AgWater Solutions Project
Case Study

Choice of Irrigation Technology: Opportunities and Constraints for Adoption of Agricultural Water Pumping Technologies by Small Farmers in Cooch Behar District, India

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The AWM Project
The AgWater Solutions project was implemented in five countries in Africa and two states in India between 2008 and 2012. The objective of the project was to identify investment options and opportunities in agricultural water management with the greatest potential to improve incomes and food security for poor farmers, and to develop tools and recommendations for stakeholders in the sector including policymakers, investors, NGOs and small-scale farmers.

The leading implementing institutions were the International Water Management Institute (IWMI), the Stockholm Environment Institute (SEI), the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), International Development Enterprises (iDE) and CH2MHill.

For more information on the project or detailed reports please visit the project website http://awm-solutions.iwmi.org/home-page.aspx.

Disclaimers

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Executive Summary

Appreciating that access to irrigation water is an important first step in improving incomes of small and marginal farmers and in helping them move out of poverty, there has been a growing interest in the large range of low-cost agricultural water management technologies in semi-arid developing countries. Given the wide range of socio-economic-agro climatic and water availability conditions prevailing in different regions and the dynamic nature of these conditions, narrowing down the choice of an appropriate technology often becomes a difficult process. The present study attempts to address some of these issues relating to choice of irrigation technology by small farmers.

The study has been carried out in select regions of Cooch Behar district located in the eastern state of West Bengal in India. The choice of Cooch Behar for the present study was driven by a number of considerations, the most important being the presence and use of a range of alternative technologies for irrigation by small farmers in an analogous locale thereby providing a perfect investigational setting for the study of the objectives set forth for the study. An implicit important consideration that has also weighed in selection of this district has been the enormous donor interest in learning more about the positioning of treadle pump technology *per se* as also in relation to some of the other irrigation technologies by small farmers in a fast changing/emerging technological scenario.

The results obtained on the performance and prospects of different irrigation technologies suggest that treadle pumps served a useful purpose when these were introduced about 15 years ago in a near technological vacuum and were adopted by some farmers despite some of the negative features of treadle pump technology. An examination of current use status and current sales performance of treadle pumps in the study area suggest that the technology has become dated and there are no new takers for this technology. The treadle pumps are being timed out in Cooch Behar district. Any additional efforts or money (public or donor) spent on stimulating treadle pump technology in the study region or those regions similarly placed will not serve the intended purpose of improving accessibility of irrigation to small and marginal farmers and in helping improve their incomes.

There has been a substantial uptake of both Chinese and Indian made diesel pumping sets for irrigation. Diesel engine technology holds a great promise in the study region. Lack of access to investible financial resources to invest in these pumps by some small farmers has constrained investments in these pumps. However some positive features of this technology has permitted use of this otherwise indivisible technology in to a divisible technology through establishment of an extensive, competitive, affordable and generally reliable informal rental market for diesel engines.

We envisage that the type of progress diesel pumping sets have made on the irrigation scene of the study area in the last few years is likely to continue for a few more years to come. Electric motor however is the most desirable choice of a majority of the farmers for irrigation pumping. Low maintenance and running cost and ease of usage makes EM as the most desirable choice for irrigation by all the farmers. Due however to constraints on availability of electricity connections and/or high cost of extending the electricity connection to the farmers' field (which cost has to be borne by the farmer) from the nearest access

point, the uptake of electric motors for irrigation, though picking up fast, will still take a few more years before they can make the inroads in to irrigation scene which diesel engines have been able to make. Going by the experience of some of the other regions of the country where electric tubewells predominate the irrigation scene, a number of farmers still prefer to maintain a diesel engine as a standby arrangement due to frequent power cuts that are often made in the agricultural power supply.

Some of the key points that emerge from analysis of our data from the study region provide clues to some important steps that could facilitate more efficient path to irrigation technology adoption

- Adoption of/ investment in irrigation technology does not necessarily follow the path of orderly movement up the technology ladder – no technology- manual (TP) technology- hire in of motorized technology- investment in diesel motor technology- investment in electric motors. It is therefore not always necessary to start technology uptake efforts from the bottom of the pyramid.

- It has to be remembered that technology adoption is a dynamic process and a technology appropriate at one point of time/ under one set of prevailing conditions need not necessarily remain appropriate at all points of time/ changes in prevailing underlying conditions.
- Low cost of technology does not necessarily encourage farmers to invest in the technology. A farmer who otherwise cannot afford to invest in an expensive technology such as a diesel engine or an electric motor may still not invest in an inexpensive technology such as a treadle pump due, besides other factors, to availability of motorized pumping equipment on hire even if such an option is more expensive than investing in an owned treadle pump.

- Lack of access to investible financial resources to meet the upfront cost of investment has been cited by a number of the sampled farmers as an important factor constraining investment in irrigation technology of their own. Provision of finances for investment in irrigation technology at subsidised lending rates would provide a boost to private investment and access to irrigation.

1. Introduction

Agricultural production is a complex process which requires farmers to take decisions with respect to what crops to produce, how much area to allocate to different crops and what production technology to use for performing different crop operations to achieve the desired objective, generally, profit maximization. The decision making process is influenced by a set of constraints that a farmer faces with respect to physical availability, awareness and access to different resources, technologies, means of production, and input-output markets. Given the role of these factors in influencing farmers' choices, any change in any of these factors can alter the outcomes of the farmer's decisions. The decision making is therefore not a static but a dynamic process.

One of the important decision variables in this multi-dimensional input-output choice matrix is the choice of an appropriate technology for crop irrigation. Choice of an appropriate irrigation technology has to be evaluated in this broader decision making environment that a farmer faces. Several options exist – not to irrigate, irrigate using a traditional manual technology (such as a treadle pump), motorized technology (a diesel engine, an electric motor), alternative combinations of these technologies, using these technologies in isolation or in combination with water conserving technologies etc. Concurrently, the farmer faces the option of either investing in a particular technology for using it or opting for the choice of hiring in of technology from equipment hire market, if such a market exists. In a fast changing scenario of available technological options and/or prices of these technologies the problem of choosing an appropriate technology/ technology mix gets further complicated. A technology appropriate at one point of time/ under one set of prevailing conditions may not be appropriate at another point of time/ under a different set of conditions. Thus a technology appropriate for a given scenario of water availability conditions may or may not be appropriate for another set of water availability conditions. The core issue is that technology choice is far more complex than generally assumed.

There has been a growing interest in the large range of low-cost agricultural water management technologies in semi-arid developing countries. Given the wide range of socio-economic-agro climatic and water availability conditions prevailing in different regions and the dynamic nature of these conditions, narrowing down the choice of an appropriate technology often becomes a difficult process. The present study addresses some of the issues in choice of irrigation technology for small farmers with a special focus on treadle pump technology.

Research questions

1. What factors determine investment in irrigation by small and marginal farmers? What is the relevance of technology (appropriateness, availability, quality, price, after sales service) versus non-technology factors (price, credit availability, markets for outputs) in influencing farmers' investments in irrigation.

2. What factors influence the choice of technology for irrigation? What factors are likely to influence the decision of treadle pump owning farmers to switch over to motorized pump technology?

3. What has been the experience of farmers with the use of different irrigation technologies? What are the areas for their non-satisfaction? What interventions do they think would motivate non-users to invest in irrigation?

4. What is the preferred irrigation technology of farmers who have so far not invested in any irrigation technology? What are the reasons for their preference? If a treadle pump is not a preferred technical choice, why? Under what conditions would such farmers be willing to shift their choice in favor of a treadle pump?

Treadle pump : a low cost irrigation technology

The treadle pump is an elegant foot operated water lifting device which, by using the force of suction, lifts water from rivers, swamps, reservoirs and shallow wells from depths ranging from 0-8 meters. Treadle pump technology is widely believed to be a pro-poor, poverty alleviating technology due to its demonstrated potential for low-cost irrigation and suitability for small-scale farming. Since a treadle pump is appropriate for irrigating 1 hectare or less of cultivable land, small and marginal farmers are best suited to use these pumps.

The treadle pumps were perhaps introduced by International Development Enterprise (IDE), an international NGO, in Bangladesh during late 1980s. With support from the Canadian International Development Agency (CIDA) and the Swiss Agency for Development and Cooperation (SDC), IDE implemented a program to stimulate the rural mass marketing of treadle pumps in Bangladesh and over a 15 year period almost 1.5 million treadle pumps were purchased and installed by small farmer customers at an unsubsidized, fair market price. Encouraged by the response to adoption of treadle pump technology, the treadle pumps were subsequently introduced in several Asian countries including India, Nepal, Cambodia, Sri Lanka, Vietnam, Philipines, Mynamar and also extended to several African countries –Zimbabwe, Malawi, Zambia, Senegal, Ghana, Ethiopia, Haiti, Tanzania, Kenya, Mali, Burkina Faso etc.

