Water and the Other Three Revolutions Needed to End Rural Poverty

By: Paul Polak (July 2004)

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Abstract: Eight hundred million of the current 1.2 billion people who earn less than a dollar-a-day live in rural areas in developing countries. Since more than 550 million of them earn their living from agriculture, poverty eradication depends on increasing their income from farming. The Millennium Goals for hunger and poverty in the semi-arid tropics will not be met without four simultaneous revolutions. A revolution in water is needed to develop and mass disseminate a whole range of new affordable small plot irrigation technology. A revolution in agriculture is required to enable smallholders to produce a variety of high value marketable labor intensive cash crops. A revolution in markets is needed to open access to inputs and to profitable markets for their high value crops, incorporating effective strategies for aggregation, quality control, and decentralized value-added processing. Finally, a revolution in design based on the ruthless pursuit of affordability is needed to support the other three revolutions. This paper describes the rapidly growing micro-irrigation revolution exemplified by the $250 million (US) in new net annual income now being earned by Treadle Pump farmers, and outlines the key features of the other three revolutions required to meet Millennium Poverty Goals.

Key Words: Affordable irrigation technology, development theory, drip irrigation, market creation, water storage, smallholders, Millennium Development Goals, International Development Enterprises (IDE)

Introduction

1.2 billion people earn less than a dollar-a-day, and 800 million continue to go hungry. The United Nations' Millennium Development Goals for 1990-2015 aim to cut in half the proportion of these poor and hungry people by the year 2015. But with business as usual, the Millennium Goals for hunger and poverty have little hope of being achieved. This is especially true for those living in the semi-arid tropics. In 1999, 37% of the population in South Asia lived in extreme poverty, compared with 44% in 1990, not much progress toward the 22% millennium target. The situation in Sub-Saharan Africa is even worse, with 47% of the population living in extreme poverty in 1999, compared with 48% in 1990[1]. The prevalence of underweight children in South Asia and Sub-Saharan Africa in 1990 and 2000 follows the same pattern[2]. Nothing less than a revolution in development theory and practice is required if we are to have any hope of reaching the millennium poverty and hunger targets.

That is not to say that what we have been doing is wrong. The "Green Revolution" has had a profound positive impact on increasing the global grain supply, raising wages and employment for farm laborers (usually the poorest of the poor), and decreasing the price poor people pay for staple foods, which makes up a 50-65 percent of their daily budget. But while all this is necessary, it is far from sufficient for poverty eradication. What we need to do now is implement a series of practical market-driven strategies to increase the income of poor people from one dollar-a-day to three dollars or more. Seventy percent of the dollar-a-day people in the world live

in rural areas in developing countries. Ravallion[3] projects that this will exceed half until 2035 despite urbanization. Since at least two-thirds of these rural poor people derive their primary livelihood from agriculture, this requires finding ways to substantially increase their income from farming.

The key to increasing the income of rural people in developing countries is to improve the profitability of small farms. I use the term profitability because it is the bottom line net cash income that will most profoundly shape their path out of poverty. Farm laborers, too, gain from rising small-farm profitability if achieved labor-intensively, pushing up employment and wage-rates**.** Micro-irrigation is a powerful force in improving both the profitability of small farms, and the income earned by farm laborers. Such a market-driven, affordable, irrigation based cash crop approach is capable of dramatically increasing the income of 40 – 100 million of the dollar-a-day rural poor families, as well as improving their food security. But none of this can happen until the development community recognizes that most of the poverty in the world to-day is centered on what happens on farms smaller than one hectare, typically split into three to ten separate plots.

