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TUBEWELL IRRIGATION IN BANGLADESH

James Morton

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TUBEWELL IRRIGATION IN BANGLADESH

JAMES MORTON

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TUBEWELL IRRIGATION IN BANGLADESH

James Morton

1. INTRODUCTION

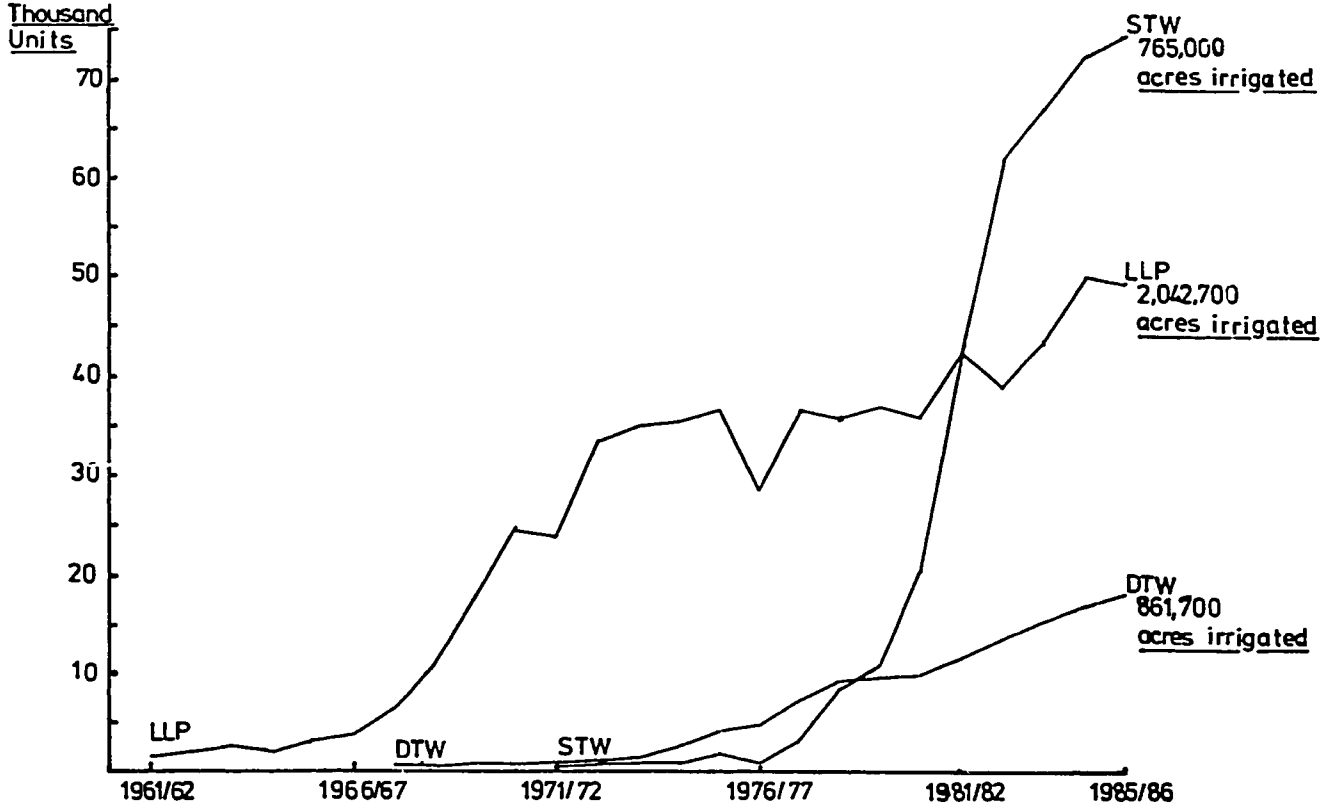
Traditional methods of raising surface water to irrigate dry season crops have made an important contribution to agricultural production in Bangladesh for a long time. More recently, the 1960s, 1970s and 1980s have seen a rapid expansion in the use of mechanical pumps in order to bring much larger areas under command. Figure 1 illustrates the pattern of expansion. During the early part of the period, low lift pumps (LLP) made the largest impact although deep tubewells (DTW) were also introduced on the higher ground. Hand tubewells (HTW) and shallow tubewells (STW) came later, but there was a particularly rapid expansion in the numbers of STW in the early 1980s. There have also been many gravity-fed surface irrigation schemes in Bangladesh but these raise different issues and are not considered here.