Over the last two decades or so the introduction of this simple device in the developing world has brought about a significant revolution in small-scale irrigation. Treadle pumps can be easily manufactured and maintained at a low cost in rural workshops and have significantly improved irrigation to marginal and small farmers and led to significant increases in their incomes..

Impact of treadle pumps

Several studies undertaken to make an assessment of treadle pump on the farm economy generally show a positive impact with increases in incomes of farmers adopting this technology. 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.).

One of the most comprehensive 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" has been undertaken by Tushaar et.al (2000). The authors

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?" Based on a review of available evidence from a variety of studies complemented by their own study, the authors conclude 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 neighbourhood 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, the figure indicated by Polak (n.d), appears to be 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 implications of these findings are significant for the role TP technology can play in the region. A recent study commissioned by IDEI estimated the potential market for treadle pumps in India at 7 million (Indicus Analytics: 2003). The IDE estimate is that eastern India and the Nepal Terai have an ultimate market potential for some 10 million TPs[1].

2. Methodology

Study area

The present study was carried out in regions of Cooch Behar District, which is located in the eastern state of West Bengal in India. The choice of Cooch Behar was driven by a number of

[1] Going by the sales of treadle pumps in the region the estimated potential of TPs seem to be out of place with the reality. There are only a handful of dealers who are able to sell a thousand or more pumps during a season. In fact 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. The recent sales data provided by IDEI, presented in Table 1 above also provide testimony to the low uptake of treadle pumps..

considerations, the most important being the presence and use of a range of alternative technologies for irrigation by small farmers in the same locale thereby providing a good setting to explore all the research questions. Another important consideration was the enormous donor interest in learning more about the relative positioning of treadle pump technology relative to other irrigation technologies by small farmers in a fast changing technological scenario. Cooch Behar provided an ideal site for this consideration as well.

The district of Cooch Behar is bound by district of Jalpaiguri in the north and north-west, Assam in the east and the India-Bangladesh border in the south and south-west (Figure 1). The total geographical area of the district is 3,387 sq. km. The district is divided into 12 development blocks and has a total of 1,190 villages with 128 Gram Panchayats. As per the 2001 census, the population of the district was 2.5 million with a population density of 732 persons per square kilometre. The literacy rate is 66 per cent. Of the total population, about 91 per cent live in rural area and the remaining 9 per cent is urban. More than 50 per cent of the population belong to a Scheduled Caste. Koch Bihar is the headquarters of the district. More than 93 per cent of operational holdings in Cooch Behar are below 1 hectare.

Cooch Behar is a flat region with a slight south-eastern slope. The soil is alluvial and of recent formation. It is mostly sandy and loose. Six river systems cut through the district flowing in a south-easterly direction. The district has a highly humid atmosphere and abundant rains. The annual average rainfall is 3,201 mm. About 70 per cent of the annual rainfall is received during the south-west monsoon season.

The dynamic ground water resources of Cooch Bihar district have been estimated jointly by the Central Groundwater Board (CGWB) and State Water Irrigation Department (SWID), following the norms laid down by the Groundwater Estimation Committee (GEC) 1997 methodology and projected as on 31.02.04. The reconciled figures are in Table 1.

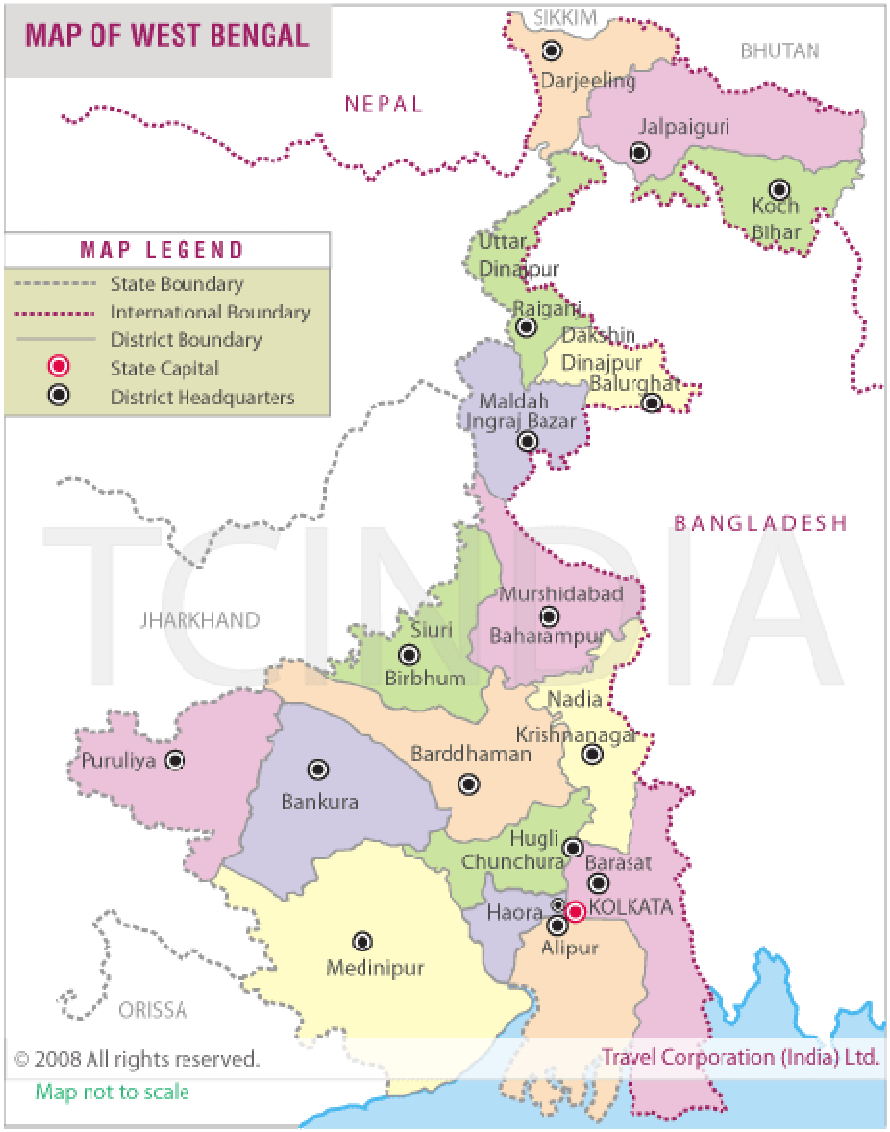

Figure 1. District demarcated map of Cooch Behar

Table 1. Groundwater Scenario in Cooch Behar District

Total ground water resources	23,1636 ham
Net ground water availability	20,8499 ham
Existing ground water draft for all uses	34,782 ham
For irrigation	31,081 ham
For domestic and Industrial water	3,701 ham
Stage of ground water development	18.57%
Allocation for domestic and industrial water supply requirement up to 25 years	5,006 ham
Net groundwater availability for future irrigation development	17,2412 ham
Categorization of blocks	All blocks are categorized as "safe"

Source : CGWB

The groundwater availability is at a comfortable level in Cooch Behar district which enables use of both manual and motorized technologies for groundwater withdrawal. The farmers in the district were amongst the earliest users of treadle pump technology when treadle pumps were smuggled in from neighbouring Bangladesh where this technology was first introduced. Subsequently, donor driven programs for promoting treadle pumps were introduced, implemented mainly by International Development Enterprise (IDE) during the mid- 1990s. Farmers in the district were also amongst the earliest users of relatively less expensive and light weight Chinese diesel pumping sets. Availability of diesel pumping sets triggered the development of an informal diesel engine rental market giving tough competition to treadle pumps. Concurrently, the Government of West Bengal under its initiative of improving electricity supply in rural areas for both domestic and irrigation purposes, facilitated the introduction of electric pumps for groundwater withdrawal adding another dimension of complexity in choice of technology for irrigation pumping.

Data collection

Data were collected from a sample of farmers from Cooch Behar District of West Bengal selected using a stratified random sampling scheme . Given the special significance of the study to learning the functioning of treadle pump technology, the selection of study areas was made on the basis of intensity of use of this technology for irrigation pumping.