The single most important feature of dollar-a-day farms in developing countries is that they are very small. Between 1960 and 1990, the average farm size in India shrank from 2.7 hectares to less than 1.6 hectares, divided into three to ten separate plots, and population growth continues to drive farm size downwards[4]. Average farm size in Bangladesh in 1999 was .72 hectares, down from .9 hectares in 1983, and 70% of farms are less than one hectare[5]. I refer to these farmers who typically cultivate less than two hectares as smallholders. While farm size in Sub-Saharan Africa is somewhat larger, only 3% of cropland is irrigated (as against 40% in South Asia); mainly for that reason, African land productivity is much lower. Most of these farms are divided into four or five separate parts. Achieving the Millennium Goals for poverty and hunger reduction therefore requires finding ways to substantially increase the bottom line profitability of one hectare farms divided into separate 1,000 square meter plots. A primary focus on profitability dictates that smallholders exploit their comparative advantage in the marketplace, which is the production of labor intensive, high value marketable cash crops. To accomplish this, and in so doing make real progress in achieving the Millennium Goals on poverty and hunger, what is required is nothing less than four revolutions, centered on the specific context of the 1,000 square meter plots and one hectare farms of typical smallholders.

1. A revolution in water is needed to open access for the rural poor to income generating affordable small plot irrigation and affordable, income generating domestic water.

2. A revolution in agriculture is needed to open opportunities for small farm enterprises to develop new varieties of fruits, vegetables, herbs and other labor-intensive high value crops optimized for small farms, and the smallholder based agricultural practices required to produce them.

3. A revolution in design is needed, based on the ruthless pursuit of affordability, to develop a whole new generation of income generating technologies that serve the rural poor.

4 Finally, a revolution in markets is needed to create new markets that open smallholder access to affordable small plot irrigation and inputs, and to new markets for the high value crops they produce.

This paper describes the experience of IDE over the past 25 years in the design and rural mass marketing of affordable, expandable, small plot irrigation technologies to smallholders through the private sector, and outlines the revolutions in design, agriculture and market creation required to achieve the Millennium Goals on hunger and poverty. The concepts, approaches, and technologies I describe are principally derived from on-farm interviews with more than three thousand smallholders in developing countries, and their active participation in both technology development and application.

Tripling Small Farmer Income Our experience in developing countries demonstrates that smallholders can earn additional net annual income of $500 US or more with the following scalable practical steps.

1. **Open access to water control for crops.** This requires a farmer invest in affordable small plot water pumping, storage, and application technologies and sufficient and available water sources.
2. **Increase yields and productivity of staple crops** to the point each small farm family can grow a year's supply of staple crops like rice if farm size permits. Most smallholders are highly risk averse, and are reluctant to invest in cash crops until they can grow enough staple crops to keep their family fed. IDE has employed simple techniques in several countries like deep placement of fertilizer pellets in subsistence rice plots, which both lowers cost and significantly increases yields. If the risk of hunger can be eliminated, most smallholders are ready to risk growing diverse labor-intensive, high-value cash crops. But improving productivity of staple crops on small farms has a limit. Farm sizes keep dropping, and below a threshold farm size, it becomes impossible to grow enough wheat, rice or maize to keep the family fed. For farms under a half-acre in most places, the only way to keep the family fed and move out of poverty is to produce and market high-value cash crops, and use some of the income they generate to address staple food deficits.
3. **Invest in labor intensive, diversified, high value marketable crops.** Labor rates in rural areas in the west are some fifty times higher than in rural areas in developing countries. To take advantage of the low opportunity cost of their labor, as well as the superior agricultural performance of small family farms, dollar-a-day farmers need to invest in growing high value intensively cultivated irrigated cash crops. To lower risk, since future market prices are virtually impossible to predict, farmers usually prefer to grow four or five different high value cash crops rather than one. Farmers in Maharastra, for example, have routinely been able to earn net cash return of $500 US from a variety of drip irrigated crops such as pomegranate, sweet lime, baby banana, eggplant, and other vegetable crops during the dry season.[6]
4. **Exploit market opportunities and remove key constraints to market access.** Wealth creation for smallholders depends on access to local, regional, national and/or export markets for high value crops.

THE FOUR REVOLUTIONS NEEDED TO END RURAL POVERTY

I. A Revolution in Water: Opening Access to Affordable Small Plot Irrigation

Conventional western water pumping, storage, and conveyance technologies are too expensive to be affordable for most smallholders in developing countries and difficult to scale down to fit the needs of their small plots. The design and mass dissemination of a whole new generation of affordable small plot irrigation technology will have a more dramatic positive impact on the lives of the rural poor than the introduction of personal computers created in the west. But to fill this huge market gap, radically different new approaches to the design and dissemination of irrigation technology are required.