Despite the strong positive contribution to agricultural production, tubewell irrigation has become a subject of intense debate. Two points have attracted considerable attention:

1. Efficiency of utilisation - since the early period of DTW irrigation there has been disappointment that the irrigated acreages, per unit of rated discharge, have persistently fallen short of that which is estimated to be technically feasible. The norm has been 50 to 60 acres per 2 cusec DTW against a potential of more than a hundred. STW performance is equally poor. Drop out rates have also been high and much equipment has gone out of use or been diverted to non-irrigation purposes as a result.

2. Equity - There has been widespread concern that rural elites would capture control of minor irrigation equipment and use

BADC SUPPLIED MINOR IRRIGATION EQUIPMENT



that control to further strengthen their position and exploit their neighbours. The coinage "waterlordism" sums up this possibility.

An attractive thesis links these two concerns, suggesting that the controlling elite deliberately restricts the irrigated area because the power to deny water is a weapon in factional struggles, even a means to prevent the poorer farmers benefitting. Much research work has, as a result, focused on the social aspects of tubewell operations: the interactions between the operator and the farmers and between both parties and the supporting government agencies. A number of projects have endeavoured to overcome these social constraints through cooperative or landless group management.

One purpose of this paper is to suggest that this emphasis on command area, together with social and equity factors, has obscured other aspects that are equally important and less well researched. These include:

1. Land Class - The land resource in Bangladesh forms one vast alluvial plain and there appears to be little variation. There are, however, significant differences in soil type and susceptibility to flooding. These variations affect the whole farming system. Evidence will be presented below showing marked differences in irrigated area per DTW between one land class and another.

2. Farming Systems - Everyone grows rice. However this apparent lack of variation once again conceals important differences in cropping pattern and technique. There are three growing seasons: Aman (Monsoon), Rabi/Boro (Dry Season) and Aus (Early Monsoon). The varieties grown and the techniques used are different for each season. Farmers must manage complex combinations if they are to achieve the optimum balance between the three rice seasons and between rice and other crops. The introduction of irrigation can

mean that substantial adjustments to the balance are necessary affecting all three seasons, not just the dry season.

3. Intensity - Depending on the land class and the farming system used, the way irrigation affects the system varies widely. In some cases it may enable a one hundred percent increase in crop intensity, in another it may actually lead to a small reduction. Although improved yields may still provide significant benefits in the latter case, it is almost inevitable that irrigation will prove less profitable and less attractive where it does not offer the chance to increase the number of crops grown per year.

4. Water Requirements - Crop water requirements, more precisely pumping requirements, are central to all calculations relating to mechanical irrigation, yet there is relatively little information on the amounts of water applied and the extent to which these fall short of or exceed the optimum. Much of the planning work that has been done, is based on theoretical crop requirements, the biological optimum. This may differ widely from both the economic optimum and the actual amounts applied, i.e. the farmer's own optimum. The fact that the economic water application is variable, depending on the cost of water and the value of the product, is usually ignored.

5. Financial Returns - There is a body of data on the profitability of the main irrigated crop, boro rice, although even that could be improved. The major lack is data on the profitability of other crops in the system, especially those in competition with boro rice. Since 1985, there has been a deceleration in the rate at which new tubewell irrigation equipment is being installed. This slowdown is a strong, if indirect, indication that the financial returns are not as attractive as they appear on the basis of existing data.

It is generally accepted that food self-sufficiency is a priority that must override all others in Bangladesh. However, the economic return to tubewell irrigation may be relatively low and the foreign exchange costs of achieving self-sufficiency high. The most cost-effective use is, therefore, very important. This depends on two factors: the choice of the most economical equipment and the efficiency with which it is used once it is installed.

In Section 2, an attempt is made to consider all the possible reasons for poor tubewell performance under four broad headings: technical, social, land class and economic. It is concluded that the last two have much the most significant impact on irrigated areas. In the context of land class, it is emphasised that irrigated area is a poor measure of economically efficient performance. The Net Incremental Cropped Area, a measure of the change in intensity, is a much better proxy although the Net Incremental Production is the only true measure. (For simplicity, however, the phrase 'irrigated area' is used except where the more exact definition is required.)

In Section 3, an analysis is made of the way in which the most economical technology mix is to be decided. This is a complex problem, the resolution of which involves all of the factors mentioned above. The distinction between the economic and the biological optimum crop water requirement is crucial. Time is a further complicating factor. It is necessary to decide not merely which technology, HTW, STW, or DTW, is most appropriate for each area in the long term but also how long the development period should be and which technologies may be appropriate in the short term, interim phases of that period.

