45

Research Report

Pedaling out of Poverty: Social Impact of a Manual Irrigation Technology in South Asia

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M. Alam
M. Dinesh Kumar
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and
Mahendra Singh

International Water Management Institute

Research Reports

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Contents

Glossary

dhenkuli:	a traditionally used manual water-lifting device, with a bucket tied to one end of a pole that rests on a bamboo frame
karin:	an artesian spring
Krishak Bandhu:	a brand of treadle pump sold in Bangladesh
mistry:	technician or mechanic
shenna or taar-balti:	a manual water-lifting device made of a large bucket or container with ropes tied on two ends
tenda or *Lathakuri*:	a variant of the *dhenkuli*

Abbreviations and Units

IDE	International Development Enterprises			
RDRS	Rangpur Dinajpur Rehabilitation Service			
TP	treadle pump			
InRs	Indian rupee	US$1.00	=	InRs 41.00
Tk	Taka (Bangladesh currency)	US$1.00	=	Tk 50.00
NRs	Nepal rupee	US$1.00	=	NRs 69.00
qtl	quintal	1.0 qtl	=	100 kg

Note: Currency exchange rates are averages for the period of the study.

Summary

This paper offers an assessment of the social impact of treadle pump technology for manual irrigation in eastern India, the Nepal Terai, and Bangladesh, South Asia's so-called "poverty square." This region where 500 million of the world's poorest people live is underlain by one of the world's best groundwater resources. Treadle pump technology can be a powerful tool for poverty reduction in this region. It "self-selects"[1] the poor and it puts to productive use the region's vast surplus family labor. It is claimed that the treadle pump could raise the annual net household income by US$100, on the average.

This report reviews evidence from a variety of studies—including our own—designed to test these claims, and concludes that:

a) Treadle pump technology does self-select the poor, although the first-generation adopters tend to be the less poor.

b) It does raise net annual incomes of adopter households by US$50-500, with the modal value in the neighborhood of US$100. It transforms smallholder farming systems in different ways in different sub-regions; in north Bengal and Bangladesh, treadle pump adopters take to cultivation of high-yielding rice in the *boro* season while elsewhere adopters turn to vegetable cultivation and marketing.

c) Treadle pump use results in increased land-use intensity as well as "priority cultivation." Adopters use crop-saving irrigation in a large part of their holding but practice highly intensive farming in the "priority plot."

d) Average crop yields on "priority plots" tend to be much higher than yields obtained by farmers using diesel pumps or other irrigation devices.

e) The income impact of treadle pump technology varies across households and regions, but US$100 per year is a conservative estimate of the average increase in annual net income. Less enterprising adopters achieve fuller employment at an "implicit wage rate" that is 1.5-2.5 times the market rate. The more enterprising take to intelligent commercial farming and earn substantially more.

For a marginal farmer in this region with US$12-15 to spare, there could hardly be a better investment than a treadle pump, which has a benefit-cost ratio of 5, an internal rate of return of 100 percent, and a payback period of one year. It thus ideally fills the need of the marginal farmers in the Ganga-Brahmaputra-Meghna basin. The challenge lies in its marketing; exceptional ingenuity seems to be required to put the treadle pump in the hands of millions of rural poor. In Bangladesh, where this has become possible, over a million pumps sold so far probably do not account for a large proportion of the irrigated area but have certainly reached a significant proportion of Bangladesh's rural poor. In eastern India and the Nepal Terai, the technology was introduced only in the 1990s and, therefore, total sales have been in the neighborhood of 200,000 against an estimated ultimate potential of 9-10 million. For a significant impact on poverty in the region, treadle

[1]In the sense that the technology has an inherent bias toward smallholders and against large landowners.

pump sales need to quickly cross the 100,000 per year mark in eastern India and the Nepal Terai, possibly by recreating the conditions that led to Bangladesh's 3-year long sales boom during the early 1990s, which very nearly saturated its treadle pump market. If International Development Enterprises (IDE), the NGO that promotes the treadle pump, wants to achieve this feat, it must improve on three aspects of its business strategy:

- First, it needs to do serious rethinking on its current strategy of offering only a single high-quality, high-price product and consider placing on offer several price-quality combinations; this seems critical, especially in view of the Bangladesh experience, which suggests that the treadle pump demand, especially in regard to first-time buyers, is highly responsive to price and hardly responsive to quality.
- Second, IDE needs to review the pros and cons of the tight, IDE-controlled marketing organization it has created in India and explore whether its mission might not be better achieved through a "let a hundred flowers bloom" approach of stimulating competition in treadle pump manufacture and marketing.
- Finally, IDE needs to devise strategic responses to the threat posed to the treadle pump program by subsidy schemes for mechanical pumps and opportunities offered by persistent increases in the prices of fossil fuels and electricity.

Pedaling out of Poverty: Social Impact of a Manual Irrigation Technology in South Asia

Tushaar Shah, M. Alam, M. Dinesh Kumar, R. K. Nagar, and Mahendra Singh

Introduction

This research covers South Asia's so-called "poverty square," which comprises eastern India, the Nepal Terai and Bangladesh—the heartland of the Ganga-Brahmaputra-Meghna basin (fig.1). The region, which contains 500 million of the world's poorest people, has one of the world's most remarkable groundwater resources, available at a depth of 1.5-3.5 m.[2] The population density is over 500 per square kilometer and over half of the total farmlands are operated by marginal farmers owning an average of 0.8-0.9 hectare of farmland (GOI 1999). The average size of holding in the region has halved every 15 years since 1960. Fragmentation of landholdings is an issue; for example, the average parcel size was 0.11 hectare in Bihar and West Bengal in the mid-1980s (Rao 1996). Agricultural productivity in eastern India stagnated during the 1990s, after an initial surge in yields and total farm production during the belated onset of the green revolution in the 1980s (Bhalla and Singh 1997; Saxena 2000). Overall, the region has low agricultural productivity, which perpetuates its rural poverty.

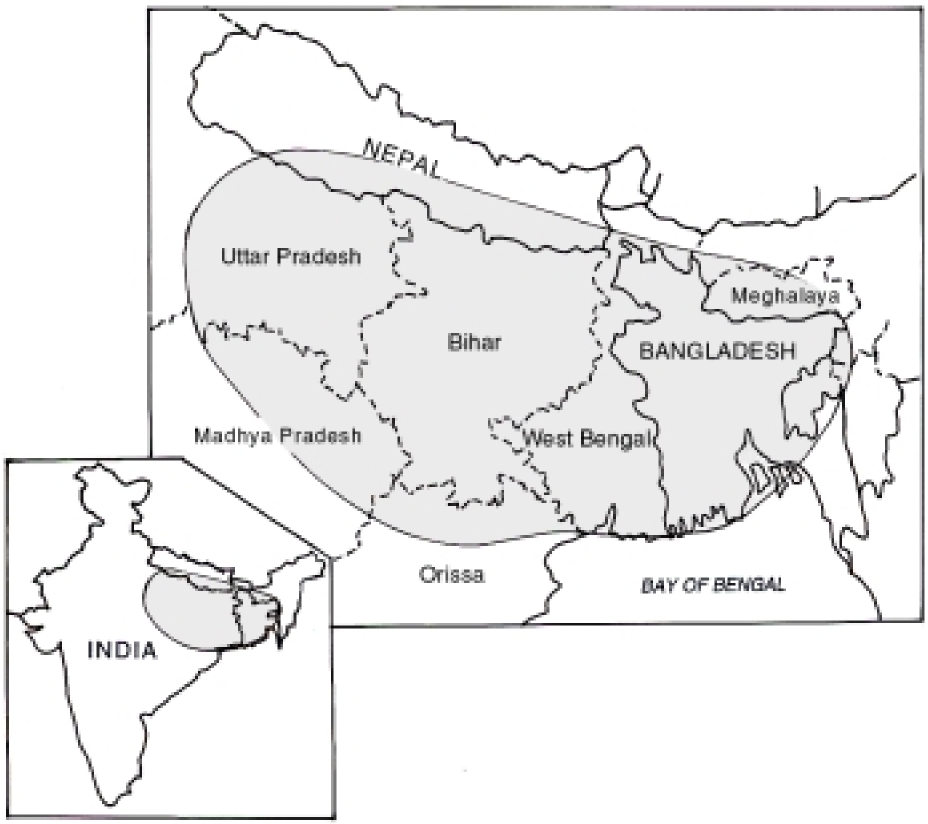
Development of groundwater irrigation has long been held out as the answer to the region's socio-ecological malaise (Chambers, Saxena and Shah 1987; Shah 1993; Rao 1996). Besides improving livelihoods, intensive groundwater irrigation is expected to alleviate the acute flood-proneness and waterlogging of the region. Growing private investment in tubewells is already beginning to do this. However, the majority of the poor are unable to accumulate enough capital to participate in this "pump revolution." The emergence of water markets has improved their indirect access to pump irrigation water, but without sufficient competition, water markets can be exploitative and arbitrary (Shah 1993; Shah, Indu and Paleja 1998; Shah and Ballabh 1996).

For a long time, the smallest diesel pump on offer in eastern India has been a 5 horsepower pump, which is too large for the multitude of marginal farmers. For these farmers, the only alternative to this was the traditional manual water lifting devices, which were useful for protective irrigation but have limited use in green-revolution agriculture. Low-cost treadle

[2]According to estimates made by India's Central Ground Water Board, of the total national groundwater irrigation potential of 64.04 million hectare meters, 23.85 million hectare meters are concentrated in Uttar Pradesh, Bihar, Orissa, and West Bengal. According to India's National Academy of Agricultural Sciences, the proportion of renewable groundwater recharge used is only 8.4 percent in Orissa, 19.2 percent in Bihar, 24.2 percent in West Bengal, and 35.8 percent in eastern Uttar Pradesh.

FIGURE 1.

South Asia's so-called "poverty square"– eastern India, the Nepal Terai and Bangladesh.



pump (TP) technology has been advocated as "ideal" for them, for it provides them with direct access to irrigation at an affordable cost. According to Dixit (1993), "... about 40 million 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 labor and delivering only a fraction of the water needed." For these farmers, the TP might be a great boon! Based on such calculations, the ultimate market potential for TPs in eastern India, Bangladesh and the Nepal Terai—the region with high groundwater tables—was estimated by International Development Enterprises at 10 million. International Development Enterprises (IDE) is an US-based NGO that promotes the TP.

Many claims have been made about the benefits of TP technology: it self-selects the poor, it is easier to install and operate, and its benefit-cost ratio is high. TP users are able to grow a wider menu of crops, cultivate their land more intensively, and increase their cropping intensity and crop yields. Every TP sold, it has been claimed, results in an annual increase of US$100 in the net income of a very poor household (Polak, n.d.). At this rate, if and when IDE does saturate this potential market, it will have accomplished one of the most ambitious and well-targeted poverty-alleviation interventions the world has even seen, by

increasing the net annual income of South Asia's poorest rural households by one billion dollars, and that, at little cost to the public funds. No wonder, Paul Polak, the chairman of IDE, wrote: "The treadle pump is the harbinger of a new agricultural revolution greening millions of postage stamp sized plots in the heart of the world's poorest and hungriest areas ... a treadle pump installed on a tubewell costs thirty-five dollars, less than one-tenth of the cost of a diesel pump …' (Polak, n.d.: 4). This study attempts to test these claims and explores issues involved in realizing the full potential of the TP.

Treadle Pump (TP) Technology

A treadle pump (TP) is a foot-operated device that uses a bamboo, or a PVC or flexible pipe for suction to pump water from shallow aquifers or surface water bodies (fig. 2). Since it can be attached to a flexible hose, a treadle pump is useful for lifting water at shallow depths from any source such as pond, tank, canal, or catchment basin or from tubewells up to a maximum height of 7 meters. It performs best at a pumping head of 3.0-3.5 m delivering 1.0-1.2 l/s (figs. 3 and 4).

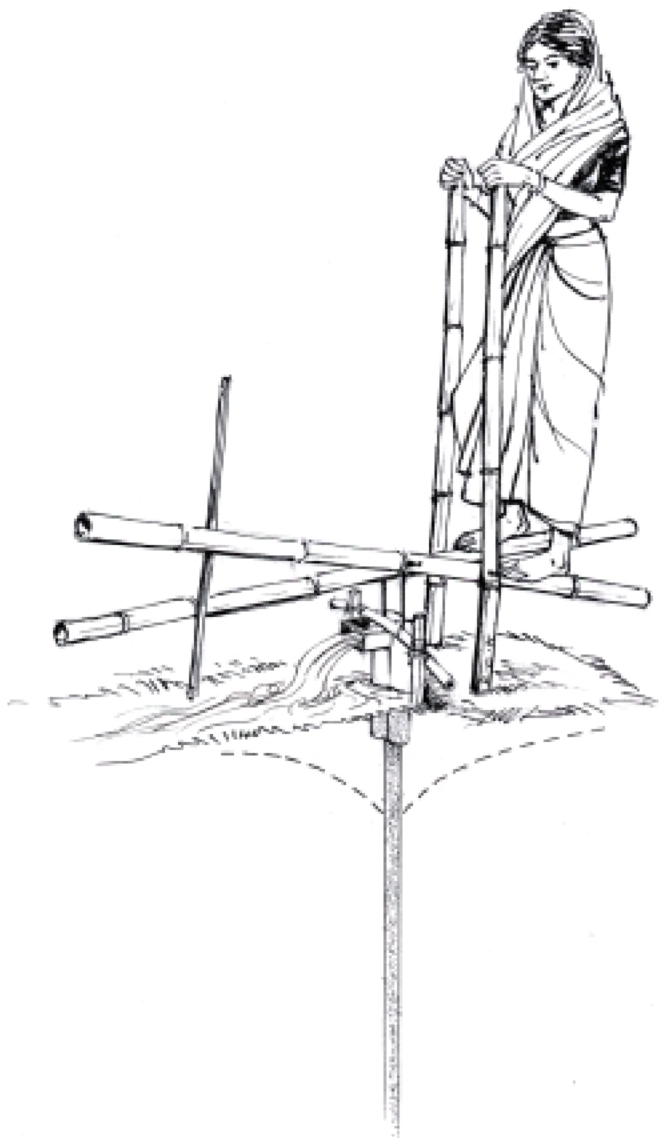
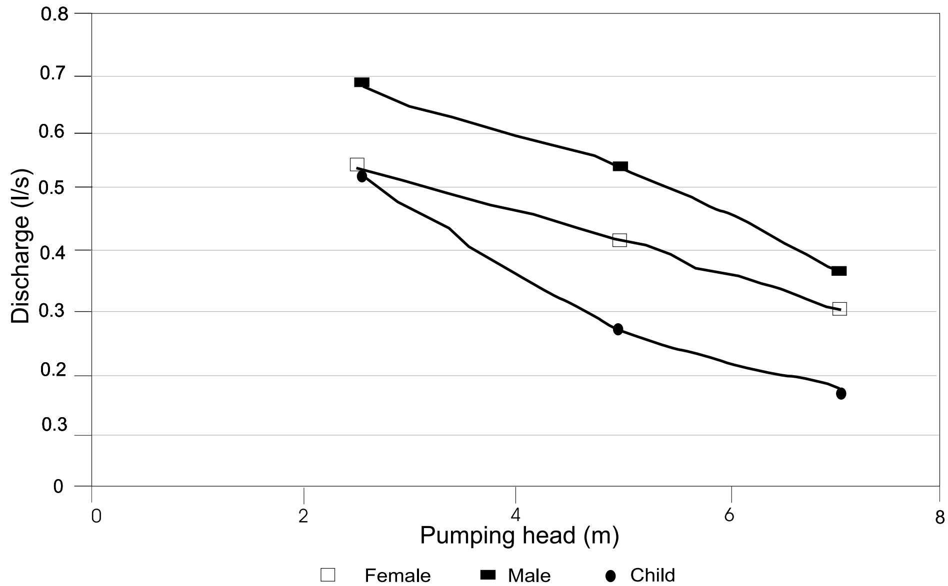


FIGURE 2.

