DISMANTLING THE BARRIERS TO THE GREEN REVOLUTION FOR SMALL FARMERS

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The Green Revolution now appears to have run its course. High yielding varieties of wheat, corn and rice have tripled world grain production. But the spectacular annual increases in the global harvest have disappeared, while world population (5.6 billion) continues to grow. Lester Brown's predictions that the Green Revolution would change the face of world hunger have turned into the sobering realization that global carrying capacity is reaching its limit.

It is now possible to answer the provocative question posed by Clifton Wharton's article in Foreign Affairs 1969 "The Green Revolution, Cornucopia, or Pandora's Box?" It has proved to be both. Cornucopia has come in the form of huge gains in the global grain harvest, self-sufficiency in grain production for many developing countries, and continuing progress in the development of improved seed varieties. Pandora's box has let loose environmental pollution by pesticides and fertilizers, deterioration of irrigated soils from water logging and salinity, loss of biodiversity, and unsustainable patterns of mechanization and energy consumption. Most importantly, one billion people continue to experience severe hunger and poverty. An increase in rural jobs would lessen the pressure for urban migration.

The Small Farmer and World Hunger

The 75% of the farmers in developing countries who cultivate less than five acres hold the key to world hunger. These small farm families survive on meager incomes and go hungry for at least part of the year. They are disproportionately distributed in food deficient rural areas. A single disastrous crop failure can turn small farmers into landless laborers or send them into urban ghettos. If the world's subsistence farmers could triple their harvest by gaining access to irrigation, they would eliminate their own hunger and produce an income generating marketable surplus. The increased harvest in food deficient areas would redress the food distribution imbalance. The increase in labor requirements for growing, harvesting and processing the crop would create jobs for rural landless laborers and increase the income available to buy food.

The Impact of the Green Revolution on Small Farmers

A vigorous debate continues about the differing impact of Green Revolution seeds, fertilizer, and pesticides on large and small farmers. Critics assert that the Green Revolution makes rich farmers richer, and poor farmers poorer. Proponents argue that since the biological technologies of the Green Revolution can be purchased in very small quantities, they are divisible, and therefore neutral with respect to farm size. Both critics and proponents agree that increasing rural jobs and harvests by small farmers would improve global food security.

Two questions beg answers:

1. Do significant reversible barriers exist that block the access of small farmers and rural laborers to Green Revolution benefits?

2. What can be done to increase the agricultural productivity and income of small subsistence farmers and landless laborers?

BARRIERS TO THE GREEN REVOLUTION FOR SMALL FARMERS

The most important barrier to increased productivity of small farmers is their lack of access to divisible, affordable mechanical devices for irrigating, tilling, harvesting, and transporting the crops they grow on their small plots.
In order of importance, the key existing reversible barriers to an increased harvest for small farmers include the following:

1. Absent Access to Affordable Divisible Irrigation Devices. While some small farmers have access to canal irrigation, the average farm size served by large canal schemes is well over five acres. Private and public tubewells are increasingly popular, but the high cost and limited divisibility of mechanized pumps limit access to groundwater by small farmers. The cheapest diesel pumpset on a tubewell costs $500 (US) and does not pay for itself on less than five acres. For the majority of the world's farmers who cultivate less than five acres and earn $300 or so a year, a purchase price of $500 is not affordable. Without affordable irrigation, the benefits from small farmer access to divisible high yielding seeds and fertilizer are minimal.

2. Absent Access to Cost Effective Tilling, Harvesting, and Transport Devices
Harvesters, trucks and tractors are too big, too expensive, and totally out of place

on very small plots. The bicycle is the most widely used rural transport device. But the $32 cost of the cheapest bicycle available in India is out of reach for the majority of poor farmers who need it. A whole new spectrum of downsized affordable devices is needed that improve the efficiency of small plot tilling, harvesting and transport. This is not a niche in the marketplace. It is a chasm.

3. Current Mechanical Agricultural Technology is not Affordable Affluent societies prefer breakthroughs that improve the efficiency of a technology to innovations that lower its price. Poor people in developing countries, on the other hand, admire efficient tools, but lack the money to buy them. In the 1840's, one worker with a sickle could harvest a half of an acre of wheat a day. An improved scythe called a cradle was introduced that could harvest an acre a day, and then a horsedrawn reaper which could harvest two acres. Each of these innovations doubled efficiency, but more than doubled cost. The modern combine has the capacity to harvest a thousand times the acreage of a typical small farmer, at a cost that is totally out of reach. The persistent and unyielding pursuit of affordability is a prerequisite for the design of practical tools for small farmers.