This attempt to bring together all the elements that affect tubewell irrigation, raises more questions than it answers. It is hoped that it will, at least, indicate what is needed for a full evaluation of the various classes of equipment in use and

highlight some areas where efforts to improve performance might be concentrated.

2. EQUIPMENT FACTORS

The reasons for poor tubewell performance may be sought in five separate areas:

i. Poor technical performance of the well
ii. Social barriers
iii. Mode of operation
iv. The land class
v. Economics

2.1 TECHNICAL PERFORMANCE

Aquifer problems, poor well design and poor construction can all mean that a tubewell does not produce the amount of water (discharge) it should. It is natural therefore to look for a connection between the discharge of the installed wells and the area irrigated. Several studies have, nevertheless, reached the conclusion that discharge is rarely a significant factor. One example may be quoted:

> "The research reported here has confirmed the occurrence of lower than design discharges and inefficient canal layouts with high conveyance losses, but it has shown that these are not related with the performance of the minor irrigation equipment".
> (Biswas, et al, 1986.)

The study quoted covered 100 units managed under a number of different institutional arrangements in two relatively small areas in Tangail and Dhaka districts. Monitoring data from the IDA DTW II Project, taken in conjunction with the project records of well performance at the time of installation, allow an

analysis of the same question for over 1000 deep tubewells in 36 upazilas of Dhaka, Mymensingh and Kishorganj districts. This analysis confirms that even when only one technology under one institutional arrangement, DTW under the IDA project, is considered, discharge is not a significant influence on well performance as measured by the irrigated area. The correlation coefficient calculated for the relationship between the irrigated area at each DTW in 1987 and the discharge of the well measured at installation was only 0.041, indicating that discharge has almost no influence on area.

The conclusion must be that at the majority of sites, some other factor prevents the achievement of a large irrigated area. Most are too small for tubewell discharge to be a constraint. "While technical deficiencies existed there was no shortage of water except where cooperation among farmers and water suppliers had resulted in a considerable expansion of the command area." (Biswas, et al, op cit.)

It has also been suggested that slow engine running speeds are a factor. There is certainly evidence that some equipment is run at below the specified speed. There appear to be several reasons for this. It is, for example, often easier to manage smaller quantities of water, especially where distribution channels are weak and prone to collapse. Reducing rpm reduces the discharge to a manageable level. There is, also, a widespread feeling that slow running reduces the risk of breakdown and contributes to a longer machine life. In many cases this may even be true,. especially where poor construction means that vibration is high. In general it is clear that the "engine speed setting is a rational economic decision designed to economise power costs rather than an independent variable explaining performance". (Biswas, et al, op cit.)

If low discharge or slow running speeds were the major factor behind the small irrigated area, it would be expected that the equipment would be used for long hours in order to compensate.

Once again the IDA DTW II monitoring data does not support this. The hours operated on the busiest day of each month was recorded. The average of this, which is very much a maximum figure, for all wells monitored did not exceed 8 hours, even in peak season.

There is one indirect manner in which the technical performance of the equipment could affect the irrigated area: if it was so unreliable that farmers would not risk an irrigated crop. As will be discussed, the water market in many areas of Bangladesh is highly competitive and farmers often switch from one tubewell to another for their water. Unreliability is one of the commonest reasons for changing to a new supplier. However, switching between suppliers does affect the overall irrigated area; one well's loss is another one's gain. There is less evidence of farmers refusing to risk an irrigated crop because they did not trust the equipment.

To sum up, it does not appear that the technical performance is a major constraint to command area utilisation, at the present level of operation. This is not to say that there is not considerable scope for improvements in well design, installation and maintenance. Costs of operation could be substantially reduced at may sites. Nevertheless the major barriers to tubewell performance lie elsewhere.

2.2 SOCIAL FACTORS

"The widespread factional conflicts among farmers, the conflicting interests and relationships between large and small farmers and the understandable suspicions that are held of the motives of richer farmers who typically come to control water supplies, often lead to failure of cooperation over the distribution of water". Thus Palmer-Jones in his paper 'Research on the Landless Programme of Proshika', (in Biswas, et al, 1986) neatly sums up a common perception of the situation.