A treadle pump (TP) consists of a sheet metal or cast iron pump box, a bamboo frame with two treadles, and a bamboo or PVC strainer. The pump box has two cylinders welded together with a single suction inlet at the bottom and two plungers. The diameter of the cylinders varies for different water outputs and water-level depths. 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 passes through the filter and rises up the suction pipe to the pump and is discharged 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 TP 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 (Orr et al. 1991:9).

FIGURE 3.

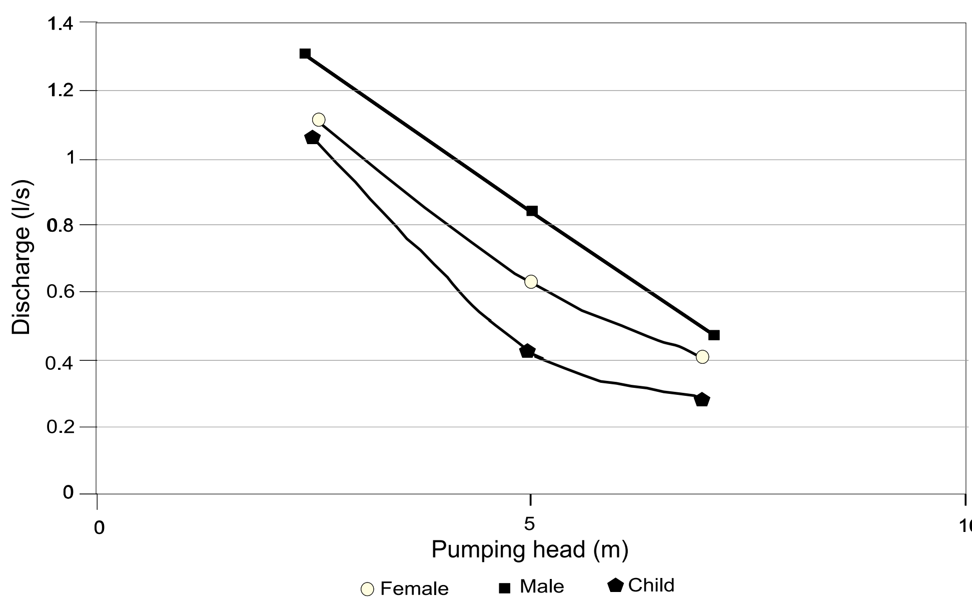
Manual pump test: Discharge by pumping head and user type (female, male, or child) for 3.5-inch treadle pump.



Source: NBTDP 1996.

FIGURE 4.

Manual pump test: Discharge by pumping head and user type (female, male, or child) for 5.0-inch metal treadle pump.



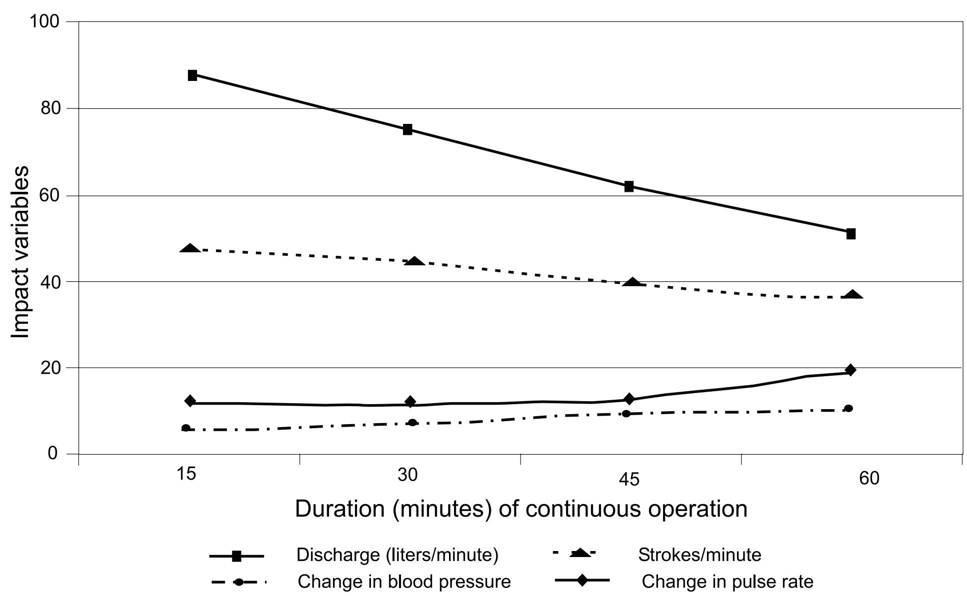
Source: NBTDP 1996.

No significant adverse health impacts of TP use have been recorded except for aches and pains experienced by first-time users.[3] Tests on health impacts of TP operation at suction depths of 2.25 m and 2.85 m (figs. 5 and 6) show, as expected, that the pulse rate and blood pressure increase during non-stop operation and that the rise is steeper at greater suction depths. It is not surprising that the stroke rate declines over time and most operators do not operate the treadle pump for more than 30-40 minutes continuously.

In terms of the ease of operation, the TP is considered to be a distinct improvement over a variety of traditional manual irrigation devices in use in eastern and northern India for centuries. Compared to hand pumps used in irrigation and popular in many parts of the Ganga basin, the TP is easier to use and more productive. Its output is in the range of 0.6-0.8 l/s at a lift of 4.5 m while the hand pump delivers about 0.5-0.6 l/s (figs. 3 and 4).

FIGURE 5.

Physiological impact of pedaling at a suction depth of 2.25 m.



[3]"Across the board, users complain of aches, pains and cramps in the lower limbs and of course the tedium of treadling. But few have linked the treadle to any ailments that they might have developed." (Ramaswamy and Sengupta 1999:26)

FIGURE 6.

Physiological impact of pedaling at a suction depth of 2.85 m.

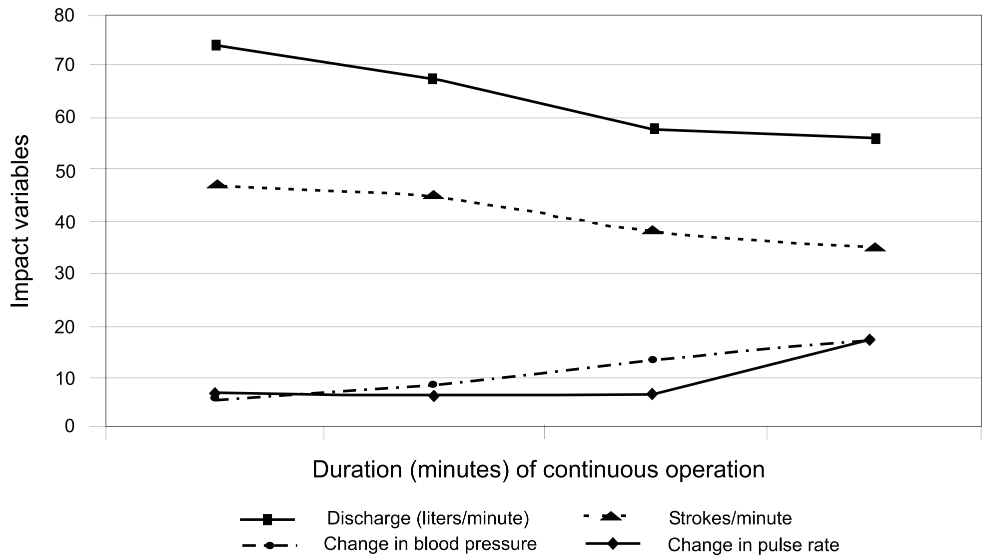
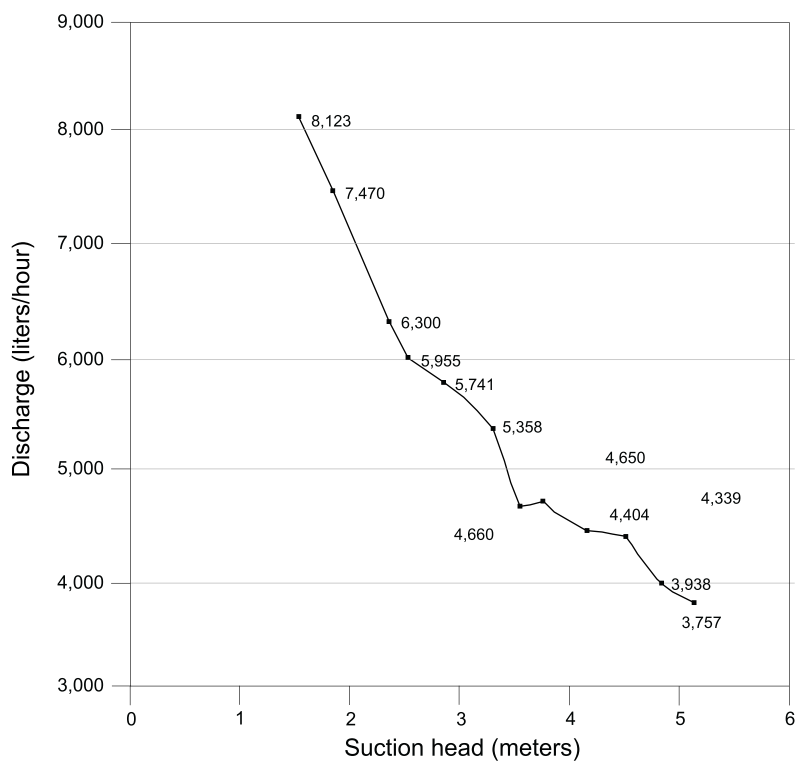


FIGURE 7.

Relationship between suction head and treadle pump discharge (RDRS tests in Bangladesh).



Farmer assessment of these devices, however, takes into account other parameters besides ease and output. In the course of a Focus Group Discussion in December 1998, a group of farmers in the Puri district of coastal Orissa evaluated three devices, the TP, the *tenda*,[4] and the *shenna*.[5] The farmers ranked them in terms of ease of operation, water output, capital cost, and maintenance cost as shown in table 1. The main advantages of the TP are ease of operation and low cost of maintenance and repair. The tenda costs about US$6.5 (InRs 266) to set up and as much per year to maintain. The shenna is cheaper to make and maintain and also has very good water output, but is laborious and requires two persons to operate and therefore does not offer the independence the other two offer.[6]

Like other manual water lifting devices, the TP is good for low-lift pumping. A World Bank commissioned study in Bangladesh found the "comfortable discharge rate" of the TP—at a power input rate of 30 watts over the Basic Metabolic Rate (BMR) of 62—to be 50-55 liters per minute at a pumping lift of 3 m. Above 3.5 m pumping lift, the discharge dropped off and at 5 m it was down to 18 liters per minute at 30 watts over BMR (Orr et al. 1991:14). The output tends to be significantly higher for large diameter cylinder pumps at shallow pumping heads. As the pumping head increases, the "optimal" cylinder size decreases, and so does the discharge per unit of effort (fig. 7).

The most attractive feature of TP technology is its low cost; the cheapest bamboo TP costs about US$12; the more expensive metal and concrete pump, complete with a bore hole well and a pump frame, costs US$25-35. Cost estimates provided by manufacturers and marketers vary widely and are sometimes misleading. Figure 8 shows the actual amounts spent by 400 small farmers in installing TPs in

TABLE 1.

Ranking of treadle pump, shenna, and tenda by a group of Orissa farmers.

	Water output per hour	Ease of operation	Capital cost	Maintenance and repair
Treadle pump	2	1	3	2
Shenna	1	3	1	1
Tenda	3	2	2	3

[4]*Tenda* or *Lathakuri* is a traditionally used manual water-lifting device in which a bucket is tied to one end of a pole that rests on a bamboo frame. The other end of the pole carries a counterweight tied to a rope. The operator stands on a plank laid across the rim of an open well, lowers the bucket to fill water, and pulls the rope tied to the other end of the pole to raise the bucket. The *dhenkuli* is a variant of the same technology.

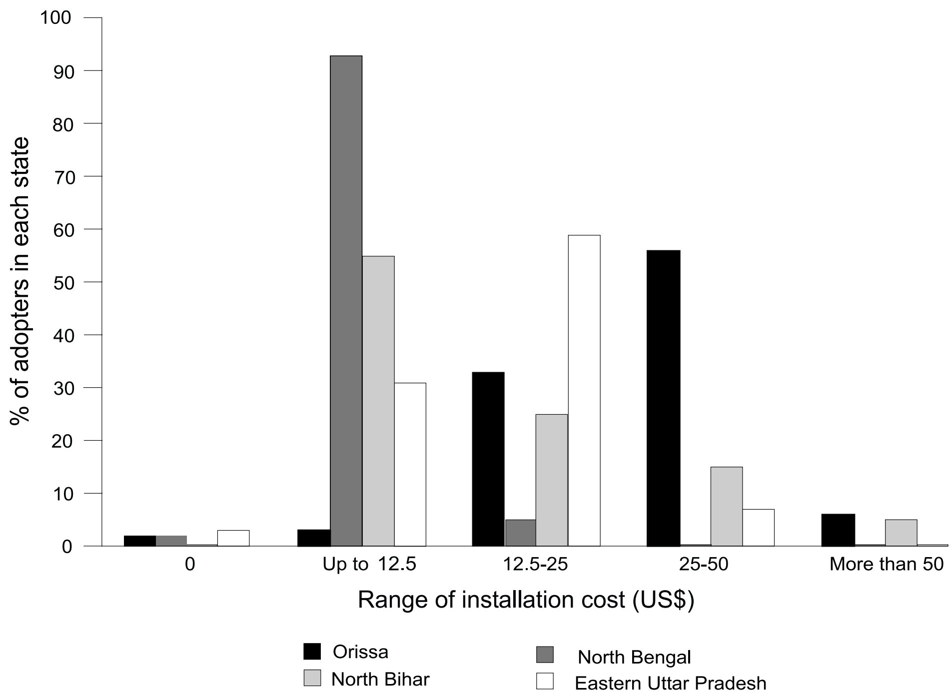
[5]*Shenna or taar-balti* is a large bucket or container with ropes tied on two ends. Two persons dip the container to fill it and then lift and swing it to empty the water into a channel.

