of the most productive natural ecosystems in the Southern Africa region. Dambos are traditionally used as sources of water for domestic purposes, agricultural production, livestock grazing, hunting, gathering and fishing. Dambos support a wide variety of wildlife and birds. Despite the importance of dambos they remain low on the policy and research agendas of southern African countries.[4]

While the total acreage of dambos in Sub-Saharan Africa is extensive, not all dambos are necessarily suited for cultivation and may require fertilizers to replenish nutrient deficiencies.

[1] Shalwindi, Utilization of Dambos in Zambia, 1986.
[2] Scoones, I. Wetlands in Drylands: Key Resources for Agricultural and Pastoral Production in Africa. IIE Dryland Networks Programme Issues Paper #38, 1992.
[3] Balek (1977), quoted in Adam et al., 1977.
[4] Kokwe, Sustainable Use of Dambos in Southern Africa, 1993.

Some dambos are situated in remote locations, out of reach of population centers making them less accessible for cultivation. Therefore estimating the total potential acreage for smallholder irrigation requires more in-depth analysis. However it is safe to say that the productive potential of dambos in Sub-Saharan Africa is very substantial: perhaps as great as 900,000 hectares.

Classification. Dambos are located within a variety of agro-ecological zones with different characteristics relating to the elevation, climate, rainfall pattern, soil structure and chemical composition. Verboom's research from 1969–1972 classified plateau dambos into 3 categories on the basis of soil pH levels and the species composition of dambo vegetation and flora.

> ***Sweet dambos*** contain soils from lime-rich rock with pH above 6.5 with the associated plant species common to the soil type. Acacia trees are commonly found growing on the fringes of sweet dambos.
>
> ***Intermediate dambos*** containing soils developed from mixed sediments with pH levels between 5.5 and 6.5. Species of vegetation are a combination of sweet and sour dambo plant species.
>
> ***Sour dambos*** are common to areas in the northern parts of Zambia where rainfall is higher and soil pH levels are below 5.5, and also southern Zambia where granites and basement complex rocks are common. Vegetation of sour dambos consists of many types of sedge.

In 1999 the Environmental Council of Zambia classified dambos in Zambia in a slightly altered version from Verboom as follows:

> ***Barotse sand dambo system*** occurs in Western Province in Zambia and is distributed on sand substrate. These cover larger areas and can be either seasonal or perennial.
>
> ***High rainfall dambo system*** includes perennial dambos that are part of the drainage system and are found in the higher rainfall zones of northern Zambia. Because of prolonged saturation these dambos have swamp-like characteristics.
>
> ***Medium rainfall dambo system*** occurs on the Southern, Central and Eastern Plateaus of Zambia where rainfall averages less than 1000 mm per annum. These are generally seasonal dambos that feed the drainage systems; their water table remains relatively high throughout the year.
>
> ***Valley dambo system*** occurs in the Luangwa and Zambezi valleys. These dambos can be found outside the main drainage system and are situated primarily on karoo soils and are similar to the Mopane pans. They are mainly seasonal dambos as dry seasons are more prolonged.[5]

Dambo Usage. Dambos in populated areas are subject to a variety of potentially competing uses, including the production of vegetables and other cultivated crops, grazing, fishing and hunting, and environmental conservation uses.

> ***Grazing Livestock.*** In many parts of Southern Africa dambos are used as grazing lands for livestock. Previously, during colonial times the view was that dambos were to be

[5] Ferreira, Dambos: Their Agricultural Potential, Farming in Zambia, 1977.

retained primarily for water conservation purposes. Although grazing of dambos was discouraged, the Zambezi flood plain and Kafue faults in Zambia continued to serve as traditional grazing areas. More liberal views regarding the use of dambos in Zambia prevailed after independence was acquired.[6]

Sweet dambos have a higher grazing capacity than the Intermediate and Sour dambos because of an abundance of nutritious plant species with higher protein content found in Sweet dambos. Sour dambos and parts of Intermediate dambos are composed of wiry and unpalatable vegetation. Grazing capacity of Intermediate and Sour dambos can be improved through the burning off of grass and planting fresh pastures of species adaptable to moist conditions.

Crop Production. Cultivation of dambos is common in many parts of the sub-Saharan region. Vegetable varieties that thrive on moist, organic soil conditions, such as tomatoes, cabbages, rape, onions, beans, and Irish potatoes, are commonly planted in dambo regimes. Successful dambo farmers have learned to plant in the mid- to lower levels of dambos and to make use of residual moisture and capillary flow from shallow water tables. To prevent the possibility of waterlogging, seedlings are planted on raised beds or ridges. Construction of ridges on the lower slopes of dambos is not advised to avoid unnecessary soil erosion.

Pumpkins, green peppers, eggplant, spinach, groundnuts, carrots, lettuces, sweet potatoes and radishes can also be effectively cultivated in dambos. In regions where frost can be problematic vegetables less vulnerable to colder conditions, such as cauliflower, Brussel sprouts, asparagus, and celery, may be grown. However, these vegetable varieties are less common among small-scale farmers in most parts of sub-Saharan Africa. Green maize is another crop popular with the farmers that is successfully cultivated on dambos during the dry season.

During the rainy season, vegetable crops are more difficult to manage and normally require greater attention and higher cost inputs to prevent infestation by pests, funguses and diseases. However, all three dambo categories are suitable for the growing of rice during the rainy season. Western Province of Zambia is particularly suited to rice cultivation. In the central axis of the dambo where heavier clays are predominant, higher yields can be obtained provided that flooding does not rise above 0.5 meters. During the colder dry season months of June through August rice growth is inhibited by cooler evening temperatures. At higher elevations above 1300 meters, lower temperatures retard rice production.

Wheat is a crop that can be widely grown in dambos. Irrigated wheat is grown primarily in the dry season because of the susceptibility to diseases during the rainy season. Wheat grows well in dambos of regions where rainfall is moderate and night frosts are less common. The optimum time to plant is from mid April to early May.

[6] Shalwindi, Utilization of Dambos in Zambia, 1986.

Dambos of Zimbabwe

Zimbabwe has a dambo area of 1.28 million ha or 3.6 % of the country's land area.[7] Because of inequitable colonial land allocation, the majority of the highveld, which is the area with most dambo, is mainly used for commercial farming. The estimated 260,000 hectares of dambo land in communal areas represents an important resource for Zimbabwe's peasant small-scale farmers. It is estimated that Zimbabwe gardens cover 15,000 - 20,000 ha.

The dambo are located mainly on the gently sloping highveld plateau above 1200 m (see map). Within this central watershed, dambo density is greater towards the north where mean annual rainfall is above 800 mm.

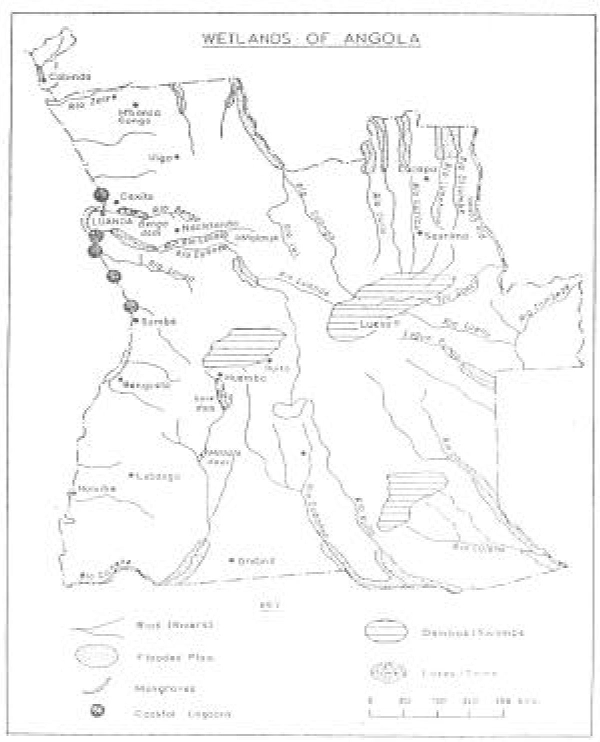


Figure 2. General distribution of wetlands in Angola

Zimbabwe's dambos vary between *headwater dambos* (no channels, broad and sometimes coalescing); *stream dambos* (adjacent to second or third order stream channels); *residual dambos* (narrow and linear, typical along first order side streams).

Cropping Patterns. There is no fixed season for most crops. Farmers plant and harvest various crops, mostly vegetables, throughout the year. The only exception to this is maize and rice, which are generally planted in August/September and harvested in January/February.

In drought years, when dry fields are unproductive, this pattern varies, with many households growing a second crop of maize on their gardens from February to May. The common vegetables are tomatoes, onions, cabbage, rape and other green 'leafy crops'.

On the dry fields, cereals and pulses are grown and form a larger part of the diet for communal area households in the dambo areas. These crops are maize, groundnuts, round nuts, 'nyemba' (dried beans), cowpeas, and 'rapoko', which is mainly used for beer brewing. Sunflower, which is grown by a few families, both for cattle feed and to sell to the grain marketing board.

Inputs. There are four major fertilizers applied to improve soil fertility in Zimbabwe's dambo areas: (1) chemical fertilizers, (2) animal manure, (3) anthills, and (4) composted manure.

7 Whitlow, 1984.

Ninety percent of the manure is available from kraals for most households. The majority of the households in these areas still rely heavily on manure to maintain their soil fertility. Twenty-three percent of the households with gardens depend on manure collected from around the grazing area to provide or supplement their supply of manure. Over 70 percent use cattle manure on the dry fields and gardens throughout the year. Fewer than 6 percent use anthills. Also about 60 percent use compost.

Water supply. Thirty percent of the households usually obtain water for drinking and cooking purposes from open wells in the dambo. Few households walk more than a kilometer to obtain domestic water. The sources do not vary greatly between seasons, although in the dry years dambo wells become particularly important as protected wells on the higher land dry out. In most areas, the most common alternative source of drinking and cooking water is a covered well. Wells located in gardens are used for irrigation and clothes washing, not for drinking water supply. Wells designated for drinking water are not used for clothes washing.

Wells for domestic water supply on the dambo are located outside the gardens and close to the homes. It is expected that the level of contamination in domestic dambo wells would be much higher than that in protected wells. A coliform count of less than 10 per 100 ml is normally acceptable; the contamination of dambo wells tends to be less than that of covered wells. This is because only two or three households use dambo wells, while covered wells are shared by surrounding schools.

Dambo Irrigation

Methods

Buckets and Hand Dug Shallow Wells. Traditional methods of buckets or watering cans are still the most common form of irrigation practiced among the poor small-scale farmers. Buckets and watering cans are affordable; however the lack of efficient pump technology limits the production capability and efficiency of these small-scale farmers.

Farmers customarily dig shallow pits in the dambos to access water and use buckets to draw and reticulate water for irrigation. IDE and the Ministry of Agriculture in Zambia have experimented with the shallow tube well construction. However, more support must be provided in terms of training to farmers in low cost hand auger methods.

Treadle Pumps. Before IDE began its Small-Scale Farm Irrigation Program in July 1997, the Kasisi Ecumenical Center was promoting a rower pump technology with a pressure treadle pump design based on an ATI model. The design had some shortcomings in function and durability and the price ($200) was beyond the reach of most small-scale farmers.

The practice of growing vegetables in dambo areas during the dry season has been on the increase since the introduction of IDE's low-lift treadle pump technology. With over 2000 small-scale Zambian farmers adopting treadle pumps, accessing water in dambo lands is not an obstacle for farmers irrigating vegetable gardens. Vegetables are grown for both household consumption and for sale on local markets to generate cash income.

Constraints

Constraints for increased dambo cultivation of cash crops are (1) access to markets, (2) access to credit, (3) competing uses (e.g., livestock grazing, fishing and hunting). Also, little is known concerning the fragility of the dambo environment. It is critical to study environmental impact as an integral part of crop cultivation initiatives.

Current Status of Irrigation Technology

Hakaindi 2000 Pressure Pump. IDE modified the original Bielenberg Pressure Pump model by:

1) Designing a flange on the pump head to create a reliable seal on the pressure chamber,
2) Repositioning the fulcrum point, thereby increasing the leverage and improving ease of operation,
3) Decreasing the cylinder size from 4 inches down to 3.5 inches thereby reducing hydraulic losses, increasing suction lift (4-5 meters) and pressure head (9-10) meters.

The Hakaindi 2000 Pressure Pump has a total pumping lift of 14 meters with an output of 1-2 liters per second. The cost of the pump is $90 (plus the cost of flexible hose).

Low Cost Drip Irrigation Systems. During September 1999, IDE imported the first low cost drip irrigation systems from the IDE India program. The major advantages of drip irrigation are 1) water savings, 2) labor savings, 3) improved quality and 4) increased yield. Two drip kits are described below.

Bucket Kit. The bucket kit consists very simply of a 20-liter bucket, a plastic tap, plastic filter, fittings, and 11 meters of 12 mm drip line with 13 pairs of 1.5 mm diameter (internal) micro-tubes. The bucket kit delivers water to 4 rows of a given crop. Each micro tube irrigates 4 plants for a total of 104 plants per bucket kit. This drip system requires only one meter pressure head to operate and is easy to set up and maintain. These kits sell for approximately $5 in India.

Drum Kit: The drum kit consists of a plastic tap, filter, drip supports, fittings, a sub-main line of 16mm diameter, 5 lateral lines 12 mm diameter and the 1.5 mm diameter micro tubes. The drum itself can be purchased as the water supply tank and a small one-meter high stand can be constructed of rough-cut wood on which to mount the 200-liter drum. The layout is simple and easy to install. The drum kit irrigates 5 x 104 plants = 520 total. Under general sub-tropic conditions on clay like soils the drum can be filled about 2 and a half times during a day. This results in about 40% water savings and in Africa where farmers must carry water longer distances drip will also bring a substantial labor saving in addition to higher quality and greater yield.

IDE has been importing small-scale drip irrigation systems from a supplier in Johannesburg, RSA. These systems are based on the drip irrigation systems designed by IDE-India. These kits come in 3 sizes:

- 100 square meters priced at $42,
- 200 square meters at $79, and
- 500 square meters priced at $208.

The plastic extrusion industry in Zambia collapsed with the reduction in copper production. It was necessary to resort to importation from suppliers in the Republic of

South Africa. The high transport costs to deliver a high volume product is reflected in the pricing structure. The high cost will prohibit mass adoption, and therefore IDE is looking for investors who would consider setting up plastic extrusion production in Zambia.

The **Pressure Pump** will complement the drip as it can pump water up into the storage tank wherever the water levels are within the suction limit. The pump has been tested to pressure water up to 8 meters of vertical lift, using a 1.5-inch diameter outlet pipe.

The response of small-scale farmers in both Zambia and Zimbabwe has been highly positive, giving IDE the motivation to raise funds for the development of the low-cost drip irrigation program in Africa.

Diesel Pumps are three times as expensive in Sub-Saharan Africa than comparable models sell for in countries like India, with a 5-hp diesel pump costing in the range of $1500. This is far too expensive to be affordable to virtually all small farmers. Electricity is rarely available to power electric pumps in dambo areas.