Clearly, one overriding factor, and one that can only be solved by balanced development in the Bangladesh economy as a whole, is the intense pressure of population and hence competition for a meagre farm livelihood. Against this background there are, however, two separate forms of tension: the social, where irrigation is caught up in some wider struggle within the community, and the financial where the battle is more direct, between the operator of the tubewell, as the supplier of water, and the irrigating farmers, as consumers of water. This latter aspect is considered in the next section.

"Widespread factional conflicts" reflect the vertical divisions with society, that is to say between kinship or neighbouring groupings. "Conflicting interest and relationships between large and small farmers" reflect the tendency to polarisation by social class in rural society. Such horizontal, class divisions are incompatible with vertical factional divisions. In order to maintain factional unity all classes are likely to have an interest in working together and vice versa.

It is not easy to assess the extent to which the evident social tensions in rural Bangladesh are caused by class rather than faction, a question well beyond the scope of this paper. It should, however, be noted that although the distribution of land is unequal, it is almost continuous. That is to say that there is no clear point at which a dividing line between "small" and "large" farmers can be drawn. The elimination of the medium-sized farm is one of the first signs of agricultural stratification and of emerging class divisions. The large farms get larger and the small, smaller and a gap appears in the middle. The fact that there is no such gap in the distribution of land in Bangladesh indicates that class divisions are as yet relatively weak. The techniques used, and the levels of intensity, are also very similar on all classes of farm. There is little evidence that economies of scale are driving out the middle farmer and creating two distinct classes of operation.

Nevertheless, it might be that powerful irrigation equipment will increase the power of the better-off to an extent that a process of agricultural stratification is reinforced, or set in motion. This would be expected to manifest itself through increased sales of land by the medium and small farmers and through the larger farmers preferring to operate a greater proportion of their land themselves rather than lease it out. The 1985/86 Annual Evaluation Survey of IDA deep tubewell sites (EPC, 1986) found no evidence that this was happening. Sales of land were negligible at all levels and the larger landowners rented out a substantial proportion of their holdings. An earlier study in a different area reached similar conclusions. "The position regarding rural elites must be kept in perspective. In the study area, land holdings are relatively uniform in size and even the farmers with larger holdings are working farmers." (MMP/HTS, 1982.)

Even if class divisions did exist, it is difficult to see how they should be a barrier to efficient tubewell use. If larger farmers wished to use their control of a tubewell to squeeze out their neighbours, their goal would be to gain control of the smaller farmers' land and then use their tubewell to irrigate it once they had done so. In short, it is more likely that the efficient use of tubewell equipment will lead to class stratification than it is that class stratification will be a block to such efficient use.

To sum up, it is difficult to derive a logical mechanism that explains how class-based social tensions might pose an obstacle to efficient tubewell operation. In addition, the evidence that social factors of either type are a major factor is not as compelling as is often reported. "Only in one of twenty live schemes studied was there the <u>possibility</u> that social factors were sufficiently strong to disrupt the group." (MMP/HTS, 1982.)

2.3 MANNER OF PAYMENT

Except where complicated by social factors, "the suspicions that are held of the motives of the richer farmers who typically come to control water supplies", described in the Palmer-Jones quote above, reflect the tensions that are to be found between any group of consumers and their supplier. From the consumers' point of view, the principal points of conflict are the quality of the service supplied and the cost. The suppliers' main concern is to ensure payment.

Palmer-Jones and Mandal have shown that the manner of payment is "one economic variable quite strongly associated with (tubewell) performance" (Palmer-Jones & Mandal, 1987). It seems most likely that the payment system is closely linked to the state of the consumer-supplier relationship and it is worth trying to analyse the implications of each particular system. There are three systems in common use. The first one broadly accords with that recommended under the government sponsored Irrigation Management Programme (IMP). That is to say that the operator, or the cooperative group, draws up a budget in advance of the season and calculates a per acre charge for water. In principal this charge includes allowance for the costs of capital repayment, depreciation, pump driver's wage, etc. However, there are many variations. Sometimes the capital charge is collected separately and it is common for the driver to be paid in kind. In almost all cases the charge is paid in several instalments through the season rather than as a lump sum in advance.

The second approach is for the major variable cost, fuel, to be charged for separately at the time of watering. A lower flat-rate, per acre charge is still made to cover fixed costs. At the extreme this system requires each farmer to bring his own fuel and hand it to the operator at the time he wants to water his field. It is possible to see a collection of old bottles, jugs and pots of diesel queued up outside a pump-house when this system is being used. Clearly this could lead to heavy water

losses if farmers from different parts of the command area called for water at the same time. Stopping and starting the engine too often would also be wasteful. In fact, it appears that the farmers do usually organise themselves into sensible groups so that a block of fields is irrigated on one session even though each man brings his own fuel.