[6]In the course of a Focus Group Discussion with farmers in Sunugordi village (Puri district, Orissa), three disadvantages of both shenna and tenda came to light: a) they use up a good deal of land because they need a pond-like shallow structure to lift water from; b) these structures need a source of water such as a canal, else they have no water when it is needed most; c) these ponds are normally outside the field and water has to be conveyed some distance using open, unlined channels, which causes seepage losses. TP is normally located to minimize such distance.

eastern India during 1994-96. Very few of the farmers in this sample—except in coastal Orissa, where salinity requires costly concrete pumps to avoid corrosion of the metal pump head—spent more than US$25 on the TP assembly and bore hole well. At current rates, the estimated capital cost of developing canal irrigation potential in South Asia is US$4,000-4,500 per hectare. The cost estimate for developing tubewell irrigation potential is US$800-1,000 per hectare; with TP technology new irrigation potential could be created at a cost of US$100-120 per hectare with the poorest farmers being the beneficiaries.[7]

FIGURE 8.

Capital cost of installing the treadle pump, incurred by 400 farmers in eastern India.



Source: AIMS 1997.

[7]The capital cost of creating diesel pump irrigation during the 1985-89 period was estimated at InRs 9,600/ha (US$1.00 = InRs 26.00), and that for developing canal irrigation potential at InRs 50,000/ha (Dixit 1993:10). Figures in Postel 1999 (page 62), which are based on 1991 World Bank funded irrigation projects, suggest that the capital costs are much higher: US$3,766/ha for pump irrigation and US$5,584/ha for gravity flow irrigation. Emphasizing this aspect of the treadle pump's virtue, Paul Polak once asserted, "The cheapest five horsepower diesel pump on a tubewell costs 500 dollars, 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.). The cheapest bamboo TP in the IDE range costs InRs 380-425 and a TP made of sheet metal and PVC suction pipe is priced at InRs 800-825. The concrete pumps made for saline coastal areas in Orissa cost more than the metal pumps (Bhanot 1999:9).

Promotion and Marketing

TP technology was developed and promoted on a commercial scale by International Development Enterprises (IDE), an US-based NGO. Its mission is: "*To improve the social, economic and environmental conditions of the world's poorest people by identifying and marketing low-cost, sustainable, appropriate technologies that can be manufactured locally and sold at a fair market price*." It believes in focusing its energies on a "core business," in professionalism, and in achieving a significant impact. In each country where it operates, IDE local teams enjoy a high level of autonomy in designing and managing their organizations, programs, and approaches. This has resulted in wide differences between the ways it operates in Bangladesh and India.

In Bangladesh, where IDE played an instrumental role in popularizing TP technology since 1985, numerous NGOs and private entrepreneurs are involved in the manufacture and marketing of a variety of branded and unbranded TPs. They are independent of each other and, largely, independent of IDE. In Bangladesh, 84 private manufacturers now produce TPs and market them through the normal trade channels. They fix prices and profit margins. IDE-Bangladesh tries to stipulate pricing and quality standards but these do not seem to stick. IDE-Bangladesh aggressively promotes the *Krishak Bandhu* brand of TP, which is based on generic technology, and this benefits all those involved in the TP business.

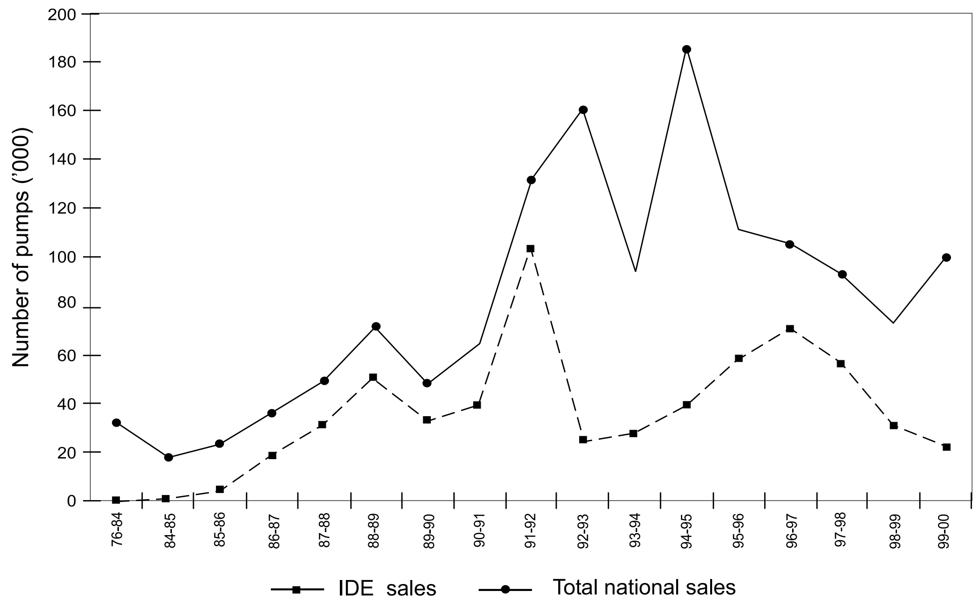
IDE-India has evolved a totally different strategy in which it presides over a tightly run network of TP manufacturers, distributors, dealers and *mistrys.* A small number of manufacturers makes TPs to IDE specifications and markets them solely under the *Krishak Bandhu* brand name owned by IDE. They are marketed through an IDE appointed network of distributors and dealers with intensive promotional support from an impressive IDE field organization. All strategic marketing decisions on the retail price, marketing margins at each level, and designs to be promoted, are made by IDE, which assumes direct responsibility for quality control by deploying its own quality-control staff at manufacturing facilities.

IDE recognizes that the litmus test of the ultimate success of TP technology is the volume of sales. In Bangladesh, it is claimed that some 1.3 million pumps[8] were sold since the mid-1980s, including replacement demand (fig. 9). The bulk of these sales occurred in a 3-year TP boom during the mid-1990s. Eastern India and the Nepal Terai have an ultimate market potential of some 10 million TPs (Ananda Mohan De, quoted in Bhanot 1999) but the total sales in eastern India and the Nepal Terai have only reached the 200,000 mark and IDE has a long way to go to reach the market potential.

[8]This magic figure of 1.3 million for TP sales in Bangladesh that has been reported in various IDE documents is not based on a census. There is, however, much indirect support to the proposition that annual production of TPs in Bangladesh during the first half of the1990s has been in the neighbourhood of 145,000. The MRC-MODE (1993) study enumerated and surveyed over 35 manufacturers with an average production of 3,600 units per year, and estimated the total TP production of Bangladesh in 1993 to be 155,000. If 85-90 independent private producers sustained production at 130-150 thousand for several years in a row, it is reasonable to believe that the annual demand would be in that range too, since most of these small time operators would find it prohibitive to carry large inventories. In fact, based on their survey, MRC-MODE (1993:29) concluded that even big manufacturers carry hardly any inventory from year to year; and dealers and wholesalers would generally not keep large stocks of a product that is not moving fast. Taking these factors into account, it does seem reasonable to suppose that Bangladesh has sold more than a million TPs although probably no more than 700-800 thousand are in operation after making allowance for asset retirement. Gunner Barnes, the Norwegian engineer who invented the TP, thinks 1.3 million may well be an underestimate (personal communication of 20 October 2000).

FIGURE 9.

Treadle pump sales in Bangladesh, 1986 to 2000.



Source: Metha 2000:14.

Research Issues

Four aspects of TP technology make the study of its social impact interesting and important. First, the claim is not merely that TP technology is financially and economically viable but its income impact (claimed to be US$100 per year per adopter household) is *disproportionately high* compared to its capital cost (US$20 per pump). Second, the technology has the unique property of self-selecting the poor, which makes it ideal as a poverty-reduction intervention. Third, the potential that the TP technology offers for substituting muscle power for fossil fuel—and the positive externality that so results—does not enter the market calculus.[9] Fourth, indirect impacts of a growing TP economy too would fail to get reflected in market valuation. For example, producing, marketing, replacing, and servicing a large population of TPs themselves would create new employment and livelihoods. These are important social benefits in conditions

[9]South Asian pump irrigation—supported in 2000 by at least 15 million diesel pumps—most likely uses up some 4.5-6.0 billion liters annually of diesel-equivalent of nonrenewable energy (valued in India at US$1.70-2.25 billion in 1999). In areas with deep watertables, there is no alternative to diesel or electric pumps; but in eastern parts of South Asia, gainful opportunities for efficient substitution of muscle power for fossil fuels can create a positive "externality" that might be an important beneficial impact of TP technology. But a small farmer is unlikely to buy a TP because it will save diesel for his country or spare the world a bit of global warming.

of large-scale, open or disguised unemployment. In this report, however, we focus on the central research question: "Is TP technology really capable of raising the net income of its South Asian adopters by anything like a billion dollars a year?"

Besides a number of mostly unpublished studies that we have drawn upon, we test the veracity of the claims made about TP technology based on a 1998 survey of some 2,400 households. These households are from 12 villages selected from 6 locations, north Bihar, north Bengal, eastern Uttar Pradesh, coastal Orissa, the Nepal Terai, and Bangladesh (see table 2 for a profile of the households surveyed and table 3 for the general profile of the locations). Only 300 of these households had purchased TPs; just 158 owned diesel pumps, 550 households were landless, and 1,360 were land owning but without pumps. The density of diesel pumps is an indicator both of the degree of mechanization of agriculture as well as the depth and breadth of the pump irrigation market. As fig. 10 shows, there are wide variations in this across locations, and these have major implications for the uptake of TP technology, as shown later in this report. Table 3 shows that in locations other than Bangladeshi villages, the history of TP use is short, and the spread of the technology too is limited; in that sense, this assessment is somewhat premature. It also suggests that the introduction of TP technology has replaced rain-fed farming, other forms of manual irrigation, and irrigation with purchased diesel pumps; besides, it has induced the cultivation of new crops.

TABLE 2.

Profile of the surveyed households.

	Treadle pump owners	Diesel pump owners	Pumpless smallholders	Landless households	All households
Jaipur, Nepal Terai	11	2	56	13	82
33-Bigha, Nepal Terai	54	1	76	11	141
Haldimohan, north Bengal	43	30	321	80	474
Salajunga, Orissa	23	7	101	23	154
Tharuwadih, eastern Uttar Pradesh	28	51	417	109	604
Dostpur-Khairabi, north Bihar	31	47	320	160	558
Khamer-Taherpur, Bangladesh	89	11	22	47	169
Sreepur, Bangladesh	21	9	47	107	175
Total	300	158	1,360	550	2,357

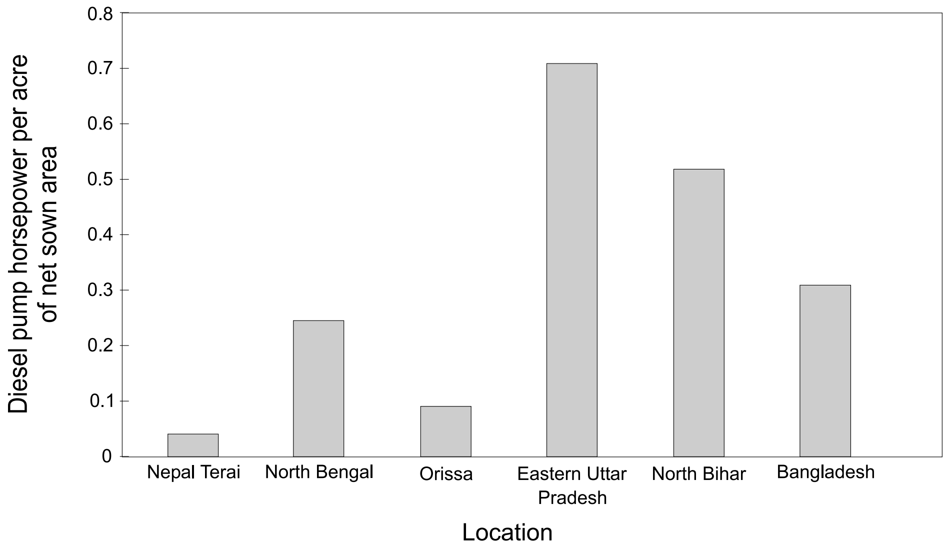
TABLE 3.

Overall pattern of TP usage across locations.

	Nepal Terai	Coochbehar, north Bengal	Puri, Orissa	North Bihar	Eastern Uttar Pradesh	Bangladesh
Breadth of spread of TP technology	Moderate; 1/3 of the target households	Low; 1/7 of the target households	Low; 1/8 of the target households	Low; 1/15 of the target households	Low; 1/20 of the target households	High in Khamer; 1/2 of the target households
Length of experience with TP technology	2-3 years	1-2 years	1-2 years	2-3 years	2-3 years	10-12 years
Deepening of machine culture in irrigated agriculture	Low: only 3 diesel pumps in 2 villages for 200 households and 340 acres	Moderate: 30 diesel pumps for 400 house-holds and 550 acres	Low: 7 diesel pumps for over 200 households and 350 acres	High: 47 diesel pumps for 560 house-holds and 300 acres	High: 51 diesel pumps for 600 households and 450 acres; threshers and tractors widely used	Moderate: 11 diesel pumps for 170 households and 160 acres
What did the newly introduced treadle pump technology replace?	Rain-fed farming; manual irrigation devices like *dhenkuli* and *karin*	Rain-fed farming; swing basket; purchased pump irrigation water	Rain-fed farming; *tenda* irrigation; purchased pump irrigation water	Rain-fed farming; hand pump irrigation of vegetables; purchased (diesel) pump irrigation water	Rain-fed farming; purchased pump irrigation water	Rain-fed farming; swing basket; purchased pump irrigation water

FIGURE 10.

Diesel pump density (horsepower per acre of sown area) of study locations.



Evidence: Who are the First-Generation TP Adopters?