4. Technology Design Ignores Small Farmer Preferences Far too little attention is paid to subsistence farmers as customers. Small farmers are risk averse and reluctant to purchase a new tool unless it can pay for itself in less than a year. Long on labor and short on capital, they are unlikely to invest more than fifty dollars in any mechanical device. Most development organizations who make tools available to small farmers fail to take into account these subsistence farmer preferences.

5. Existing Technology Dissemination Practices Fail to Reach Small Farmers The Consulting Group for International Agricultural Research (CGIAR), a network of agricultural research organizations and the most influential such group in the world, has been much more effective in influencing governments and policy makers than in directly reaching subsistence farmers. New grass roots dissemination strategies need to be designed and implemented to steepen the slope of the diffusion curve for small farmer oriented agricultural technology.

6. Subsidies Constrain Access to Cost Effective Technologies Subsidies for small farmers are endemically popular among governments in developing countries. But they paradoxically inhibit small farmer adoption of the technologies they are designed to promote. When a subsidy is announced, small farmers delay their purchase until the subsidy becomes available. Producer inventories are flooded, and when and if subsidy funding becomes available, it reaches only a fraction of the demand which has been artificially inflated by the subsidy itself. Also, wealthier farmers are better able to pay bribes to gain access to subsidies than their small farm neighbors.

Shallow mechanized tubewells were subsidized in Bangladesh, for example, to make them available to poor farmers organized in co-operatives. Larger, wealthier farmers quickly took advantage of the subsidy by forming nominal co-operatives that installed subsidized wells. They then sold excess water at high prices to the small farmers for whom the subsidy was intended. Lowering the cost of technology to make it both affordable and profitable at a fair market price makes subsidies unnecessary.

REMOVING THE BARRIERS

Opening Access to Affordable Small Plot Irrigation Devices

The most important barrier to the Green Revolution for small farmers is their lack of access to affordable irrigation. Modern irrigation technology has been designed to fit the needs of the 25% minority of the world's farmers who cultivate more than five acres. The potential to increase opportunities for irrigation for small farmers is enormous.

Huge untapped resources in surface and ground water could be made available to small farmers. But no irrigation devices currently exist in the technology spectrum between counterbalanced buckets, which are too inefficient, and diesel pumps, which are too expensive. Currently available human powered water lifting devices like swing baskets have significant limitations in cost, efficiency, and durability. Persian Wheels, the most commonly used animal powered waterlifting device, are costly because of their large size and weight, and can only operate on expensive large diameter wells. At a cost of $500 to install and $300 a year to operate, small diesel pumps are too expensive to be affordable for subsistence farmers, and do not pay for themselves on small plots.

India's experience illustrates this small plot irrigation deficit. It has become self-sufficient in grain production, but large poor and hungry populations remain. Rice is the most important subsistence crop, but yields remain under two tons per hectare, less than half of the yields in China and Japan. The fact that forty-five percent of India's rice crop is irrigated, compared with virtually all of China's and Japan's, accounts for most of this difference.

One sees vast brown plains in the winter dry season in Uttar Pradesh, where population density is high, plot sizes are small and water tables are less than 4 meters from the surface! Under similar conditions, larger farmers in India have profitably purchased and installed 12 million electric and diesel pumpsets. With appropriate irrigation equipment, India's small farmers could plant high yielding varieties of rice. They could eliminate the risk of crop losses from unseasonable droughts in the rainy season. They could mitigate the risk of destructive monsoon floods by planting irrigated modern varieties of rice in the dry season.

The development of a variety of affordable irrigation devices between buckets and diesel pumps, customized for plot sizes between 0.1 and 5 acres, would profoundly improve the productivity of small farms. Three recent innovations in affordable small scale irrigation technology demonstrate how the small farmer irrigation obstacle to an increased harvest can be removed.

Three Innovations in Affordable Small Plot Irrigation

1. A Thirty-Five Dollar 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, it is powered by walking on two bamboo treadles. This activates 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 tubewell at an unsubsidized price of $35, less than one tenth of the cost of a diesel pump.