Those involved advance two reasons for adopting this system. First, it significantly reduces the supplier's collection problem if the consumer pays at least part of the costs himself. Second, it provides an incentive to economise on the use of water and allows the farmer to control the major quality factor, the amount of water he gets. Under the flat rate system, every farmer is going to demand as much water as possible since it costs nothing extra and this is a natural source of conflict with the supplier who will want to minimise his operating time.

More technically, the direct fuel supply system introduces an element of marginal cost pricing in that the owners of more distant fields, which require longer pumping to offset channel losses would, in theory, have to supply more fuel. In practice, it appears that the fuel is not always measured to this degree of accuracy. Often there is merely a rule-of-thumb measure that decides how much fuel must be supplied for a given area.

The last method of payment is by crop share. The most common rate at present is one quarter, although there is evidence that it is variable according to market conditions. (Palmer-Jones, & Mandal, 1987.)

It would appear that payment by crop share offers the consumer, i.e. the farmer, advantages. First, it means that the supplier has a direct interest in supplying sufficient water. Second, there is an element of what might be called marginal product pricing. That is to say that those who achieve a high yield pay more and those who do not, especially those on the margins of the command are who receive less water, pay less. There are,

nevertheless, reported cases of farmers resisting a change to this system.

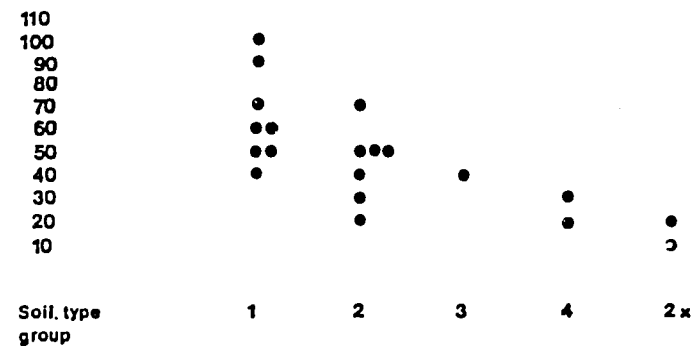
The fuel-supply and the crop share system represent two opposite poles in one important sense. The first minimises the operator's working capital investment in that he does not finance the major variable cost. Under the crop share system, on the other hand, the operator finances all the working capital right up until the harvest. This represents a saving to the farmers and hence is a further advantage to them. Despite this survey, results have shown that both systems perform worse, at least in command area terms, than the flat rate charge. (Palmer-Jones & Mandal, 1987.) It is possible that it is the common factor between the two systems that is important. Both minimise the management problem, in particular over the collection of water charges. Where management is weak or relations between the tubewell manager and the farmers are poor then command areas are likely to be small and both sides are more likely to opt for one of the two payment systems described. Where there is more trust, the more formal payment system is preferred and at the same time a greater irrigated area is achieved.

2.4 LAND CLASS

A small survey of 20 DTW carried out as part of the feasibility study for the Asian Development Bank (ADB) Second Tubewell Project (MMP/HTS, 1982), indicated that land class was a significant factor in the way the tubewells performed. Irrigated areas varied markedly over a range of land classes. However, this was shown to be a very imperfect indication of the tubewells' performance because crop intensities in classes with high average command areas were much lower. The net incremental cropped area (NIA) attributable to tubewell irrigation was therefore much more even between land classes. It must be stressed that it is the latter parameter, the net incremental area, that is the true measure of tubewell performance, not the