A major challenge in designing poverty alleviation programs is how to avoid directing these programs at the wrong targets, by minimizing the proverbial α- and β-errors.[10] In this context, the hypothesis about the propensity of TP technology to self-select the poor is critical. If true, in a random selection of TP adopters, the poor should dominate and in a random selection of the rural nonpoor with an opportunity to adopt TPs, non-adopters should dominate (fig. 11). The 1998 survey of the sample of 2,400 households shows (fig. 12) that the TP adopters come second to diesel pump owners in terms of landownership; they are not the poorest landowners, and certainly not the landless. In this sample, the households that do not own pumps are far more numerous, and in some ways worse off, than the landless.

Other studies support this conclusion. The AIMS (1997:204) study, in a survey of 400 adopters and 200 potential adopters, found that the average size of landholding of TP adopters is higher than the overall average by 15 percent in Orissa, 66 percent in Bihar, 55 percent in

[10]In this particular context, α-error would mean the exclusion of the poor in a poverty alleviation program and β-error would mean the inclusion of the nonpoor. The sum of the two reflects the cost of choosing the wrong target, which is known to be high in most poverty alleviation programs. For example, the hand pump technology consumed huge subsidies but its targeting was always problematic. The Orr et al. (1991) study of Bangladesh concluded that the TP targeted the poor better than the No. 6 hand tubewell (HTW) pump because of the latter's much higher capital cost. The average landholding of HTW adopters (in the 1975-76 survey) was 1.54 ha while it was targeted at those with 0.61 ha or less. They found that the average TP adopter owned 0.25 ha of land.

FIGURE 11.

The treadle pump self-selects the poor.

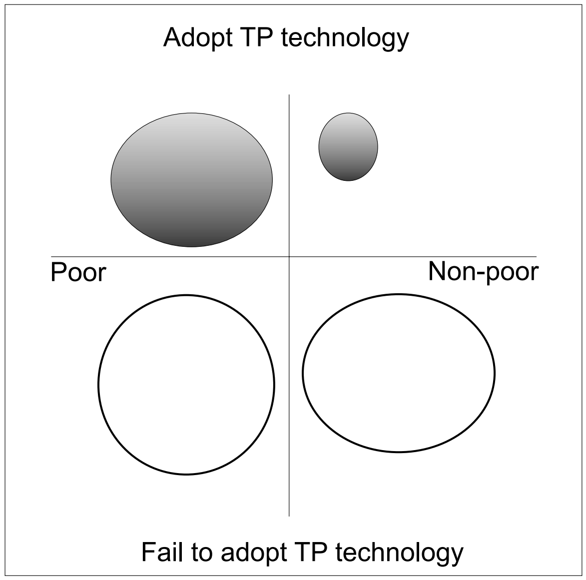
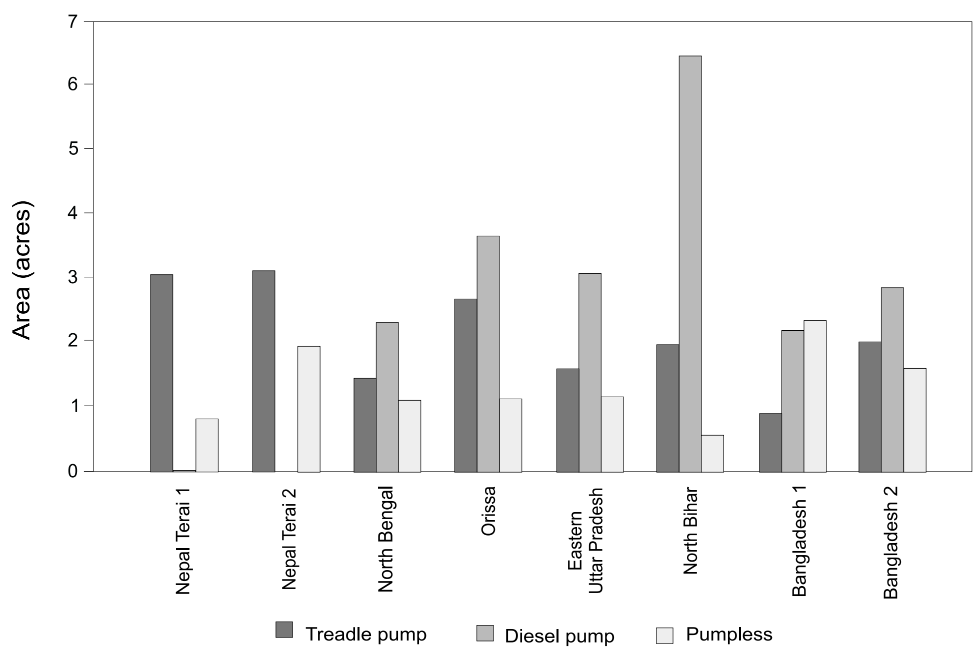


FIGURE 12.

Average landholding (acres) of households in the sample areas.



Note: 1.0 acre = 0.4047 hectare.

TABLE 4.

Results of two independent studies (1995) in Puri district (Orissa) and Gorakhpur mandal (eastern Uttar Pradesh).

Item	TP users	Buyers of pump irrigation water	Diesel pump owners	Non-irrigators
Mallik (1995): Results of a survey of 20 households each				
Sample size	19	20	20	20
Backward castes	17	19	18	20
Operated holding area (acres)	3.2	3.07	4.69	1.94
Shah, Indu and Paleja (1996): Treadle pump study in eastern Uttar Pradesh				
Sample size	95	151	134	NA
Average operated area (acres)	2.014	1.65	4.23	NA

Notes: 1.0 acre = 0.4047 ha; NA = not available

north Bengal and 17 percent in eastern Uttar Pradesh. Similar results were obtained in an earlier survey of a sample of TP adopters in the Balasore district of Orissa (RCDC 1994:4) and in the Orr et al. (1991:35) study in Bangladesh. A 1995 survey of 80 farmers in Puri district by R. M. Mallik, a Bhubaneshwar-based economist, and a 1995 survey of 300 farmers in Gorakhpur mandal by Shah, Indu, and Paleja (1996) also reached similar results (table 4).

This has led to the "TP trickle down" hypothesis: first-generation TP adopters, who are pioneers in some sense, tend to be less poor; over time, as the technology blends into the social fabric, the poor tend to adopt it and the less poor, early adopters seem to acquire diesel pumps or simply switch back to buying irrigation water sold by diesel pump operators. Limited evidence from two Bangladesh villages offers some indirect support to this suggestion. In Khamar-Taherpur, the Bangladesh village where TP technology was introduced in the late 1980s, many early adopters were not marginal farmers and, over time, rejected the technology in favor of buying diesel pumps or purchasing irrigation water. The poorest in the village adopted the TP after a lag of several years but stayed with it. In the control village (Sreepur), where the technology was just introduced, this same scenario is being played out again. As shown in fig.12, the average landholding of TP adopters in the first village (Bangladesh 1 in fig. 12) is less than that of diesel pump owners as well as pumpless farmers. However, in the control village (Bangladesh 2 in fig.12), the average landholding of TP adopters is greater than that of pumpless farmers.

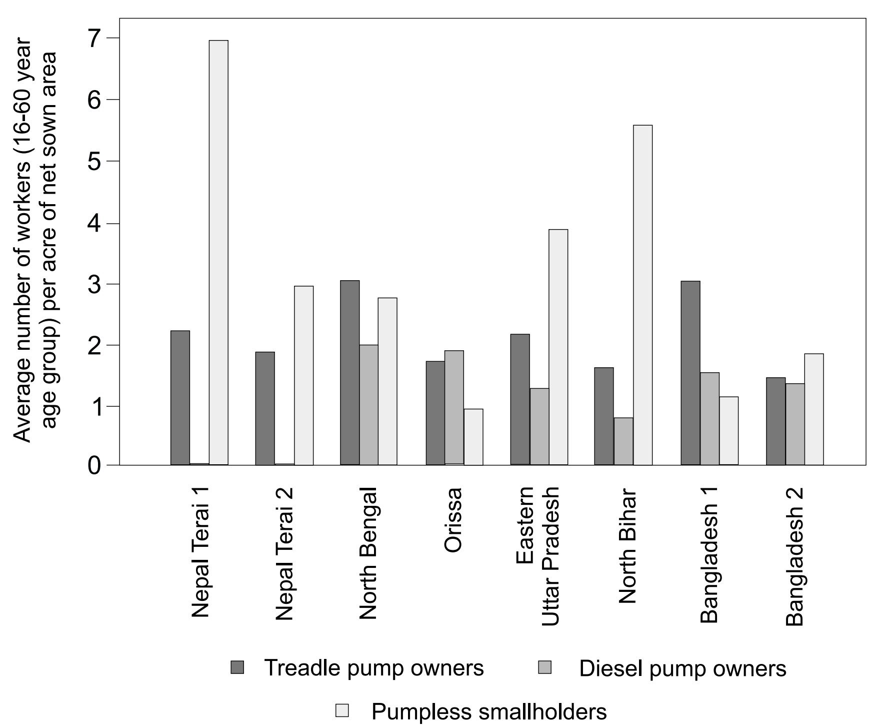
Abundant family labor is a crucial requirement for TP adoption and, a priori*,* we should expect labor-surplus families to embrace TP technology more than others. Suggesting that "the farmers using TPs in irrigation are marginal landholders having large family sizes," HURDEC (n.d.: 1) compared family sizes of adopters and non-adopters but did not find the difference significant. The findings of the AIMS (1997) study were similar: the average adopter and non-adopter family sizes were, respectively, 6.5 and 6.1 persons in Orissa, 5.5 and 4.86 in north Bengal, 8.1 and 7.6 in Bihar, and 8.2 and 7.4 in eastern Uttar Pradesh. But adopters also have larger landholdings relative to the pumpless and their labor to land area ratio may be lower than that of the pumpless households. If we take family labor per unit land area as a measure of family labor availability, then the survey provides only weak support for the presumption that labor-surplus families embrace TP technology

more than others (fig. 13). Indeed, the pumpless households almost everywhere have more family labor per unit of cultivated area compared to TP adopters. Again, the limited evidence from Bangladesh points to the need for a more nuanced understanding of the TP adoption process. In the case of the two Bangladesh villages, we find that in the study village, which has had a longer "adjustment period," those households with more family labor have stuck to TP irrigation. In the control village, the first generation TP adopters, like elsewhere in India and the Nepal Terai, have been those who have had more resources and dynamism rather than abundant family labor.

Factors like the availability of investable funds, capacity to cope with uncertainty and risk, and access to knowledge influence first-generation TP adoption more than the "TP fundamentals," such as the availability of surplus family labor and holding size best suited for TP irrigation, which determine the intrinsic comparative advantage that the technology offers. After some time, however, a "shakeout" seems to occur, with large landowners who find TPs to be unsuitable dropping out, while smaller landholders adopt the technology and stick with it. Another overarching pattern that emerges is that certain communities—such as the *Malis* in eastern Uttar Pradesh and the *Khushwahas* in north Bihar that are traditional vegetable growers and sellers, and Bangladeshi Muslims in north Bengal who are driven by the refugee work ethic—are enthusiastic first-generation adopters. The farming system embraced by these communities is in some fundamental ways different from the "grain-based" farming systems.

FIGURE 13.

Availability of family labor and TP ownership.



Empirical Evidence: Direct Impacts of TP Irrigation

Is TP Technology Land Augmenting?

On the impact of TP irrigation on smallholder farming, a major claim often made is that it frees the farmer from dependence on rain-fed irrigation and provides the capacity to raise crops in winter and summer. For the poor farmers constrained by the small size of their smallholdings, TP technology can work as a land-augmenting intervention. Does this really happen? The answer is yes, it does happen, but the gains seem insignificant and variable across locations (table 5 and fig. 14). In the Nepal Terai and north Bengal, the land-augmenting impact of irrigation per se seems doubtful. In Orissa, the land-use intensity of TP adopters and non-adopters is comparable and significantly lower compared to diesel pump owners. Our conjecture is that this is because all marginal farmers in the Orissa villages close to towns place a great deal more emphasis on vegetable growing using a variety of traditional muscle driven irrigation devices whereas the diesel pump owners rely more on grain-based cropping patterns. Moreover, vegetable-based smallholder farming systems are driven not by the size of the area under cultivation but by the intensive use of green-revolution inputs and family labor. In eastern Uttar Pradesh and north Bihar, the land-augmenting impact of TP irrigation is significant. Because there are very active diesel pump irrigation water markets here, TP adopters use a skillful mix of purchased irrigation water and TP water to get the best of both technologies. They use TPs exclusively for vegetables but use the mix for grain crops. So effective seems to be this combination that in both the regions, larger farmers with diesel pumps too have taken to TP irrigation, not as the mainstay of their farming but as an

TABLE 5.

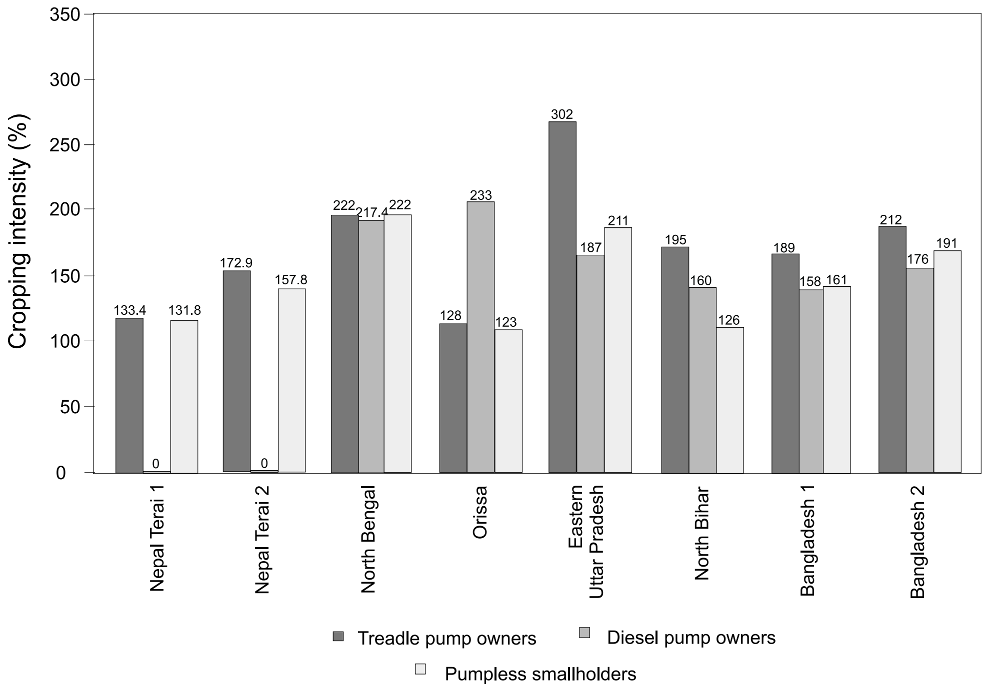
Land-use intensity (%) achieved by the different groups of the study sample.