Data on sales or use of treadle pumps in different parts of the district were not available from or not collected by any official agency in the district. Because of its involvement in the promotion and near monopoly in the sales of treadle pumps in the district, IDEI is the only agency which could provide data on sales and use of treadle pumps. IDEI could however provide data only on the combined sales of treadle pumps in different blocks of the district for the period from 2005-2009. A total of 1,190 treadle pumps were sold by IDEI during the period from 2005-2009 in Cooch Behar District (Table 2).

Table 2. Sales of Treadle Pumps in Different Blocks of Cooch Behar : 2005-09

Block	Number of villages	Treadle pump sales 2005-09	Average sales/block/year	Average sales/village in 4 years
Cooch Behar 1	149	1,525	381.25	10.23
Cooch Behar 2	119	269	67.25	2.26
Dinhata 1	135	450	112.5	1.77
Dinhata 2	119			
Haldibari	62	310	77.5	5.00
Mekhliganj	154	2,233	558.25	14.50
Mathabanga 1	102	1,539	384.75	15.09
Mathabanga2	93	507	126.75	5.45
Sitai	53	208	52.00	3.92
Sitakuchi	72	284	71.00	3.94
Tufanganj1	77	772	193.00	5.85
Tufanganj2	55			
Total	1,190	8,097	2024.25	6.80

Source: Sales data provided by IDEI

Based on this information, we selected two blocks from amongst those blocks which have high sales of treadle pumps during this period and one block from amongst those blocks with low sales but in geographical proximity to blocks with high sales . The highest selling blocks are Mathabanga I and Cooch Behar I. From amongst the lowest selling blocks we selected Sitalkuchi, which has a common boundary with both the highest selling blocks. Another consideration in selection were logistic considerations in organizing data collection work. Three blocks in close proximity helped us in more efficient organization of our data collection field work.

Ten Gram Panchayats with the highest proportion of crop area irrigated were selected. Three villages from each Gram Panchayat were selected. From each of the villages we randomly selected small farmer households belonging to three broad groups of farmers: owners of treadle pumps, owners of motorized equipment and non-owners of any irrigation equipment. The total number of farmers selected was 271. The distribution of the final sample amongst three categories of households is shown in Table 3.

Table 3. Distribution of Sample amongst three categories of households

Category	Sample Size	Proportion
Owners of treadle pumps	60	22
Owners of motorized equipment	120	44
Non-owners of any irrigation technology	91	34
Total	271	100

The data was collected through personal interviews using questionnaires. We were assisted in this task by staff from the Centre for Development of Human Initiatives (CDHI), Jalpaiguri, a local NGO. In addition to the data collected from sampled households, the study uses data collected during extensive field visits undertaken in the district, semi-structured discussions

with a cross section of knowledgeable groups of farmers, agricultural equipment suppliers and sellers, grassroots officials and interviews with a number of other official and non-official stakeholders. The primary data have been complemented by secondary data that was available from published and unpublished sources.

Farmer profile

We present in Table 4 a brief profile of the sampled farmers distinguished on the basis of the type of irrigation technology owned/used. The average size of ownership holdings of different categories of households vary between 1.01 to 1.81 acres. Leasing-in and leasing-out of land on the margin is quite common in the study region. Farmers do lease-in and lease-out land sometimes for one season only. After accounting for land lease operations, the average size of operational holding of sampled farms varied between 1.03 and 1.83 acres. Since there is adequate rainfall during kharif season, irrigation is normally not required. Farmers generally apply irrigation when rains are late or to meet occasional crop water requirements. Irrigation is generally applied during rabi season. The proportion of cultivated area irrigated during kharif varied between 44 and 56% between different categories of farmers, and during rabi between 81 to 94%. The proportion of area irrigated does not provide information about the volume of irrigation water applied, its adequacy or its application at the required time. The average number of plots per holding did not differ significantly between different groups of households.

Table 4. Land Holding of Sampled Households (in Acres)

	Treadle Pump Owners		Non- Owners of Irrigation Equipment		Motorized Pump Owners	
Sample Size	60		91		120	
Season	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Owned land	1.08	1.00	1.33	1.33	1.81	1.77
Leased-in	0.11	0.11	0.06	0.07	0.06	0.08
Leased-out	0.08	0.08	0.02	0.01	0.04	0.09
Operated	1.11	1.03	1.37	1.39	1.83	1.76
Fallow	0.09	0.10	0.10	0.29	0.25	0.43
Cultivated	1.02	0.93	1.27	1.10	1.58	1.33
Cultivated Land Receiving Irrigation	0.54	0.88	0.56	0.97	0.89	1.08
% Cultivated land receiving irrigation	53%	95%	44%	88%	56%	81%
Average number of Parcels per holding	2.73		2.43		2.96	

The sampled farmers from three broad groups of irrigation technology users did not differ significantly in terms of either the level of education or the social category (mainly caste) to which they belonged (Table 5). Most of the sampled households were literate. About two-thirds had studied at least up to primary level of education. About 80% belong to Scheduled Caste or Scheduled Tribe. Agriculture has been the main source of income for almost 70% of the sampled farmers who derived more than 50% of their income from farming. Motorized pump owners were deriving more than 82% of their income from agriculture.

Table 5. Characteristics of sampled households

	Treadle pump owners	Non-owners of irrigation equipment	Motorized pump owners	All
Total number of sampled hhs	60	91	120	271
Education level				
-Illiterate	10 (17)	15 (16)	10 (8)	35 (13)
-Primary	44 (73)	56 (62)	84 (70)	184 (68)
-Secondary	5(8)	15 (16)	24 (20)	44 (16)
-More than secondary	1(2)	5 (6)	2 ((2)	8(3)
Caste				
-General	7 (12)	10(11)	24(20)	41(15)
-Other backward caste	3(5)	9 (10)	6(5)	18(7)
-Schedule caste/schedule tribe	50(83)	72 (79)	90(75)	212(78)
Estimated % of total income derived from crop production				
< 25	1(2)	11(12)	3 (2)	15(6)
25-50	16(27)	29 (32)	19 (16)	64(24)
50-75	14(23)	15 (16)	21(18)	50(18)
>75	29(48)	36 (40)	77 (64)	142(52)

Note: Figures in parentheses denote percentages

Owners of treadle pumps and motorized pumps, even before investing in their own private irrigation technology, had been using irrigation and were convinced about investing in irrigation. About 61% of these farmers had been irrigating their crops even before investing in irrigation. Of these, 45% were hiring diesel engines, 14% were buying water from neighboring farmers, while 32% were using either gravity flows of surface water or using some traditional technologies for lifting water (Table 6).

Table 6. Status of Irrigation before investing in irrigation technology

	Treadle Pump Owners	Motorized Pump Owners	All
Total number of sampled HHs	60	120	180
Number of farmers who were irrigating their crops even before investing in irrigation technology	37 (62)	73 (61)	110 (61)
Technology used for providing irrigation			
- Hired TP	0 (0)	4 (6)	4 (4)
- Hire in DE	22 (59)	28 (38)	50 (45)
- Hire in EM	0 (0)	6 (8)	6 (5)
- Buy water from neighbors	3 (8)	12 (16)	15 (14)
- Other ways (surface gravity, buckets etc)	12 (33)	23 (32)	35 (32)

Figures in () indicate percentages.

Availability of casual labor

Availability and cost of labor is an important factor influencing the choice of crops cultivated and the choice of technology for performing different crop operations (Table 7). In the case of irrigation technology, availability and cost of labor is likely to significantly influence choice of manual (treadle pump) versus motorized technology (diesel engine or electric motor). Over time, the agricultural labor availability in a region may change due to several factors such as out migration and availability of increased employment opportunities in non-agricultural sectors. In the study region there has developed over the years a significant shortage of agriculture labor. More than 85% of all the sampled households said there is either acute shortage of labor, or labor is not available at all, or if available the wage rates have become very high.

Table 7. Status of casual labor availability for agricultural operations

Labor availability situation	Treadle pump owners	Non- owners of irrigation equipment	Motorized pump owners	All
Easily available	3(5)	6 (7)	5 (4)	14 (5)
Not available/acute shortage	42 (70)	63 (69)	83 (69)	188 (70)
Available but wage rates are very high	9 (15)	14 (15)	18 (15)	41(15)
Availability varies according to season	6 (10)	8 (9)	14 (12)	28(10)
Total	60 (100)	91 (100)	120 (100)	271(100)

Figures in () indicate percentages.