Low Cost Small Plot Sprinkler Irrigation is not common, in part because of the high capital cost of putting water under pressure and also because no organization has promoted low-cost sprinklers. However, IDE believes that developing a market for micro-sprinklers among small-scale farmers is possible with sufficient support to the marketing effort.

Case Study: Treadle Pumps on Dambos Increase the Income and Productivity of Small Farmers in Zambia

Background

Zambia's potential for irrigation development is estimated at 410,000 hectares.[8] Surface water resource potential is 237 million cubic meters/day in an average year and 136 million cubic meters in a drought year. Ground water potential is estimated at 5.7 billion cubic meters per year, which represents 8% of annual rainfall. However, the total irrigated area in Zambia is estimated at only 100,000 hectares, less than 25% of the country's potential. The majority of irrigated land is done under large-scale commercial schemes (e.g., Nakamaballa Sugar Estates) and medium-scale farms. However, the emerging small-scale farmers have untapped potential. The main irrigated crops include sugar cane, wheat, coffee, fruits and vegetables.

Assessment and Pilot Phase

In 1996 FAO funded a regional 4-country assessment (Tanzania, Malawi, Zimbabwe and Zambia), and contracted IDE as consultants. In the year following the initial assessment, an IDE technical expert introduced the Bangladeshi Deki suction pump, which had a proven track record in Asia. The pump was set up at various locations around the country, primarily on dambos, rivers and dams. Farmers' reactions were monitored. Field tests with dambo farmers received an enthusiastic response. Considering critical factors such as the hydro-geologic conditions (large area of dambo lands), enthusiastic small-scale farming community (940,000 smallholders),

[8] Euroconsult, 1987; ACIL, 1992.

existing poverty levels, and the Ministry of Agriculture's strong interest, Zambia was selected as the country most suited for launching a treadle pump program.

IDE Zambia Program Initiation

In 1997, IDE began a Treadle Pump program for dambos in Zambia. Thousands of small farmers, without help from the government or development agencies, had initiated the profitable cultivation of vegetables on dambos within reach of cities and towns. They used simple 1-3 meter hand dug wells as a source of irrigation water, and distributed the water by bucket. At the request of FAO, IDE shipped 350 "Deki" treadle pumps from Bangladesh.

During the first year of operation, 1997-1998, IDE-Zambia modified the Deki pump after field tests indicated that farmers preferred a moveable "Chova" River Pump model over the simple tubewell "Deki" Treadle Pumps. Over the next three years, IDE modified the River treadle pump further by strengthening the steel bases and framework of the "Chova" River Pump to make it more robust, easier to set up and operate. With the suction lift at 7-8 meters, delivery rate is 1-2 liters per second. This model is currently being sold on the retail market at $62. It is the highest selling model to date.

IDE's program began as a small 3-person team in 1997, expanded to 12 members by the end of 1999, and entered the year 2001 with a 20-person team that is covering approximately 50% of the Zambian countryside where 940,000 families operate small-scale farms. Strides have been made since the initial introduction of the treadle pump in July 1997 to the spread of the technology countrywide. At the request of Zambian small-scale farmers and IDE's implementing partners, IDE has conducted training activities and promotional demonstrations in all 9 Provinces.

Description of Program: Steps in the Development of a Treadle Pump Supply Chain

Import of Bangladesh Treadle Pumps. As a first step, with the support off FAO, a container of treadle pumps was imported from Bangladesh. Field tests on dambos proved that treadle pump irrigation was highly advantageous for small farmers as compared to using the traditional watering methods using buckets and watering cans. Enthusiastic Zambian farmers rapidly expanded their irrigated areas and increased production.

Initiating Local Manufacture. During the first year of operation, IDE trained three manufacturers to produce quality treadle pumps. As the demand increased, competition was required to reduce prices. During the second and third years, nine more manufacturers were trained to ensure that supply matched demand, bringing the total to 12 trained pump producers, including 5 producers in the outlying Provinces. Workers in twelve small-scale carpentry shops were also trained to produce the wooden treadles and pulley components. Pump production creates new employment opportunities and earns extra income for both small- and larger-scale pump producers and carpentry shops.

Optimizing Affordability. Rural villagers and small-scale farmers face tremendous financial challenges simply to survive in a country where the currency is losing value at a rate of almost 100 per year. Pricing of products must be realistic to avoid sharp increases in retail and manufacturing prices that will stifle the product (treadle pump/ drip) demand and customer (poor farmers) access; 100% mark-ups on manufactured goods are not uncommon in the Zambian marketplace.

IDE holds regular consultations with manufacturers to negotiate periodic price adjustments. This is done by IDE on behalf of retailers that are supplied through the established delivery network. (Communications with retailers is often difficult as telephone access in rural areas is limited.) IDE's objective is to convince suppliers to keep mark-ups reasonable and to understand the financial situation of the targeted customers, small-scale farmers. After new prices are established with manufacturers, IDE recommends a retail price with a modest mark-up (10-15%) to the dealers; again keeping in mind the concept of affordability.

The price of standard three and a half inch Chova River Treadle Pumps available in Zambia was reduced from $200 plus down to $62. Quality of locally manufactured pumps was improved, and the portable "Chova" River Treadle Pump proved to be the most popular model.

After the pressure pump was redesigned, the popularity with small-scale out-growers farming in dambos of Central Province increased. The first 80 farmers participating in the two IDE out-grower schemes have preferred Hakaindi Pressure Pumps because of the increase in total lift (14 meters), the high output and the fact that the delivery pipe can be easily maneuvered to feed furrows without relocating the pump itself. In response increased demand for pressure pumps, IDE trained four manufacturers to fabricate the Hakaindi Pressure Pumps, at a price varying between $78 to about $89 (US)

Establishing Private Sector Distribution. IDE's role in facilitating the development of the private sector network entails the selection and training of manufacturers, product pricing, quality control, assembling, packaging (wholesaling) and transporting treadle pumps produced by manufacturers to a network of dealers recruited and trained by IDE. Certain mechanisms are needed to stimulate interest on the part of manufacturers and retailers who had little motivation to risk entering a new and untested product market. Required is the generation of product demand to a level where demand is substantial enough to sustain a profitable production and delivery chain. At that level, IDE may scale down marketing and promotional activities, and more importantly, withdraw from its temporary role of wholesaler.

IDE has established a retailing network in its 5 Provinces of operation to a total of 18 retailers who are marketing pumps and poly-pipes on behalf of IDE. IDE has continued consulting with retailers to maintain affordable prices on pumps and polythene pipes.

Marketing and Promotion. IDE's primary marketing objective is to facilitate the efficient delivery of high volumes of appropriate irrigation technology to the farmers at an affordable cost within a sustainable pricing structure that yields returns to all components of the private sector delivery chain.

IDE headquarters staff and field-marketing officers have been conducting regular demonstrations at agricultural shows and field days in village centers and at homestead levels. On-site demonstrations are conducted in front of IDE offices in Lusaka, Choma, Chipata, Kapiri and Petauke. Drama team performances involve villagers acting out skits that combine humor with the message of the advantages of treadle pump irrigation. IDE's records indicate that over 12,500 farmers have been reached through field demonstrations, agricultural field day events and training sessions. Thousands of additional people have been exposed to treadle pump technology through agricultural shows, television and news media coverage. The results of this effort have culminated in creating a high level of awareness and demand for treadle pumps and drip irrigation systems.

Personnel. The program has assembled a group of young local professionals to respond to the ever-growing challenges of the project. The rise in demand of micro- irrigation technologies and support services required to sustain the project (such as capacity building, market and credit development) necessitated the recruitment of additional staff to the program. Currently IDE employs 24 well-trained Zambians.

Market Development. Linking small-scale farmers to established markets such as Agriflora, Sunripe, Freshmark and Chankwakwa has enhanced the impact of the project on small-scale farmers. Farmers are expected to have a higher, steady and continuous income. These links to the market have also had a positive impact on pump sales.

Capacity Building. Farmer training in agronomy and farm management is having a positive impact on farmer yields and quality of produce. As a result of increased yields and improved quality of produce plus the link to markets, farmers' incomes have also increased. Increased farmer yields and income has led to achieving food security and poverty reduction.

Micro Finance. Linking farmers to low interest credit through ZATAC has facilitated the acquisition of micro irrigation technologies by small-scale farmers. This linkage has contributed to increased pump sales and increased farmer incomes through accessing the horticultural export market.

Results:

- ?? 1,987 pumps sold since program inception in 1997;[9]
- ?? 13,909 new beneficiaries (based on 7 per family);
- ?? Twelve private sector manufacturers;
- ?? 100 jobs created through local manufacture and retail sale of treadle pumps;
- ?? 1,987 total acres under new vegetable production (1,987 pumps x 1 acre/pump) multiplied by two growing seasons per year yields 3,974 acres under production
- ?? Farmers' net incomes increasing in the range from $100 per year up to $1,000 per year (average reported increase in income is $250).
- ?? 18 private sector retailers are selling treadle pumps, pipes and accessories.
- ?? Four manufacturers were trained to produce the pressure pump model.[10]
- ?? 40 non-governmental and governmental organizational partners.
- ?? IDE is working closely with Zambian Ministry of Agriculture, Food and Fisheries (MAFF) extension agents in training on technology installation and use.
- ?? IDE has registered requests for the treadle pump from all 9 Provinces.
- ?? IDE has linked small-scale farmers to a low interest credit facility under a micro-credit scheme operated by a collaborating partner called ZATAC.
- ?? 60 small-scale farmers in Lusaka rural linked to horticultural export market through Agriflora;
- ?? 20 small-scale farmers linked to tomato export project to Sweden under Chankwankwa in Kabwe.

Irrigation Productivity. The pump allows the farmer to irrigate his\her land in a shorter time span and on average provides 60 percent savings of time. Ultimately these savings allow farmers to expand their gardens. In cases where a farmer has been linked to a market such as Agriflora--a horticultural export company and Chankwankwa--a dried tomato export project--the farmer has been able to increase the irrigated land by as much as one hectare. On average the treadle pump farmers are able to irrigate in the range of 0.25 hectare to 1 hectare of land.

In light of the empirical data gathered to date, IDE estimates that the average treadle pump farmer in Zambia irrigates approximately 0.5 hectare of land, mainly between March and November. This allows these farmers to plant and harvest two irrigated vegetable crop cycles within this 8-9 month period. With close to 2000 treadle pump users, estimated hectares under treadle pump irrigation totals about 1000 hectares. The third crop is a rainfed crop: maize, sorghum, sweet potatoes, pumpkins, groundnuts, cotton, and sunflower. These crops are generally planted in November and harvested in April or May. According to the 1998-99 census carried out by the Zambian Central statistics office, 941,167 small- scale farmers are producing yields at the following levels:

Crops	Quantity (tons)	Total Sales (Kwacha*)
Cabbage	2,546	2,576,693,000
Tomato	14,087	4,695,754,000

[9] The selling price of the river pump is $62. Interviews with farmers indicate that this price can readily be repaid in one growing season (there are three growing seasons per year in Zambia). Farmer investment in pumps totals: 1,987 x $62 = $123,194.

[10] The pumps are capable of delivering water to destinations 10 meters above the pump itself. This technology has great potential in Zambia but due to low production quantities, is not produced frequently, and consequently is cost-prohibitive.

Onion	393	392,742,000
Carrots	22	21,512,000
Green beans	100	75,646,000
Green maize	584	438,374,000

* 1998-99 average exchange rate was approximately 2,500K = $1US

Socio-Economic Impact. Information gathered by IDE through farmer assessments shows a range of increased income from $100 to $1000 per year. Average farmers are earning additional net income from $150 to $ 350 per year. This category of farmers consists mainly of families who exceed their family subsistence requirements and sell their surplus produce to neighbors and open markets in the communities. More successful farmers are generating net profits ranging from $350 to $1000 per year. In these cases the farmers are most likely linked to established markets and micro-financing arrangements. While these farmers are a minority, the profits recorded from them have been very encouraging. IDE's experience has been that the majority of these successful farmers have been exposed to farm management and agronomic practice training programs. The decisive factor in their success has been their link to established markets such as hospitals, missions, prisons, schools, and horticultural export markets.

Key Constraints

1. Large distances and scattered population, and underdeveloped roads and infrastructure constrain effective supply chain distribution systems.
2. Limited access to credit.
3. Constrained access to inputs.
4. Need for expanded BDS services for scaling up.
5. The high cost of suction polypipe has also been a limitation to the farmers in accessing complete irrigation systems.
6. High cost of steel and raw materials has increased pump prices.
7. Shortages of accessories including injection mould technology has made it necessary till now to import rubber cups and plastic valves, which increases treadle pump cost. Local injection mould technology would address this problem.
8. High inflation rate in Zambia, averaging 25-30 percent, plus depreciation of the Zambian currency by 37.5% has had a negative impact on treadle pump business.
9. High cost of energy and power.
10. Limited access to regional, national, and export markets for crops.

Strategies for the Expansion of Micro-Irrigation

As is evident from the case described above, a holistic approach to small-scale irrigation development is required to lift impoverished farmers to a sustainable level of increased productivity, to attain food security and higher levels of income generation. A program strategy that facilitates provision of a comprehensive package of technical services, inputs, and technologies to small-scale farmers and establishes strategic linkages to markets is essential to the success of the program. Developing a sustainable private sector service network to meet the needs of small-scale farmers is critical to the financial success of farmers and the service providers themselves and will result in a greater and longer lasting social-economic impact.

A variety of approaches can and must be used to make small-scale irrigation development possible. Specific approaches will depend on location and output market opportunities.

One type of approach is based on out-grower schemes. IDE works closely with a series of out-grower projects. Included in these is the Chakwankaw tomato out-grower scheme that now engages a group of 12 treadle pump farmers in Central Province. Sunripe Food Processors is another private sector partner with whom IDE is planning to start a tomato out-grower scheme in Chikupi Camp, Kafue District, and also in Mumbwa, Central Province. In addition, IDE is negotiating with Freshmark (in the Copperbelt), a major food procurement company on the possibility of engaging smallholder enterprises in out-grower schemes.

Presented here in more detail is the dambo out-grower scheme in Katuba, Central Province of Zambia that was established during the 2000 irrigation season. As of March 2001, 73 small-scale farmers are participating with the plan of linking another 300 farmers to the horticultural export growers' scheme within the coming year.

Description of one Approach: IDE/Agriflora's Small-Scale Family Farm Enterprise [SSFFE] Out-Grower Scheme

Enterprising small-scale farmers are selected and organized into small societies of about 50 members. After formation of the SSFFE Out-Grower Associations, meetings are held to explain the basic aims, requirements and potential support to be provided. The farmers are given the range of crops that will be grown for export. Meetings are followed by visits from IDE-Agriflora agronomists to each of the participating SSFFE to ascertain acreage, soil fertility, water availability and irrigation system requirements in relation to expected production. An assessment of each farmer's financial situation is also conducted to determine the farmer's current income levels and constraints in terms of accessing necessary agricultural inputs.

Agriflora offers the farmer an interest-free, 120-day credit facility for inputs such as seeds, fertilizers and chemicals. SSFFEs who are selected are then provided with seeds, fertilizers and other inputs for the crops to be planted. Included in the package of inputs are affordable irrigation systems. IDE facilitates the supply and installation of low cost treadle pumps and possibly low cost drip systems. Farmers (SSFFEs) enter into a contract agreement with Agriflora and IDE, authorizing Agriflora to make deductions from their payments at harvest time, with Agriflora providing a guaranteed price and commitment to package and export the quality-approved produce on behalf of the farmer. This arrangement ensures that the credit from the revolving fund will be paid back and recycled to purchase more pumps and pipes from the suppliers.

