Opening Access to Affordable Micro-Plot Irrigation for Small Farmers

By Paul Polak, Bob Nanes, and Jim Sample[1]

Abstract:

The mass marketing of affordable small holder irrigation has a remarkable multiplier impact on agriculture productivity and farmer income. International Development Enterprises, a Colorado-based non-profit development group, has designed technology and established marketing strategies that have enabled the sale of over 1.34 million treadle pumps in five developing countries since the early 1980s for which data are available. Many thousands of pumps also have been sold in Cambodia, Zambia and Haiti for which data are still being collected. The organization's approach makes it possible for the pump users, usually small farmers, to buy the technology at an affordable price from locally-based manufacturers and distributors. Since 1985, a total investment of $12.9 million[2] by donors and $39.8 million by farmers has produced $656 million in increased income from crops for farmers. IDE is using a parallel strategy to mass market a range of small-plot, low-cost drip irrigation systems in countries with developing economies.

Three quarters of the farmers in developing countries cultivate less than five acres. The productivity of these "micro-farmers" is the key to solving the growing problem of food security in the world.

The adoption of high yielding seeds and fertilizer combined with access to irrigation has tripled the global grain harvest in the past 30 years. But the harvest of micro-farmers has failed to keep up. The main constraint to achieving a similar increase in the harvest of small farmers has been lack of access to affordable and divisible irrigation.
Western design processes have concentrated on optimizing efficiency rather than affordability. The result is that most technology innovation produces large scale and expensive approaches rather than small-scale and inexpensive solutions.

Critical access to affordable micro-irrigation is beginning to be provided by the recent design of low-cost micro-plot devices like treadle pumps, and drip and sprinkler irrigation systems. Rural mass marketing of these devices through the private sector in rural areas, right down to village level, has made them available to the micro-farmers who have been by-passed. Rural mass marketing is the key to sustainability, in that this

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[2] All financials in this article are in U.S. dollars.

activates the private sector, creates demand and ensures continued supply of spare parts and replacements.

A Portrait of Micro-farmers in Developing Countries

A typical micro-farmer's holding may be divided into 4 or 5 micro-plots, so tiny that modern western agricultural devices have no relevance. For example, 60% of farms in Bangladesh are less than 2 acres[i], and in Bihar (India) holdings are less than 2-1/2 acres)[ii]. In Egypt 95% of holdings in 1984 were less than 5 acres[iii], while in China following the 1952 redistribution, 300 million landless peasants received 0.4 acres.[iv]

The typical small farm cash income of $200-$300 a year or less makes the purchase of irrigation technology, such as a $350 five-horsepower diesel pump, totally out of the question. In Nepal, a 5-hp engine requires a command area of 5 acres. Commercial drip irrigation technology in India is not available for plots under 1 acre.

A Generation of New Affordable Micro-irrigation Devices

Affordable micro-irrigation devices have been designed and mass marketed to micro-farmers in several countries by International Development Enterprises (IDE), a Denver, Colorado-based non-profit development organization[v]. IDE's experience shows that the design and adaptation process requires 10% of IDE staff's time and effort. The other 90% is spent on the mass dissemination strategy to put the technology in the hands of micro-farmers. This requires a long-range effort focused on rural mass marketing, through the establishment of private sector networks consisting of enterprises that manufacture, distribute, and install the technology. Rural mass marketing focuses on creating demand and ensuring availability at the village level.

The IDE method for technology adaptation, which requires affordability and divisibility, initially puts prototypes in the hands of small farmers. The technology is then redesigned or modified using farmers' feedback. The same adaptation process is followed when micro-irrigation devices that work in one country are transferred to a new country, or into different agro-climactic conditions. Detailed small farmer feedback also is used as a basis for the design of a rural mass marketing strategy.