	TP owners	Diesel pump owners	Pumpless smallholders
Nepal Terai 1	133.4	n.a.	131.8
Nepal Terai 2	172.9	n.a.	157.8
North Bengal	222	217.4	222
Orissa	128	233	123
Eastern Uttar Pradesh	302	187	211
North Bihar	195	160	126
Bangladesh 1	189	158	161
Bangladesh 2	212	176	191

Note: n.a. = not applicable.

FIGURE 14.

Cropping intensities achieved by TP owners, diesel pump owners, and pumpless smallholders.



ingenious method of optimizing between cash and food grain crops. [11]

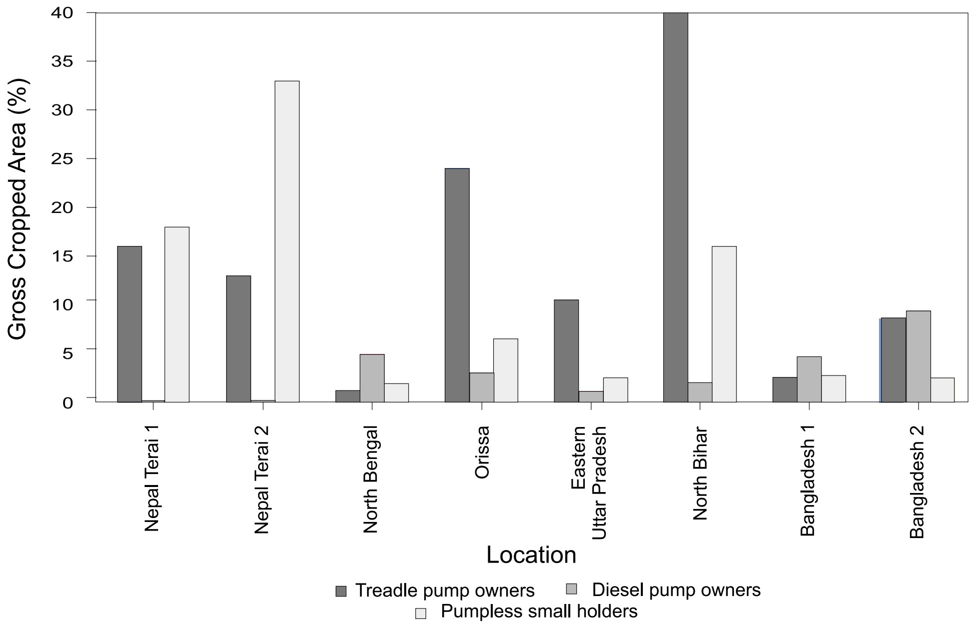
Other studies provide clearer and more positive evidence on the land-augmenting impact of TP adoption. The Orr et al. (1991: 45-46) study in Bangladesh, for example, found that:

- 31 percent of the land that was previously left fallow in the boro or rabi season was brought under cultivation;
- more lowlands than uplands came under cultivation;
- more land that was previously fallow was brought under boro or winter cultivation in Pirganj where the focus of TP adopters was on modern boro rice cultivation rather than vegetable cultivation; and
- in Aditmari, farmers grew more vegetables.

[11]There is little "pure" rain-fed farming in this region. Therefore, our comparison mostly is of TP farmers with farmers using other forms or sources of irrigation. In the Nepal Terai, it is with farmers using artesian springs or *karins,* a traditional water lifting device for irrigation. In north Bengal, the comparison is with the pumpless who are dependent either on rain-fed farming or purchased pump irrigation water. In Orissa, many pumpless farmers used tenda and performed as well as TP adopters in vegetable cultivation. Because manual irrigators in the Orissa village were close to important retail vegetable markets, their incomes from vegetables were actually higher than that estimated here using average farm-gate prices. In eastern Uttar Pradesh, the comparison is with the pumpless who are dependent on purchased diesel pump irrigation water. Income from vegetables is somewhat overstated because "upper caste" TP owners do not sell vegetables but distribute their surplus among friends and relatives. *Koiris*, the main TP adopter group here, however, are specialist vegetable sellers. TP owners in eastern Uttar Pradesh commonly use their pumps for supplementary irrigation for rice or wheat during periods of moisture stress. In north Bihar, the comparison is with smallholders who used hand pumps for irrigating vegetables but also purchased diesel pump irrigation water. In both the Bangladesh villages, purchased diesel pump irrigation water was the mainstay of the pumpless. Here, the average pumpless household in the sample had a significantly larger landholding and Gross Cropped Area. Although TP adopters obtained significantly higher yields of all the TP irrigated crops, the smaller average area under crops compared to the pumpless reduced their output per household.

FIGURE 15.

Gross Cropped Area (%) under vegetable crops in the sample areas.



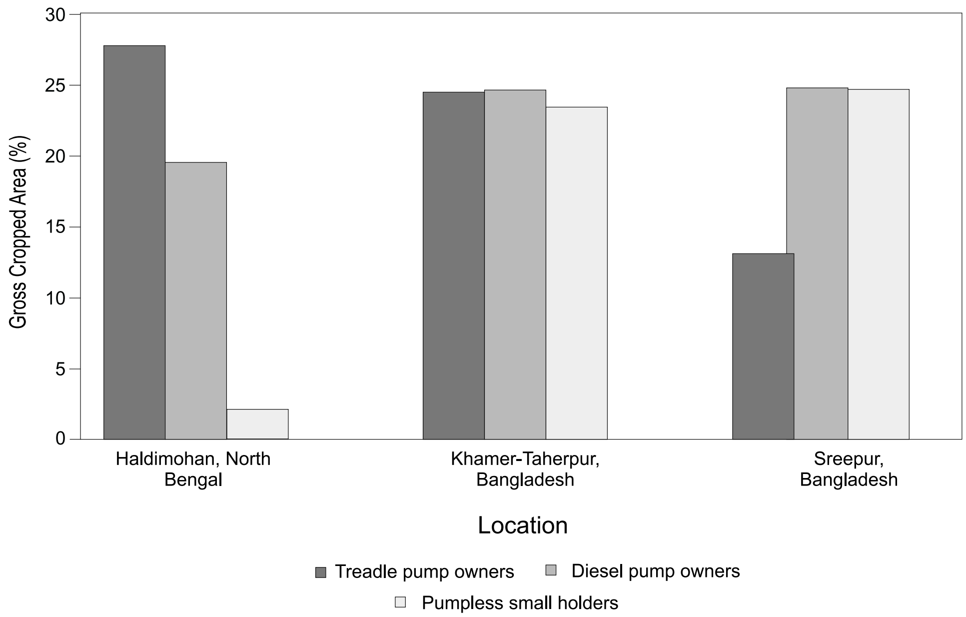
Cropping Pattern

Among the changes that TP adoption seems to bring about, changes in the cropping patterns and farming systems adopted by smallholders are more significant. TP technology enables farmers to grow crops they were not able to grow earlier, and potential TP adopters identify this as a Unique Selling Point (USP) of the TP. For example, farmers could cultivate "china boro," a highly popular, high-yielding rice that performs best with intensive application of inputs and deft water management, using TP irrigation. In north Bengal and Bangladesh, china boro is considered a prize crop. In the Nepal Terai and eastern Uttar Pradesh, the TP has emerged as a specialist "vegetable grower pump" so much so that many diesel pump owners maintain a TP on the side to water their vegetable plots (fig. 15). In Bangladesh, although the "vegetable grower pump" stereotype is well entrenched, the uses of TP irrigation are more diversified and include its use for cultivation of china boro. And these patterns get amply reflected in the cropping patterns that emerge from our survey. In north Bengal, the TP impact on increased china boro cultivation is very striking. However, in the Bangladesh villages, pumpless farmers irrigate china boro with purchased irrigation water at a huge cost. In Sreepur, the control village where TPs arrived recently, adopters took to vegetable cultivation in a major way.[12] In

[12]M Alam, who carried out the Bangladesh study, however, suggested that if the farmers were given a free choice, there would probably be more TP irrigated china boro in Sreepur than he found in the course of his survey. Most TPs in Sreepur were supplied by an NGO, which obtained an undertaking from the adopters that they would use it only for growing vegetable crops!

FIGURE 16.

Gross Cropped Area (%) under boro rice: North Bengal and Bangladesh.



Orissa, eastern Uttar Pradesh, north Bihar and the Bangladesh control village, the cropping patterns adopted by TP users is significantly tilted in favor of vegetable crops (fig. 16). In the two villages of the Nepal Terai, there is no significant difference in cropping patterns between adopters and non-adopters, presumably because the watertable is so close to the ground that most non-adopters irrigate from artesian springs. TP irrigation here does not ameliorate irrigation deprivation in any significant sense, at least in the villages studied.[13] Other studies we came across showed that the Nepal Terai has highly variable conditions and that TPs have brought about far bigger changes than our study of two villages suggests.

Intensive Cultivation in Priority Plots

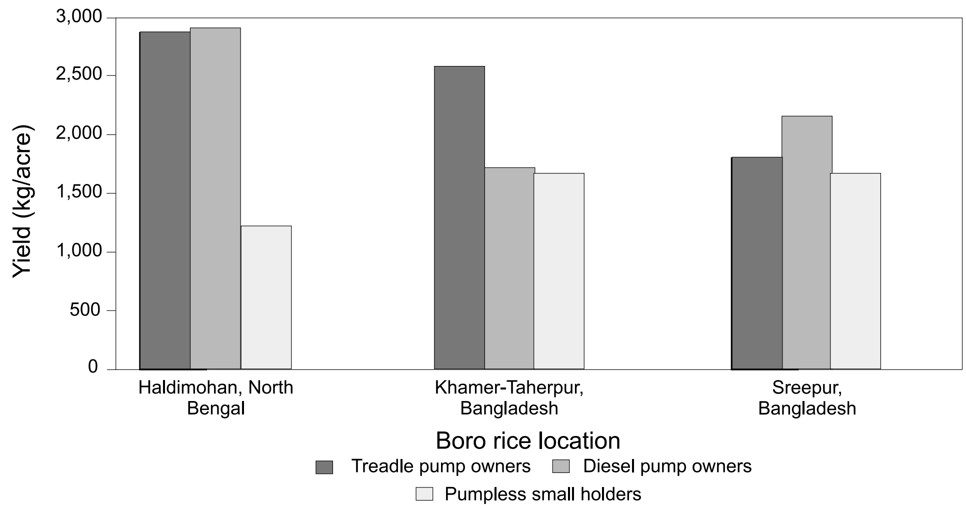
The most significant impact of TP irrigation occurs probably through increases in crop yields. Harvests of TP irrigators are almost always significantly higher than harvests of the pumpless, and often exceeds harvests of diesel pump owners. The yields of china boro in the sample area villages bear this out (fig. 17). In north Bengal, adopters matched the yields of diesel pump owners, which were over twice that of the pumpless. In the Bangladesh study village (Khamer-Taherpur), TP adopters outdid diesel pump owners as well as the pumpless by a factor of 1.6. Diesel pump owners in the control village (Sreepur) obtained higher boro rice yields;

[13]The HURDEC (n.d.) study compared the results of a survey of 100 TP adopters in the Nepal Terai. It found that before TP adoption nearly half of the adopters surveyed used hand pumps, a quarter used diesel pumps, canals, rower pumps, buckets or springs, and only a quarter pursued rain-fed farming. However, it concludes differently on the impact of the TP. It found that: “Crop production after the installation of TP has dramatically increased. Varieties of vegetables cultivated in winter and summer have increased in number and quantity; the number of farmers practicing vegetable cultivation has also gone up to 85 percent … (these grow) three to forty vegetables in winter. The farmers have been attracted towards cultivation of vegetables even during the summer, which brings them immediate returns in monetary terms.” Since the HURDEC study does not look at non-adopters at all, it is somewhat hard to be sure if the increased spread of vegetable cultivation is *because of* TP adoption or whether it is a more generalised phenomenon.

The Orr et al. (1991) study found new crops grown—much more on uplands than medium lands—included cabbage, wheat, tomato, spinach, potato, onion and several others.

FIGURE 17.

Impact of treadle pump: Boro rice yields.



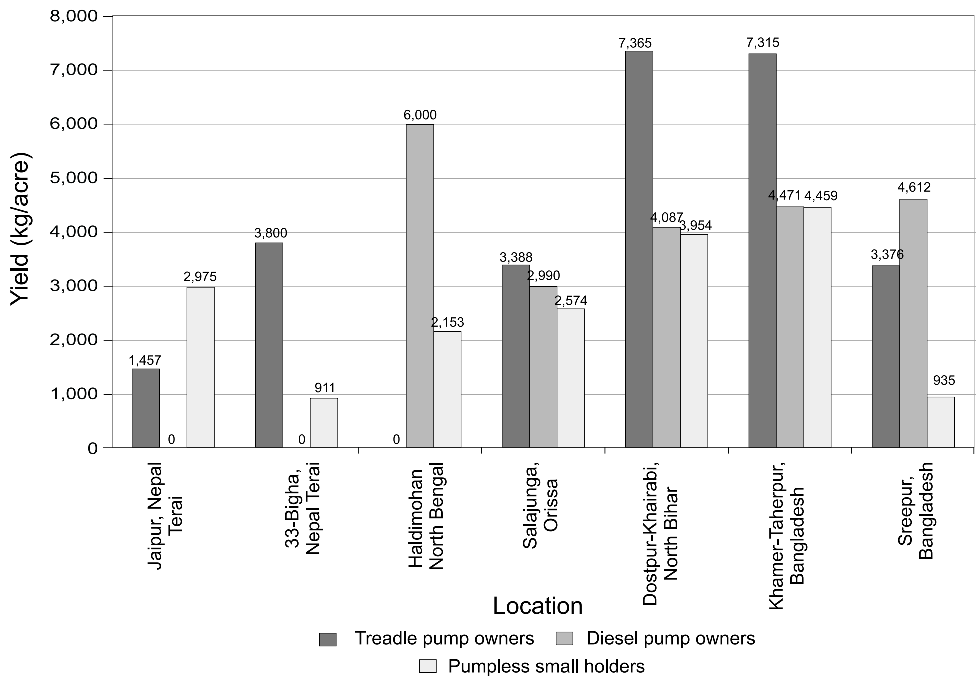
Note: 1.0 acre = 0.4047 hectare.

but as we noted earlier, the focus of TP owners was on vegetables of which they harvested 20 mt/ha. In the north Bihar site, the *koiri* TP adopters, with generations of vegetable growing experience, harvested an unbelievable 45 mt/ha of green vegetables, inspiring some *Thakurs* too to take to TP irrigation just for their vegetable plots. The story is the same with potato (fig. 18), which became the preferred crop of TP adopters across locations. Barring the Nepal Terai, adopters harvested significantly higher potato yields compared to the pumpless as well as diesel pump owners. In eastern Uttar Pradesh and north Bihar, TP owners harvested average potato yields in the neighborhood of 16-17 mt/ha, which are 60-70 percent higher than the yields of diesel pump owners. When the production per farming household is considered, TP owners do not seem to be badly off. What they could not obtain due to constraints of size of landholding they more than made up for through various combinations of higher crop yields, better cropping intensity, and more high-value crops such as boro rice, vegetables and potato (fig. 19).