Production is year-round involving a mix of crops such as green peas, sugar snaps, Helda beans, asparagus, gooseberry, green chilies, okra, mangetout, and baby corn.[11] After planting, IDE/Agriflora field teams will provide the farmers with relevant extension services including advice on methods of land preparation, amount of seed required, planting dates, and target yields, sustainable agro-technology and training in farm management systems. Participating Small-Scale Family Farm Enterprises (SSFFE's) will be advised on the appropriate crop rotation schedules and methods of erosion control to prevent environmental degradation. Field workshops will be organized by IDE to allow farmers to interact and learn from each other. MAFF extension

[11] The main crops grown are baby corn, mangetout, sugar snaps and fine beans. Other products are produced and sold on mutual agreement between Agriflora and the SSFFE's. The planting program is designed to produce approximately 123,200kg of mangetout (@$0.66/kg), 123,200 kg of sugar snap, 72800kg baby corn @ $ 1.32/kg and 141,600kg of fine beans @ $0.58/ kg annually. (These are fixed prices for actual kilograms that are exported. The costs of freighting, packing materials and commissions are deducted before the farm gate price is paid. Therefore, all the costs of on-farm input must be taken from the farm gate price, including fertilizers, pesticides, labor, irrigation costs and seed).

officers will be encouraged to attend and participate in workshops and contribute to farmer support activities.

Agriflora will provide crop-spraying services to meet the needs of the Small Scale Family Farm Enterprises. As the crop matures, Agriflora spraying teams will visit each farmer on a periodic basis to monitor and control disease and pests to ensure higher quality yields. Strict regulations from the European Union regarding chemical use and maximum residue levels on vegetables must be adhered to. Agriflora and IDE agronomists will conduct regular inspection for crop diseases, pests and quality control of produce.

Upon harvest into plastic crates, the small-scale farmers will deliver produce to a mini-grading shed at the central collection point. Samples of each delivery are graded and small-scale farmers are paid a pack-out export percentage before the produce is loaded onto the refrigerated truck and transported to the Agriflora packaging plant.

At Agriflora's state of the art packinghouse situated near Lusaka International Airport, a work force of over 500 ensures that the produce is packed according to the AEU's specifications and standards for processing, grading, packing and distribution of fresh vegetables. After processing and packaging Agriflora delivers the produce to the Airport for export destinations in Europe and the Republic of South Africa.

Plan of Action to Rapidly Expand Micro Irrigation in the Dambos

Assessment. A regional assessment of potential for small-scale irrigation in Tanzania, Malawi, Mozambique, Zimbabwe and Angola (also Caprivi Strip in northern Namibia), would need to be conducted. The focus would be on identifying dambos and river basins with small-scale farming activities already in existence. Needs of these small-scale farmers will then be assessed in terms of production constraints, irrigation technology applications, inputs required, market linkage potential and cash crops with smallholder potential.

Also assessed are private sector agri-businesses, local manufacturing and technology supply capacity, agricultural export companies and local market situation. Finally, government interest in participating in the initiative is ascertained.

Implementation. The following series of activities will need to be engaged in.

Identification, Adaptation, and Field Testing of Water Delivery Technologies
In a process similar to the one that proved successful in the Zambia test case, identify and adapt affordable waterlifting and distribution technologies like different versions of Treadle Pumps and low cost drip systems for large-scale dissemination through the local private sector.

Partnership Formation. Establish partnerships with NGOs that are in place and working in agricultural development. Recruit interested private sector agri-business companies involved in seed fertilizers and input supply manufacturers and dealers in farming technologies and other agriculturally related service providers.

Community Mobilization. Organize farmers into out-grower association based on the Zambia model. Provide training and strengthen organizational capacity of the Associations.

Market Linkage Formulation. Collaborate with the private sector partners and facilitate linkages between Out-grower schemes and marketing services.

Business Development Services. The overall objective is to build the capacity of small-scale rural farm families to produce fresh vegetables for both local and export markets through developing market network linkages, thereby increasing cash earnings for small-scale farm family enterprises. This will be accomplished by providing family farm enterprises access to services needed to improve their production capacity. These services will be provided through a private network to be developed by the project and implementing partners. Services will include:

- Recruitment and training of local manufacturers to produce treadle pumps;
- Recruitment of plastic extrusion and plastic injection manufacturers for production of drip irrigation systems;
- Recruitment and training of input suppliers (seeds fertilizers, pesticides etc.);
- Establishing a franchise network of pumps, pipes drip equipment and small-scale farm input supplies throughout the region;
- Development of affordable food processing technologies to increase value of produce and profits;
- Marketing and promotion of technologies; and
- Agricultural extension services.

The project will need to provide technologies, marketing expertise, technical training to farmers in agronomy and farm management and training to small-scale agri-business enterprises. The project should concentrate on developing the supply side of technologies and capacity building services in support of irrigation to improve production. This is accomplished through further development of private enterprise networks which manufacture and supply appropriate irrigation technologies and training to rural farm families.

The private sector needs to be harnessed for the provision of horticultural services necessary to produce high quality, high value vegetables for the international export market. Private sector links to the international export markets provide an outlet for rural farm family enterprise produce. This will provide a reliable source of cash income not previously realized. Local markets will also be explored and out-grower groups will be organized to grow on contract.

Potential

It is estimated that given sufficient resources to scale up the activities in support of smallholder development in the dambos through the systematic introduction of affordable micro-irrigation technologies, it will be possible to reach at least 1 million smallholders in dambo areas, who will bring a total of some 400,000 hectares under irrigation and consequent intensive horticultural production.

Annex 3. The Ganga-Brahmaputra-Meghna Basin

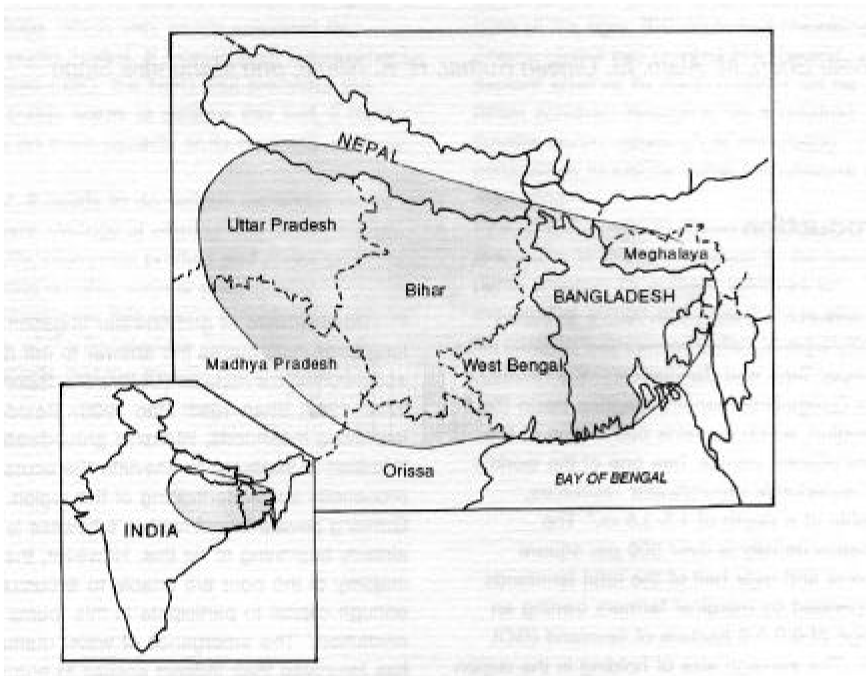
The Case: Installation of more than1.6 million Treadle Pumps through the local private sector in Bangladesh, the Gangetic delta of India, and the Terai of Nepal.

Project Period	Bangladesh: Started in 1986; India: Started in 1990; Nepal: Started in 1994.
Farmers Served	Over 1.6 million farm families to date (10 million individuals).
Water-related Technologies	Treadle Pumps (Standard Pump, Deep Set Pump, Pressure Pump, River Pump, Plastic Pump, Cement Pump)
Increased Aggregate Annual Income	$203,000,000
Irrigated Crops	Rice, vegetables
Most Important Lessons Learned	1. Affordability of microirrigation technology may be the single most critical factor in the dissemination process amongst smallholders. 2. A large majority of resource-poor farmers do not have access to credit facilities. 3. Smallholders are inherently risk-avoiders and need to see a product produce high income for 1-2 years before they invest. 4. Suppliers or agricultural inputs are key providers of supplies and information for small farmers, and their technical knowledge and business-related capacities must be strengthened and developed. 5. The Treadle Pump stimulates the emergence of water markets, and creates demand for lead-on markets for small motor pumps. 6. A large void exists in the market for small plot irrigation between buckets on the one hand, and diesel pumps on the other: this points to huge opportunities for low-cost microirrigation technologies.
Key Constraints to Scaling up:	1. Limited credit facilities for smallholder farmers. 2. Poor development of output markets for high-value crops to be produced by smallholder farmers. 3. Only poorly developed technology packages of smallholder production systems for high-value crops. 4. Poorly developed commercial supply systems of inputs and technical information aimed at the smallholder consumer.
Potential Impact:	It is estimated that close to 8 million smallholder families can be reached with microirrigation technologies over a period of 15 years.
Potential New Areas Under Microirrigation	1,500,000 hectares

The Ganga-Brahmaputra-Meghna Basin

CHARACTERIZATION OF THE AREA

The area of Bangladesh, eastern India, and the Nepal Terai has been described as South Asia's poverty square. It is the heartland of the Ganga-Brahmaputra-Meghna basin, contains 500 million of the world's poorest people, and has available a huge groundwater reservoir at a depth of 1.5-6.0 meters, replenished every monsoon season, only a fraction of which is currently utilized.[1]



In this poverty square, the majority of people live in rural areas and derive their principal income from agriculture. But the region has low agricultural productivity, and the farms are small and fragmented. For example, 75 percent of the landholdings in Bihar in 1981-82 were less than one hectare[2], and 75 percent of the farms in Bangladesh were less than two acres in 1978[3], with farm size in both Bangladesh and India steadily decreasing over time. A typical farmer in Bangladesh farms a total of one and a quarter acres divided into five separate quarter acre plots.

[1] Shah, Tushaar, Alam, M, Kumar, M.D and Nagar, R.K., and Singh, M. Pedaling out of Poverty: Social Impact of a Manual Irrigation Technology in South Asia. Research Report 45, International Water Management Institute, Colombo, Sri Lanka, 2000.

[2] Yugandhar, B N and Lyer, K G, eds., Land Reforms in India, Bihar Constitutional Constraints. Volume 1, Sage Publications, New Delhi, 1993.

[3] Jannuzi, F T, and Peach, James T. Bangladesh: A Strategy for Agrarian Reform, In Studies in Agrarian Reform, Prosterman, R L, Temple, M N and Hanstad, T M, ed. Lynne Rienner Publishers, Boulder Colorado, 1990.

According to Shah, "development of groundwater irrigation has long been held out as the answer to the region's socio-ecological malaise"[4]. But prior to 1986, the majority of farmers lacked access to affordable irrigation devices that fit the needs of their small plots. The cheapest diesel pump on a tubewell cost $500, and did not pay for itself on less than five acres. The available simple manual water lifting devices that were cheap enough to be affordable, like a bucket with a rope, were not efficient enough to be practical. A standard hand pump was often used for irrigation, but the arm action required to activate it is bio-mechanically inefficient and leads to rapid tiring. In the early 1980's, the Rower Pump, introduced by the Mennonite Central Committee and disseminated by International Development Enterprises (IDE), and the Treadle Pump, introduced by Rangpur Dinajpur Rural Service (RDRS) and mass disseminated by International Development Enterprises (IDE), provided an affordable water lifting device that fit the needs of small plots and could be mass marketed through the local private sector.

CASE STUDY: INSTALLING OVER 1.6 MILLION TREADLE PUMPS THROUGH THE LOCAL PRIVATE SECTOR

Gunnar Barnes, a Norwegian volunteer for RDRS, a Lutheran-backed development organization in Bangladesh, and his colleagues, developed a marketable design of the Treadle Pump[5] on the sensible notion that a small farmer should be able to buy a manual irrigation pump for a price equivalent to the value of a sack of rice. He and his colleagues supported the development of four small manufacturers, and began to promote Treadle Pumps in the northern provinces of Rangpur and Dinajpur.

Starting in 1986, IDE assumed leadership in promoting the technology in the rest of Bangladesh, and in other countries. The first step was to build an effective private sector dealer network. In the beginning, IDE bought Treadle Pumps from partner-manufacturers, conducted 100 percent quality control procedures, put an IDE logo on pumps that passed inspection, selected village dealers, and took a 10 percent commission for its work. Selecting effective dealers became an art. If the dealer was too small, he/she was less likely able to buy an inventory or to command respect in the village. If the dealer was too big, potential profits available from Treadle Pump sales were not significant enough to be attractive. Like Goldilocks and the Three Bears, the trick was to select the dealer that was "just right", and to build enough sales volume for him to make a decent profit.

Well drillers, or mistries, are village mechanics who install Treadle Pumps and it is critical that they install the pump properly in order for it to work effectively. To facilitate proper well installation as well as Treadle Pump promotion IDE conducted a continuing two-day diploma training course, which trained several thousand well drillers.

[4] Shah, 2000, op cited.
[5] Orr, Alistair, ASM Nazrul Islam, and Gunnar Barnes, 1991.
The Treadle Pump. Dhaka, Rangpur Dinajpur Rural Service.

In the beginning, IDE conducted 100 percent quality control of Treadle Pumps in addition to training installers, to ensure that the first pumps in each village worked properly. IDE field staff provided follow-up services on initial installations in each area. Field staff also carried out village promotion activities and facilitated sales by private sector dealers. IDE learned from market studies that most small farmers had never heard of Treadle Pumps and didn't know what they were. This made clear that they had to initiate a number of activities to increase product awareness, linked to providing specific opportunities for customers to get on a Treadle Pump and try it out.

To this end, IDE distributed thousands of calendars, leaflets and posters understandable by people who couldn't read. A troupe of traveling actors was hired who gave performances in open-air settings of a Treadle Pump play which attracted rural audiences of 1,000 – 2,000 people per performance. A full-feature 90-minute entertainment movie using top Bangladeshi male and female leads and a well-known director was produced. In it, the money earned by a Treadle Pump was central to the plot. The movie played to an audience of a million people a year. Troubadours with small bands sang songs about Treadle Pumps at village markets, and handed out leaflets to onlookers.

Small farmers gather at local and regional markets and bazaars, and this provides an ideal opportunity for smaller events that introduce potential customers to Treadle Pumps. One effective strategy has been to arrange for a small band to write a song about the Treadle Pump, which attracts an audience to whom leaflets are distributed, while in the background one of the players operates a Treadle Pump on a stand.