Two Innovations in Affordable Small Plot Irrigation

1. A $30 Human Powered Pump for Half an Acre of Vegetables

The treadle pump is the harbinger of a new agricultural revolution greening millions of postage stamp sized plots in the world's poorest and hungriest areas. A simple looking device, one model is powered by walking on two bamboo treadles. Other models include steel construction of the treadles and preformed concrete platforms and tubes. The treadles activate two steel cylinders that are made in a village workshop. Gunnar Barnes, a Norwegian engineer, designed the pump so that a small farmer could buy it by selling a sack of rice. A treadle pump can be installed on a tube well at an unsubsidized price of $30, less than 1/12 of the cost of a diesel pump.

Over the past 14 years several thousand village dealers and well drillers have sold and installed over 1.3 million treadle pumps in Bangladesh. Farmers in Orissa in Eastern India have replaced diesel pumps with treadle pumps to irrigate winter vegetables. With unskilled labor costs at 60 cents a day and rising diesel costs, a treadle pump cuts pumping costs in half.

By irrigating half an acre of dry season vegetables, a small farmer increases net income by $100 a year, diversifies crops, gains access to clean drinking water, and shortens the three month period of hunger. It has been estimated that there is a market for up to 10 million treadle pumps in Bangladesh and India by 2010. This would add 2.5 million hectares in irrigated acreage and $1 billion a year in increased net small farmer income.

2. A $5 Expandable Modular Drip Irrigation System

In semi-arid areas where water is precious, large farmers use drip irrigation to minimize evaporation losses by delivering water directly to the roots of plants. At a cost of a $750 an acre for crops like vegetables, current drip systems are not affordable for small farmers in India. A standard drip system uses a tank, a filter, and plastic drip lines to deliver water to each drip point in the field. Hundreds of emitters at each drip point control drip rate and prevent clogging. Plastic drip lines and emitters are key contributors to cost.

To make drip irrigation affordable for small farmers, IDE designed a system that cuts the cost of drip systems by two-thirds. The investment in the number of plastic drip lines (lateral lines) is reduced by replacing emitters with low-cost micro tubes, configured so that it is only necessary to use one lateral line for every two-three rows instead of one per row. Another approach is to replace emitters with simple holes and to make the drip lines shiftable.

Expensive filters are replaced with simple washable cloth filters and candle filters. The pressure in the system is reduced by using a simple bucket, or a 55 gallon drum placed two-to-three meters above the field.

A farmer with very little capital can invest in a $5 bucket kit that irrigates a kitchen garden-size plot and use the profit it generates to expand the system. To facilitate such expansion, these low-cost drip systems are designed to be expandable like a Lego® set. A farmer can begin with a 20 square meter micro-plot and expand the system in steps up to an acre.

The IDE low-cost drip systems were subjected to lab and field test studies. A system using holes made with a heated punch as emitters showed uniformity rates of 85%, while systems using micro tubes had uniformity rates of approximately 90%.[vi] Side-by-side tests were conducted in India comparing water use and crop yield for conventional drip, IDE low-cost drip systems with conventional drip, and conventional surface (flood) irrigation for mulberry, cotton, sugar cane and vegetables. The tests revealed that both conventional and low-cost drip used less than half the water of surface irrigation and produced significantly higher yields. There were no observable differences in performance between low-cost and conventional irrigation.[vii]

Further information about the drip irrigation program is provided below.

The Treadle Pump Story

Opening up access to affordable small holder irrigation can have a profound multiplier impact on agriculture productivity and the income of small farmers. This is well illustrated by the results that highlight IDE's experience with treadle pumps in four Asia countries.

Each farmer makes an investment of $30 to install a treadle pump and earns an average of $100 year net cash income from the investment. Some donor funds are invested in stimulating market demand for the product and facilitating a private sector system of manufacturers, dealers and village technicians to make it sustainable and available. A very high leverage in results is obtained.

There is evidence to suggest that affordable small plot irrigation devices like low-cost drip will produce the same high leverage impacts as treadle pumps.

IDE learned much of its methodology for all of its irrigation products and services in the mass marketing of the foot operated treadle pump

IDE implemented a national rural mass marketing program for treadle pumps in Bangladesh, making the technology known through billboards, calendars, and demonstrations at village and regional markets. A 90 minute entertainment movie featuring top Bangladeshi movie stars embeds the treadle pump into the plot, and the movie shown in open air settings reaches an audience of a million people a year.