General infrastructure

Table 8 presents information about access to the general infrastructure by different groups of sampled households. In terms of access to roads and markets, all the three groups were similarly placed. In terms of distance to diesel pumping stations, which could influence the decision to invest in a diesel pump, also all the three groups were equally placed[2]. However in terms of access to electricity, both for domestic consumption and irrigation, the treadle pump owning group of farmers were not at the same level as the other two groups. Since access to electricity is a prerequisite for investing in an electric pump, the treadle pump owning farmers are at a disadvantage vis a vis the other two groups. The same holds to some extent for access to institutional credit facilities within the village of residence, although that may not be necessarily true for access to institutional credit *per se*.

[2] Since diesel pumping stations are located at a distance, an informal market for sale of diesel has also developed. Some local sellers and shopkeepers procure diesel from these diesel pumping stations in big drums and then retail them to small consumers at a price. Quite often these resellers adulterate the diesel and also short charge the quantity while selling. Since small farmers with meagre diesel requirement at a given point of time prefer to buy diesel from these sellers than trying to procure their small diesel requirements from pumping stations directly.

Table 8. Access to general infrastructure

	Treadle pump owners	Non-owners of irrigation equipment	Motorized pump owners	All
Total number of sampled households	60	91	120	271
Average distance from metaled road (km)	0.96	1.17	1.73	1.37
Average distance from input market (km)	2.44	2.48	2.64	2.54
Average distance from diesel station (km)	12	11.38	13.53	12.47
Availability of Electricity for domestic use (Number responding in affirmative)				
- In your village	23	64	89	176(65)
- In your home	10	30	72	112(41)
Availability of electricity for irrigation (Number responding in affirmative)				
- In your village	23	44	86	153(56)
- In your farm	8	21	50	79(29)
Availability of institutional credit facilities within the village (Number responding in affirmative)	17	29	27	73(27)

Figures in parentheses denote percentage to total number of households.

3. Opportunities and Constraints for Adoption of Irrigation Technologies: Owners of Treadle Pumps

Treadle pumps in the study area

Prior to 1995 treadle pumps were hardly known in North Bengal (Cooch Behar is part of this region); with the exception of border villages where treadle pumps smuggled in from Bangladesh had become popular. In one of these areas, two small workshops were manufacturing treadle pumps (50-200/yearly). Given the large popularity of treadle pumps in Bangladesh, the general lack of familiarity in adjoining North Bengal was surprising – an indication that innovations do not necessarily spread. The outlook for treadle pumps looked bright as they were far superior to other manual lift systems such as spring pumps.

The treadle pump yields 1-1.5 liters/second, sufficient in North Bengal to irrigate 0.2 hectares of commercial vegetable crops. The cost of a treadle pump, including the development of a bamboo well with local techniques, was typically around USD 25. The investment under normal circumstances could be earned back within a season. Water tables in large parts of North Bengal are quite high, in most cases falling within the maximum suction range of the treadle pump (25 ft). North Bengal was also not widely served by diesel pump sets, a technology which treadle pumps could compete with[3] (Arcadis 2001).

[3] In the end, in some but not all-parts of North Bengal, treadle pumps appeared to push out some diesel pump sets, particularly since the hiring charges for the heavy weight diesel pump sets included a transportation charge, thus raising the effective costs per pumped hour for small farmers considerably.

The promotion of treadle pumps in North Bengal was undertaken by International Development Enterprise (IDE), as part of the North Bengal Terai Development Project Area, consisting of Jalpaiguri District, Cooch Behar District and Siliguri subdivision of Drajeeling District. Promotion started in dry winter season of November 1995-April 1996.

Growth in sales of treadle pumps in their initial years of introduction in North Bengal Region

In the first year of sales (1995-96), 903 treadle pumps were sold[4]. This better than expected sales in the first year was in part a result of a shortage of diesel at the end of the irrigation season. IDE played the main role in these efforts.

In the second sales season (1996-97), based on a consumer surveys it was targeted to sell 11,000 treadle pumps in the season. The price of the treadle pump was raised to INR 375. Prompted by some treadle pump dealers the Government of West Bengal announced that it might include the treadle pump in a package of subsidized (50%) agricultural implements under the Integrated Cereal Development Project (ICDP). The subsidy scheme was however withdrawn not long after it became effective. In all, about 920 pumps were sold under the subsidy scheme. The end of the season recorded a sale of 2,400 branded and 1,253 non-branded treadle pumps.

In the third season (1997-98), the price of a treadle pump was raised marginally from INR 375 to INR 390. The promotion activities were expanded to the entire vegetable and dry season rice belt of North Bengal. In spite of a credit facility made available to dealers, the sales of branded treadle pumps at the end of third season were 2,584. In addition an estimated 500 non- branded pumps were also sold. This was achieved following an intense promotion campaign, consisting of more than 1,600 promotional events (market demonstrations, village demonstrations and short campaigns) including 67 widely attended video shows.

In the fourth season (1998-99), sales increased but there was no big jump. The fourth season recorded sales of 3,000 branded pumps and 500 non-branded pumps.

The fifth season (1999-2000) saw reduced sales of 2,500. Non -branded treadle pump sales were also down to about 200 (Arcadis 2001)

Thus, in the initial five years of intense promotional efforts some 11,500 treadle pumps were introduced. An estimate of promoting the technology of treadle pumps over the five year period worked out to INR 1100 per treadle pump sold. However, the cost of the promotion campaign exceeded the turn over. With promotion costs fully subsidized, the campaign had to face the devil of distortion: no correlation between subsidized promotion and real demand.

[4] These figures relate to the whole of North Bengal project area and not to Cooch Behar District alone

Subsequently, in the 2000-01 the overall sales were 989 branded KB pumps with the best results obtaining from Cooch Behar District. By the end of March of 2001, IDE started withdrawing from the area. In an evaluation done in November 2001, it became clear that after IDE withdrew the supply chain IDE was managing also collapsed because IDE was acting as a supplier after the wholesaler pulled out in 1999 because of a conflict. Efforts to directly link dealers with the manufacturer in Kolkatta failed (Arcadis 2001).

Looking at the pattern of sales of treadle pumps over five-six years, intense promotional efforts did not evoke the expected response or the level of success expected from the availability of a small, farmer friendly technology at an affordable cost.

Results from survey

Year of purchase

Four of our sampled households had bought these treadle pumps prior to their formal introduction in Cooch Behar. Most sampled households bought their treadle pumps during the period between 1995, the year when these were formally introduced, and in 2002, shortly after IDE had started to withdraw (from March 2001) from active sales in the region. In the following years, the sales of treadle pump started to decline and only 16 of our sampled households bought their treadle pumps after 2003. Since the data on purchases presented in the Table 9 use different class intervals, we present in the last column the average number of purchases by sampled farmers per year. The sales, after peaking at five pumps per year during 1995-2002, declined to 1.8 and 2.3 pumps per year in subsequent block of years. The estimated average (unadjusted for year of purchase) price paid for a treadle pump was INR 440.

Table 9. Distribution of sampled farmers according to year of purchase of treadle pump

Year of purchase	Number of farmers who bought a treadle pump	Percent	Numbers per year
1990-1994	4	7	0.8
1995-2002	40	67	5
2003-2006	7	11	1.8
2007-2010	9	15	2.3
Total	60	100	2.9

Factors that influenced farmer investment in treadle pumps

Why did the farmers invest in this technology? Was the decision influenced by some of the advantages that treadle pump technology offers vis a vis other water lifting technologies? Or was the decision to invest driven by constraints on farmers from investing in an alternative technology and thereby excluding all other technologies from a farmers' choice set.

The results obtained point to the fact that investment in a treadle pump was both a result of considered opinion influenced partly by the advantages a treadle pump and the prevailing circumstantial constraints (Table 10). Some of the positive features that influenced investment in treadle pumps included: easy to install, operate; no or little operation and maintenance costs, no need to fetch diesel/petrol; small and fragmented land holdings;

mobility; and the great price advantage the treadle pump technology offered vis a vis other technologies. The most important factor was lack of finances to invest in high cost alternative technologies. It does not seem to be the case that farmers were influenced to invest by a compatible water table regime, availability of sufficient family labor for treading, robustness of technology or lack of information about alternative technologies.

Table 10. Factors that influenced farmers' choice of investing in treadle pumps over other technologies

Factors	Details	Number of farmers	Percentage
Demonstration effect	Saw demonstration by NGOs/ individuals/ at fairs/neighborhood users	16	27
Technological factors	Easy to install, operate, use	24	40
	No or little operation or maintenance cost/ no need to fetch petrol, diesel for using it	43	72
	Very sturdy technology- long life	4	7
Water regime	TP compatible water table	3	5
Labor availability	Had enough family labor for treading/ could hire treading labor	5	8
Land related	Small size of farm, fragmented holding, low water requirement, advantage of TP mobility	40	67
Price related	Low price of TP	27	45
	Got free/ subsidized	8	13
Finance related	Lack of finances to invest in other technology/ dealer facilitated purchase on installments/ other technologies more expensive	25	42
Access to information	Did not have information about other technologies	6	10

Note: Totals may not tally due to multiple answers.