Over the past ten years several thousand village dealers and well drillers have sold and installed one 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 a hundred dollars a year, diversifies crops, gains access to clean drinking water, and shortens the three month period of hunger. Ten million Treadle Pumps will likely be installed in Bangladesh and India over the next ten years, adding two and a half million hectares in irrigated acreage and a billion dollars a year in increased net small farmer income.

2. A Hundred and Fifty Dollar Animal Powered Tubewell Pump

Dry season irrigation of thirsty crops like rice and sugar cane requires a greater volume of water than a Treadle Pump can comfortably deliver. Most small farmers in Asia plow rice with a draft animal. These animals are relatively idle during the irrigation season and can lift 5 times as much water as a person.

Since ancient times, the Persian Wheel, a large waterwheel powered by a bullock walking in a circle, has been the traditional animal powered waterlifting device in Asia. It has two flaws that make it too expensive to compete with mechanized pumps. First, the wheel is heavy, and weight is a critical predictor of cost. Second, the large diameter, hand-dug well required to accommodate the wheel costs much more than the tubewell used by diesel and electric pumps. Because of this, twelve million subsidized electric and diesel pumps effectively replaced

Persian Wheels in India during the Green Revolution. But their $500 cost puts them out of reach for small farmers.

To provide an affordable animal powered pump, my colleagues and I designed a lightweight irrigation pump that fits on a low cost tubewell. This three cylinder piston pump is activated by a draft animal walking in a circle. It costs $150, including the cost of the tubewell, one third of the cost of a five horsepower diesel pump. The animal powered pump produces two thirds of the water of a five horsepower diesel pump at a quarter of the operating cost. It has the added advantage that the fodder consumed by a working animal is renewable, nonpolluting, and much cheaper than diesel.

With successful diffusion of the animal powered tubewell pump, a small farmer in Asia can gain access to affordable irrigation by purchasing a Treadle Pump and use the income it generates to buy an animal powered Pump that produces enough water to irrigate an acre of dry season rice, or three acres of dry season vegetables.

3. A Fifty Dollar 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 $1,000 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, my colleagues and I designed a system that cuts the cost of drips systems by 90%. We designed portable drip lines that can be moved several times a day. This reduces the number of plastic drip lines to one for every ten rows of plants, instead of one for every row. Cost is further reduced by replacing each 20 cent emitter by a simple hole punched in the plastic distribution line. An off the shelf 20 liter plastic tank raised 2 meters above the field and fed by a pump or gravity flow from a stream provides the constant low pressure head needed to move water through the system. Low cost connectors allow the farmer to customize the system to his fields like a Lego set. These strategies reduce the capital cost of a drip system for half an acre of vegetables to $50.

Field tests with mulberry cultivation in southern India and vegetable production in the hill areas of Nepal verified the effectiveness of the low cost drip system and its popularity with small farmers. Because it doubles the amount of land irrigated by the same amount of water, the low cost drip system conserves both water and the energy required to pump it. Since the small farmers who have used it report that it also cuts irrigation labor in half, the low cost drip system is likely to be rapidly adopted for small plots in the world's hilly and semi-arid areas.

Widespread adoption of these three small scale irrigation devices alone- Treadle Pumps, Animal Powered Pumps, and Low Cost Drip Irrigation, could add 20 million irrigated hectares for small farmers, and increase net annual income of 250 million poor rural people by 8 billion dollars a year.

BETWEEN SICKLES AND HARVESTERS

A remarkable facet of agriculture in Japan, which produces the word's highest yields for rice, is that farmers used horses instead of tractors until after the second world war. Horses were better suited to five acre rice farms than large, expensive tractors. When cheaper, lighter tractors that could operate efficiently in small, wet rice fields became available, they were quickly adopted. This provides a paradigm for the radical design changes that are needed to customize bulky and expensive modern agricultural machinery for small subsistence plots.

It makes no sense to use a hundred thousand dollar combine to harvest a quarter acre of wheat. Designing divisible technology for small farms starts with reversing the historical design process to find the earlier technology best suited to current requirements of plot size, affordability, and cost of labor. This earlier design is then modified to incorporate modern low cost techniques, components and materials. It is then customized to fit the requirements of the crop being grown and the type of agriculture being practiced. An important final design criterion is that the technology be capable of paying for itself in less than a year. Using this design strategy, a continuum of devices for each key agricultural function can be designed to fit different points on the critical small farm variables of affordability, plot size, prevailing labor rates, and type of agriculture practiced.