In Bangladesh, using a national rural mass marketing program, IDE installed over 1.3 million treadle pumps through the local private sector. IDE has implemented similar projects in India, Nepal, Cambodia and Zambia, resulting in combined sales of 150,000 treadle pumps per year.

The 1.3 million treadle pumps generate a net cash income of $620 million per year for these small farmers. Similar benefits were realized in other countries, as shown in Table A-1.

On the investment dollar scale, for each $1 invested by an IDE donor and matched by an individual farmer's $3 investment, there has been $50 in increased income for the farmer, a 50:1 investment multiplier ratio for the donor and a 16:1 investment return ratio for the farmer. After 14 years, Bangladesh has retumed $93 in income increases for every dollar invested by the donor.

Table A-1 IDE Treadle Pumps Investments and Returns (1985-98)*

Program	*Pumps*	*Donor Investment*	*Farmer Investment*	*Est.Cumulative Increase in Income*
Bangladesh 13 yrs	1.2 million	$6.7 million	$33.4 million	$620 million
India 5yrs	120,150	$4.27 million	$5.4 million	$32.4 million
Nepal 4 yrs	10,700	$792,000	$589,000	$2 million
Cambodia 4 yrs	97151	$1.2 million	$369,170	$1.69 million
Total	**1.34 million**	**$12.9 million**	**$39.8 million**	**$656 million**

*For the analysis an average cost of $30 per installed pump has been used (the farmer investment). Costs vary from country to country from $23 to $60. As a program matures the installed price goes down. Donor investment includes all funds for the country program, including R&D costs, recurrent administration and overheads, training and special studies. Return on investment has been calculated at a conservative $100 per year in increased income. RIIEDA Evaluation in 1992 showed increase in Bangladesh averaged $134 and a recent study in Nepal estimates increases in farmer income between $110 to $120. The conservative figure is used to account for pumps out of service and variations from year to year because of environmental climatic conditions.

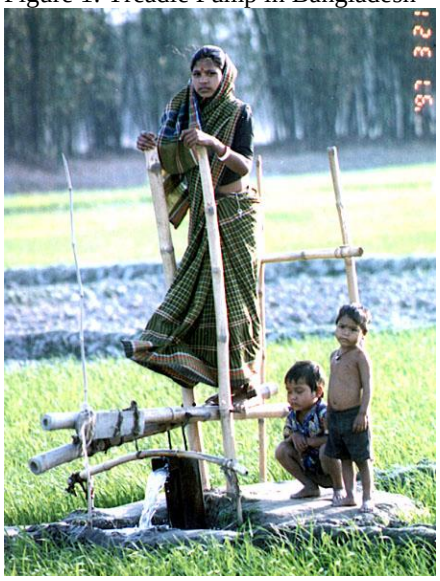
Projecting to 2008 for Nepal (a scenario of eventual growth to 20,000 annual sales, 93,200 cumulative) indicates a donor investment of $3 million, a farmer investment of $3.5 million and a retum in the form of increased income (net) of $33 million, or a donor development dividend of $11 for each dollar spent.

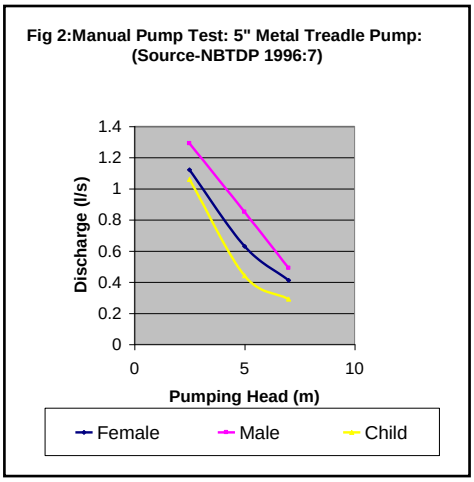
Projections on Cambodia are for a cumulative dissemination of 60,000 by 2008 based on a donor investment of $3.7 million, farmer investment of $2.3 million, and predicts a total increase in farmer income of $21 .8 million over the period.