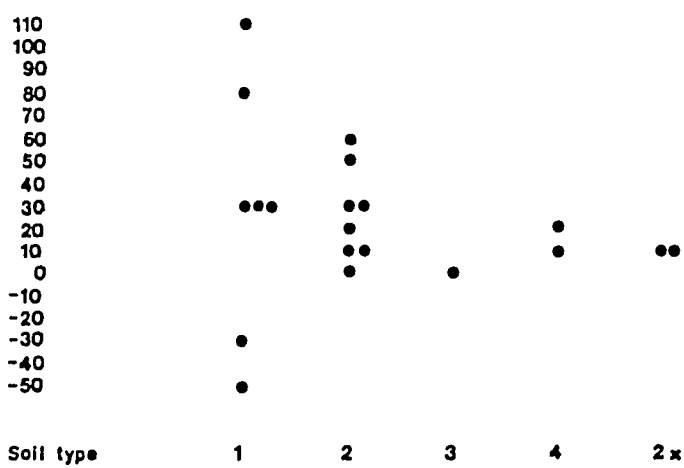
FIGURE. 2

RELATIONSHIP BETWEEN SOILS & COMMAND AREA



RELATIONSHIP BETWEEN SOIL TYPE & INCREASE IN CROPPED AREA

AFTER DTW INSTALLATION



Note; Each ● represents one scheme
Total cropped area = command area x cropping intensity

source - MMP/HTS 1982

irrigated area. Figure 2 illustrates the way both the irrigated area and the increase in cropped area (NIA) varied according to land class in the ADB study.

The five soil types shown in the figure are described as follows:

Group 1 - good paddy soils
2 - other paddy soils
3 - light, arable non-paddy soils
4 - unsuitable soils including very light soils
5 - unsuitable sites in Madhupur tract.

The most striking feature is the relatively poor performance of the good paddy soils in NIA terms. Much more research is required on the way the various farming constraints interact before this can be fully explained. However, since it may cause surprise that irrigation can be used without a significant impact on crop intensities it is worth discussing the most extreme case, which is by no means unusual.

In low lying areas, typical for good paddy soils, the traditional pattern combines a major monsoon crop, deep water rice, with limited areas of early dry season crops such as mustard. The rice is largely at the mercy of the floods and the secondary crop depends on residual moisture. Neither yields particularly well but both are cheap to grow as expensive inputs are not used. Under these circumstances it can be attractive to convert to an irrigated dry season crop, boro rice. This allows the use of a full HYV seed and fertiliser package, generating substantially higher yields. It does, however, mean that both the deep water rice and the secondary crop are given up and a small reduction in crop intensity results.

It is not clear why it is not possible to combine the boro and deep water rice crops. It may be that there is not enough time between the end of the boro harvest and the arrival of the floods to allow the deep water rice to be planted. Whatever the reason,

the loss of the monsoon crop represents a major opportunity cost attributable to tubewell irrigation. The net benefits of irrigation are therefore significantly less in these areas when compared to those where the introduction of an irrigated boro crop does not preclude a second, monsoon season rice crop.

Analysis of the irrigated areas reported in the monthly monitoring of DTW under the IDA II Project reveals substantial differences by land class, confirming at least the first stage of the ADB study's conclusions: that land class affects performance. Table 1 shows the results. The table also shows the percentage of high land and the percentage of land with permeable soils in each class, these being the characteristics that are most likely to affect tubewell performance.

These results make it clear that land class is a highly significant factor. Even if classes with relatively few operating wells are excluded, there is a difference of over 15 acres per well between the better and poorer land classes. The difference between the best and worst is 44 acres. Most noticeable is the fact that almost all those land classes where the average irrigated area is over 50 acres have less than 10% permeable land. Only two classes, 2A and 7D, which have less than 10% permeable have less than 50 acres irrigated.

Where the proportion of permeable soils is higher and the acreage is lower, the situation is less clear cut. For example, class 3A has an average area 14 acres higher than 3C for nearly identical percentages permeable. Classes 7F and 7G have nearly the same acreage for widely different combinations of high and permeable land.

Table 1: IDA II DEEP TUBEWELLS BY LAND CLASS, 1987 IRRIGATION SEASON

Land Class	Highland %	Permeable %	AV crop area acres/DTW	No of DTW operating
2A	31.5	3.8	48.4	19
2B	86.0	6.0	56.8	24
3A	66.3	18.3	48.3	108
3B	4.9	9.4	60.9	9
3C	30.2	19.6	34.6	17
4A	62.0	0.8	55.1	114
4B	17.6	0.2	56.7	61
4C	55.4	0.0	55.5	155
5B	0.0	0.0	68.9	8
5D	100.0	60.0	56.2	4
6A	46.2	51.2	39.2	30
6B	12.4	20.9	41.5	209
6C	0.0	3.6	59.4	8
7A	86.2	66.6	41.6	28
7B	58.6	53.8	41.8	90
7C	40.6	35.6	25.0	2
7D	70.0	0.0	41.8	11
7E	81.3	25.8	39.8	37
7F	65.7	39.4	48.8	29
7G	1.0	11.1	47.6	9
9E	1.1	0.0	58.5	8
9H	12.0	0.0	60.0	3

NB: Land classes as described in Consultants Working Paper No 14 Annex I, IDA DTW II Project, BADC Dhaka. Classes 7A to 7G are on the Madhupur tract, an area of higher land with distinctive orange soils. All the other classes are on the floodplains of the Padma and old Brahmaputra rivers.