Prior to the opening time of large regional markets, a procession of three rickshaws with portable Treadle Pumps being pumped on a platform at the back of the rickshaw, accompanied by a microphone, form a procession through villages attracting potential Treadle Pump customers to the upcoming event or demonstration. A critical component of all demonstration and promotion strategies is to have a Treadle Pump available, and to encourage the potential customer to get on the Treadle Pump and pump water with it.

Village dealers play a key leadership role in promotional activities. For example, when a movie performance is scheduled, Treadle Pump dealers bring potential customers to the movie publicize the performance beforehand, and most importantly convert the interest in Treadle Pumps generated by the movie into sales.

In the early 1990's IDE established a demonstration program using 300 exemplary farmers in highly visible locations to encourage small farmers, not only to purchase and install Treadle Pumps, but also to provide critical information about diversified high-income crop strategies that could optimize their income. The demonstrations were linked with dealers, so that a dealer could take a potential customer to a small farm using a Treadle Pump.

An important factor in making the private sector system of producers, dealers, and well drillers economically sustainable is that for most of the period that IDE has been involved with Treadle Pumps in Bangladesh, it has only been involved directly with 25 percent of the private sector players in the market. IDE's role has been to facilitate, stimulate, and shape the market, but as soon as a vigorous private sector marketplace was established, it was not possible, nor desirable, to control it.

For the first three years (1986 to 1989), IDE made sure that the initial Treadle Pumps installed were of high quality by maintaining 100% quality control procedures, training installers, and using field staff to check on installations and carry out follow-up service visits. By 1989, sales had risen exponentially to 60,000 per year, and IDE had handed over its direct role as a wholesaler to private sector distributors. Fifty percent of the marketplace now consisted of new producer/dealer networks that entered the marketplace because they saw an opportunity to make a profit. After 1989, these new market players consistently controlled 25-35 percent of the market, and IDE's activities influenced them, but did not control them.

One type of enterprise that entered the market was the small, fly-by-night copycat producer who quickly made a few hundred very poor quality pumps that only lasted a few weeks before failing, and then disappeared before customers realized they had been fleeced. IDE quickly learned that it was impossible to control these fly-by-night copycat operators. What was possible, however, was to launch a variety of activities to educate customers to differentiate between high and low quality products, and make an informed decision on which product to purchase.

Because of what was learned from the competitive marketplace, from 1989 on IDE promoted three different quality levels of Treadle Pumps in Bangladesh, based primarily on the thickness of the sheet metal used to produce the pump, workmanship, and type of foot valve used. The cheapest model recommended by IDE used 18-gauge steel, was rated by IDE to have at least a 2 year life. The most expensive model had an expected life of seven years. The cheapest model instantly captured about 50 percent of the Treadle Pump market, and has remained the highest volume seller.

An important part of IDE's promotional activities has been to influence key decision-makers to support the Treadle Pump program. In this arena, Swiss Development Cooperation, who funded the program, has played a major leadership role. For example, in recognition of Switzerland's 700th birthday, SDC held a two-day Anniversary Celebration at the top hotel in Dhaka that featured the Treadle Pump program.

A critical part of the process facilitating Treadle Pump adoption was the careful design and implementation of a strategy to collaborate with, and support other organizations in Bangladesh who were interested in incorporating Treadle Pump projects as part of their program. The Grameen Bank, for example, launched an initiative, which at its height installed 25,000 Treadle Pumps in one year, facilitated by credit available through the organization. As part of this effort, the Grameen Bank set up their own Treadle Pump manufacturing enterprises.

India

In 1990 IDE introduced Treadle Pumps into India for the first time. Geographically, Bangladesh is just the end of a very long and rich shallow aquifer that also covers West Bengal, northern Bihar, and eastern Uttar Pradesh. There are large areas of shallow aquifer in coastal Orissa also. This area of Eastern India, with very high monsoon rainfall and flat topography, also has a population of nearly 300 million of the poorest people in India, all in a similar socio-economic situation as the people of Bangladesh. IDE initially started a program in partnership with AFFPRO, a local federation of NGOs. IDE provided training to three manufacturers to produce the Bangladesh-model pumps, trained the local installers, and trained the NGO workers. The local partners then promoted the product with their beneficiaries. Within a year about 2,000 pumps were installed. With this success, IDE obtained funding from Swiss Development Cooperation (SDC) to start a program in Orissa, the poorest state in India. This was the beginning of a long partnership with SDC, which eventually saw the spread of the Treadle Pump program to Uttar Pradesh, Bihar, West Bengal, Orissa, and Assam. To date, nearly 250,000 Treadle Pumps have been sold in India.

Very early during the expansion of IDE's activities in India, it was felt that marketing the pumps would be simpler if the installers did not have to construct a bamboo super structure in order to operate the pump. The idea was to have a single unit that could be easily carried on the back of a bicycle, attached to the top of a tubewell with no special construction necessary, and the farmer could pedal his/her way to prosperity. Thus was developed the first variation on the Bangladesh bamboo pedal Treadle Pump. The steel pedal Treadle Pump consists of two steel pedals attached to cylinders with a steel frame. In several areas, this pump became very popular, and pressure pump modifications of this model have been successfully introduced and marketed by Approtech in Kenya.

IDE India followed the Bangladesh model of Treadle Pump promotion, using independent local producers (strictly quality controlled), a massive dealership system (more than a thousand dealers), and a mass information campaign that included most of the elements that had made the Bangladesh program a success. As is evident from the number of pumps installed (250,000+), the model worked again.

Nepal

The “Nepal Terai” is a narrow strip of land along the southern border of Nepal. This northernmost strip of the Gangetic plain also has similar hydrologic, cultural, and economic conditions to Bangladesh and Eastern India. With more than 45 percent of the population of Nepal concentrated in this strip (about 10 million people), and with well over half of the cultivable land, the Terai region acts as the breadbasket for all of Nepal. In 1993 IDE started two pilot projects to test the feasibility of marketing Treadle Pumps in the Terai of Nepal. By 1994, studies showed the acceptability of the technology to farmers, and IDE started its third Treadle Pump mass marketing campaign, largely along the lines of those already existing in Bangladesh and India. Sales rose steadily over the ensuing years, and there are currently more than 30,000 Treadle Pumps in Nepal. In the year 2000, the more than 7,000 Treadle Pumps installed actually exceeded the number of diesel shallow tube wells installed. Once again the formula developed first in Bangladesh succeeded to bring irrigation and added income to small farmers in another area of the Gangetic plain. A study in Nepal showed net benefits of $117 per farmer per year, very similar to the benefits accruing to Bangladeshi farmers.[6]

Results

More than1.35 million small farmers in Bangladesh, 250,000 farmers in India, and 30,000 farmers in Nepal now have purchased Treadle Pumps. Recent studies have verified that each of them earns new net income of at least $100 a year. One fifth of these farmers earn a new net income of $500 a year[7]. The net income of 1.6 million families has been increased by more than $160 million per year, bringing almost 10 million poor people in the Gangetic plain a long way on the road out of poverty. And the Treadle Pump has now been marketed in other areas including South-East Asia, West Africa, Southern Africa, and the Caribbean.

Treadle Pump Models

One interesting development has been the proliferation of different models of Treadle Pump to fit specific needs of farmers in certain locations. The following are a few of the variations on the basic design of a twin-cylinder, foot-powered pump:

> **Cement Pump:** This pump was developed in India in response to saline conditions in several coastal areas of Orissa. The metal pumps were rusting quickly so someone came up with the idea of using plastic cylinders encased in a mini cement slab. Several thousand of these have been sold in the saline area of coastal Orissa.
>
> **Plastic Pump:** This was a Bangladeshi solution to the same problem of salinity in coastal Bangladesh. An injection-molded model, made from high-density polyethylene has been broadly marketed in southern Bangladesh.
>
> **River Pump**: This model was first developed by IDE in Vietnam in 1996. In 1998 IDE modified it as a metal pedal-operated pump. This model now is used extensively in Africa. In places with large amounts of surface water, farmers want to be able to come to the river-, lake-, or canal-side, lay down their pump, throw a hose into the water, and start pumping. At the end of the day, they pick up the pump and hose and go home. The design integrates the pedals and cylinder (as in the India steel pedal pump), but has a side intake hose, and quite often an integrated handle for stability of the user.
>
> **Pressure Pump**: This is a model of Treadle Pump that can deliver water through a hose to elevations above the level of the pump. It has several applications.

[6] HURDEC, Socio-economic Impact Assessment of Treadle Pump program in Siraha and Saptari Districts, 1997
[7] Tushaar Shah, Socio-economic Impact Study

Growers of betel leaf in Bangladesh want to be able to wash the leaves periodically. Farmers quite often want to fill a tank of water for household use. Some farmers need to deliver water to a field that is up-slope from, and not adjacent to the water source. In Africa, some farmers like to water their plants by hose, which also saves water over the flooding technique. This type of pump can also be used to fill a small tank to run mini drip irrigation kits.

Deep-Set Treadle Pump: This pump was developed in Bangladesh for areas where the water table is slightly below the suction limit. With a set of extended cylinders, this pump can pull from as deep as 50 feet, i.e., 30 feet deeper than a normal Treadle Pump. This pump may become more important in the future as water tables drop in the dry season.

Impact

There have been many studies done of the impact of Treadle Pumps on the lives of farmers in the Gangetic plains.[8,9,10,11] The outcomes of these studies have been remarkably consistent across the region. The following are the general impacts:

1. The Treadle Pump is self-targeting to small farmers. In most areas, land holding of farmers purchasing Treadle Pumps is less than one hectare. This is due to the labor intensiveness of the technology.
2. Treadle pumping is a family activity, with men, women, and children sharing the burden.
3. In Bangladesh and West Bengal, farmers are using the pump partially to grow an extra crop of rice. This is increasing food grain self-sufficiency and food security.
4. In all areas, farmers are using the pump to diversify their cropping pattern. They are adding vegetables and other high value crops. They are also using higher yielding varieties of grain crops.
5. Use of other inputs, such as fertilizer and pest control, has increased with Treadle Pump use.
6. Income has increased by $100 to $500 per year per family. This is a significant increase for families in one of the worlds poorest regions, where per capita GDP averages less than $200.
7. Increased income is spent on food, housing, education, and farm investments.
8. Family nutritional status improves through increased consumption of vegetables, especially in the dry season.
9. Farmers use Treadle Pump to increase cropping intensity, often growing three crops a year.
10. Use of Treadle Pump has stemmed the flow of migration out of the village in many localities. Farmers prefer to earn income on their own farm when given the opportunity.

---

[8] Alam, M, Hossain, K.M., Socio-economic Impact of Treadle Pump Irrigation in Bangladesh, BIDS, 1999.
[9] Singh, M., Pedal. Pump Irrigation in Eastern Uttar Pradesh, A study on Social and Economic Impacts, IDE, 1999.
[10] Socio-economic Impact Assessment of Treadle Pump Program in Siraha and Saptari Districts, HURDEC, 1997.
[11] Shah, Tushaar, et al, Pedaling out of poverty, SDC, 1999.

11. The Treadle Pump is often the farmers' first encounter with agricultural machinery, and has led to poor farmers' increased comfort with use of machinery.

Lessons Learned

?? **Affordability is a critical variable for small farmers.** IDE staff were uncomfortable with Treadle Pumps that lasted less than seven years. When farmers were given a choice of a two-year pump that was cheap, a four-year pump that was a little more expensive, and a 7-year pump that was still more expensive, more than half of the farmers preferred the cheapest, two-year model. Farmers make decisions based on their own set of criteria, not ours. To the small farmer, availability of cash capital is one of his major constraints. Once the farmer has entered the world of cash crop production, purchasing a second pump is not as big a problem. But the entry level is critical.

?? **Formal credit facilities rarely exist for poor farmers wanting to buy a Treadle Pump.** Commercial banks do not want to deal with such small loans. There are also social barriers to poor farmers entering a bank and dealing with bank officers. Grameen-type banks are different, but they are still not available in most locations in the region. However many farmers use local "informal" credit sources such as moneylenders. These lenders have very high interest rates and extreme penalties for non-payment.

?? **Most poor farmers are very conservative, and want to see a product generate high income for a couple of years before they invest.** This goes back to cash shortage, but also includes the very precarious economic and nutritional status of small farmers in the region. When failure could lead to lack of food on your family's plates, then you're decision making logic is much different than we are used to in the west. Therefore, farmers want to be absolutely sure that something will work before they invest. Seeing a neighbor using it successfully is the best motivation.

?? **Business Development Services are needed for the supply chain.** The suppliers of agricultural inputs are key providers of supplies and information for small farmers. It is important to build the capacity of these merchants through technical training, introduction of appropriate technology packages, and creating upstream and downstream linkages. These shops can become the major service provider to the farmers, reaching where the government extension services have failed to penetrate.

?? **The Treadle Pump stimulates the emergence of water markets.** Nobody wants to do hard manual labor if they can afford mechanization. In Bangladesh, the average new income produced by Treadle Pumps is $100 annually, but one fifth, or 250,000 Treadle Pump users, can earn new income of $500 per year. Over the last ten years, the price of the smallest diesel pump in Bangladesh and India has dropped from $500 to $150, and by producing new income of $500 a year, the

Treadle Pump has produced at least 250,000 new customers for the smallest diesel pump. But diesel pumps produce more water than the average farmer needs, so it is natural to sell the excess water, stimulating the emergence of water markets. While this may inhibit the sale of Treadle Pumps, it expands small farmer access to affordable irrigation, which is the purpose behind the Treadle Pump program.

?? **A very large void exists in the market for small plot irrigation between buckets on the one hand, and the diesel pump on the other.** The Treadle Pump experience verifies this huge market gap, but shows that the Treadle Pump is only the first of a large number of affordable small plot irrigation devices needed to fill the gap. Other technologies are now beginning to emerge. These include:

- **Low cost drip.** Drip systems developed for semi-arid areas are also applicable in the region. Once farmers have some cash income, they can decrease labor requirements and increase water productivity by using more efficient irrigation systems.
- **Low-cost water storage systems.** Inexpensive water storage systems made from plastics have been developed in China. These "water bags" can be filled quickly, and the water then released slowly using drip systems.
- **Horticulture kits for the landless.** IDE has been experimenting with the idea of putting together a small kit meant for cultivating less than $100m^2$ of vegetables in an intensive manner. This would be ideal for landless farmers who have only a small plot of land surrounding their homestead. By including all the necessary inputs, including a set of picture instructions, the farmers will be able to earn a little income from this otherwise useless plot of land. The kit includes drip system, fertilizer, organic pest control, and quality seeds.
- **Micro-diesel.** In order to fill all the gaps in the water market for small farmers, IDE is working to apply smaller horsepower diesel pumps to the Gangetic plains. Ultimately it would be ideal to have a range of engines available from 0.5hp up to the currently available 3-5 hp models. Farmers could thus work their way up the ladder of mechanization.

FUTURE POTENTIAL

In the Ganga-Brahmaputra-Meghna Basin

What is the total potential market for Treadle Pumps, micro-diesel pumps, and other water technologies in Nepal, Bangladesh, and Eastern India? Informed estimates by IDE are 2.5 million for Bangladesh, 5 million in India, and 300,000 in Nepal.

How can this potential be realized?