Current status of use of treadle pumps

In addition to information on investment in equipment, what is equally important is to know if, after purchase, it is used and how frequently? What are the possible reasons for discontinuance of use of the equipment? If some of the reasons for discontinuance are addressed, will farmers be willing use the equipment again?

Of the 60 sampled farmers only 5 (8%) reported still using the treadle pump as main source of irrigation. The remaining stopped using it either totally or as a main source but use it occasionally as a standby arrangement (Table 11). The results obtained indicate that about 13% of the farmers either totally discarded or stopped active use of their treadle pumps as the main source of irrigation just one year after use. More than 50% stopped using the treadle pumps as a main source of irrigation after four years. However, there are 19% who have used it for 8 or more years before either stopping or relegating it as a secondary

source. The average use of treadle pump before it was put to either disuse or as a secondary source was 4.85 years. Some of the farmers who abandoned the use of the treadle pump completely are using their old treadle pumps for priming diesel engines. Some other farmers after dismantling one barrel of the treadle pump made of cast iron are using it as hand pump for drinking water purposes.

Table 11. Number of years of use of treadle pumps as a main source of irrigation before its disuse/ relegated to secondary source

Total number of sampled farmers		60
Number of farmers who are still using treadle pumps as the main source of irrigation		5 (8%)
Number of farmers who have either stopped using treadle pumps or relegated treadle pump to secondary position		55 (92%)
Number of years of use as main source before stopped using so	Number of Farmers	Percentage
1	7	13
2	5	9
3	9	16
4	7	13
5	7	12
6	6	11
7	4	7
8	2	4
>8	8	15
Total	55	100
Weighted average years of active use		4.85

While up to 2002, very few farmers had stopped using their treadle pumps or relegating their status to standby equipment, the process of disuse started picking up thereafter. By 2006, almost 53% of treadle pump owners had either stopped using treadle pumps or putting them to use only occasionally. The pace of abandonment of treadle pumps as a main source of irrigation developed quickly in the last 4-5 years, during which period the remaining 47% of treadle pump owners also reported having stopped active use of their treadle pumps.

Table 12. Pace and pattern of disuse of treadle pumps

Year stopped using treadle pump as main source of irrigation	Number of farmers	Percentage
Before and up to 1994	2	4
1995-2002	7	13
2003-2006	20	36
2007-2010	26	47
Total	55	100

Several factors seem to have contributed to the observed pattern of disuse of treadle pumps. Before 2002, the water availability situation was at a more comfortable level in the region; diesel pump technology was not that widely available due either to high cost of technology or high use cost as compared to small size of holdings; electricity connections for irrigation pumping were few or not available, and if available then electricity supply was a problem; rental markets for diesel engines and water markets had not developed. Small farmers therefore had little or no choice except to use a treadle pump or practice rainfed farming. Subsequent periods saw a large influx of diesel pumps. Imported and initially smuggled Chinese petrol/diesel pumping sets started making inroads in the study area. Extension of electricity connections to rural areas had also started by that time, which encouraged investments in electric pumps. Indian manufacturers of diesel engines, facing the heat from imported Chinese diesel engines, also came up with lighter, better quality and relatively cheaper versions. As a result of large scale availability and investments by farmers in easily transportable diesel pumping sets, an informal but very competitive water market for hiring in/out diesel pumps developed. Access to mechanized technology coupled with rising avenues for employment both within agriculture sector (due to increased availability of irrigation) and non-agriculture sectors (mainly services including rickshaw pulling), labor wage rates, in the face of severe labor shortages (in part also accentuated by implementation of employment generating program like MGNREGA of Government of India), started to rise making opportunity cost of labor spent on treading very high. These factors, coupled with reluctance of the family labor to undertake treading due to health related issues, to a large extent contributed towards changing the preference of the farmers in favor of using mechanized pumping for irrigation and abandoning of treadle pumps.

The results obtained suggest that it is the push rather than the pull factors that have encouraged disuse of treadle pumps for irrigation. The primary factors that have led to disuse of treadle pumps relate to labor related issues (non-availability, refusal by family labor, health related labor issues, opportunity cost of labor etc.) coupled with low and insufficient water output available with the use a treadle pump (Table 13).

Table 13. Factors contributing to disuse of treadle pumps

Total number of sampled farmers		60	
Number of Farmers who have stopped using treadle pumps		55	
Number of farmers who are still using treadle pumps		5	
Factors that contributed to decision on discontinuing use of treadle pumps as primary source of irrigation		Number	%
TP Related technological factors	After purchase realised TP is useless technology so stopped using it	6	11
	My TP had lived its life and had become unserviceable	3	5
	Lack of spares and service facility/ high cost of repair	0	0
Water output	Water output is very low- insufficient for my size of land holding and/or cropping pattern	18	33
Water level	Water table has gone down; TP unable to lift water	5	9
Labor	Not enough family labor, family refuses to treadle, hired labor for treading not available or expensive	34	62

Totals may not tally due to multiple answers.

Meeting irrigation water requirements

If almost all the treadle pump owning farmers have stopped using treadle pumps as a main source of irrigation, then how are these farmers meeting their irrigation water requirements? Fifty-three of the 60 treadle pump owing farmers (88%) reported that they hire-in pumping equipment.

Investing in a motorized pump

Given an opportunity, do treadle pump owning farmers aspire to invest in a motorized pump or would they be happy to continue with the existing arrangement of relying on the pump hire market? About 77% of the farmers reported that given an opportunity they would be willing to invest in such a technology. So what constrains them for investing? The results obtained from our survey suggests that neither the availability of equipment in the market, nor worries about operating and maintenance costs, nor the quality of equipment has deterred these farmers from investing in pumping equipment. The most important factors are the lack of access to finance for investment and the high cost of technology.

Table 14. Factors dissuading farmers to invest in motorized technology

Total number of farmers		60
Number of farmers willing to invest in a motorized technology		46
Reasons for not investing	Number of farmers	Percentage
High cost of technology	20	43
Quality of technology (quality, life of equipment, lack of dealer guarantee on equipment)	8	17
O and M cost (spare parts not available, cost of repair high, mechanics not available for repair)	4	9
Availability (of equipment, diesel) a problem	2	4
Lack of access to finance for meeting the cost	23	50
Other	2	4

Can treadle pumps be rejuvenated?

Based on their experience of use and disuse of treadle pumps over a number of years we attempted to ascertain if the treadle pump technology holds any promise in the future and what could be done to revive treadle pump technology. While all except three farmers indicated that there is no scope for revival of treadle pump technology. The three somewhat optimistic farmers were of the view that if treadle pumps can somehow be re-engineered or motorized, some farmers might return to using treadle pumps in their new form. Whether this is possible is a question that needs to be examined by engineers. Even if it is technically possible, one would need to examine the relative cost of providing irrigation through this version of treadle pumps vis a vis other technologies such as cheap diesel engines that are currently being used on a large scale in the study area.

4. Opportunities and Constraints for Adoption of Irrigation Technologies: Owners of Motorized Pumps

Motorized pumping technology in Cooch Behar: Influx and current status

In the last one decade or so, motorized pump technology has made significant inroads into the irrigation scene of Cooch Behar District. Motorized pumping technology, based either on diesel engine powered pumping sets or electric motor powered wells and tube wells, has revolutionized irrigation scene in the study area. The user friendly nature of technology, a range of options and brands to choose from, easy availability of equipment of different sizes and weights, ready availability of spare parts, the presence of numerous trained mechanics to repair the equipment, and the existence of a ready large market for equipment hiring has made investment in this technology an attractive investment proposition[5].

This is not to imply that motorized technology is a new technology and was not available in the study region earlier. Diesel pumping sets have been available and have been in use in the study region for several years. However, the high cost of technology precluded small farmers from investing. The heavy weight of the equipment made this otherwise divisible technology (through custom hiring of the equipment) an indivisible technology by restricting its movement from farm to farm and thereby prohibiting its use by farmers who could not afford to invest on their own. Manufacturers of diesel engines probably never gave much consideration to the huge potential of the equipment hire market for diesel engines. Lack of access to electricity in rural areas restricted adoption by farmers of this otherwise less expensive and more convenient electricity operated motorized technology for irrigation.