Key Existing Constraints in Access to Irrigation for Smallholders

1. Top down or bottom up irrigation? The rapid expansion of irrigation that contributed as much as the adoption of high yielding varieties of seeds to the success of the green revolution was based on the adoption of large-scale western irrigation technologies in developing countries. The operation and maintenance problems of large canal systems were addressed by a second irrigation revolution advocating farmer-managed systems. The extensive leakage of many canal systems provides lower cost access to groundwater irrigation through farmer investments in tubewells, but even the cost of a shallow diesel tubewell in Bangladesh in the 1980's started at $500 US, far too expensive for dollar-a-day farmers. Rather than starting with large expensive western technology, and assuming that it can be used effectively by smallholders, the affordable irrigation revolution starts with defining the irrigation needs on individual small farms, and then designing irrigation technology cheap enough to be affordable on dollar-a-day incomes, small enough to fit existing plot sizes, and attractive enough to reach at least a million small customers through private sector marketing at an affordable price.

2. Affordability. At $1,800 US a hectare ($0.18 US per square meter) for vegetable crops in India and much more in Sub-Saharan Africa, the commercially promoted drip irrigation systems are much too expensive to be affordable for smallholders. The same can be said for conventional water pumping and water storage technologies. Treadle pumps brought the entry level price for efficient pumping in Bangladesh down to $25 from $500 US for a five horse diesel pump set, and low-cost drip irrigation is now available for 4 cents a square meter in India, down from 20 cents a square meter for conventional systems. Field experience in South Asia and Sub-Saharan Africa suggests that the tipping point for market take-off requires reducing the cost of conventional irrigation technology by roughly 80 percent.

3. Divisibility. A 40 kilogram bag of fertilizer or a 20 kilogram bag of seeds can be divided easily to any size that fits the customer's needs, but most mechanical technologies, like tractors or drip irrigation systems, are "lumpy" inputs because they cannot easily be divided into smaller pieces. Radical changes in the design process for irrigation technology are required to bring the effective size down to the scale of 1,000 square meter and smaller plots. For example, a variety of low-cost IDE drip systems are now available that start at a 20 square meter kitchen garden sized system, at an entry level price of as low as one dollar.[7]

4. Expandability. To be attractive to small farm customer, small plot irrigation systems not only must be available at an entry level cost that fits the farmer's pocketbook and size that fits small plots, but also each technology should ideally be infinitely expandable as farm income increases. A small farmer in India who invests $8 US in a new 200 square-meter IDE drip system that generates $100 US in new net income can seamlessly double or triples its size for the second season of use by investing some of the $100 US in new net income it generates.

5. Profitability and Market Attractiveness. Because of the vast unmet need in the marketplace, a practical threshold rule of thumb for new small farm irrigation technology is that it must show a net return of at least 100% on its purchase price (300% is more common) in one

growing season and command a market for the sale of at least one million units at an unsubsidized fair market price. A compelling reason for marketplace adoption is that shifting from rainfed crops to affordable irrigation significantly reduces risk for dollar-a-day farmers.

Initial Breakthroughs in Affordable Small Plot Irrigation

Figure 1 Treadle pump in operation

1. Treadle Pumps. Experience over the last 15 years with treadle pumps provides a powerful illustration about the kind of positive impact on poverty eradication that can be triggered by widespread adoption of affordable small plot irrigation technologies. In the 1980's, the World Bank had invested in a deep and shallow tubewell initiative in Bangladesh which made available subsidized diesel pump sets capable of irrigating from 2 to 20 hectares. While these initiatives were successful in expanding irrigated acreage, they had a negative, or at best neutral, effect on poverty because they tilted access to irrigation to larger wealthier farmers. IDE began a project to mass market treadle pumps which had been designed by Gunnar Barnes and introduced by the Rangpur Dinajpur Rural Service, the development organization he worked for[8]. As with other forms of affordable small plot irrigation, farmers themselves were key players in the evolution of the technology. The unsubsidized retail cost of a treadle pump and the tubewell it is installed on is $25 US, compared with the $500 US cost of the cheapest diesel powered pump and tubewell assembly available at the time it was introduced. The treadle pump is a suction pump powered by human energy which activates two reciprocal cylinders through a waling motion on two bamboo or metal treadles (See Figure 1).