Any action program would need to include:

1. Availability of credit. Preferably credit can is established directly through the supply chain.
2. Identification of region-specific high-value cash market crops, and development of a package of inputs and information to disseminate to small farmers so they can successfully produce and market.
3. Training of agricultural input dealers, both in business development practices and in providing their customers (the smallholder farmers) information and advice in the use of inputs and the diagnosis of production problems.
4. Work on simple technologies to grow vegetables off-season. This can often double or triple profits.
5. Train personnel from NGO's and government agencies how to develop the local business sector for the benefits of the farmer.
6. Teach mass information dissemination techniques to more NGO and government agencies.
7. Focus agricultural research institutions on the task of developing technologies for small farmers, and on seeing them through to the dissemination phase.

Groundwater Development Potential in the Terai Region of Nepal

The rapid adoption of Treadle Pumps by smallholders in the Terai resembles the process started much earlier in Bangladesh. But there is one big difference: In Bangladesh over the last five years, there has been a rapid increase in the purchase of low-cost diesel pumps, accompanied by rapidly developing water markets. Low-cost imported Chinese diesels have taken over much of the market, and a small farmer with new income generated by a Treadle Pump can now buy a 3-hp Chinese diesel pump for $150. But this process has failed to materialize in Nepal, where the cheapest diesel pumps still cost in the range of $500, water markets are rare, and major donors have focused on deep tubewells, which are too expensive for most small farmers.

A major opportunity exists for the rapid rational development of affordable groundwater access in the Nepal Terai. This begins with the rapid further expansion of the adoption of Treadle Pumps through the private sector. A second step is the stimulation of private sector import, distribution, and installation of affordable Chinese and Indian diesel pumps, combined with training programs to improve quality of tubewell installation and improved agricultural production systems. Opening access to credit and markets would be important steps in this initiative. The facilitated adoption of mechanized and Treadle Pump should be organized to facilitate the rapid emergence of water markets, which will further expand smallholder access to affordable irrigation water.

Implications in Other Parts of the World

The experience in the Ganga-Brahmaputra-Meghna basin may well have application to other parts of the world with shallow lifts. For example, in Guizhou province and the adjoining two provinces with natural greenhouse conditions, there may be a market for more than one million river and pressure Treadle Pumps. Based on initial farmer reaction to Treadle Pumps in Guizhou Province, there may be a larger potential market for Treadle Pumps in China than that of Bangladesh. Other similar markets may exist in the Ukraine, parts of South America (Peru, Ecuador, Colombia, Brazil). What is the market for drip systems and low cost sprinklers powered by pressure pumps? Could this be as big as the Gangetic basin market? There could be a global market potential for as many as 20 million Treadle Pumps. Given the potentially large areas onto which the experience from the Gangetic River basin may be projected, it would be highly relevant to take a closer look at these areas and potentials.

Annex 4. The Deccan Plateau

The Case: In a three-year project in the Deccan Plateau, IDE has promoted low-cost micro irrigation technology for smallholder farmers.

Project Period	1998 to present
Farmers Served	10,600 farm families to date (60,000 individuals)
Aggregate Annual Income	$850,000
Irrigated Crops	Vegetables, fruits
Water-related Technologies	Drip irrigation (two kits: kitchen garden kit [24 m^2]; drum kit [90 m^2]. Micro sprinkler irrigation. Rope-and-washer pump. Rainwater harvesting. Low cost water storage.
Most Important Lessons Learned	1. Commercial and government-sponsored micro irrigation programs aimed at the medium- and large farmers have zero impact on the resource-poor farmer 2. To be successful with the smallholder community, micro irrigation technology must take into consideration the unique circumstances of the smallholder. It must be affordable, and must be accompanied by associated services (credit, other inputs, training). 3. In water-scarce areas, such as those represented by the Deccan Plateau, micro irrigation practically is the only avenue by which smallholders stand a chance to derive significant economic benefits from their holdings. 4. Micro irrigation technology for resource-poor farmers is highly complementary to the very large government-sponsored micro watershed management programs in India. Given the preciousness of scarce water, the demand for water-saving technology is immense, thus assuring conditions that are favorable for large-scale dissemination of low-cost microirrigation technology. 5. Microirrigation dissemination strategies for the smallholder community must be accompanied by provisions for the supply of associated inputs, including information/training on production practices.
Key Constraints to Scaling up	1. Limited access to credit for micro-irrigation products and associated farm inputs; 2. Poorly developed infrastructure; and 3. Long distances to market centers.
Potential Impact	Over a 15-year period, some 7 million smallholder families may be reached with microirrigation technologies and associated inputs/ services. With estimated additional net income of $300 per family, the aggregate impact will be on the order of 2 billion dollars of net additional income for the Plateau.

THE DECCAN PLATEAU

Characterization of the Area

Nearly three-fourths of the total area of India is located on a vast plateau region called "The Deccan Plateau", which resulted from a volcanic eruption that occurred millions of years ago. This area now consists of large parts of four states, i.e., Madhya Pradesh, Maharastra, Karnataka and Andhara Pradesh. The plateau has similar physical characteristic thus the area presents a lot of similarity: a large area covered under thick forests; a large concentration of aboriginal tribes living there; very poor economic conditions of the tribes; most of the tribes primarily dependant on minor forest produce; poor infrastructure in the tribal areas; very low levels of literacy/health among the tribes; and water table beyond 200 meters. Because of such a large similarity among the natural resource in this plateau region, the Deccan Plateau presents itself as an obvious region for developmental intervention.

The following table provides some major statistics about the major states[1] of the Deccan Plateau.

	Madhya Pradesh	Maharastra	Andhra Pradesh	Karnataka
Total area (km^2)	443,446	307,690	275,068	191,791
No. of administrative districts	45	31	23	20
Rural population ('000)	50,842	48,396	48,621	31,069
% rural population to total population	77	62	73	69
Holdings 0–2 ha ('000)	5,053	6,003	7,183	3,848
Households below poverty line ('000)	5,334	6,045	3,265	2,875
Rural literacy (%)	36	56	36	48
Per capita income (Rs)	2,878	6,184	4,507	4,075
Rainfall (mm)	1,160	975	887	1,758
Net cultivated area ('000 ha)	19,740	18,021	10,362	10,790
Net irrigated area ('000 ha)	4,775	2,470	4,029	2,194
Irrigated area to cultivated area (%)	24	14	39	20

The Case: IDE's Experience with Micro Irrigation in the Deccan Plateau

To address the problems faced by a large number of small and marginal farmers residing in the "Water Scarce Region" of India, IDE undertook a pilot project from 1997 to 2000. During this period IDE adapted the basic technology of micro irrigation to develop a range of Affordable Micro Irrigation Technologies (AMIT) that are appropriate and affordable for the needs of small farmers in this region. IDE also undertook field-testing and test marketing to get farmers feedback and understand the potential of these technologies. During this period over 10,000 small and marginal farmers of India purchased these kits. On average, these farmers have earned an average net income of Rs.

[1] As per 1991 census

300 from bucket kits, Rs. 3,000 from drum kits for vegetables, and Rs. 15,000 from drum kits for papaya cultivation per year.

During the fieldwork, IDE worked in all the four major states of the Deccan Plateau and some of this work is briefly provided below.

Madhya Pradesh is the largest state of India having the highest area under forests and highest population of Tribals. In 1997 IDE started its operation by opening one field office at Indore. Over 1,100 farmers of Madhya Pradesh have already purchased AMIT kits in the last three years. The biggest achievement here has been in partnership with the largest government-run watershed program of the country - the Rajiv Gandhi Watershed Mission. Madhya Pradesh has a very high potential for AMIT.

Maharastra is the third largest state of India accounting for over 60 percent of the total drip installation in the country. The government of Maharastra pioneered the introduction of drip nearly 15 years ago by providing heavy subsidies. Jain Irrigation, is the largest drip-irrigation company of India, is also represented in the state. Maharashtra also has over 40 small-scale drip irrigation equipment manufacturers. But most of the drip systems in the state have gone to rich growers of grape, banana and sugarcane. Although there is good awareness about drip irrigation in Maharastra, no systems were owned by any smallholder among the tribal communities when IDE opened its operation in 1997. IDE established one regional office at Nagpur and two field offices at Aurangabad and Amravati; 2,200 farmers have purchased AMIT kits in the last three years. Maharastra is also serving as the main source of drip components to the rest of the country. Small farmers of Maharastra offer a very good potential for AMIT.

Andhra Pradesh is the fifth largest state of India in area and population. This is also one of states most prone to seasonal cyclones. Politically, this is the most progressive state of India for development, which makes it extremely interesting to have an operation in this state. We began our operation in Andhra Pradesh in 1998. Nearly 600 farmers have already purchased AMIT kits in the last two years.

Karnataka is the eighth largest state of India in both area and population. IDE began its operation in Karnataka in 1997 to promote micro irrigation among sericulture farmers and in 1999 also started promoting AMIT kits. In the last three years over 1000 farmers of Karnataka have purchased micro irrigation kits.

Product Selection and Marketing Strategy

In selecting products and services tailored to the needs of identified market segments, IDE used the following criteria:[2] (1) the layout and operation should be simple and easy for farmers to understand; (2) farmers should be able to install the systems themselves; (3) the initial investment for purchasing the systems should be within the purchasing power of the small, marginal, and landless farmer/horticulturalist; and (4) the systems

[2] IDE India Business Plan: April 2000 to March 2005.

should be divisible so that farmers can install small units to begin with and expand these in the future by adding other units (strategy for affordability). Based on these criteria, the following products and services were selected for broader dissemination:

Stage of investment	Micro Irrigation		Horticulture Package			Targeted Client	Annual Net Profit
	Product Description	Price	Product Description	Price	Service Description		
Step I	Bucket kit	$5	Mixed vegetable seeds	$5	T.A.: How to grow a kitchen garden	Rural women	$8
Step II	Drum Kit (V) Water tank Area: 80 m^2	$18 $10	Improved vegetable seeds, fertilizer, pesticides	$22	T.A.: How to cultivate and market seasonal vegetables	Poor with some access to water	$81
Step III (invest profits from Step II)	Drum kit (H) Area: 130 m^2	$18	High quality seedlings, fertilizer, pesticides	$100	T.A.: How to cultivate and market high-value annual produce	User of drum kit (V), wanting to upgrade	$252
Step IV (invest profits from step III)	Drum kit (O) Area: ½ acre	$90	High quality saplings, fertilizer, pesticides	$30	T.A.: how to cultivate and market high value perennial produce	User of drum kit (V & H) / Poor w/ orchard	$174

Shown above are two sets of input costs: the cost of micro irrigation, plus the cost of the accompanying horticulture package.
V = vegetable drum kit; H = horticulture (papaya) drum kit; and O = orchard drum kit.

These products and services, priced from US $5 to US $120[3], were designed to meet the needs of rural women, tribal landless farmers, small and marginal farmers engaged in horticulture, and small commercial nurseries. Because AMIT products are divisible and can be expanded over time and/or used for multiple micro plots, they fit well with the financial and land resources of micro horticulturalists. For instance, at a cost of $10 (bucket kit and horticultural inputs), a small-scale horticulturalist can experiment with drip and vegetable production at very little risk. To increase the affordability of horticultural inputs, IDE is working with agri-input dealers and other providers to promote the sale of small, affordable sachets of fertilizer and pesticides.

As illustrated in the above table, each subsequent package of products and services constitutes a step-up in terms of investment and profitability. Profits from step 1, representing a one-season vegetable crop, can be used to advance to the second step, which involves a medium-term investment in a crop such as papaya. The third step entails a longer-term investment in a perennial crop. This product/service mix is meant to match different market segments, and to assist poorer farmers to enter the market incrementally as their personal financial resources permit.

[3] Combining drip and horticultural package.

To create demand for AMIT products, IDE is collaborating with more than 50 NGOs working in watershed management in Gujarat and Maharashtra. These NGOs have significant outreach, and have provided IDE with ready access to the target group. As part of the existing AMIT program, IDE explored the feasibility of leveraging promotional efforts through this network of NGOs who have their own staff and resources. All NGOs involved in AMIT used their own funds. Despite this requirement, over 200 NGOs contacted IDE, showing overwhelming interest in the technology. The following table shows in a nutshell the market relationship IDE plans to promote.

Service provider	**Product**	**Service**	**Client**	**Payment mode**
NGO	Technical Assistance	Promotion / demonstration, training and info services	Farmer	Free public good
Manufacturer	AMIT components	Credit	Assembler	Bundled in the price of the product
Assembler	AMIT kits	Installation & maintenance guide	Farmer	
	Farming system booklets	Crop demonstration	Farmer	
Ag-input dealer	Micro sachets of fertilizer and pesticide	Application & dosage guide	Farmer	
Nursery	Fruit and vegetable saplings	Plantation guide	Farmer	
Farmers Group	Credit	Marketing support	Farmer	Fee for service

Strategy to Move Forward

Constraints to Scaling up of Micro Irrigation

IDE conducted a market research study to find out the demand side and supply side constraints for scaling up of micro irrigation in semi-arid India. These constraints are presented below:

Demand side constraints faced by poor farmers include: (1) lack of information about drip irrigation, high-yielding horticultural inputs, and improved management practices; (2) inability to access government subsidies for drip irrigation, and (3) lack of access to credit for purchasing AMIT Plus products and services.

Supply-side constraints include: (1) financial restrictions faced by manufacturers, distributors, and dealers of micro irrigation products in obtaining government subsidies; (2) lack of products developed for, and suitable for smaller farmers; (3) lack of promotional and/or information services to expand awareness, interest, and adoption of micro irrigation products; and (4) insufficient numbers of drip dealers in remote rural areas.

To meet the needs of small and marginal farm households, it is necessary to develop the market for affordable drip irrigation technologies and horticultural services that can be applied profitably to micro-sized plots. To penetrate the potential market, whatever initiative is undertaken will need to address the demand-and supply-side constraints explained earlier.

Successfully penetrating the AMIT market will require addressing these constraints and ensuring that customers are willing to pay for drip and horticultural services. The fact that all AMIT customers invested resources into horticultural packages equal to the cost of AMIT testifies to their willingness to pay for AMIT and associated input products and services. While historical sales of AMIT indicate that small and marginal farmers are willing to pay for drip irrigation technologies, the existence of a subsidy program also suggests the potential for problems. In fact, IDE specifically surveyed farmers regarding their willingness to pay a market price for AMITs in the face of government subsidies for alternative types of irrigation systems.

In the customer survey,[4] farmers gave the following reasons for their preference for AMIT over the systems available under the subsidy program: (1) the subsidies are limited, and richer farmers are better able to compete for them; (2) the bureaucratic process required to obtain subsidies was too time consuming and often unsuccessful; and (3) the micro irrigation systems sold under the subsidy program are designed for larger plots, and required an assured water source, as well as a lifting device.

[4] Naik and Dixit, ibid.

Output markets for fruits and vegetables are also essential for successful market penetration. IDE market research reveals that Maharashtra is an important producer of oranges, mangos, grapes and bananas, which are marketed nationally. Consequently, Maharashtra has a well-developed wholesale marketing network for horticulture. Mumbai, the capital of Maharashtra, is the commercial capital of India and is the biggest hub for such marketing activities in India. Naturally, linkages will need to be established between AMIT customers and these wholesale markets.