This technological void in diesel engine technology was filled by cheap light weight multi-fuel operated (kerosene, diesel, petrol) engine sets manufactured in China. These engines made their way into the study region initially through smuggling from neighboring Bangladesh. Cooch Behar shares India's noncoastal international border with Bangladesh and this made smuggling a relatively easy option. Despite the poor manufactured quality of Chinese equipment and its short working life (sometimes as low as 3 years or less) these pumps became an instant success in the region. Smuggled pumps were freely available and the administration did not interfere. Those farmers who could afford to invested in these pumps at the first available opportunity and used these pumps not only for meeting their own, often meager irrigation requirements, but for hiring out to farmers in their neighborhood. Given the huge ready market available for hiring of pumping equipment, the investing farmers could generally recover their investments in less than two years, thus making investments profitable notwithstanding their short working life.

In keeping with the wide ranging trade reforms undertaken in India and coupled with the emerging popularity of the Chinese engines, the import of Chinese pumping sets was made legal. This paved the way for development of a more organized market for regulating the sale of Chinese pumping sets and made their availability to buyers hassle free. The legal

[5] Spare parts both imported from China as well as made in India are available. One of the dealers told us that he makes more money selling spare parts than by selling iDE's pumps.

import of spare parts has also been permitted. Seeing a threat to their market share by the influx of cheap Chinese pumps, the Indian manufacturers, with Kirloskar as the market leader, brought in smaller, lower horse power, cheaper and relatively light weight diesel pumping sets[6]. In keeping with the general Indian customs of manufacturing sturdy, durable and longer lasting equipment, the Indian manufactures made diesel engines of smaller size and better quality than those imported from China, although they still weigh almost double a Chinese pump and also priced at almost 70-80% higher. Concurrent with these developments, a large market for second hand diesel engines also developed whereby a famer could buy retrofitted diesel pumping sets at much lower prices. Over the years, Indian pumps have acquired a significant market share in the diesel engine market.

While no data is available on the current sales of Chinese and Indian made diesel pumping sets in the district, informal trade estimates suggest that Indian made diesel engines now account for 60-70% in diesel engine sales. Those farmers who can afford to invest in an Indian pumping set are going for Indian diesel engines while those who cannot afford to spend so much still prefer a Chinese pump A majority of the farmers who earlier invested in a Chinese pump, after having seen its performance and after having earned additional money from the use of the pump, are now buying Indian pumps after their Chinese pump has lived out its life.

The emphasis by the West Bengal government on making electricity connections for irrigation more easily available is also gradually changing the technology choice scenario for irrigation. Given that the operating cost of providing irrigation with this option is the lowest (even if electricity is priced and charged on actual consumption basis) farmers are likely to switch over to this technology once they have the electricity connection installed on their farm. Currently, the electricity connections are not that easily available and the farmer is required to bear the capital cost of extending the electricity conduit from the nearest accessible point to his farm, which is quite an expensive proposition, especially for those whose farms are far from the nearest access point. This cost is discouraging farmers to opt

Results from Survey

Characteristics of investors in motorized technology

Status of investment in irrigation technology prior to investment in current motorized pumps.

Who are these farmers who have invested in motorized pumps? Did they invest in any irrigation technology prior to investing in a motorized pump? Are these first time investors in irrigation technology or have they graduated from prior investment in treadle pumps?

[6] The Chinese made diesel engines are priced at around INR 10,000. The most popular brands (accounting for almost 80% of the Chinese diesel engines) are CD 170 (4 HP) and CD 175 (5.5 HP). The fuel consumption is about 400 ml per hour. The Indian manufacturer Kirloskar has also introduced about two years ago a competing diesel engine – Kirloskar Versa – which is roughly comparable in terms of fuel consumption with Chinese diesel engines. This is a 4 HP DE with an RPM of 1800 and costs around INR 18,000. Kirloskar however is more efficient – water discharge with Chinese pump is about 30% less than that with Kirloskar.

The results from our survey (Table 15) show that of the 120 sampled motorized pump owners, only 10 (about 8%) had invested in any irrigation technology of their own prior to their current investment. The remaining 92% are first time investors in an irrigation technology. Of the 10 sampled farmers who had previously invested, four had invested in treadle pumps and six in diesel engines. All four investors in treadle pumps have now switched over to diesel engines. Of the remaining six earlier investors who had earlier invested in a diesel engine, four have moved over to investing in an electric motor, while the remaining two have again invested in diesel engines of a different make and better quality.

Table 15. Status of investment in irrigation technology of those households who had invested in irrigation prior to current technology

Total sample size				120
Number of farmers who had invested in some irrigation technology prior to current investment				10
Type of technology	Technology status earlier	technology currently invested in		
		Treadle pump	diesel engine	electric motor
Treadle pump	4	0	4	0
Diesel engines	6	0	2	0
Electric motors	0	0	0	4

Status of irrigation application prior to investment in the current pumping equipment
Only 10 of the 120 sampled households had invested in any pumping technology prior to their investments in current motorized pumping equipment. Since the majority of the farmers had not invested in any pumping equipment of their own, were they at all applying irrigation, and if so what methods were they using?

The results from our survey show that not all farmers were applying irrigation. Only 61% of the sampled farmers were applying irrigation to their crops, the rest were practicing rainfed farming (Table 16). Of those irrigating their crops, 38% used diesel engines. About 32% of the sampled users purchased water directly from farmers in their neighborhood. About 16% used surface irrigation through gravity flow to irrigate their fields.

Table 16. Status of irrigation before investing in the current pumping equipment

	Yes	Percent
Were you irrigation your crops earlier	73	61
If yes, technology/method used		
Treadle pump-owned or hired	4	5
Diesel engine- owned or hired	28	38
Electric motor- owned or hired	6	8
Surface water-gravity flow	12	16
Others (buying water)	23	32

Why invest in a motorized technology?

Unlike surface water, which can be applied through gravity flow, if terrain conditions so permit, use of groundwater requires a motive power to draw water from under the ground. In the study area, where the water availability at most places is at a relatively comfortable depth, both manually operated treadle pumps as well motorized pumps of various types and sizes can be employed to draw groundwater. Why is it that the farmers who have invested in motorized technology have opted for this technology and not a treadle pump? What are the primary factors that have driven their investment in this technology? There could be a large number of factors ranging from large water requirements to effortlessness with which the motorized technology can be employed for drawing water. What have been the more important factors that have enthused the sampled motorized technology owning farmers to invest in this technology over other say treadle pump technology?

The results obtained suggest that from amongst the various factors influencing the choice of technology in favor of motorized technology, the relatively more important factors have been the size of land holding and consequently the large water requirements and, ease of installation and use of technology (Table 17). Some of the other relatively more important factors that have influenced choice of motorized technology have been non- availability of labor for treading, reasonable and affordability of prices of motorized technology, light weight and easy mobility, and lots of opportunities for hiring out the equipment. Some of the factors such as availability or otherwise of dealer guarantee about the quality of product, low fuel consumption, sturdiness or life of the machine etc have not been able to deter their decision in favor of investing in a motorized technology.

Table 17. Factors influencing choice of motorized pumps over other water lifting technologies

Total number of sample farmers			120
Number of farmers who have invested in motorized irrigation technology			120
Factors	Specific concerns	Number of farmers	%
Land	Large size of land, consolidated land etc	90	75
Water	Large water requirements, depth to water table	87	72.5
Influence	Influenced by dealers/NGOs, demonstration at some exhibition	2	1.7
	Saw neighbor using it	14	11.7
Price	Reasonable price, recent fall in prices	28	23.3
Subsidy	Got subsidy/free	21	17.5
Fuel price/running cost	Subsidy on fuel/electricity/ distance from diesel station	19	15.8
Finance	Availability of finance, access to cheap credit	15	12.5
Technology	Ease of installation - simple to use	87	72.5
	Low fuel consumption	9	7.5
	Light weight-easy mobility	22	18.3
	Low maintenance, after sales service available	18	15.0
	Dealer warranty	6	5.0
	Sturdiness, long life	6	5.0
Crop	Cultivates/ intend to cultivate high water using crops	15	12.5
Hire-in problems	Difficulty in hiring in of machine	13	10.8
Hiring out	Lots of opportunities for hiring out	20	16.7
Labor	Little family labor/hired labor not available	29	24.2
Crop economics	High prices for irrigated crops/market for irrigated crop developed	22	18.3
Social	Enhanced social prestige	12	10.0

Totals may not tally due to multiple responses.