In the late 1980's, with support from CIDA (Canada) and later SDC (Switzerland), IDE implemented a program to stimulate the rural mass marketing of treadle pumps through the local private sector. The marketing program IDE developed consisted of a network of 75 manufacturers, several thousand village dealers, and several thousand village well drillers who graduated with a certificate from a three day IDE training program. This program focused on a variety of marketing and promotion activities aimed at increasing sales volume. This included wall posters, troubadours performing at village markets, rickshaw procession, and a 90 minute entertainment movie with the treadle pump in a central role that played to an audience of a million people a year[9].

The economics of the treadle pump program in Bangladesh provides an instructive illustration of the leverage that is made possible through the wide scale dissemination of affordable small plot irrigation technologies. Over a 15-year period, one and a half million treadle pumps were purchased and installed by small farmer customers at an unsubsidized fair market price. The total donor investment in IDE's treadle pump development and dissemination program, provided by CIDA and SDC activities, was $10 million (US). These donor funds leveraged an investment of $40 million (US) by smallholders themselves, who purchased the pumps and wells. This small farmer investment continues to generate a net return of $150 million US each year for these dollar-a-day farmers who purchased the pumps.[10, 11]

Another 500,000 treadle pumps have been disseminated by IDE in India, Nepal, Cambodia, and Zambia. Meanwhile, Enterprise Works Worldwide has disseminated treadle pumps in Francophone West Africa[12] and Approtec has sold some 35,000 treadle pumps in Kenya and Tanzania[13] FAO and many other organizations are now involved in treadle pump programs in a variety of countries in Asia and Sub-Saharan Africa.[14, 15]

The global impact of treadle pumps on alleviating rural poverty is unmistakable. But does this represent one unusual high impact technology that can never be repeated, or does it represent the tip of the iceberg in a whole host of high impact affordable small plot irrigation devices for smallholders?

Figure 2 Low Cost Drip Irrigation

2. Low-cost Drip Irrigation. Increasing crop per drop in the Semi-Arid Tropics increases in importance with growing water scarcity, but the adoption of efficient irrigation water application technologies by smallholders has been hampered by its high cost and limited divisibility. However, efforts to reduce the cost were never widely adopted. Thirty-five years ago, after receiving drip irrigation equipment from Mexico, Chou En Lei sponsored an initiative to lower its cost so that it could be widely adopted in China. The resulting micro tube systems developed at the Yanshan Institute by Qui Wei Duo and his colleagues at the Yanshan Institute were widely tested on greenhouse crops, fruit trees, and wheat planted in rows but has never been widely adopted in China[16]. In the United States, Dick Chapin, whose company pioneered the use of drip tape, began introducing twelve-dollar kitchen garden bucket kits in Africa in the 1980's[17].

IDE began applying what it had learned from treadle pumps to the design and private sector marketing of low-cost drip systems in Nepal in the 1990's with a shiftable drip system using simple punched holes for the outlets with baffles[18] over them, and IDE India developed a micro tube based system[19,20,21]. A significant feature of these low-cost drip systems is that they operate at pressure heads of only one to three meters, thus they can be supplied from simple tanks supporter a meter or two above the ground (see Figure 2).Small farmers themselves created a drip irrigation system price breakthrough for pre-monsoon cotton using very clear, thin-walled "Pepsi" lateral lined tubing[22] with pin-holes poked in it to water each cotton seedling. The system only lasted six weeks or so, which worked well for pre-monsoon cotton but did not last long enough for crops like vegetables. IDE-India engineers then strengthened the "Pepsi" system by adding carbon black to retard deterioration from sunlight, and using high quality LLDPE for the lateral lines. Varying wall thickness made it possible for smallholders to choose the life and cost of the system that fit their needs.