The Treadle Pump Technology[viii]

The treadle pump is a foot-operated device that uses a bamboo or PVC or a flexible pipe as suction/ tube-well to pump water from shallow aquifers or surface water bodies. It consists of a sheet metal or cast iron pump-head, a bamboo frame with two treadles and a bamboo or PVC strainer (Figure 1). The pump-head has two cylinders welded together with a single suction inlet at the bottom and two plungers with or without a rope and pulley.

Figure 1: Treadle Pump in Bangladesh



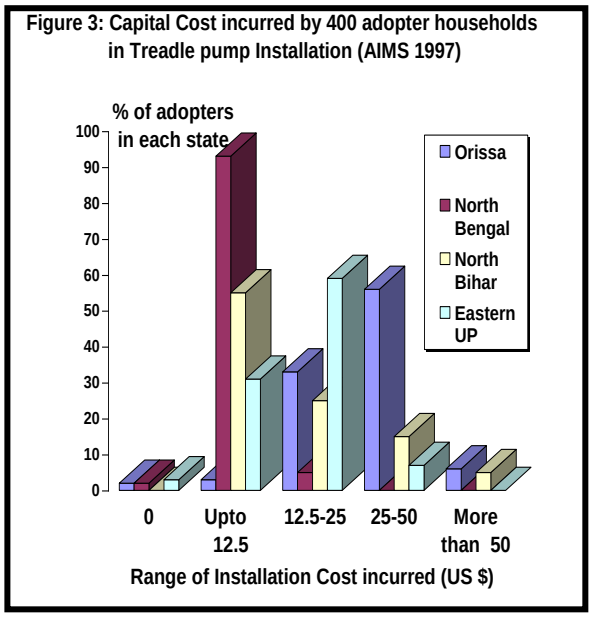


The diameter of cylinders varies for different water outputs and to fit existing buckets (or piston seals). The cylinders are joined together at the base by a junction box, which connects through check valves to the suction pipe. As pedaling commences, water penetrates the filter and rises up through the suction pipe to the dynamic groundwater level. From there, it is lifted in a pulsating stream following the strokes of the two pistons. The action of the two cylinders provides a virtually continuous stream of water. This makes the treadle pump more efficient than single cylinder pumps where energy is needed to reaccelerate the water column after the longer pause in the change over between strokes.[ix]

The pump—which can also be attached to a flexible hose for lifting water--is useful for lifting water from shallow depths from any source such as ponds, tanks, canals, or catchment basins. It can lift water up to a maximum height of 7 meters but gives best performance of 1-1.2 l/s at a pumping head of 3-3.5 m. (see Figure 2).

It is claimed that the treadle pump is simple to install and easy to operate by men, women and children; and it is ideal for vegetable cultivation but is also used extensively to irrigate small plots of HYV paddy. We found that labor sparing, crop saving irrigation to wheat, tobacco and jute enables treadle pump irrigators to harvest remarkably higher yields compared to rain-fed farming. According to VK Dixit[x], about 40 m farmers, roughly half of India's total farm families, live in areas that are suitable for the (treadle) pump and about half of these presently have either no means of irrigation or are using

very primitive means involving more back-breaking labour and delivering only a fraction of the water needed. For these, the treadle pump might be a great boon!



The best part of the treadle pump technology is its cost; the cheapest bamboo treadle pump is installed for less than $12; the more expensive metal and concrete pumps cost $25-35 complete with a bore and a frame. Cost estimates provided by manufacturers and marketers vary widely and are sometimes misleading; but Figure 3 reports on the actual amounts spent by 400 small farmers in installing treadle pumps in Eastern India during 1994-96; very few except in coastal Orissa—where salinity requires the costlier concrete pumps to avoid corrosion of the metal pump-head—spent more than $25 on the treadle pump assembly and bore; by far the majority spent $25 or less. The going rate for the capital cost of new canal irrigation potential in South Asia is $4000-4500/ha; new tubewell irrigation potential costs the society $800-1000/ha to create; treadle pump technology creates new irrigation potential at $100-120/ha and is self-selecting to the poorer farmers.[xi]

Cutting the Cost of Drip Irrigation by Two-Thirds

A sister technology now being applied in several of the same countries is drip irrigation. In semi-arid areas where water is precious, large farmers use drip irrigation to minimize evaporation losses by delivering water directly to the roots of plants. At a cost of a $750 an acre for crops like vegetables, conventional drip systems are not affordable for small farmers. A standard drip system uses a tank, a filter, and plastic drip lines to deliver water to each drip point in the field. Hundreds of emitters at each drip point control drip rate and prevent clogging. Plastic drip lines, filters and emitters are key contributors to cost.