Pace and pattern of adoption of motorized technology

An analysis of the pace and pattern of investment in motorized technology presents some interesting results. Investment in motorized technology by a majority of the farmers has been a relatively recent phenomenon. Up to 1995, only 3% of the sampled farmers had invested in motorized technology (Table 18). The pace of adoption subsequently increased, first gradually and then quickly, as the availability of technology improved, choice of brands, makes and sizes increased, availability of electricity connections improved, confidence of investors moved up, and prices stabilized or slightly declined. Almost 68% of our sampled farmers invested in motorized pumping technology in the last 5-6 years from 2005. The mechanization of irrigation technology is taking place at a much faster rate now than what it has been just a few years earlier.

Along with the increasing pace of adoption of motorized technology there have also been some significant shifts in the nature of technology mix adopted between diesel engines and electric motors. With new electricity connections being released for irrigation and improved supply of electricity to rural areas, farmers are finding it more convenient and economical to use electric motors for groundwater withdrawal. Of the 120 farmers who made investment in motorized technology over the years, 37% had made these investments in electric motors. Up to 2004, out of 38 farmers who made investments in motorized pump technology, only 4 (11%) had invested in an electric motor. Subsequent to that the pace of adoption of electric motors for irrigation increased substantially. With passage of time, more farmers are going for electric motors, and in the latest period 2007-10 out of 57 investments made, 53% were made in an electric motor.

Table 18. Pace and pattern of growth of motorized irrigation: number of sampled households who bought irrigation equipment during different years

Period	Number of farmers who invested in a			Percent of electric to total
	Diesel PS	Electric	Total	
Up to 1995	4 (5)	0 (0)	4 (3)	0
1996-1999	5 (6)	1 (2)	6 (5)	17
1999-2001	10 (13)	3(7)	13 (11)	23
2002-2004	15 (20)	0 (0)	15 (13)	0
2005-2007	15 (20)	10 (23)	25 (21)	40
2008-2010*	27 (36)	30 (68)	57 (47)	53
Total	76 (100)	44 (100)	120 (100)	37

Figures in parentheses denote percent.

Another important feature of the adoption of motorized technology has been a change in the origin and source of motorized equipment. Concurrent with the changing mix of diesel and electric pumping sets there have also been changes in the type of equipment purchased by investors. Tracing the origin of manufacture of the equipment (Chinese versus Indian) suggests that investors do carefully weigh the quality of equipment, its durability and anticipated life, problems of frequent breakdown and of course the price before making a decision[7]. Almost two-thirds of our sampled diesel engine owning households reported having invested in an Indian made diesel engine[8]. Given the fact that most of our sampled households made these investments in recent years, by which time they had had an opportunity to assess the Chinese equipment and the new Indian made diesel engines, the tilt in favor of Indian made diesel engines has not been totally unexpected.

[7] To cut down on costs there have also been some other attempts made by dealers and local mechanics to devise 'hybrid' pumping set combinations by installing on a Chinese diesel engine a locally made Indian pump. While a Chinese pump costs around Rs 1200, the locally made Indian one is available for Rs 500-600.

[8] While the Indian made Kirloskar Versa weighs about 75 kg (including base), Chinese pumps weigh about 45-65 kg.

Apart from quality difference between Indian and Chinese pumps, another important factor that could have also tilted the scale may have been the availability of a government subsidy on diesel engines which conform to standards of equipment manufacturing. As part of a Centrally Sponsored Scheme (CCS) on mechanization of agriculture, the Government of West Bengal has been giving farmers a 50% subsidy on the purchase of diesel pumping equipment[9]. This subsidy is available only on pumps conforming to Bureau of Indian Standards (BIS) quality specifications. Since Chinese pumps do not conform to this requirement, buyers of Chinese equipment do not qualify for the subsidy. A 50% subsidy makes Indian pumping sets as cost effective as Chinese pumps[10]. A similar subsidy facility available in the neighboring state of Assam has been contributing indirectly to increased availability of Indian diesel pumping sets in Cooch Behar. A large number of farmers in Assam, who are eligible for the government subsidy, after getting the subsidy sell their brand new pumping sets to farmers or shops in Cooch Behar at a price much lower than the market price of the equipment. Quite often the Assamese farmers do not even take delivery of their pumping equipment from the dealer and there are middlemen who give a small cash amount to the beneficiary farmer and do all the paper work, and after taking delivery from the dealer supplies it to a farmer or shop in Cooch Behar for a commission.

The electric motors made in China offer no apparent comparative advantages. There are several manufacturers of electric motors in India manufacturing electric motors of all sizes varying from as low as 1 HP and up. Some Chinese electric motors are available in the market but these are less preferred by Indian consumers. Thus, almost all the sampled households who had invested in an electric motor had invested in an Indian made product[11].

Table 19. Origin of make of pumping equipment

Type	Indian	Chinese	Total	Average HP
Diesel	50 (65.8)	26 (34.2)	76 (100)	4.28
Electric	43 (97.7)	1 (2.3)	44 (100)	1.44
Total	93 (77.5)	27 (22.5)	120 (100)	

Figures in parentheses denote percentages.

[9] This is not to imply that all farmers who want to buy the equipment can do so by taking a subsidy. In practice, there are a limited amount of funds available every year and depending on the funds available, a few farmers are selected and given subsidy each year.

[10] Up to 50% subsidy (or INR 10,000 or whichever is less) is available on Kirloskar and other BIS marked pumps. The subsidy program is implemented by WB Seeds Corporation. A subsidized Kirloskar is thus available for around INR 9,000.

[11] According to an estimate provided by the largest dealer of pumping equipment in Cooch Behar district, in Cooch Behar district the relative contribution of different WEM are as follows: Electric- 30%; DE (Indian) 40%; DE (Chinese) 30%, TP (< 1-2%). As per his estimate, there were about 100,000 WEM in the district about 4 -5 years ago. Today also probably the total number is the same but there have been technological replacement between different technologies.

Farmers' Satisfaction with Choice of Motorized Technology

Having invested in a variety of motorized technologies are the farmers on the whole satisfied with their investment decisions? Of the 120 farmers who had made these investments, 109 (91%) reported that they are happy with the choice of technology they invested in. The remaining 11 were not fully satisfied on account of certain problems they encountered (Table 20)

Table 20. Reasons for dissatisfaction with the use of technology

Total number of sampled households		120
Number of farmers unsatisfied with the use of technology they invested in		11 (9%)
Reasons for dissatisfaction	Number of farmers	Percentage
Frequent breakdown of equipment	3	27
Small life of equipment	1	9
After sales service unreliable/ inefficient	1	9
Spare parts not available/ not of good quality	4	36
Mechanics for repair not available/ expensive	3	27
Availability of diesel/electricity a problem	2	18
Rising cost of diesel	5	45
Others	3	27

Note: Totals may not tally due to multiple answers.

5. Opportunities and Constraints for Adoption of Irrigation Technologies: Non-Owners of Irrigation Equipment

A large majority of farmers have not invested in any irrigation equipment of their own. They either depend on the equipment hire market or practice rainfed farming. With increasing sales of diesel pumping sets and fast developing equipment hire market, the availability of the equipment on hire has improved and hiring rates for pumping equipment have become very competitive. As a result, while some of those who have not invested in pumping equipment of their own may have deliberately done so, others who may be willing to invest may have been constrained by factors which limit their investment ability.

Results from Survey

Lack of ownership of irrigation equipment and application of irrigation water

Of ninety-one sampled households selected from amongst this subgroup of households, 89 do not currently own any irrigation equipment. Do farmers who do not own any irrigation equipment not apply irrigation? Is ownership of irrigation equipment a necessary condition for accessing and applying irrigation water? The results from our survey show that this need not be the case. More than 86% of our sampled households who did not own any irrigation equipment have been applying irrigation water (Table 21). Only 14% do not apply any irrigation. In the absence of ownership, these farmers apply irrigation by hiring in irrigation equipment either from those farmers in their neighborhood or hire in from the wider market. Of the farmers who have been applying irrigation by using hired in equipment, about 83% hire in diesel engines, while the remaining 17% hire in electric motors. However none of the farmers reported hiring in a treadle pump.

Table 21: Non-ownership of irrigation equipment and methods of irrigation.

	Number	%
Total number of sampled households	91	
Number of households who do not irrigate their crops	13	14
Number of households who irrigate their crop	78	86
Sources of irrigation used by farmers who irrigate their crops		
Hired treadle pump	0	0
Hired diesel pump	65	83
Hired electric motor	13	17
Buy water from others	0	0

Factors constraining irrigation investment

When such a large majority of non-equipment owning households have been applying irrigation water by hiring in equipment, it is unlikely that the non-investment is due to lack of awareness about the benefits of applying irrigation or lack of information about irrigation technologies. Why is it then that such a large number of farmers have not invested? What constrains them for investing in irrigation?