On the demand side, any project intervention will need to:

- develop products and service packages tailored to the needs of identified market segments;
- engage in promotional/demand creation activities;
- develop linkages with a network of NGOs interested in demonstrating and disseminating information on the benefits of AMITs and horticultural production using improved inputs and practices;
- develop a profitable private sector supply chain (made up of manufacturers, distributors, agri-input dealers, and agents) to produce, distribute and sell AMIT and affordable service packages;
- promote business linkages among industry firms, and among firms and relevant NGOs (which provide micro finance services), universities, and government agencies; and
- phase out donor-supported activities (i.e. exit from the market).

Potential

The Deccan Plateau houses about 18 million farm families living below the poverty line. It is estimated that at 40 percent of these families, or some 7 million smallholder farm families, could benefit from micro irrigation over a 15-year years period. Assuming that on average these technology-adopting smallholders will micro irrigate an average of 700 m^2, the total area to be brought under micro irrigation in the Deccan Plateau would amount to some 500,000 hectares.

Annex 5. Poor Hill Areas of Asia

The Case: In Himachal Pradesh (India), and in Nepal, IDE projects are developing local, commercial supply systems for of microirrigation technology (drip and micro sprinklers) and associated inputs and training for smallholder farmers.

Project Period	Nepal: Project started in 1996; Himachal Pradesh: Project started in 1998.
Farmers Served	7,600 farm families to date (44,000 individuals).
Water-related Technologies	Rainwater harvesting, low-cost water storage, drip irrigation, micro-sprinkler irrigation
Increased Aggregate Annual Income	$900,000
Irrigated Crops	Off-season vegetables.
Most Important Lessons Learned	1. With intensive training, subsistence farmers can convert to income-generating, market-driven off-season diversified horticulture in 18 months. 2. To accomplish this, training in modern irrigation methods like low-cost drip is integrated with information and training on modern inputs. 3. Government agencies can act as "wholesalers" of technical advice, and as a conduit to domestic and international funding of development projects. 4. Private sector merchants are a key component of implementing programs in agricultural intensification and micro irrigation. 5. Research institutions should focus research on small-scale technologies appropriate to hill farmers, and not just try to transplant western technologies meant for larger farms.
Key Constraints to Scaling up:	1. Limited credit facilities for smallholder farmers. 2. Limitations in access to water. 3. Poorly developed input and output markets for smallholders. 4. Poor infrastructure (transportation, accessibility);
Potential Impact:	Of the total of 18 million smallholder families, some 40 percent (i.e., more than 7 million) may be expected to introduce microirrigation technologies in a 15-year period.
Potential New Areas Under Microirrigation	500,000 hectares

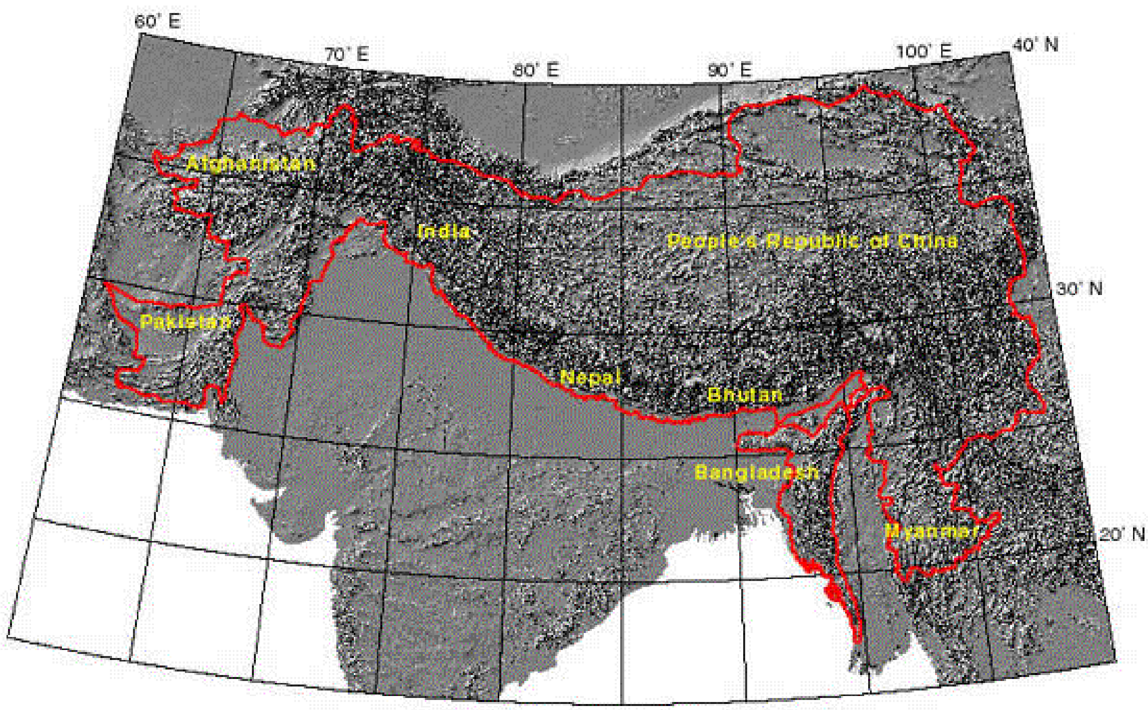
Poor Hill Agriculture in Asia

Characterization of the Area[1]

Among the world's mountain areas, Asia contains the largest, highest, and most populated mountain systems. More than 200 million people live in mountain and upland areas. Another one billion people downstream are affected by mountain conditions.

Hindu Kush-Himalayas

Of particular interest to the Global Initiative's long-term goal is to contribute to agricultural development and poverty reduction through dissemination of microirrigation in the Hindu Kush-Himalayas (HKH); a mountain chain extending over 3,500 km, the home of over 150 million inhabitants and encompassing the mountain areas of parts or all of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The region is not only the world's highest mountain region, but also it's most populous.



[1] Based on information published by International Centre for Integrated Mountain Development (ICIMOD) 4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal (2001).

Population. Population estimates are provided in the following table.

Area and Population of The Hindu Kush-Himalayan Region

Country	Inclusions	Area (in km²)	Population in 1997 (approx., in millions)	Density per km²
Afghanistan	25 out of 30 provinces	390,475	15.54	40
Bangladesh	Chittagong Hill Tracts	13,295	1.14	86
Bhutan	Entire Territory	46,500	0.71	15
China	All of Tibet and Qinghai and parts of Yunnan and Sichuan	2,420,266	30.45	13
India	All of 8 and parts of 3 Northern States	461,139	41.16	89
Myanmar	All districts in the 4 states of Kachin, Chin, Shan and Rakhine	317,629	10.10	32
Nepal	Entire territory	147,181	21.66	147
Pakistan	North Western Frontier Province, FATA, Northern Areas, AJK and 12 Districts of Balochistan	489,988	31.13	63
	Total	4,286,473	151.89	35

It is generally the case that poverty in the mountainous areas of the region is much more pronounced than in the flatter areas down below. A country-by-country analysis looks as follows.

The hill districts of ***Bangladesh*** rank lower than the national average in many indicators other than GDP, which is somewhat misleading due to low population density and higher availability of land and forest resources per capita. Drinking water and sanitation coverage is often half that of the plains and mean years of schooling much lower than the national average.

Although ***Bhutan*** is abundantly endowed with natural resources, there is awareness of the major gaps in social indicators. Adult literacy in Bhutan is 40%. Under 5 mortality is 184 per thousand population, and daily calorie supply only 90% of the requirements.

China claims to have made tremendous strides in reducing poverty and attaining higher social development during the past decade. However, 40% of the people are still without access to safe water and 90% are without sanitation. This figure is definitely higher in the impoverished mountain areas. Himachal Pradesh fares best among the Indian HKH states with a ranking of 7 in the disaggregated Human Development Index for **India**.

Next comes Assam with a rank of 11. Uttar Pradesh has large areas in the HKH region but only a fraction of the population in the HKH region and ranks 15 with a much lower than national average adult literacy rate. Tiny Manipur in the Northeast has the highest incidence of HIV infection, associated with intravenous drug abuse. The industrial labor force in the Indian HKH region is less than half of the national average.

In ***Nepal***, thirty districts, mostly in the hills and mountains, have a literacy rate of less than 30%. Nearly 30 districts, again in the isolated mountain/hill areas have less than 1 km of road density per 100sq. km of area. Twenty-six districts have an infant mortality rate of over 100, the highest being 201 in the far western mountains. Spatially, underdevelopment is largely concentrated in the far and mid-western hills and mountains where physical and social infrastructure is also very limited.

In ***Pakistan***, adult literacy in the North Western Frontier Province (NWFP) and Balochistan, the two provinces of the country within the HKH region, stands at 27% and 20%, respectively. These rates are well below the national average of 35%. Rural Balochistan is the least developed within the entire country, holding last position in disaggregated HDI ranking.

Afghanistan has been in a state of war for almost two decades now and is among the world's ten poorest countries.

Myanmar has very little published data. However, the status of human development in the hills compared to other parts of the country is not encouraging. Myanmar has high literacy rates, putting it above most other HKH countries in HDI ranking.

Agriculture. In the region, more than 85% of the population earns their income from agriculture. Currently, most of the on-farm activities are oriented toward raising staple crops for home consumption. Farm units earn cash typically from off-farm, seasonal employment either in the fields of wealthy farmers, or by migratory labor. Throughout the region, lack of water control prevents agricultural producers from engaging in high value crop production.

Water Resources. The Hindu Kush – Himalaya region statistically is one of the wealthiest areas of the world in water resources. It is the source of water for nearly 500 million people in the mountains and nearby plains. The mountains are the source of 7 major Asian river systems: the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, and the Mekong. It also contains the largest mass of ice and snow outside the Polar Regions. Therefore it is truly ironic that most of the inhabitants of this region suffer from periodic water shortages. [2]

The reasons for this are as follows: First, the area is governed by a monsoon climate. The southwest monsoon occurs in the summer (June to September) and dominates in the East and Center. The western disturbances occur in the winter (November to March) and dominate in the West. Eighty percent of the area's precipitation falls during these monsoon seasons. Thus, even where precipitation is intense, scarcity of water is common during the dry period.

Secondly, in most of the region, people reside on the hillsides and ridges, and not in the river bottoms. Due to the very steep terrain, though there may be a raging river below a village, lifting that water to the hillsides may involve a lift of several hundred meters and would be prohibitively expensive. Consequently, in the dry season, people end up utilizing upland water sources such as streams and springs. While these are plentiful in number, the total volume of water in these upland sources makes it a scarce commodity. Residents first priority is to develop these sources for household use, leaving limited quantities for irrigation.

Traditionally irrigation has been developed by building canal systems in the river bottoms. The success of these systems has been limited, especially when built by outside agencies with minimal community participation. But even where they have been successful, the impact of these systems on the society as a whole is questionable. First, ownership of the land in the river bottoms is heavily tilted in favor of wealthier farmers, so the water is going to those farmers who

[2] Banskota, Mahesh, Chalise, Suresh, Waters of Life, Perspectives of Water Harvesting in the HKH, ICIMOD, Kathmandu, Nepal, 2000

need it least for their livelihoods. Second, because the river bottoms are far from the homestead, women's participation in these canal systems is almost non-existent, despite the fact that women are heavily involved in agricultural activities near the home. So the development of these bottomland canal systems develops a scarce resource in favor of wealthy men, largely excluding the poor and women.

On the other hand, there is a huge, unexploited opportunity to use piped precision irrigation from small mountain streams to produce horticultural crops in the HKH region. These water sources can be used to irrigate small plots of high value crops in close proximity to the homestead. This opens up the opportunity for the poor and women to participate in water resource development and income generating activities.

Experience to Date

International Development Enterprises (IDE) has been working in Himachal Pradesh (India), and in Nepal for the last 3 and 5 years respectively, to help farmers transform their subsistence, migration oriented farm units into thriving enterprises by investing their own money in a series of inputs, using those inputs to produce horticultural products with proven market demand, and earning profits by selling the production in various domestic markets. The goal is to bring benefits of a growing cash economy to the majority of the population of small farmers by promoting on-farm, income-generating, enterprise activities, all made possible on the basis of availability of water through low-cost microirrigation. A more detailed account of the Nepal experience follows.

IDE-Nepal has been developing markets for agricultural inputs, including micro irrigation technologies, for the past six years. Micro irrigation includes local versions of drip, micro-sprinkler and mini water storage systems for upland farmers in the hills. Input markets supplying seeds, fertilizer, pest control, and irrigation technologies have been focused on poor farmers with minimal land. Specifically, IDE has been supporting the production of vegetable crops to increase the cash income of small farm units. The goal has been to transform farmers from subsistence to micro-enterprise market production orientation. IDE has worked with over 33,000 farmers both in the Terai as well as in the hills[3], who have increased their annual net income, on average, by more than $100. The majority of these farmers were not commercial growers prior to involvement in IDE programs.

A comprehensive training package of vegetable cultivation was developed in order to bring non-growers quickly into the business of commercial vegetable cultivation. Additionally, low-cost water storage devices have been developed for drip irrigation systems, and low-cost micro-sprinkler systems have been developed for watering of closely spaced crops.

IDE-Nepal promotes smallholder development in the form of:

1. Capacity building of agricultural input dealers through training in an appropriate package of inputs for small farmers;
2. Promotion of increased vegetable production through promotional activities and technical training of farmer groups; and
3. Creating linkages between private entrepreneurs and farmers/farmer groups through public meetings, workshops and personal contacts.

[3] The number of hill smallholders in Nepal who have purchased low-cost micro irrigation technology is 3,300. In Himachal Pradesh, some 4,300 smallholders have adopted micro irrigation technology.

This approach has resulted in:

1. More small farmers (including women) becoming micro entrepreneurs through vegetable production;
2. Increasing the production and income of existing vegetable producers;
3. Increasing local farmer access to input markets and output markets in which to sell their produce on a sustainable basis.

The following is a typical community profile in the hills of Nepal. This one is from a group of villages around a small market town in Lamjung District in Western Nepal. The area consists of 14 different castes/ethnic groups comprising some 800 households with an average family size of just under six. Fifty four percent of the families own less than .5 hectare and 86% own less than 1 hectare of cultivable land. The average annual per capita income is $108, with 75% of the families engaging in agriculture as their primary source of income. Less than 50% of the people are regular users of agricultural inputs.

There are two local NGO's and one government agriculture office operating in the project area, and a large number of formal and informal farmers' groups. The farmers' groups average about 20 members each and include groups set up by local NGO's and self-started groups such as "Mothers' Groups" in which women meet and carry out various group activities. There are no functional linkages between the various agencies, and a lack of technologies appropriate for the farmer.[4]

Thus we can see that a typical farming community consists mostly of small (micro might be a better word) farmers eking out an existence on marginal hillside land, and with minimal access to agricultural inputs or the institutional infrastructure necessary for improving their lives. IDE programs have worked to help farmers gain access to appropriate inputs, while building the capacity of the private sector and farmers groups to support the on-farm income generating activities.

IDE has been conducting extensive promotion of commercial vegetable cultivation for the last 4 years in the Western region of Nepal. Program beneficiaries have consisted of a large number of farmers, including women, with little land or income, whose best income opportunity is commercial vegetable cultivation. Women are often involved in vegetable cultivation activities and their program participation has been monitored in terms of purchase of technology, participation in training events, and participation in group activities.