To make drip irrigation affordable for micro-farmers, IDE staff, working with farmers in their fields, designed a variety of low-cost drip systems that cut the cost of conventional systems by two thirds[xiixiiixiv]. The cost of materials was reduced by making a lateral line movable so that it could be used on 4-10 rows of plants rather than one. The cost was further reduced by replacing emitters with microtubes or baffled holes, which are

cheaper, plug less frequently, and are easier to unplug. They also make it possible to use simpler lower cost filters. Four low-cost drip systems are now available.

1. **Bucket Kits** consist of a simple household bucket attached to a pole at shoulder height, which supplies a drip line with 26 microtubes, each of which waters four plants. A starter bucket kit costs $5 in India, including the bucket, and irrigates a 25 sq. meter kitchen garden to feed a family of 6, using 2-4 buckets of water a day. If the family sells some of the crop, they can use the profit to expand their system.

2. **The Drum Kit** uses a 200-liter drum instead of a bucket, and uses five lateral lines to irrigate a 125 square meter plot for a cost of $25. It can be expanded in 125 square meter increments at a cost of $14 for each expansion unit.

3. **Shiftable Drip Systems.** The shiftable drip system reduces capital cost by using increased labor. This is done by making lateral lines shiftable, so that each line is capable of irrigating ten rows of plants instead of one[xv]. Water drips out of baffled holes or curled micro-tubes instead of more expensive emitters.

4. **Larger Low-cost Drip Systems** for 1000 to 10,000 square meters cost $625 a hectare for crops like cotton. One lateral line can irrigate four rows by using microtubes. This does not include the cost of a pressure pump.[xvi]

Several thousand IDE low-cost drip systems have been purchased by micro-farmers in Nepal, India, Sri Lanka and Vietnam. Cost-benefit studies similar to the one cited above for treadle pumps are now being conducted in the drip irrigation program market areas.

Conclusion

Opening the access of small farmers in river delta areas in Asia to treadle pumps has generated $656 million in new income for small farmers over a 14 year period. This $656 million in new net income has come about as a result of investment of $40 million on the part of farmers and $13 million in donor support. There is strong evidence to indicate that the leverage impacts from mass marketing low-cost drip and sprinkler irrigation will be equal to or greater than those of treadle pumps. Such remarkable high leverage impacts can be achieved by opening the access of small holders in developing countries to a whole new generation of affordable small plot irrigation devices.

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[v] More details about IDE are available at its web site www.ideorg.org

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[xi] The capital cost of creating diesel pump irrigation during 1985-89 period was estimated at INR 9600/ha and for canal irrigation potential at INR 50,000/ha (Dixit 1993:10). Sandra Postel, in her book Pillar of Sand, (Pp 62) uses figures based on 191 World Bank funded irrigation projects and suggests the capital costs to be much higher: $ 3766 for pump irrigation and $ 5584 for gravity flow irrigation. Emphasizing this aspect of the treadle pump's virtue, Paul Polak, the chairman of IDE, the organization that promotes the technology, once asserted: 'The cheapest five horse power diesel pump on a tubewell costs $500 and requires at least 2 hectares to pay for itself. The majority of the world's farmers farm less than 2 hectares and earn less than three hundred dollars a year, putting diesel pumps totally out of reach' (Polak N.D.). And the cheapest bamboo version treadle pump in the IDE range costs Rs 380-425 and the costliest—made of sheet metal and PVC suction pipe-- priced at Rs 800—825. The concrete pumps made for saline coastal areas in Orissa cost more than metal pumps.

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