The results (Table 22) suggest that lack of access to finances for investment has been the most important constraining factor. Easy access to the equipment rental market and small size of operational holding have been some of the other factors that have constrained farmer investment.

Table 22. Factors constraining investment in irrigation by non-owners of irrigation equipment

Total number of sampled households			91
Number of households who have never invested in any irrigation equipment			89
Reasons for non-investment			
Factor Group	Specific factors	Number	% of Non-Investors
Physical	Small size of land holding	19	21
Water Access/ Availability	Enough Rainfall – Irrigation not required	0	0
	No surface water in the vicinity	1	1
	Irrigate using gravity flow of surface water	0	0
	Groundwater table very deep	1	1
	Cultivate low water using crops.	1	1
	Irrigate using buckets etc	1	1
Water Market	Equipment available on hire from neighbors/market	28	31
	Water available from neighbors for purchase	7	8
Financial	No money to invest	62	70
	Credit facilities not available	14	16
Technological	Lack of awareness about different technologies	3	3

Totals may not tally due to multiple responses in some cases

Willingness to invest in an irrigation equipment and preferred technology for irrigation

Of the 91 non-equipment owning households, 13% are not willing to invest in irrigation notwithstanding the above factors (Table 23). Of the remaining 87% of households who are willing to invest, all expressed their preference for either diesel or electricity. A small number of farmers expressed a preference to invest in both technologies but a relatively larger proportion preferred to invest in electric motors. Given the comparative economics of providing irrigation through electric pumps the choice appears to be rational. However, choice of a diesel engine, primarily because of non-availability of electricity connections, and its convenience of easy farm to farm mobility is not much far behind. About 35% of the farmers reported their preference for a diesel engine. None of the sampled households had a preference to invest in a treadle pump.

Table 23. Willingness to invest in irrigation and favored choice of irrigation technology

	Number	%
Total number of sampled households	91	
Number of households who would not like to invest in an irrigation technology	12	13
Number of households who would like to invest in an irrigation technology	79	87
Preferred Irrigation Technology		
Treadle pumps	0	0
Rope and washer pumps	0	0
Diesel pumping sets	38	48
Electric tube well	45	57
Any other		

Note: As some farmers expressed their desire to invest in both diesel and electric, the totals may not tally.

Why not invest in a treadle pump?

The sampled farmers gave a number of reasons for their unwillingness to invest in a treadle pump. The most important of these relate to labor; either non-availability of labor for treading or the high cost of labor, and health related impacts of treading on labor (Table 24). Part of this antipathy to treadle pumps is also due to the demonstration effect. Some of these farmers have seen and discussed with other farmers who had used treadle pumps and based on their experience they had made an assessment of their own and decided against investing in this technology. In fact, 56% of the farmers see treadle pumps as a useless technology with no future. It is important to note that the decision not to invest in treadle pump was made in the light of full awareness about some of the positive features of treadle pump technology, such as the low-cost, favorable economics of investment. If some of the important concerns raised by the farmers were to be addressed, would they be willing to reconsider their decision? Just one of the sampled farmers responded in the affirmative. The remaining farmers are unwilling to reconsider.

Table 24. Factors inhibiting the choice of treadle pump as a favored irrigation technology choice

Total number of sampled farmers			91
Number of farmers willing to invest in irrigation technology			79
Number of farmers indicating treadle pump as their most preferred choice			0
Factors inhibiting treadle pump as a favored choice		Number	%
Demonstration effect	Neighbors/friends purchased treadle pump but are not happy using it	37	47
Technological factors	Useless technology – has no future	44	56
	Irrigating with treadle pump is a time consuming process	35	44
	Concerns relating to poor quality of treadle pump available, problems of spare parts availability, after sales services etc.	15	19
	Cannot draw water from greater depth	3	4
Water output	Water output is very low- insufficient for my size of land holding, not suitable for water intensive crops	45	57
Labor	Not enough family labor, family refuses to treadle, hired labor for treading not available or expensive	70	89
Health	Treading causes pain in joints	51	65
Cost and access to credit	Expensive, not enough money to invest, lack of access to credit	4	5
Hiring out	Limited scope for hiring out	13	16
Availability	No treadle pump dealer in the vicinity	0	0
Gender	Not gender friendly- women find it difficult to treadle, women resent investment in treadle pump	7	9
Economic and social prestige	Uneconomic to invest in treadle pump- cost of irrigating with treadle pump is more than the revenue it generates through increased crop yields	5	6
Others		0	0

Totals may not tally due to multiple answers.

6. Conclusion

The treadle pump is a useful and affordable technology and offers great potential for raising incomes of resource poor farmers through provisioning of water for irrigation at a nominal cost. While not undermining the immense utility of treadle pumps, it has to be kept in mind that the choice to invest in a particular technology is not a one-time decision. Treadle pumps served a useful purpose when they were introduced 15 years ago. One of the contributing factors was the high cost of alternative technologies.

An examination of the current use status and the sales performance of treadle pumps suggests that the technology has become dated and there are no new takers for this technology. Given the technologies now available and the rapidly falling cost of these

options, farmers are not willing to invest in treadle pumps even if some of the negative features were addressed. Treadle pumps are being relegated to history in Cooch Behar District. Any additional efforts or money (public or donor) spent on promoting treadle pump technology in the study region or those regions similarly placed will not serve the intended purpose of improving accessibility of irrigation to small and marginal farmers and in helping them improve their incomes.

There has been a substantial uptake of both Chinese and Indian made diesel pumping sets for irrigation. Diesel engine technology holds great promise in the study region. Lack of access to financial resources by some small farmers has constrained investment. However, some positive features have permitted use of this otherwise indivisible technology into a divisible technology through establishment of an extensive, competitive, affordable and generally reliable informal rental market for diesel engines. There has also developed a market for sale of second hand equipment.

Due in part to the great promise this technology holds for irrigation water provisioning, there have also been technological improvements by manufacturers and the diesel pump market is undergoing some important changes. Chinese pumping sets are increasingly facing tough competition from Indian manufacturers. Although the Indian made sets cost almost 70-80 per cent more, they are of superior quality and longer lasting. Informal market estimates suggest a share of about 60-70% of current sales between Indian and Chinese diesel pumping sets.

We envisage that the progress diesel pumping sets have made on the irrigation scene of the study area in the last few years is likely to continue. Electric motors, however, are the more desirable choice of a majority of the farmers due to their low maintenance and running costs and ease of use. Due to constraints on the availability of electricity and the high cost of extending an electricity connection to the farmers' field, the uptake of electric motors for irrigation, while picking up fast, will take a few more years to make the inroads. Going by the experience of some of the other regions of the country where electric tube wells predominate, a number of farmers prefer to maintain a diesel engine as a standby arrangement due to the frequent power cuts in the agricultural power supply.

Factors that could facilitate the uptake of an appropriate irrigation technology in the study region

The analysis suggest a number of steps that could facilitate a more efficient path to irrigation technology adoption:

- Adoption of and investment in irrigation technology does not necessarily follow an orderly movement up the technology ladder. It is therefore not always necessary to start technology uptake efforts from the bottom of the ladder.

- Technology adoption is a dynamic process and a technology appropriate at one point in time need not remain appropriate at all points in time. Treadle pumps may have been an appropriate technology when they were introduced and there were no alternative or competing technologies

available. With the availability of a range of options to achieve the same goal of accessing irrigation water, the treadle pump technology may no longer be appropriate.

- The low cost of technology does not necessarily encourage farmers to invest in a technology. A farmer who cannot afford to invest in diesel or electric pumps may still not invest in an inexpensive technology such as a treadle pump due to the availability of motorized pumping equipment on hire, even if that option is more expensive than investing in his/her own treadle pump.

- Lack of access to financial resources to meet the upfront cost of investment was cited by a number of farmers as an important factor constraining investment in irrigation technology of their own. Provision of finances for investment in irrigation technology at subsidized lending rates would provide a boost to private investment and access to irrigation.

- Farmers generally rely on an equipment dealer for deciding on the type and size of irrigation equipment to buy. The equipment dealer and not the extension agency is the main source of information. This sometimes leads to inappropriate choice of technology and overcapitalization of investment. Efforts to provide technical help in equipment selection will go a long way in helping farmers choose a more appropriate technology.

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