Permeable soils affect irrigated areas in several ways. An increased crop water requirement to compensate for high percolation losses is only one of them. The ADB study (MMP/HTS, op cit) indicates that the way earth channels tend to collapse on the lighter soils is one of the biggest barriers to an increase in irrigated area.

It is clear that the most effective approach to improving irrigation performance will differ considerably between areas where low permeability and other factors allow large areas to be irrigated easily and those where soils and topography are a significant constraint. In the former it is likely that early attention to raising crop intensities will be necessary if the full potential improvement in total annual cropped area is to be achieved. In the latter, the existing emphasis on distribution techniques will continue to be more important.

2.5 ECONOMIC FACTORS

In the past, the capital cost of tubewell and other mechanical irrigation equipment has been heavily and directly subsidised. Despite moves to reduce it, there remains a considerable subsidy element, both direct and indirect. There are many rental DTW still operating despite an official policy that they be sold. Rents are well below the full cost. Even when sold, the price of a LTW is subsidised on the principle that the unit cost of DTW water should not exceed that for water from a shallow tubewell, for which the capital cost is much less per gallon of water delivered. In principle, STW are now sold at full cost. However, "as anyone who knows the reality of rural Bangladesh must realise" the widespread failure to repay loans taken out to purchase irrigation equipment represents a further massive element of indirect subsidy. (Biswas M R, et al, op cit.)

It has been suggested that the high subsidy is not a disincentive to the proper utilisation of tubewell equipment because it is a subsidy on the fixed, capital cost. Since tubewell operators will aim to fix the area irrigated by matching marginal revenue with marginal cost, which is unaffected by changes in the fixed cost, so subsidies on capital do not affect command area.

A major purpose of this paper is to demonstrate that this argument is false and to submit that much of what is seen to be happening in the Bangladesh water market is the direct result of

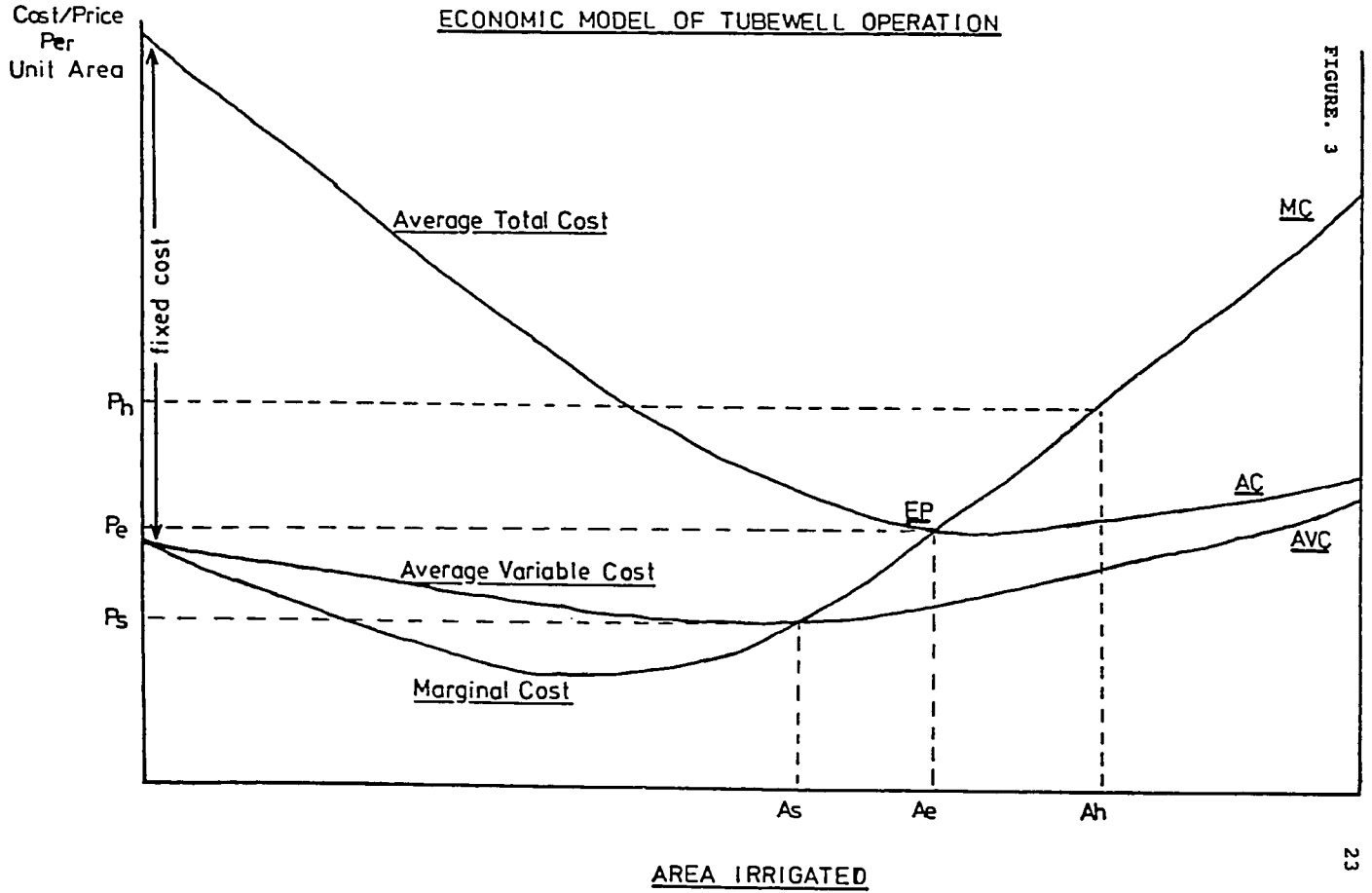
the low price of irrigation equipment. This is because the argument fails to draw the distinction between the economics of an individual firm, in this case the tubewell operator, and the economics of the tubewell irrigation industry as a whole. For the industry the fixed capital cost is a key factor directly affecting the average area irrigated per tubewell unit. This is because a low equipment price means high profits which encourages the purchase and establishment of too many units, each irrigating a less than efficient area.