IDE low-cost drip systems in India are now selling at an unsubsidized price $360 US a hectare in the Semi-Arid Tropics of India, about one-fifth the cost of conventional systems. They can be purchased for as little as one dollar (US) for a 20 square meter kitchen garden kit. As was the case with treadle pumps, low-cost drip systems are being made available to small-farm

customers through a private sector network of manufacturers, village dealers, and farmer-technicians, who will install a one acre drip system in two days for $4 US. The tipping point for sales came when we were able to bring the price down to one-fifth that of conventional systems. Sales in India alone are projected to be 30,000 systems in 2004. Well over 100,000 IDE low-cost drip systems have already been purchased by small farmers in India, Nepal, Sri Lanka, and Zimbabwe. It has become clear that conventional quality standards need to be adjusted to small farm conditions[23] and that low-cost drip systems hold great promise for small farmer wealth creation[24]. The rapid initial adoption curve suggests that eventual adoption of low-cost drip systems will significantly surpass that of treadle pumps. As far as poverty eradication for smallholders is concerned, low-cost drip systems have the added advantage of facilitating improved crop quality as well as crop per drop and lending themselves to agricultural intensification and the cultivation of high value marketable crops.[25]

3. Low-cost Water Storage. In many semi-arid areas, most of the rainfall comes in abundance in a few monsoon months consistent with rainfed agriculture. However, irrigation water is either scarce or not available during dry months when otherwise growing conditions are quite favorable and vegetable and fruit prices are at their highest. Capturing and storing monsoon rainwater for future use is constrained by the

relatively high price of conventional water storage systems. The cheapest ferro-cement tank costs a rupee (slightly more than 2 cents US) a liter in Mahrastra, India. IDE is now field-testing in Maharastra a ten-meter long, one-meter diameter, double walled plastic tube that rests in an earthen trench (See Figure 3). If these field tests are successful, we anticipate a retail cost of $40 US for a 10-thousand liter, enclosed water storage tank, one-fifth the cost of existing ferro-cement storage systems[26]. These low-cost storage systems can be used to drip irrigate vegetables at the driest time of year when prices are the highest or to store a year's supply of drinking water for a family of five. Initial farmer response indicates that if the field tests prove successful, low-cost water storage will have a small-farm customer demand in the private sector comparable to that of low-cost drip.

The Tip of the Iceberg for Smallholder Irrigation. Some two and a half million small farmers in the world have already purchased treadle pumps, and market demand for technologies like low-cost drip systems and low-cost water storage is likely to far surpass the adoption of treadle pumps. But the main lesson to be learned from this early experience is that these initial technologies only represent the tip of the iceberg; a whole range of affordable smallholder irrigation technologies is still waiting to be developed. Jack Keller and IDE engineers are working on the development of a range of affordable low pressure small plot sprinkler systems, for example, as well as a low-cost improved uniformity surface irrigation system for small farms, and IDE-India is working on a 0.6 hp $100 US diesel pump. A whole range of affordable small plot irrigation devices remains waiting to be developed.

Figure 3 Low-cost water storage

3. Improving the Performance of Existing Large Irrigation Systems Most irrigated areas depend on major and medium scale furrow canal irrigation which often performs poorly

and breaks down frequently. Getting more farmer control, more crop-per-drop, and therefore better anti-poverty results from such schemes – building on IDE lessons from micro-irrigation to reform macro-irrigation, where technology issues are largely excluded from current reform initiatives – will be even more important for mass poverty reduction. Affordable small plot irrigation systems like low-cost drip and low-cost, low-pressure sprinkler systems can be used to improve smallholder productivity, especially at the outer reaches (tail enders) on large systems, provided that investments are made in the development of affordable water storage strategies to cope with irregular and low-frequency water delivery, water turbidity, and other key constraints.