Why do TP adopters obtain better yields compared even to harvests of diesel pump owners? Farmers offered several answers: Managing the water output of a 5 horsepower diesel pump on a small plot is difficult and a good deal of the fertilizer they apply get leached. TP users manage their water better and, because they irrigate slowly and not in bursts, their plots retain the fertilizer applied in the root zones of crops. Many farmers suggested that TP users end up spending much more time on their fields compared to others or than they did earlier, and this makes them “reflective farmers” who take care of their crops better. A more plausible reason, however, is the priority farming of TP irrigated plots. As it is not possible to handle more than 0.7 acre (0.28 ha) with TP irrigation, TP users shower their TP irrigated crops with an enormous amount of green-revolution inputs, care and family labor, while growing low-risk crops on the rest of their

FIGURE 18.

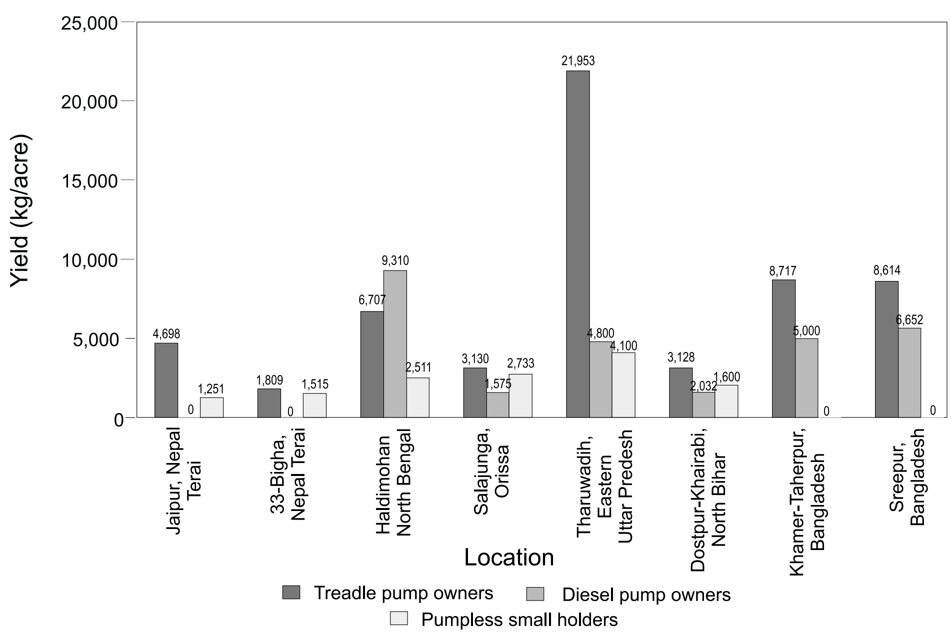
Impact of treadle pump: Potato yields.



Note: 1.0 acre = 0.4047 hectare.

FIGURE 19.

Impact of treadle pump: Green vegetable yields.



Note: 1.0 acre = 0.4047 hectare.

holding or leaving it fallow.[14] For those located close to vegetable markets, this strategy paid off handsomely; even TP adopters in north Bengal and Bangladesh who cultivated china boro were well rewarded.[15]

The Mallik survey of farmers in the Puri district of Orissa in 1995 concluded somewhat differently. It found that the primary benefit of TPs is increased land-use intensity and savings on costly purchases of diesel pump irrigation water. Somewhat surprisingly, it found no significant difference in vegetable cultivation of TP users and diesel pump irrigation water users. It found that for all groups, vegetables accounted for 10-12 percent of the Gross Cropped Area. However, the 1995 survey of Gorakhpur mandal by Shah, Indu and Paleja (1996) showed, as our more recent study in Gorakhpur mandal does, that TP adopters grow much more vegetables in relative and absolute terms compared to others. However, this survey did not capture higher cropping intensity as a significant TP impact in eastern Uttar Pradesh. On crop yields, TP adopters do distinctly better than diesel pump irrigation water buyers, and this might well be because of the greater irrigation-independence that TP adopters enjoy. Moreover, it is likely that farmers who buy water from diesel pump owners end up over-economizing on their costly irrigation water, which TP adopters probably are not forced to do. Interestingly, however, all TP adopters surveyed were also water buyers and for wheat they actually applied more purchased irrigation water per acre than even water buyers without TPs did. This probably means that adopters do not necessarily save a lot on irrigation cost, as the Mallik survey of Orissa showed. The main gain of TP adoption here is substantially higher crop yields in wheat and rice and a lot more vegetable cultivation.

Income Impact

Measuring increased income *as a result of* TP technology is difficult as it entails comparative analysis of farm budgets. Our study was not designed to do that, nor were the others we have cited. We assumed that if TP adoption significantly influences intermediate variables such as cropping intensity, cropping patterns, and crop yields, then the income impact hypothesis gets simultaneously tested, albeit indirectly. And all the evidence we have analyzed on these variables suggests that TP adoption results in significant increases in these intermediate variables and hence in the net income of adopter households. The Orr et al. (1991) study estimated net benefits per crop per hectare to range from US$120 to US$440. It also estimated the return on investment in TP to be high; the benefit-cost ratio at 3.4 and the internal rate of return (IRR) at 50.9 percent. The payback period was one season (ibid. p.58); 93 percent of the 151 farmers surveyed recovered their capital investment in one season. The figure of US $100 per household as a rough estimate of the value of annual benefit (which includes cash income, improved home

[14]The HURDEC (n.d.: 5) study concluded similarly: "(treadle pump adopters] used the treadle pump to irrigate a small area of their land … (for) the cultivation of something different from the usual traditional practice of rice and cereal production." Elsewhere, it notes, "the cultivation practice of farmers has changed. Earlier, it was confined to summer cultivation and paddy production … (now) cash crops have been the prime attraction. Cultivation is carried out in summer and winter. Many farmers have been cultivating even three times focusing on crops like chillies. Their use of fertiliser and higher-yield seeds has increased. The most remarkable benefit ... is increase in vegetable selling."

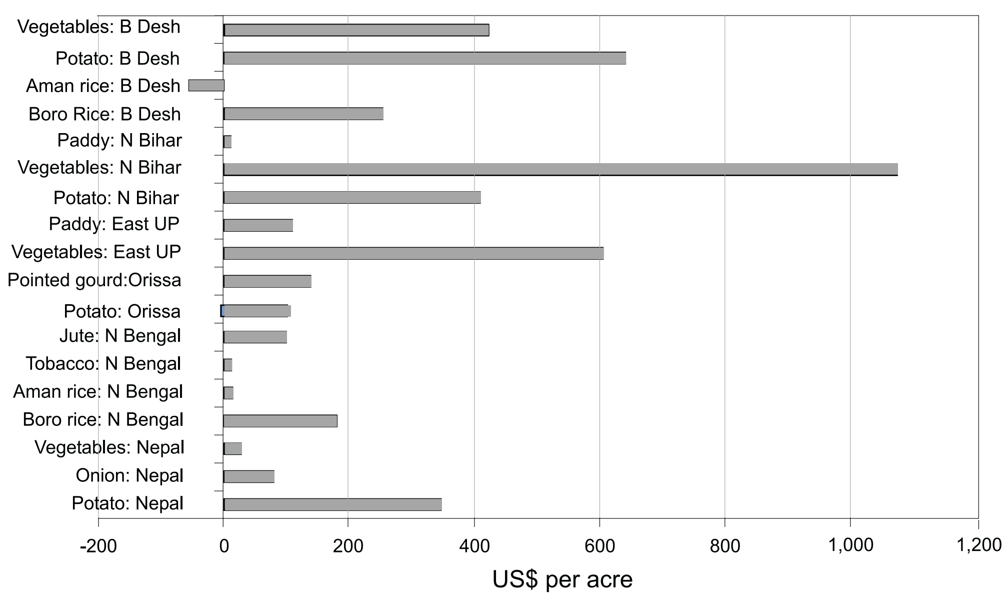
[15]The study did not seek information on farm-gate prices, marketed surplus and income from the sale of farm products. The values presented here are estimated using average farm-gate prices for all locations. There are huge variations in farm-gate prices of agricultural products across space and time. The prices used to compute the value of increased output were those collected in the course of fieldwork. The farmer prices used are: china boro, US$11/qtl of paddy; *aman* paddy, US$13.5/qtl; potato, US$12/qtl; onion, US$14.5/qtl; green vegetables, US$9/qtl; tobacco, US$23/qtl; Jute, US$19/qtl.

consumption, and saved cost of purchased water), first suggested by Paul Polak, has emerged as a sort of “income-impact hypothesis.” Our analysis suggests that while there are wide variations across households as well as regions, US $100 is probably a conservative estimate of the average net benefit per household created by TP adoption. There are many indications that the *average* is probably significantly higher for a significant proportion of TP users. One indication is the substantial increase in the yields of high-value crops under TP irrigation as fig. 20 shows. A gross income of US$300-400 per acre is common, especially because the post-adoption cropping patterns get reoriented towards high-value crops (fig. 21). The cash costs of green-revolution inputs also increase very substantially compared to the pre-adoption situation; however, cash costs of inputs are within 10-15 percent of the gross income.

The gross income per acre (0.4047 ha) is only a distant relative to the net income per household as most adopters irrigate much less than an acre with their TPs. Fig. 21 shows the increase in the gross income per household *because of* TP adoption. This takes into account changes in cropping pattern and cropping intensity, and even loss of crops grown earlier—such as *aman* and *aush* rice and jute in Bangladesh and north Bengal—due to intensive cultivation of TP-irrigated crops. And even if we take 25 percent of the total cost as the input cost (excluding the imputed value of family labor), the net income estimates in all locations, except the Nepal Terai and Orissa, would be around or substantially greater than US$100 per adopter household.

A study recently completed in the Nepal Terai (HURDEC, n.d.), which used a more appropriate “before-and-after” methodology, offers more categorical evidence on the income

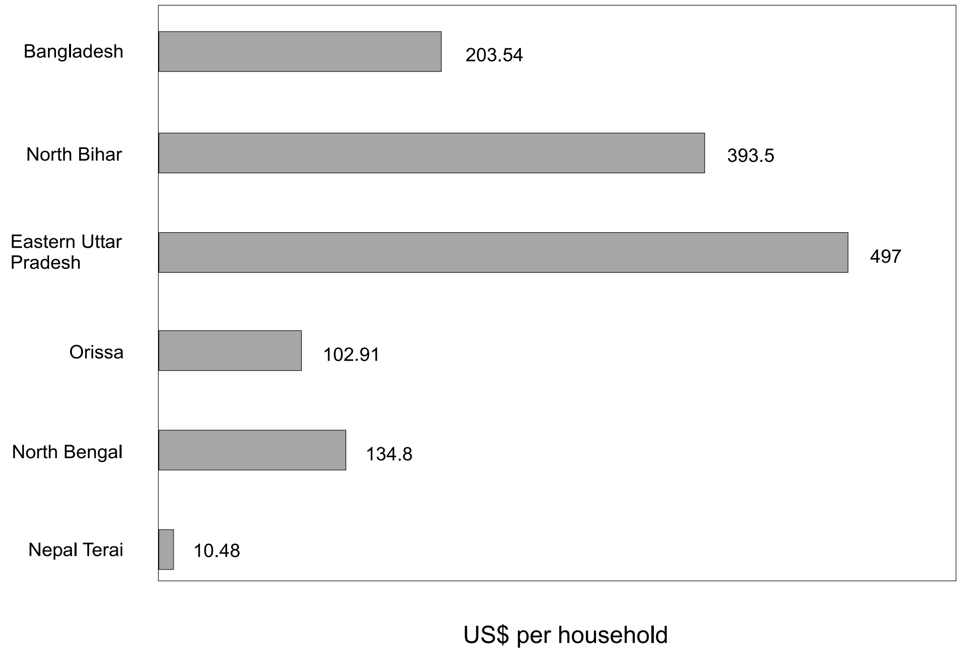
FIGURE 20.
Treadle pump income impact: Increased value of output (US$ per acre).



Notes: 1.0 acre = 0.4047 hectare; B Desh = Bangladesh; N Bihar = North Bihar; East UP = Eastern Uttar Pradesh.

FIGURE 21.

Gross farm income (US$) per treadle pump user household.



impact of TP adoption. The HURDEC analysis is based on comparing farm budgets of 100 adopter households before and after they purchased a TP. Although attractive from many angles, this method relies on farmers' recall of past decisions and is often considered open to measurement problems. However, given that the "with-and-without" method we deployed also has problems of measurement and comparative analysis, it is just as well to use this "before-and-after" method based on recall. The HURDEC results are interesting and are shown in figures 22 (gross income and expenses before and after) and 23 (net income before and after). In both the figures, the household data are arranged in ascending order of the net income after adoption.

The HURDEC study shows that for nearly 40 percent of the adopters, TP impact on net household income is in the range of NRs 3,000-4,000 (US$50-70) per household or less. For another 40 percent, it is in the range of NRs 4,000-8,000 (US$70-110) per household. For the remaining 20 percent of enterprising adopters, it is substantially in excess of NRs 8,000 (US$110) per household. This is a pattern we came across in all our location studies too. Depending upon their orientation, adopter households seem to respond to TP technology in two ways. The less enterprising among the poor use it to bring their surplus family labor into productive use and to save on costs of purchasing pump irrigation water. The saving seems to be substantial, except in eastern Uttar Pradesh and north Bihar (fig. 24); their gain is an "implicit wage" for family labor that is 1.5-2.5 times the market wage rate. In contrast, the more enterprising among the poor use TP irrigation to make a transition from subsistence farming to *reflective, small-scale commercial farming.* These farmers seem to spend more, not less, on supplementary diesel pump irrigation as in north Bihar and eastern Uttar Pradesh, because they aim at a substantially higher household farm income. It is

FIGURE 22.

Impact of TP adoption on gross household income from farming: Nepal Terai.