Vegetable production enterprises are generally family operations. They give productive employment to all members of the family including men, women, and children. An average of 250 person-days of labor is hired to cultivate each hectare of vegetables. Thus, vegetable

[4] Gurung, Jit B., Study Report on the Sundarbazaar-Bhotewodar (Lamjung) and Ratanangla (Dailekh) Marketsheds, IDE, 1999.

cultivation enterprises can be significant generators of employment, especially as these labor requirements are focused in the winter season during which labor opportunities are less.

Despite the inadequate infrastructure, commercial vegetable cultivation is the most profitable activity that the majority of farmers can become involved in. Nonetheless, farmers have identified several problems, all related to agricultural inputs or downstream markets. The commercial sector of agriculture-related merchants are present, but poorly informed, lacking in technical know-how, and poorly stocked. In addition, firms in the agriculture service sector are not linked with each other, with the farmers' groups, or with the commercial sector that is the first line of information and inputs for the farmers.

According to the Government's Agriculture Perspective Plan, there are currently 160,000 hectares of vegetables grown in Nepal, and it is safely estimated to increase by about 13,000 hectares per year over the next 20 years. This increased production is projected to be lagging behind growth in market demand.

Studies also suggest that small farmers will be interested, willing, and capable (technically and financially) of becoming involved in these productive activities. Annual sales figures on farmers purchasing micro irrigation equipment (including treadle pumps, drip irrigation, and micro-sprinklers) through IDE programs from 1995/96, and ending in 1999/2000 have increased significantly from 585 to 10,140. All of these micro irrigation systems are used for vegetable cultivation. The average total farm size of these farmers is less than 1 hectare of land, thus they are almost exclusively small farmers. This trend clearly shows the farmers' continuing interest and capability of transitioning into commercial vegetable cultivation. It also shows that the proposed technology intervention is appropriate for the described target group. Since farmers must invest their own money to purchase this equipment, sales trends are a direct measure of farmer interest, and increasing sales trends show that their neighbors view early users positively.

IDE statistics also show that 65 percent of the farmers participating in its program in the Western region are women, and the trend is for increasing women's participation. This indicates that the activities being promoted are very appropriate for women.

Sales trends reveal that the activity is profitable. A socio-economic impact study of farmers using micro irrigation in the Western Hills shows a net annual increase in profits of about $200 per farmer.[5] The profitability of this activity for merchants can be shown by merchant participation over the last five years in IDE activities. Participating merchants increased from about 30 to more than 300 over the last five years. Merchants don't become attracted to an activity that is not profitable.

Traditionally, the government of Nepal has been viewed as the main service provider to farmers. All analyses of the government role in this area show that its impact has been limited, especially in getting technologies to small farmers. IDE views the government extension service as a good technical resource for the other service providers (i.e. agro inputs dealers and farmers groups), but not as a viable service provider itself. The government can play an important role as a source of funding for development activities. For instance, with the help of a World Bank loan, the Government of Nepal has set up the Water Supply and Sanitation Fund Development Board. This autonomous board has been funding the development of water supply infrastructure on an open tender basis for several years now. Any entity (government, NGO, community, or private

[5] Gurung, Jit B., Preliminary Impact Assessment of Low-Cost Water Storage Structures in Tanahun and Kaski Districts, IDE, 2000

firm) is eligible for funding under this scheme, as long as the cost and methodology are within the board guidelines. This model can be extended to other areas such as irrigation and agricultural services.

Potential for High Impact, Cost Effectiveness, and Sustainable Incomes

IDE's experience in Nepal shows the potential to increase the number of smallholders involved in production of high value crops on small pieces of land. The cumulative number of smallholders who have had access to micro irrigation technology and improved agricultural inputs over the last five years has increased from around 1,000 to more than 30,000 (90 percent of which are in the Terai, with the remainder in the hills). Small farmers have consistently shown willingness to invest in enterprise opportunities that are within their means and capabilities. The 33,000 sales of micro irrigation technology (an investment of $7 - $20) demonstrate this clearly.

Smallholder-oriented technology packages have proven appropriate in meeting the needs of poor small farmers. Economic status in South Asia is generally correlated with size of land holding as a proxy measure for poverty. Seventy percent of the farmers participating in the programs in the hills own less than 1 hectare. These are micro-size farms in a land-based economy. Considering that more than 85 percent of the rural population earns their primary income from agriculture, farmers owning less than 1 hectare are generally very poor.

The programs described here demonstrate that irrigation and high-value crop production need not be the exclusive domain of men: fifty percent of program participants in the hill regions have been women. This percentage has been increasing steadily over the last three years with an increased focus on using women's groups as an entry point in many communities. A key indicator of impact on clients is the increase in gross profit of the smallholders. Smallholders with microirrigation have been able to increase gross profit in the first year by an average of $100, representing an increase in annual income of 17 percent. In subsequent years, farmers typically invest in the expansion of their land under irrigation, until they reach an "optimum" size under irrigation, which may range from 600-800 m^2 under micro irrigation. At that level, their net additional annual income is some $300, which represents a 50 percent increase in annual income.

Future Strategies

As is evident from the above, there are limited water resources available to upland farmers during the 8-month long dry season in most of the HKH region. But there are many streams with untapped water resources in existing hill areas that offer great opportunities for affordable precision irrigation delivered by gravity through pipe systems. These water sources can be used to irrigate small plots of high value crops in close proximity to the homestead. This opens up the opportunity for the poor and women to participate in water resource development and income generating activities In order to utilize them, there will need to be a system to deliver technology and inputs to farmers on a sustainable basis. IDE in Nepal and Himachal Pradesh have been building such a system on a limited scale over the last five years. The results of these projects are very promising and need to be replicated on a larger scale, including broader participation of government, NGO's, and the private sector. These approaches also need to be spread to other countries in the region, and the approach adapted to the particular local needs.

The twenty-year Government of Nepal Agriculture Perspective Plan states, "The hills and mountains of Nepal are a resource of potentially inestimable value. Yet they currently figure among the economically most impoverished farming areas in the world." This plan takes a strategy that they describe as, "A prioritized productivity package for demand-led commercialization". It envisages a set of "lead commodities", the development of which is supported by government, non-government and private entrepreneurs. Among these lead commodities are: citrus, vegetable seed, apples, off-season vegetables, ginger, cardamom, and coffee.[6] For all these commodities, irrigation is either essential or greatly improves quality and yields. Also, they can all be grown on upland slopes or terraces. Thus, in order to implement this plan, and in order to see that the beneficiaries of the commercialization include the poor and women, micro-irrigation (drip and sprinkler) is essential to success.

In implementing this initiative, the following are key points for discussion:

1. It is important to shift the focus of the irrigation community in the HKH region from bottomland, canal type irrigation systems to upland, pipe and tank type micro-irrigation systems (drip and sprinkler). These small-scale systems are single village size and are more amenable to community participation and financing. In addition, these systems are naturally more equitable in their impact in terms of socio-economic status and gender.
2. Private sector merchants are a key component of implementing any agriculture-based program, including micro-irrigation. Building the capacity of local entrepreneurs to give farmers advice, stock appropriate equipment and inputs, install irrigation systems, and market outputs should be an essential activity of the initiative.
3. Government agencies also have a key role to play, but not in their traditional role as implementer of development projects. First they can act as a "wholesaler" of technical advice, giving key information to the "retailers " of information such as agriculture inputs dealers, NGO's, and farmers' groups. Likewise, they have an important role to play as a "wholesaler" of domestic and international funding of development projects, setting up funding boards which fund NGO's, local governments, community-based organizations and private firms to implement development projects. These in addition to the role of government in setting sensible poor-friendly policies and developing appropriate major infrastructure (roads, etc.). Poor-friendly in this context means focusing on small-scale technologies, and not the traditional meaning of government give-away plans.
4. Community participation in terms of funding and planning of interventions is key to the success of any project. All activities should be planned with maximum self-reliance in mind, not the traditional dependency model.
5. Research institutions should focus research on small-scale technologies appropriate to hill farmers, and not just try to transplant western technologies meant for larger farms.
6. The government, NGO's, and private sector should jointly plan and implement a massive information campaign to make small farmers aware of some options to improve their livelihood. Modern mass marketing and public information techniques should be used.

Potential Size of the Microirrigation Market. It is estimated that the smallholder sector in the area consists of some 18 million family units. IDE's technical personnel working in the hills of Nepal and in Himachal Pradesh estimate that it is reasonable to expect that, given a systematic pursuit of the strategies as described above, over a period of 15 years some 40 percent of these units may eventually invest in microirrigation on their plots. Thus, assuming that some 7 million smallholders adopt microirrigation, and use it on an average of 700 m^2 each, it would be expected that over a ten-year period, an additional area of 500,000 hectares would come under

[6] Nepal Agriculture Perspective Plan, Agriculture Projects Service Centre and John Mellor Associates, January 1995, Prepared for the National Planning Commission

microirrigation. This microirrigation-led transformation of the smallholder production scene in the Hindu Kush-Himalayas area might well constitute direct net additional income for the smallholder community of some $3 billion annually, which would be a major step in poverty alleviation in this desperately poor region.

Annex 7. Winter Vegetables in China

The Case: With four million greenhouses in north China and one million farmers in river valleys under natural greenhouse conditions, Guizhou Province in southwest China could take advantage of modern irrigation methods such as low-cost drip to generate income from supplying high-value winter vegetables to north China. The case describes initial projects by IDE in Guizhou province and by the private firm Netafim in the greenhouses of North China.

Project Period	1998 - present
Farmers Served	3,000
Water-related Technologies	Netafim family drip system, River Treadle Pumps, Pressure Treadle Pumps, IDE Low Cost Drip Systems, Affordable Water Storage Bags
Irrigated Crops	Tomatoes, melons, potatoes, cucumbers, beans, squash, fruit trees
Most Important Lessons Learned	1. In north China, summer vegetables are grown for the table, and winter vegetables are produced profitably for the market in greenhouses 2. Replacing the typical flood irrigation practice in greenhouses in north China with modern drip systems significantly improved crop yield and quality. 3. Surveys in Guizhou province indicate that 400,000 farmers can take advantage of natural greenhouse conditions to grow winter vegetables without the need to build a greenhouse. 4. The greatest constraint for the 80,000 farmers now growing winter vegetables in Guizhou is the labor constraint involved in the current practice of carrying and distributing irrigation water by bucket. 5. Initial field tests in Guizhou province indicate a very strong initial demand by smallholders for river treadle pumps, ten-dollar 2500-liter water storage bags, and low cost drip systems.
Key Constraints to Scaling up:	Absence of private sector rural supply chain Access to credit Access to inputs Access to markets for crops Access to transport
Potential Impact:	Increased net income from 2 million greenhouses x $200 = $400 million annually. In Guizhou, potential new income of $500 million annually. In Guizhou, Yunnan, and Guanxi, potential new income of $1 billion+ per year.
Potential New Areas Under Microirrigation	2 million greenhouses x 1/6 acre = 130,000 hectares. In Guizhou, potential new natural greenhouse area of 70,000 hectares. In Yunnan, and Guanzi Autonomous region, potential new natural greenhouse under irrigated production area of 200,000 hectares.

The Market for Winter Vegetables in China: A Wealth Creation Opportunity for Smallholders

The Market for Winter Vegetables

The current vegetable crop in China is huge, and it is grown primarily for domestic consumption. According to the Chinese Ministry of Agriculture, the current acreage planted to vegetables in China is 220 million mu (37 million acres), and the total vegetable output is 400 million metric tons a year. Per capita vegetable consumption in China is estimated to be 140 kilos per year[1]. Shandong province in the north has the largest acreage planted to vegetables, with 20 million mu. The provinces in the south, led by Hainan Island, represent the largest current vegetable-producing region.

Vegetable production in greenhouses has grown very rapidly in the north, increasing from 50,000 mu (1 mu = 1/6 acre) in 1990, to 4 million mu at the end of 2000[2]. Since greenhouses produce multiple crops, the effective acreage of greenhouses is significantly higher. In addition to Shandong province, Gansu, Shanxi, Shaanxi, Ningxia, and Beijing provinces have all participated in the rapid expansion of greenhouse vegetable production. Each mu of greenhouse produces 6-10 metric tons of vegetables a year, and the typical greenhouse is one mu in size.

Off-Season Vegetable Production

The greenhouses in the north, and the southern vegetable producing regions such as Hainan Island, produce crops during the September to March period, when there is a limitation in vegetable production in much of China because of cold weather. But there is another vegetable off-season when prices are higher because of excessive rain in much of China during the monsoon period of September to March. This also provides an opportunity for smallholder off-season vegetable production in cooler high hills such as those in parts of Guizhou[3].

The Current Status of Vegetable Exports

In 1999, some two million metric tons of vegetables were exported, with a value of $1.4 billion. Of this total, 1.1 million metric tons were refrigerated, and .9 million metric tons were exported frozen, dehydrated, or canned. The tonnage of vegetable exports increased by approximately 25 percent in 2000, but the value remained constant because intense price cutting competition among Chinese exporters brought the price down. The resulting comparatively low price in the world market, combined with quality that meets

[1] Personal Communication, Dept of Cash Crops, Dept of Agriculture, Ministry of Agriculture, People's Republic of China interview with Mr. Zhou, Director of Dept of Cash crops, Jan 2001.
[2] Interview with Mr. Zhou, Director, Dept of Cash Crops, Ministry of Agriculture, People's Republic of China, Feb 2, 2001 Beijing.
[3] Interview with professor Li Guilian, Vice President of Guizhou Academy of Agricultural Sciences, Guyang, Jan 27 2001

export market standards, has rapidly increased China's share of the global vegetable market. For example, China is now the main supplier of asparagus for the world market[4].

The Green Label and Organic Vegetable Production and Export

It is notable that for 10 years the national government, through the Chinese Green Food Development Center,[5] has maintained a national system that certifies two grades of environmentally friendly, organic vegetables with a green label:

AA: this is equivalent to the organic food certification standard outside of China, and is used primarily for export products. The AA standard commands an export price differential of 50-300 percent. China wants to be in a position to take advantage of the international market for organic vegetables, estimated now to be 1-2 percent of the global market, and growing at the rate of 25% per year.

A: this is used primarily inside of China, and certifies that the product is produced only with judicious use of chemicals and pesticides. The A standard commands a 15 percent price differential in the Chinese market.

Current Opportunities in the Market for Winter Vegetables for Increasing the Income and Productivity of Smallholders

The Greenhouse Market in North China

According to the Ministry of Agriculture, there are now more than four million greenhouses in north China.[6] Netafim, an Israeli drip irrigation company that has been marketing irrigation equipment in China for three years, reports that the number of greenhouses in north China is closer to six million, and there is an equal number of low cost plastic tunnel structures.[7] A typical greenhouse is approximately one-sixth of an acre in size, includes a brick heat-storing wall, and a small stove for supplementary heat. It costs $1,200-$2,000 to build. Several greenhouse owners interviewed by IDE in Gansu and Shanxi provinces in 1999 indicated they were earning incomes of more than $1,000 per year, and several were in the process of adding additional greenhouses.