The NAWSA MAD Approach. NAWSA MAD is actually Aswan Dam spelled backwards. I use this term to describe the potential of the polar opposite of the large dam and canal system approach to irrigation. The NAWSA MAD approach assumes that it is possible for a small farmer to invest in capturing and storing monsoon runoff and harnessing it to drip irrigate high value crops, at a price low enough that the total investment can be paid off in the first year. Low-cost water storage and low-cost drip systems are key building blocks in this approach. Furthermore, we are field testing deep mulching, plastic mulching, and other key components now. It will take at least two years to learn if this dream of complete water system on individual small farms is technically and economically feasible.

II. A Revolution in Agriculture: Downsizing Cash Crop Agriculture to Small Plots

A revolution in agriculture comparable to the green revolution is needed to customize the intensive production of high-value labor intensive cash crops like fruits, off-season vegetables, herbs, and medicinal plants to the specific conditions of two hectare farms and 1,000-square meter plots. A process to develop new high yielding varieties of marketable cash crops optimized for smallholdings is an important part of this new agriculture. Accomplishing this will be a major challenge, given the current focus of agricultural research on optimizing the productivity of staple crops. This new agricultural revolution, as well as the revolution in design outlined below, will be described more fully in follow-up papers.

III. A Revolution in Design: The Ruthless Pursuit of Affordability

The revolutions in water, agriculture, and markets required to meet Millennium Goals on poverty and hunger cannot take place without the design and mass dissemination of a new generation of affordable technologies capable of improving the livelihoods of the rural poor. Affordable design is also the glue that makes the revolutions in agriculture, markets, and water feasible, just as important to the design of marketing campaigns and pest management strategies as to small plot irrigation technologies. It is no accident that the tipping point for sales of technologies like treadle pumps and low-cost drip systems came when IDE reduced the price to one-fifth of that of comparable devices. Because of this, I use the term "Factor Five Design" to describe the ruthless pursuit of affordability that is the keystone of effective design for poor customers. This process systematically designs around key contributors to cost for existing technologies, and identifies tradeoffs between efficiency and affordability acceptable to customers to break through cost barriers.

What most stands in the way of the design revolution needed for poverty eradication is how design is taught to students entering the field today. Students who graduate from design courses

in universities in developing countries too often are expected to use their education to get government jobs where they will never have to get their hands dirty again, much less come up with affordable solutions to village problems. In the West, on the other hand, 90% of the graduates of design schools focus all their time on solving the problems of the richest 10% of the world's customers. To design products and services that meet the needs of the three billion customers who earn less than two dollars a day requires a revolution in the way design is taught, both in western and developing countries, based on the ruthless pursuit of affordability. Finally, an organizational structure is needed to harness the creative energy of ten thousand of the world's current best designers in a process of finding practical solutions to village problems.

IV. A Revolution in Markets: Creating New Markets That Serve Poor Customers

Markets provide the institutional structure for transactions in which smallholders are buyers and/or sellers. I disagree with the notion that large farmers grow for the market and small farmers grow for the table. Small subsistence farmers in Cambodia who buy a bit of ammonium nitrate fertilizer and occasionally sell surplus rice are participants in the market. Millions of peri-urban farmers in Sub-Saharan Africa who irrigate 400 square meter vegetable plots with watering cans and carry vegetables to the village market are participants in the market. The critical question for smallholders is not whether they participate in markets, but how they can more effectively identify and capitalize on their comparative advantage in the global marketplace.

The Nature of Rural Markets in Developing Countries. Most rural markets in developing countries are riddled with holes—because they have more obstacles to overcome than mature western markets. Some of the obvious reasons include corruption, scarcity of credit, and frequent absence of protection of intellectual property rights. But a whole series of economic studies are needed to more fully understand why rural markets in developing countries function so inefficiently, and what can be done about it. The symbiotic relationship between entrepreneurs and markets that works so well in western markets, providing wealth for one side and efficiency for the other, appears to operate sluggishly or not at all in village markets. The good news is that village markets provide huge untapped opportunities for entrepreneurial investments. Experience has demonstrated that the most effective way to put critical inputs like treadle pumps, low-cost drip systems, fertilizer and high quality seeds into the hands of smallholders, is through the stimulation of a profitable private sector network of manufacturers, rural dealers, and technicians.[27] There also exists huge unexploited opportunities to create new markets for the high-value products produced by smallholders.