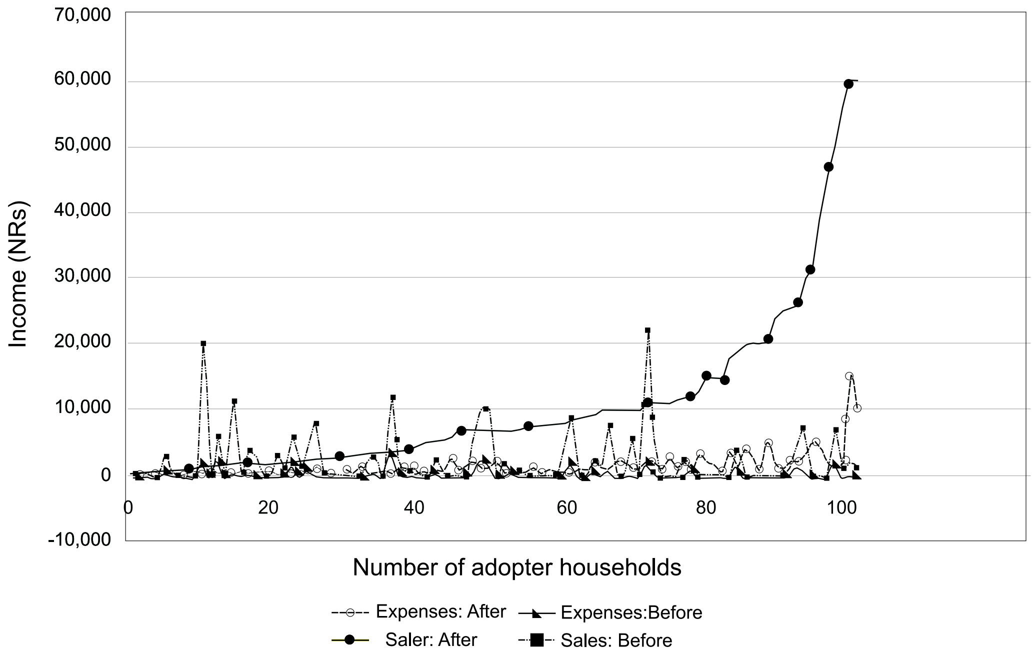


FIGURE 23.

Impact of TP adoption on net household income from farming: Nepal Terai.

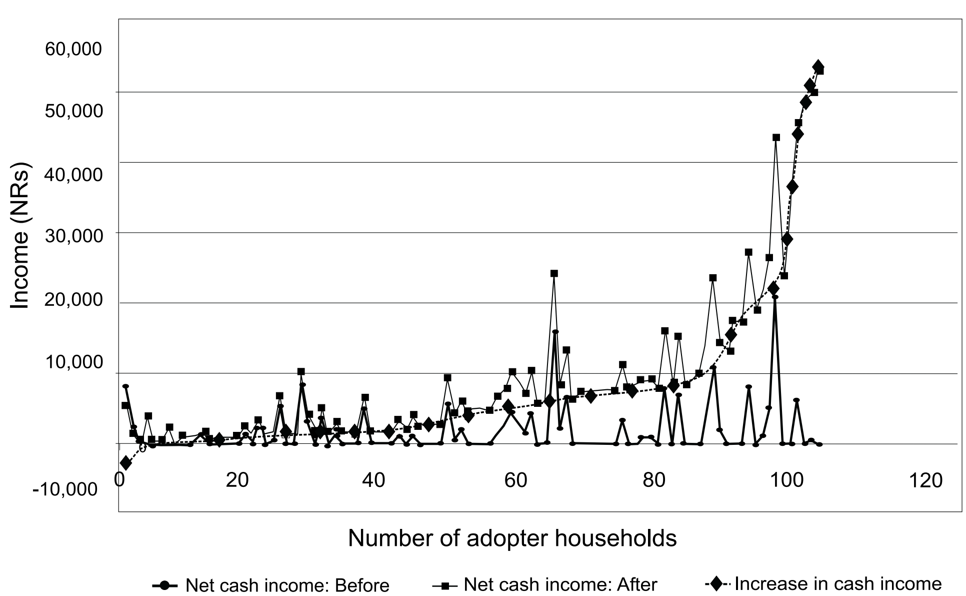
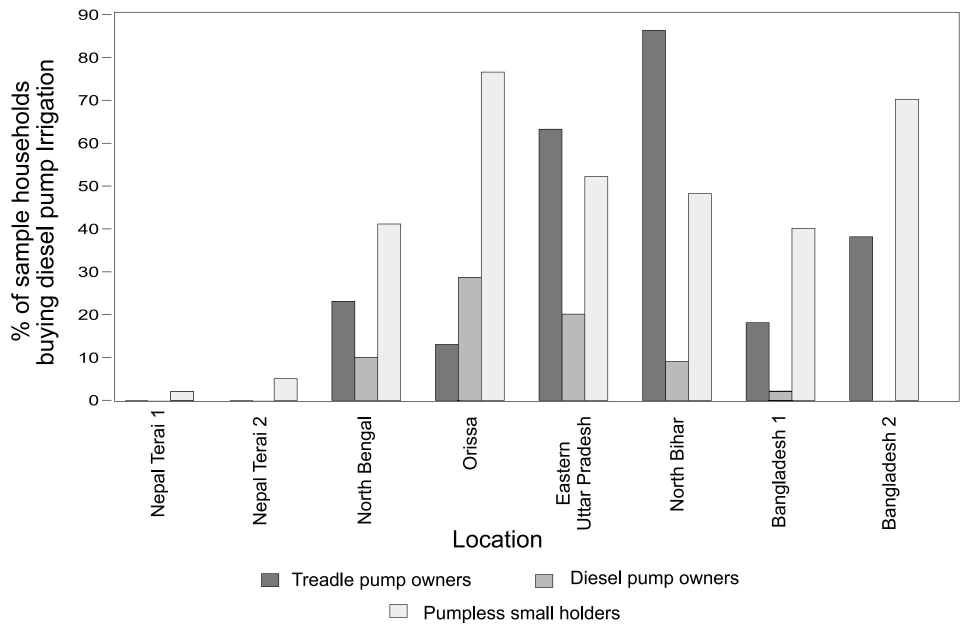


FIGURE 24.

Dependence on purchased diesel pump irrigation water.



these farmers who evolve and use new ideas like early planting to beat the market glut, husbanding hired diesel pump irrigation water with TP irrigation, priority application of inputs, building market linkages, growing new types of vegetables, and so on. Innovating, risk-taking, and searching for new market opportunities, they earn much more from TP irrigation—only a small part of their increased earning is return to their labor; the bulk of it is return to their entrepreneurial effort.

Such examples of "smart smallholder commercial farming" are very common. During a field trip in Bangladesh, we interviewed Abdul Rahim of Morjal village (Thana Raipura, Narsindhi District), one such exemplar, as a demonstration of the best that TP technology has to offer. When we met him in early September 1999, Rahim had already grossed US$1,200 by selling brinjal grown on one *bigha* (0.33 acre or 0.13 ha) over an 8-month period. He had spent US$250 on inputs so far; but 10-12 hours of pedaling per day (by two men taking turns) every day for 6-7 months is what it took to produce a steady weekly supply of 150-160 kg of brinjal for the market. By the time this crop is replaced in the following two months, Rahim would have grossed US$1,600, spent US$350 on inputs, and invested some 400 person days of mostly family labor on a one-bigha plot of what had been wasteland.

In many locations, we found indicative evidence of large-scale emulation by adopters of such remarkably successful entrepreneurial farming—at times, with disastrous effects. In the north Bengal study village, many TP adopters took to tomato and cabbage cultivation in a big way without developing any understanding of the market dynamics, and all of them suffered losses in the glut that ensued. In Coochbehar town, cabbage was sold at less than half a rupee (US$0.01) per kilogram; many farmers fed

cabbage to their livestock. The farmers we met were a frustrated lot who swore they would never cultivate vegetables again. But they sure would and they will think hard about how to beat the market glut. Where small farmers have been using TPs for some time, there is some faint evidence that in this process of “creative destruction,” the TP helps the average adopter to develop “marketing suavity.” For example, based on a survey of farmer perceptions, the AIMS (1997:207) study found that 46 percent of the adopters in Orissa, 65 percent in north Bengal, 34 percent in north Bihar and 39 percent in eastern Uttar Pradesh confirmed that they were able to sell their crops early and beat the market glut. Moreover, except in north Bihar, where only 56 percent thought so, more than 90 percent of the responding adopters confirmed that the use of the TP helped them plan their farming strategies better.

Conclusion: The Billion-Dollar Question

This study has been largely about assessing the livelihood and income impact of TP technology in South Asia. The core hypothesis has been the often-quoted claim by Paul Polak, Chairman, International Development Enterprises (IDE), that every TP sold increases the annual net income of a marginal farmer in South Asia by US$100 (Polak, n.d.; Postel 1999). Our own field research, and our review of other research, support this and suggest that Polak’s claim might even be an underestimate. The implications of this finding are significant for the role TP technology can play in the region. The IDE estimate is that eastern India and the Nepal Terai have an ultimate market potential for some 10 million TPs. If and when IDE does saturate this market potential, it will have probably accomplished one of the world’s biggest and best-targeted poverty-alleviation interventions, by increasing the net annual income of South Asia’s poorest rural households by a billion dollars! The question is, will it and when?.

All the evidence indicates that the technology has established its value; the real challenge now is marketing. To make any worthwhile impact in eastern India and the Nepal Terai, TPs have to sell not in the tens of thousands but in the hundreds of thousands every year for many years. The total sales in India and Nepal so far are around 200,000. This is, by all means, good but it is not good enough to make a regional impact either in absolute or relative terms. But for Bangladesh’s million TPs, the socioeconomic impact of TPs in South Asia would almost be a nonissue.

Why are TP sales not picking up more than they have so far is a source of endless frustration for IDE and its friends. It is certainly not for the want of effort. In our assessment, the IDE marketing organization seems to have worked to its limits. Neither does it seem to be for the lack of professionalism and marketing capability; few development organizations in these regions possess marketing suavity, talent, and professional competence as the IDE does.

Study after study has shown that the TP substantially benefits its buyer. The private benefit-cost ratio on TP investment is in the neighborhood of 5, the internal rate of return (IRR) is variously estimated to be around 100 percent, and the payback period is less than a

year (CES 1997:19).[16] For a marginal farmer with US$12-15 to spare, there are few "capital investment propositions" more attractive than a TP. Considering these, the amplified eastern Indian version of Bangladesh's 3-year TP sales boom in the early 1990s—when it sold over 100-130 thousand pumps every year—should be in place already or should be just around the corner. But nothing of this description seems to be anywhere on the horizon, as TP sales in eastern India and the Nepal Terai show no change in trend and are still behind the 100,000 per year mark. Why in Bangladesh but not in eastern India and the Nepal Terai, in each according to its market potential? This is the billion-dollar question facing IDE. And until there is an answer to this, the TP technology in eastern India and the Nepal Terai will have great potential but limited impact.

Naturally, nobody is more concerned about this question than IDE itself and IDE staff have their own explanations for the failure of the Bangladeshi TP sales boom to cross into India and the Nepal Terai. Among these are:

- TPs were introduced to Bangladesh in the mid-1980s. IDE began work in India, in the real sense, only in 1995 and in Nepal even later, and it takes time to establish a new product.

- The Bangladesh farmer is far more hard working than the farmer in eastern India.

- Loans and subsidies for diesel pumps in eastern Uttar Pradesh deter small farmers investing money in TPs.

- Purchase decisions of marginal farmers are governed by circumstances outside of their control; sale targets were not met due to drought in Bihar (as in 1997), floods in north Bengal (every second year), cyclone in Orissa (as in 1999), etc.

Each of these many explanations may have a grain of truth. But, individually or together, they still do not constitute a *complete* explanation to the riddle why we do not see on the horizons of eastern India and the Nepal Terai any inkling of the kind of sales boom that Bangladesh experienced in the 1990s. It was this sales boom that made the social impact of TP technology a subject worthy of serious study. If many things went "right" for Bangladesh, many others went "wrong" too. In Bangladesh, the TP had to compete with Chinese micro-diesel pumps, whereas in eastern India TPs are amply protected from competition because pumps smaller than the 5 horsepower diesel pump have not been available for a long time. Bangladesh had no recourse to expertise to learn how to promote a technology to the poor on such a massive scale while the IDE in India and Nepal had the experience in Bangladesh to learn from. In Bangladesh, the IDE approach to marketing TPs might have been primitive and amateurish compared to IDE-India's highly professional and strategic approach. The organization that IDE has built up in India for promotion and marketing of TPs provides it a high degree of control over strategic marketing policy variables such as quality, pricing, manufacturing, and marketing margins. IDE-Bangladesh has very little control over the TP economy of Bangladesh.

[16]To be exact, CES (1997) estimated the benefit-cost ratio (BCR) of treadle pump investment to be 5.02, Net Present Value (NPV) of net cash flow to be InRs 21,557 (over US$400), IRR to be 95.78 percent, and the payback period to be 1 year. In comparison, the hand pump was a less attractive investment with a BCR of 3.52, IRR of 29.54 percent, and a payback period of 2 years. The Orr et al. (1991) study estimated treadle pump net benefit per crop per hectare to range from US$120 to US$440; it also estimated the benefit-cost ratio at 3.4, and IRR at 50.9 percent, and the payback period was one season (ibid. p.58). Of the 151 farmers surveyed, 93 percent recovered their capital investment in one season.

More recently, IDE has been wondering whether 10 million is not an excessively optimistic estimate for the ultimate market potential for TPs. Perhaps, it is; but even if the actual potential is 10-20 percent less, the overall picture—and the nature of challenge facing IDE—does not change. Moreover, we know for sure that the bulk of Bangladesh's million TPs are sited in about two-fifths of Bangladesh, and eastern India and the Nepal Terai together are about 10 times the two-fifths of Bangladesh both in terms of the number of small farmers as well as the potential agricultural area suitable for TP irrigation. So 10 million TPs may be an overestimate of the ultimate potential but it might not require a drastic downward revision after all.

A companion study commissioned to document the "IDE Approach" (Mehta 2000) explored the nature and dimensions of the TP marketing challenge in much greater detail than we did and, significantly, Mehta's assessment of the answer to this "billion-dollar question" is remarkably similar to ours—which is that IDE-India needs to do some serious work on four aspects of its business strategy.