To gain access to the Green Revolution, the world's small farmers need a whole new generation of affordable, divisible mechanical devices like the Treadle Pump in the technology continuum between sickles and combines, bullocks and tractors, and headbaskets and trucks. International agricultural institutes in the current CGIAR network focus their efforts almost exclusively on biological technologies of seeds, fertilizer, and pesticides. It is remarkable that there is no

existing agricultural research organization that provides a disciplined, marketplace oriented focus on the design and diffusion of affordable, divisible mechanical technology to open access to the Green Revolution for small farmers. A major new initiative is needed to address this deficit.

GRASS ROOTS DISSEMINATION

Recent advances in rural mass marketing provide effective strategies to reach small subsistence farmers. Grass roots marketing initiatives have successfully used village dramas, television soap operas, and private sector dealer networks to popularize devices ranging from oral rehydration salts to family planning devices. Existing rural private sector networks of producers, dealers and service providers have direct links with small farmers and provide a rich, relatively untapped resource for the mass dissemination of affordable biological and mechanical technologies.

For example, existing private sector networks of small manufacturers and village dealers and technicians were activated to market and install a million Treadle Pumps for small farmers in Bangladesh. An initial collaborative relationship was established with four small manufacturers to ensure that the quality of initially installed Treadle Pumps was sufficiently high to attract new buyers. A variety of techniques were used to interest 50 existing private sector manufacturers and several thousand village dealers and well drillers in the profit-making opportunities presented by the technology.

Bangladeshi project staff were recruited and trained to assist local dealers and well drillers to sell and install clusters of 20-30 pumps in key market areas. This is the critical mass required for word of mouth to produce exponential sales. A

variety of proactive strategies was used to recruit local and international development organizations to promote the technology and offer credit for its purchase to small farmers. A three day training course with a certificate increased the drilling and well completion skills of three thousand well drillers, and motivated them to promote the technology.

Open air village entertainments that popularized the technology were instituted for villages without electricity. An award winning ninety minute entertainment movie in the Bangladeshi tradition was produced by a popular local director using leading local actors and actresses. In the story line, a Treadle Pump provided the dowry that made the marriage possible. The movie was shown in open air settings using a generator powered projector and a large screen, and has been seen by a rural audience of a million people a year. Village dealers were organized to play a key role in publicizing each showing and used the interest stimulated by the film to generate sales.

Three hundred demonstration sites were established by recruiting exemplary farmers growing high return cash crops irrigated by Treadle Pumps. Local dealers were encouraged to take advantage of farmer interest in demonstration plots to generate sales. In response to growing marketplace demand, new manufacturers, dealers and well drillers became involved on their own initiative. After 10 years, annual sales of Treadle Pumps have risen to 170,000, and the number of pumps installed to over a million. Similar grass roots marketing initiatives were successfully initiated in India, Cambodia, Nepal and Vietnam.

REFOCUSSING GLOBAL POLICIES

Significant improvements in rural poverty and food security require changes in the current policies of development donors and developing countries.

1. Efforts to improve rural poverty and food security in developing countries should focus on tripling the harvest of small farmers.

2. A new global agricultural research initiative should be launched to design affordable small plot irrigation, tilling, harvesting, processing and transport devices, and to implement their grass roots rural mass marketing.

3. The design process should optimize affordability by identifying compromises acceptable to small farmers, and customizing each product for small plots.

4. The local private sector should play a central role in manufacturing, distributing, and marketing these new devices to small farmers.

5. Development donors and developing countries should put a high priority on products that small farmers are willing to purchase at a fair market price. New technologies should earn at least 100% a year after expenses on their purchase price. Development projects should increase net aggregate cash income of primary beneficiaries each year by an amount at least equal to total project cost.

A new generation of affordable and efficient human and animal powered irrigation, tilling, transport and harvesting devices customized for small plots will open the door to increased harvests and income for the world's small subsistence farmers. But before tens of millions of these devices can be put in the hands of small farmers, traditional paradigms for the design and diffusion of mechanical technology need radical revision. Small farmer access to irrigation and Green Revolution inputs will increase food supply in food deficient areas, increase the income available to the rural poor to buy food, and contribute to stemming the flow to the urban ghetto. Designing and mass marketing affordable technology customized for small farms will eradicate hunger and poverty for large groups people living in the world's poor rural areas.