Stimulating Market Demand. The saying "If you build a better mousetrap, the world will beat a path to your door" is as false in the rural marketplace in developing countries as it is in mature markets. Each player in the private sector supply chain becomes profitable only when threshold sales volume is reached. A public or private sector investment in promotion and marketing three times as large as the investment in technology development is a sine qua non for opening small farmer access to affordable small plot irrigation devices.

Addressing Constraints in Smallholder Access to Markets. In Zambia, one third of the proceeds smallholders receive from the sale of their vegetables goes to transporting them from the farm to the nearest road. This provides opportunities for a whole army of new short-haul

rural entrepreneurs, but until this market gap is filled, smallholders will continue to pay excessively high prices for short haul transport. Supermarkets, both in developing countries and in Europe, are playing an increasingly dominant role in markets for fruits, vegetables and other high value crops that can be grown advantageously by smallholders[28]. To effectively gain access to supermarket buyers, smallholders may need training in how to meet new quality standards. Ways to aggregate smallholder production to meet market volume requirements through strategies like co-op formation or equitable contract farming, are even more important. The good news is that practical solutions can usually be found for most of the most common market access constraints.

Adding Value to Smallholder Crops. The price a smallholder receives for his or her high-value crop may be only a tiny fraction of its eventual retail price. Applying the principles of affordable design to the development of small, decentralized value-added village processing plants provides opportunities for increasing smallholder income as well as adding rural jobs, but they must effectively exploit a profitable niche in the marketplace. Lemon grass, for example, is a frequently grown crop in India and Sub-Saharan Africa, commonly used to season Asian dishes. But lemon grass oil, (citronella) has a high value use in cosmetics. A bottle of citronella sells at a retail price of $14 US an ounce. Several extraction methods exist, with increases in capital cost and efficiency of oil extraction from each one to the next. The cheapest and least efficient is hot water extraction, followed by steam, chemical extraction, and CO2 extraction. Would a small village-based steam extraction workshop partially or wholly owned by a smallholder co-op, and funded by social venture capital, be profitable and provide economic advantages to smallholders and landless laborers? This prototypical question applies equally well for products as diversified as roasted vacuum packaged Arabica coffee and partial processing of paprika. IDE 's experience in establishing profitable decentralized processing enterprises producing desiccated coconut for the confectionary industry in Vietnam[29] and dried Brazil nuts in the Amazon Rainforest for Ben and Jerry's ice cream in Vermont[30] suggests that many similar opportunities for adding value at the village exist.

Summary and Conclusions

Achieving the Millennium Goals for hunger and poverty requires nothing less than four simultaneous revolutions in water, agriculture, design, and markets. The two and a half million dollar-a-day farmers who increased their net income by $250 million US by buying and installing treadle pumps show what the water revolution can accomplish. Five hundred thousand of them pointed to the revolutions in agriculture and market creation that are needed by adding $500 US a year to their dollar-a-day income through growing high-value cash crops, and learning to be shrewd players in the markets where they sold them. But the global market for new smallholder low-cost drip systems ($400 US/hectare for vegetables) is likely to dwarf the world market for treadle pumps, and the promise of low-cost water storage ($40 US for 10,000 liters) now being tested is also likely to far outstrip demand for treadle pumps. A whole range of new affordable small plot irrigation devices are being developed, including micro diesel pump sets, low pressure affordable sprinkler systems and efficient surface systems for small plots.

There is strong initial interest in creating a new field of affordable design, and progress has been made in aggregating the production of smallholders and facilitating post harvest processing, although the field of creating new markets that serve small farmers is still in its infancy. Aside

from a few organizations like the Asian Vegetable Research Center (AVRDC), little agricultural research focuses on the development of high yielding, disease resistant varieties of labor-intensive cash crops suitable for increasing smallholder incomes, and the development on intensive agricultural methods of growing such crops barely exists. To chart a realistic path out of poverty, development organizations, donors, governments, and most importantly the dollar-a-day smallholders themselves need to create a new vision and commitment to address key solvable problems in water, agriculture, design and markets.

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