Quality: The first aspect is quality. In India, the IDE marketing strategy has placed enormous emphasis on quality control, so much so that its policy on brand building, channel management, pricing, and marketing margins is directly driven by the goal of ensuring high product quality. The quest for high quality has also been the primary driver of product costs. Indeed quality control through its own specialist staff is one of several ways in which IDE-India differs from IDE-Bangladesh. A significant empirical question that comes up is whether the concept of quality that IDE has pursued matches the buyer's expectations from the product and this "investment" in quality has yielded dividends in terms of product acceptance and sales. Our impression is that the few studies that exist in Bangladesh suggest general satisfaction with quality of the whole range of branded and unbranded TPs available (MRC-MODE 1993:52).[17] However, despite such extraordinary emphasis, problems of quality have always been a major TP marketing issue in India; almost every study has commented on quality problems as a source of buyer dissatisfaction. First, the quality problems were in the pump design. Recently there were problems of quality of the washer, and problems with check valves have affected the TP program in all Indian locations and it is not clear if the problems are satisfactorily resolved even now.[18]

Stake of the distributors and dealers: The second aspect is the stake of the distributors and dealers in IDE-India's TP program. At present volumes of sales, it is difficult to understand why distributors, dealers, and mistrys would have a great incentive to market TPs at IDE-fixed margins. The problem is not that margins are low but that at current volumes the total expected earnings from TPs at the dealer and lower levels are so small that the product cannot get the attention of dealers, except from

[17]The Mehta (2000:14) study lauds the role of the mechanics in ensuring customer satisfaction in Bangladesh, and notes, "2,420 private mistrys who install the pump form the final crucial link in the delivery chain. They are fully accountable for the quality of their workmanship and the performance of the products they represent. In addition to the initial installation, they provide a continuing repair and maintenance service to farmer customers to keep their pumps operating."

[18]For example, a 1995 "Mission on Pump Technology" fielded by the North Bengal Terai Development Project found poor quality an endemic problem: "About 40 percent of the installed test foot pumps were inspected and the result was not as good as was expected. Out of nine pumps visited (on one location) only one was operational and that one too was not in good shape. Washers have shrunk. Check valves don't work well, which reduces discharge and causes fast loss of prime. (In Nandanpur cluster) out of five pumps, three were removed by IDE. (In the other two) there is a clearance of 4 mm between piston washer and cylinder barrel (causing) significant leakage. In Kachua cluster, out of five (3.5" bamboo) pumps, only one was in working order. The other four pumps (suffered from) excessive piston washer clearance" (NBTDP 1995: 1).

a handful who are able to sell a thousand or more pumps during a season. A 1998 study of TP marketing dynamics in north Bengal (Shah 1998) estimated that over 80 percent of dealers sold less than 50 TPs per dealer per year. In Bangladesh, the MRC-MODE (1993) study found that a mistry sold an average of 50 TPs in a season. In the early years of a new product, dealers are willing to invest in the hope of making money in the future as volumes of sales build up, and if volumes do not build up at expected rates, they lose interest. There is thus a catch-22 situation. At much larger volumes, present margins would probably be adequate to maintain the market incentive. But these volumes cannot be reached unless the distributors, dealers, and mistrys have better overall earnings from their TP business than they do at present. In that sense, IDE-India should look forward to a day when *Krishak Bandhu* is pitted against *Kishan Bandhu,*[19] and it has to deal with the problem of mushroom growth of local manufacturers of TPs who rebel against IDE standards and IDE rule in their little market segments, as has happened in Bangladesh. That will be the first sign that the TP is ready to cross the 100,000 per year mark in India.[20] The Mehta study of TP marketing echoes this sentiment when it asserts that in Bangladesh, "as remarkable as the TP is the delivery system that put 1.3 million units in the hands of poor farmers since 1980." This delivery system today includes 84 manufacturers, 962 retailed dealers, and 2,420 mistrys (Mehta 2000: 15). To create significant socioeconomic benefit, IDE needs to blend Alfred Marshall's idiom of "market structure" with the marketing management notions of Philip Kotler.

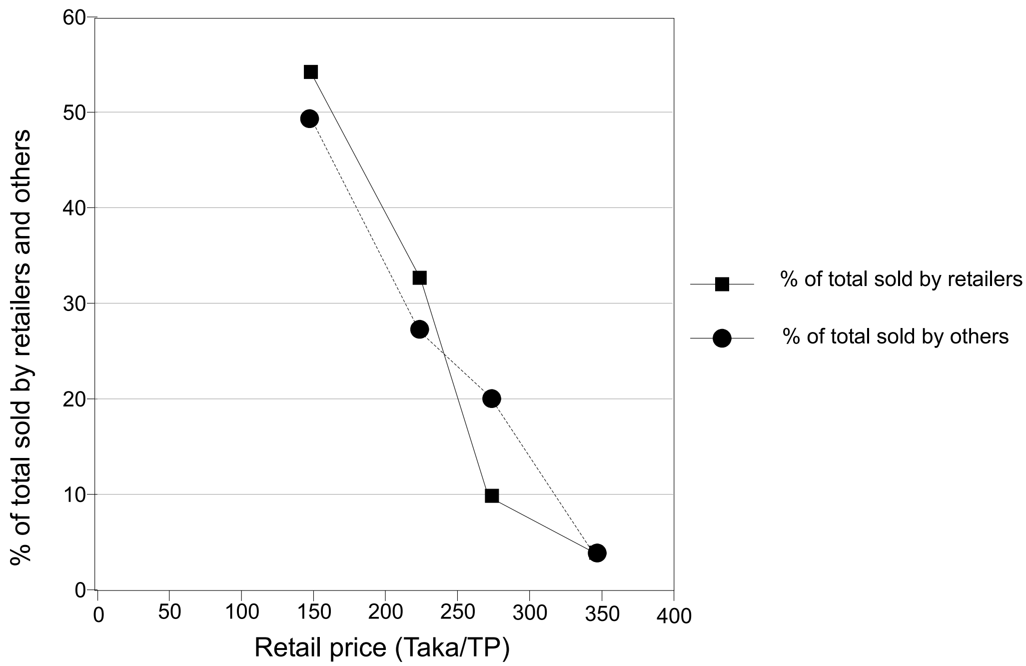
Pricing: The third important and related aspect is pricing. In our assessment, the market for TPs is far more responsive to price and far less responsive to quality than is generally believed. This is evident in Bangladesh where 84 manufacturers make and market TPs in a huge array of price-quality combinations. A 1993 study commissioned by the Swiss Development Cooperation showed that the bulk of the buying activity was concentrated in the lowest priced TPs; less than 5 percent of sales of numerous TP products available in Bangladesh were from the price range of Tk 350 (US$7) and more and over 50 percent of sales was of products costing Tk 150 (US$3) or less (fig. 25). To make doubly sure, MRC-MODE (1993:45) researchers asked their sample of farmers to weigh the factors that drive their purchase decisions, and price turned out to be the most important factor. There are also other indications that demand may be much higher if the price could be cut down to Tk 150-200 (US$3-4). In the course of a field visit to northwest Bangladesh, we found that TP dealers there have a brisk business, selling secondhand and low-priced unbranded TPs in north Bengal where IDE-India has been aggressively marketing the *Krishak Bandhu* brand of TPs. In eastern Uttar Pradesh, IDE has been promoting the sturdier but costlier metal pedal pump without notable success. However, during 1999, the field team introduced the cheaper and less

[19]One of the numerous brands—such as *Nahar*, *KPK*, *Mostafa*—under which treadle pumps are sold in the "informal" sector in Bangladesh.

[20]This relates to another crucial issue of whether the unruly, chaotic organization of TP marketing that is in Bangladesh today was a result of a deliberate and careful strategy or the default outcome of autonomous market pressure. The MRC-MODE (1993) study team met a sample of manufacturers and found that nearly 70 percent of them got into treadle pump manufacture without any external support merely because they found the demand upbeat, technology simple, and marketing unproblematic. In all three countries, it does not look as if IDE has actively prevented the mushroom growth of local manufacturers although it would, and should, control the use of *Krishak Bandhu* brand name by anyone except those meeting its quality standards. But in eastern India and the Nepal Terai, there is apparently no interest in getting into treadle pump manufacture presumably because of the weak demand.

FIGURE 25.

Price sensitivity of treadle pump demand: Bangladesh.



Source: MRC-MODE 1993:113.

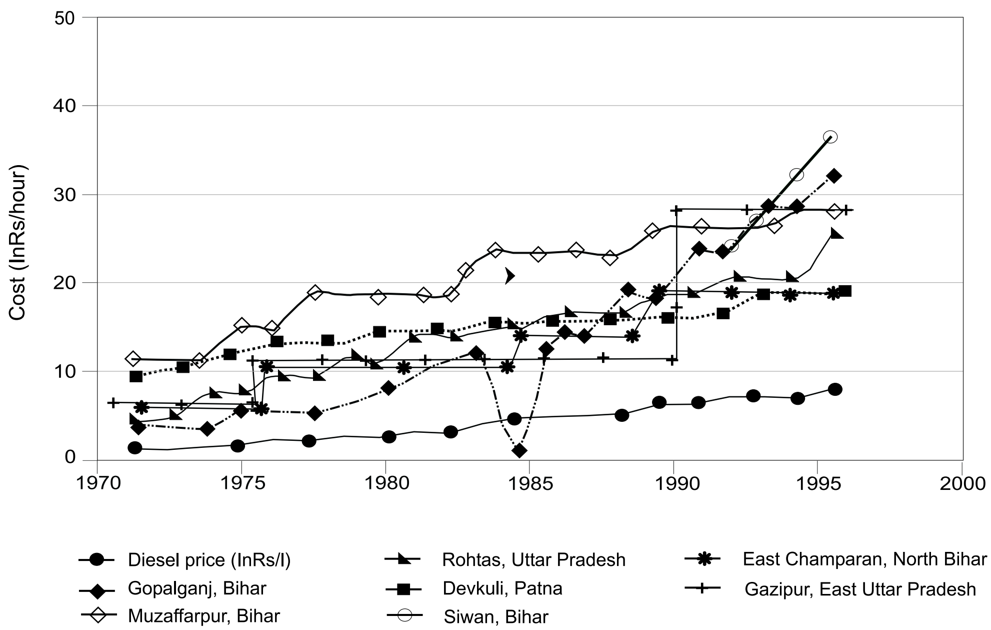
sleek bamboo TP, which has a shorter life span, and early reports indicate that the bamboo pump is doing very well and may be the first major marketing breakthrough in that region.

Our assessment then is that the price-quality combination IDE-India has put on offer probably does not match the scale of its poor customers' preferences and unless it corrects this condition TP sales in eastern India will more likely keep trotting than begin galloping as they did in Bangladesh during the mid-1990s. Mehta (2000:32) perceptively shows how IDE-Bangladesh fell in the same trap first but then emerged to generate and ride on the TP sales boom:

> "(By 1990,) while IDE's role was to exert influence on the TP market on quality, it had actually begun to virtually control it. Like a physician, IDE's approach was of prescribing medicine to a patient—in terms of what was best for the poor farmer, i.e., the best quality at *its* lowest price. When new entrants came into the market and saw the demand IDE was generating, they also offered what they thought was best. Suddenly the poor farmer was transformed from patient to customer … he had a choice between IDE's best at a higher price versus someone else's best at a lower price. He opted for the latter. In fact, he often chose the worst, for the vast differences in price hid the substantial differences in quality. However, IDE stood by its quality standards. Demand declined by more than 40 percent between 1988 and 1990. At the same time, demand of competitive producers and dealers grew by more than 300 percent. The farmer wanted a choice, and if IDE-affiliated producers

FIGURE 26.

Impact of a 35 percent hike in the price of diesel on pump irrigation cost (5-horsepower diesel pump).



and dealers were unwilling to give (actually, prohibited from giving) him a choice, he took his business elsewhere. As a result, IDE actually lost control of TP quality to the extent of even losing influence on it. This was the market's … invaluable lesson for IDE.

"(However, the period 1990-1995 saw) a change in IDE's policy on quality much to the disconcertion of staff and older producers and dealers. It began to offer three qualities of pumps: a super first quality, a standard first quality, and a market grade second quality … Once again, sales for IDE-affiliated dealers began growing substantially faster than for competition dealers. Only when the farmer was offered what he wanted was he willing to accept recommendations on what he should buy."

IDE's response to the issue of subsidy: The fourth and related aspect to consider is IDE's response to the issue of *subsidy*, not on the TP to which IDE is ideologically opposed, but its competitor, the diesel pump. In the east Indian states, there already are in place subsidies and loan schemes under which marginal farmers can get a diesel pump and a bore well at prices 25-40 percent lower than the market price, with a loan facility thrown in. These would have reduced the appeal of the TP greatly, had these schemes been working better than they are. In our opinion, a major reason why TP sales are struggling in eastern Uttar Pradesh is that the diesel pump subsidy scheme works very well there. IDE needs to take into account the fact that there is increasing pressure on governments at central and state levels to enhance smallholder irrigation through various means, including making the subsidy schemes work better.

The upshot of our analysis is: TP technology is a super-performer for the marginal farmer in the context of the Ganga-Brahmaputra-Meghna basin. It has great potential for socioeconomic impact. However, whether this potential translates into a significant impact will depend squarely upon how rapidly IDE can put TPs in the hands of the millions of the region's poor, especially in eastern India and the Nepal Terai. A big opportunity to push up sales of the TP is offered by the 35 percent increase in the diesel fuel price in India during 1999, and another rise that is imminent. This will cause great hardships for marginal farmers throughout India because they will now have to pay much more per hour of diesel pump irrigation (18-20 m^3 of water) compared to the US$0.8-1.00 they have been paying so far (fig. 26).[21] To most of these farmers, the appeal of the TP will become stronger than ever since the price they pay for water to private pump owners drives the implicit wage rate they earn on pedaling on their own TP.

IDE needs to make an opportunity out of the adversity facing the marginal farmer. Thomas Hemphill, IDE-India's Director has recently asserted, rightly, that: "There is no question that our commitment is not to the product, our commitment is to improving the socioeconomic conditions of farm families ... We are not just product hustlers, we are in this for long term socioeconomic benefit" (Bhanot 1999:9). The only way IDE can produce noteworthy socioeconomic benefit is by pulling off the marketing miracle of the millennium. And nothing can be more respectable and rewarding for the poor of eastern India and the Nepal Terai than "product hustling," if excelling in it can help IDE sell a million pumps in this region in the coming 3-5 years.

[21] In oligopolistic pump irrigation markets of the type found in eastern India, the pump irrigation price is directly linked to diesel price by a factor whose value is determined by the monopoly power enjoyed by sellers (Shah 1993). In eastern India, the value of this factor is estimated to be in the neighbourhood of 3.5. The recent hike in diesel prices by 35 percent in India will mean corresponding increases in pump irrigation prices from InRs 25-40/hour to InRs 40-65/hour. No matter how well justified on macro-economic grounds, this diesel price hike will put marginal farmers in east India to great misery. Dependent upon private pump irrigation markets, they will end up irrigating their crops with the costliest water probably anywhere in the world, at US$1.0-1.2 for 15-18 m^3 of water.

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