Current Status of Greenhouse Irrigation Technology

Some 95 percent of the greenhouses in North China are irrigated by simple surface flood methods,[8,9] in stark contrast to prevailing greenhouse irrigation practice in the West. Interviews with a small number of farmers who had installed low-cost drip systems in greenhouses reported significant improvements in water savings and crop yields after the

---

[4] Interview with Mr. Zhou, Director, Dept of Cash Crops, Ministry of Agriculture, People's Republic of China, Jan 2001.
[5] Interview with Zhang Dongke, Chinese Green Food Development Center, Ministry of Agriculture, People's Republic of China, Jan24, 2001.
[6] Interview with Mr. Zhou, Director, Dept of Cash Crops, Ministry of Agriculture, People's Republic of China, Feb 2, 2001 Beijing.
[7] Interview with Mr. Yossi Lavi, Director of Marketing, Netafim, Washington, March 3, 2001.
[8] Interview with Mr. Yossi Lavi, Director of Marketing, Netafim, Washington, March 3, 2001.
[9] Trip Report, IDE Field Visit to China, September, 1999.

adoption of drip irrigation.[10] Netafim reports significant improvement in crop yield and quality in tests of its $100 one-mu greenhouse drip system in China.[11]

The Potential China Market for Smallholder Greenhouse Irrigation

The market for low-cost drip and sprinkler-technified irrigation in China can be conservatively estimated at four million units. This is based on reaching one-half of the total market of four million existing greenhouses and four million plastic tunnel structures. Because of its size and the higher income level of smallholders with greenhouses in China, this market is likely to prove attractive to larger national and international irrigation companies like Netafim, as well as smaller local Chinese irrigation firms.

Case Study: Affordable Small Plot Irrigation for Greenhouses in Northern China

The Greenhouse Industry in North China

In the past ten years, some four million greenhouses have been built in North China to meet the rapidly growing demand for winter vegetables and horticultural crops, which command a much higher price than summer crops. A typical greenhouse is 500 square feet in size, and uses plastic sheets stretched over a semi-circular frame. This captures the sun's heat during the day, and stores it in a south-facing mud brick wall to be released at night. Bamboo mats are unrolled to cover the plastic during cold winter nights, with a stove providing booster heat when it is needed. Typically, irrigation is by flood. These northern greenhouses are a good source of income, earning $1,000 or more in the winter from 500 m^2.

Guizhou Province

Ghuizhou Province in southwest China is one of the poorest provinces in China. Its per capita income of 1,400 Yuan per year (about $170) places it second only to Tibet in poverty. Eleven-and-one-half million of its 31 million inhabitants are hill tribal ethnic minorities, like the Hmong and Buyi tribes. Ninety percent of the province is

[10] Trip Report, IDE Field Visit to China, September, 1999.
[11] Interview with Mr. Yossi Lavi, Director of Marketing, Netafim, Washington, March 3, 2001.

mountainous, with major river valleys running through it. This part of China is at the same latitude as the middle of Mexico, but because its average altitude is at 1,000 -1500 meters, its climate is more like that of California. Typical farm size in the hill areas of Ghuizhou province is three-quarters of an acre.

The Natural Greenhouse Valleys of Guizhou Province

In deep river valleys in Ghuizhou, like that of the Da Bang River, microclimates that mirror conditions in the greenhouses of the north exist from September to May. This eliminates the expense of building a greenhouse and keeping it heated.

Fields Irrigated by Bucket in the Natural Greenhouse

Professor Li Guilian, currently Vice-president of Guizhou Academy of Agricultural Sciences, refers to these areas as a "The Natural Greenhouse." She defines the Natural Greenhouse as valleys with a subtropical climate, with average annual temperatures of 18.5–21^{o} C or above, and where the temperature remains above 8 ^{o} C in January, the coldest month. Since 1979, she has been encouraging poor farmers growing winter vegetables in the Natural Greenhouse. Initially, the changeover to vegetables was not very successful. However, this changed dramatically some five years ago, when road access to these hill areas rapidly improved. Today, there are more than 200,000 mu (33,000 acres) of winter vegetables grown in 12 counties in Ghuizhou province. According to Professor Li Guilian, there are another 800,000 mu of natural greenhouse that are yet to be put under winter vegetable cultivation. Winter vegetables are usually grown on the terraces where rice is grown in the summer rainy season. Each row of plants is covered with a thin plastic sheet to lower water loss from evaporation.

Bringing Winter Vegetables from the Natural Greenhouse to the Market

When the crop is harvested, it is transported on farmers' backs, on carts, and on trucks to a regional market. The tomatoes at the wholesale market at Broken Bridge, for example, are a one-and-one-half hour's truck ride (15 kilometers) from the Han village, and the farmers who pick them usually have no information on the market price when they start off on the trip to market. At Broken Bridge, the tomatoes bought by traders from farmers are piled on the cement floor of the market, and sorted and stacked in bamboo crates by local women hired by the traders. From here, they travel as a partial load on passing trucks going to the wholesale market at Guiyang, two-and-one-half hours away. From here, they usually end up at a retail market.

Irrigation in the Natural Greenhouse

Filling Buckets for Irrigation

During the period from September to May, there is very little rainfall, and it is impossible to grow crops without irrigation. Fortunately, there is plenty of water in the river even in January, which is the driest time of the year. Remarkably, virtually all the water used to irrigate winter crops is hand carried to the crop, using a shoulder bar and two twenty-liter buckets. It is then delivered to each plant by dipper, sometimes with soluble fertilizer like urea dissolved in the water. The farmers in Xu Gan, a Han village and Le An, a Buyi village (600 families) in the middle of the Da Bang River Natural Greenhouse, identified the labor requirements of carrying water by bucket as the single biggest constraint to expanding winter vegetable production. A group of ten farmers in Le An estimated that it took an average of three hours to carry a thousand liters of water to the field by bucket, without counting the time it took to distribute it by dipper.

River Treadle Pumps

About half of the vegetable land in these two villages is less than five meters in vertical lift from the river, which makes it an ideal application for IDE River Treadle Pumps. When described, the River pump to farmers in the Han village, asked what they would be willing to pay for a pump powered by walking that could lift 3 m^3 an hour, they said 500 Yuan (about $60). It is estimated that that a river pump will cost less than 200 Yuan to produce in China.

Carrying water for tomato irrigation. These fields could be more easily irrigated with a treadle pump.

Low Cost Water Storage

The farmers in the natural greenhouse expressed great interest in low cost water storage bags that have been developed by IDE in China. A 200-liter water storage bag was left with them to test, and their reaction was that although they liked it, they needed a bigger one.

200 liter Water Storage Bag

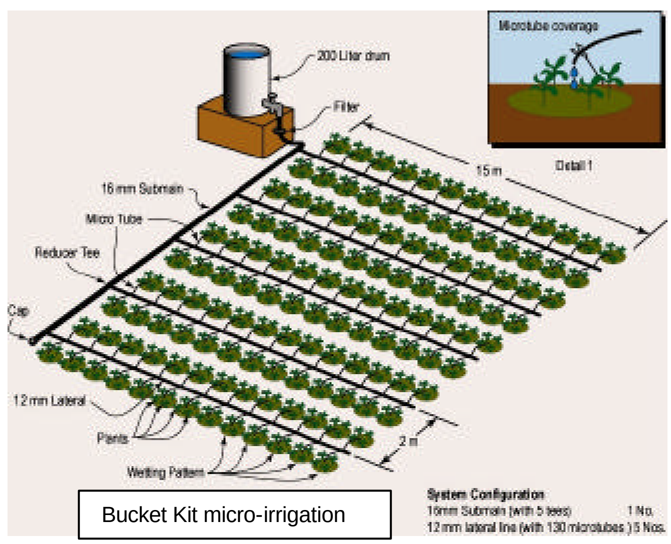
For farmers with access to electric or diesel pumps, or to springs, water storage is very important. IDE is planning to bring 1,000-liter water bags made in China, estimated to cost 70 Yuan, for testing; villagers judged that these low cost water storage bags would be almost as useful to them as Treadle Pumps.

Low Cost Drip Irrigation

Remarkably, no drip irrigation of any kind is used in the Natural Greenhouse area. Farmers were willing to take IDE's word for it that drip irrigation would use less water and improve crop yield. But in the short term, their most pressing problem is the high labor required for carrying water. Therefore, they were much more interested for now in River Treadle Pumps and low cost water storage.

In IDE's judgment judgment, because of its importance on water scarcity and crop yield, drip irrigation will become as important or more important than Treadle Pumps within three years, but its adoption is likely to take more time.

Initial Demonstration Program



Bucket Kit micro-irrigation

Starting in the spring of 2001, IDE will collaborate with Professor Li Guilian to install five demonstration sites in highly visible village locations in the Natural Greenhouse of Ghuizhou Province. Each demonstration site will install a River Treadle Pump, a thousand liter water storage bag, and a low cost drip system to irrigate one mu of winter vegetables. The water storage bag will be placed on a terrace 2-3 feet above the field to be irrigated, and the Treadle Pump will be used to fill it. The drip system will convey water under gravity pressure to each row of plants. An IDE-Bangladesh technician will spend ten days to two weeks in the demonstration area, ensuring proper installation and operation of the river pumps. Luo Guang Ying, a Chinese engineer who is a full-time staff member of IDE-China will oversee the operation of the technologies in the demonstration sites for the six-week period, and participate in farmer feedback and technology adaptation procedures. Professor Li Guilian and her staff have agreed to participate in project monitoring procedures.

Addressing the Next Series of Constraints to Increased Small Farmer Income and Productivity

Access to Inputs

Farmers visited by IDE in the Natural Greenhouse area get their seeds, pesticides, and fertilizers from government representatives and traders. Vegetable seed varieties are badly out of date. Some of the tomato seeds grown were varieties introduced more than ten years ago. Farmers practice extensive use of manure and night soil. Li Guilyan reported that she had doubled winter vegetable yields in test plots in the Natural Greenhouse area by improving input practices. A careful study of existing practices identifying opportunities for improvement is an important next step.

Access to Credit

Farmers in both the Han and Buyi village have little or no access to credit. In the Buyi village, which is poorer than the neighboring Han village, many farmers cannot afford to buy seeds, plastic sheets, and fertilizer. Consequently, they are leasing their land to Han villagers instead of cultivating it themselves. Opening access to rural micro-credit and business development services is critically needed to increase the income and productivity of poor farmers in the Natural Greenhouse area.

Access to Markets

On IDE's reconnaissance trip, were several areas were observed where crop gluts were already occurring, despite the fact that only about one-fifth of the potential greenhouse area is under cultivation. At the same time, about half of the vegetables sold in the wholesale market at Guiyang, the capital of the province, were imported from adjoining provinces, verifying major constraints in the transport and distribution of winter vegetables to the regional market. In the south along the coast, there already exists a major export zone of frozen vegetables to Japan, Europe, and North America, but because of transport deficiencies, this access to export markets has not been extended to inland vegetable producers like those in Ghuizhou Province.

Access to Transport

While transport of perishable crops from Hainan Island and Southern China as far north as the Yangtze River is relatively efficient, transport facilities for perishable goods from the south to the populous north in areas like Beijing are now chaotic and poor. Currently there are no facilities for refrigerated transport of vegetables from the south to the north by air, by rail, or by truck. The owner of a vegetable processing plant two hours west of Shanghai informed the study group that it now costs him $1500 to send a 40-foot container of frozen vegetables to Japan, $3600 to Los Angeles, and it would cost $2500 to Beijing.

These constraints in access to irrigation, inputs, credit, and markets for crops must be addressed before small farmers can realize the tremendous potential for increasing their income and productive by growing winter vegetables in the Natural Greenhouse areas of China.

Impact

Assuming that 50 percent of the 4 million greenhouses in north China adopt modern irrigation methods like drip irrigation, some 130,000 hectares of greenhouse would be brought under technified irrigation, producing a potential increase in net income of $400 million per year for 1 - 2 million families. In Guizhou Province, new natural greenhouse irrigated areas would total an estimated 70,000 hectares, generating new annual income of $500 million per year for 600,000 small farm families. Extending new natural greenhouse areas in the adjoining provinces of Yunnan and Guanxi Autonomous Region could approximately triple the acreage and income increase projected for Guizhou Province.

Annex 10: Scope of Work

Terms of reference

Study on the Dissemination Potential of Affordable Drip and Other Irrigation Systems and the Concrete Strategies for Their Promotion

Background

Over the next quarter century, water shortages will increasingly pose a fundamental obstacle to the further growth of productive agriculture. Water shortages are particularly acute in a group of countries with large poor rural populations reliant on smallholder agriculture. Although the problems involved in water management are complex, it appears that a part of the solution may be to promote the introduction of new, small-scale, low-cost irrigation technologies and market access approaches where they can improve yields of high value crops and dramatically reduce water demand while improving the quality of life for smallholders.

The World Bank has always considered small-scale irrigation as a promising option for developing countries. However, the Bank's past activities in smallholder irrigation have been minimal, and generally the Bank has focused on larger scale systems for larger plots. In addition, market-based technology diffusion via the private sector presents serious difficulties for governments as well as large international financial institutions, for neither are well-equipped to start, finance, and support very small enterprises.

The Bank and other national and international bodies are now giving smallholder irrigation increased attention for five main reasons: a) Technological advances, particularly in the area of developing affordable, small-scale waterlifting devices and drip irrigation systems; b) Shifts in the policy environment favoring private sector initiatives and increased smallholder participation; c) Heightened environmental concerns-in particular, concern for increasingly severe water shortages and food security; d) Increased focus on poverty alleviation, achievable by increasing smallholder productivity through affordable small plot irrigation; e) The emergence of viable market creation approaches for smallholder development.

Objective

The objective of this study is to clarify the site-specific dissemination potentials and promotion strategies of affordable drip systems and other existing irrigation technologies focusing on smallholders in developing countries.

Scope of Work

Conduct research to determine under which conditions smallholder irrigation technologies can be successfully applied. The study will consist of desktop review of installed systems, in-house evaluation of potential markets, field study of selective cases, and discussion with the Bank staff.

A review of installed systems will include a comprehensive technical, financial, and economic ex-post evaluation of equipment quality, availability, and affordability of at least one case in each of the following six regions based on available documents:

- ?? Southeast Asia and Pacific
- ?? South Asia
- ?? East Europe and Central Asia
- ?? Middle East and North Africa
- ?? Sub-Saharan Africa
- ?? Latin America

The study will also review, synthesize, and document available information on the impacts of installed systems on poverty alleviation via enabling production of higher value crops, reducing inputs/risks, or other means.

An evaluation of prospective markets will address assumptions and necessary complementary conditions for the effective design and implementation of dissemination programs. Past approaches toward the dissemination of irrigation systems/equipment among poor smallholders and their impacts will be documented, and anticipated social and economic benefits to these investments will also be forecast.

The above findings will be reinforced by at least two visits to the sites of most promising cases. The detailed study plan and the draft report will be presented at the Bank for the Bank staff's feedback into the study.

Reporting Format

The findings would be compiled into a report (of 15 to 60 pages as an electronic file) under the following headings:

I. Review of installed systems;
II. Assessment of the past approaches;
III. Prospective markets for each technology; and
IV. Evaluation of potential of benefits from smallholder irrigation technologies.

An appendix includes the note on the literature reviewed and other background data and information.

Timetable

The study would be undertaken in February and March 2001 with the objective of delivering the final report to the World Bank by March 30, 2001.