In their publication 'The Water Market in Bangladesh' which has already been quoted several times, Biswas M R, et al raise the question "Inefficient and Inequitable?" as a subtitle. They show extensive evidence of fierce competition between suppliers in the irrigation water market. This competition is most evident in the widespread occurrence of overlapping command areas. It is commonplace to find several STW operating within a DTW area and there is considerable overlap between STW areas as well. Although DTW siting is more controlled there are still many cases of overlapping DTW areas. Even as early as 1981/82, the ADB study, mentioned above, was reporting similar competition: "The main command area studies indicated that overlap with other irrigation units (particularly STWs) was often a distinct constraint." (MMP/HTS, op cit.) The result is that many farmers are able to choose between two or more suppliers of water.

Biswas concludes, undoubtedly correctly, that the water market is, at least, efficient. This clearly conflicts with the equally solid evidence that the equipment is not being used to its most technically efficient capacity. The crucial link between these two facts is the level of subsidy which has encouraged the establishment of excessive concentrations of tubewell equipment. In short the market is working efficiently but it is reacting to the wrong price signals.

Figure 3 illustrates the way the subsidy affects the average area irrigated per unit of equipment, i.e. per well, in a more

FIGURE. 3


ECONOMIC MODEL OF TUBEWELL OPERATION
Cost/Price Per Unit Area
fixed cost
Ph
Pe
Ps
Average Total Cost
Average Variable Cost
Marginal Cost
MC
AC
AVC
EP
As
Ae
Ah
AREA IRRIGATED

rigorous manner using an entirely standard theoretical model of an individual tubewell operation. The X axis measures the area irrigated and the Y axis the average marginal costs as well as the unit area price for irrigation. The curve marked AC shows the Average Cost per acre, the AVC curve the Average Variable Cost and the difference between them indicates the Average Fixed Cost. At zero acres irrigated this difference is equivalent to the Total Fixed Cost. As determined by the mathematics of the situation the Marginal Cost (the MC curve) lies below the AVC and AC curves while each of them is falling and cuts them from below at their lowest point.

For the purpose of this analysis the point labelled EP, where the MC curve cuts the AC curve is crucial. The argument is as follows:

1. If the price per acre irrigated is higher than Pe, say Ph, then the tubewell owner will supply Ah acres so as to equate price and marginal cost.

2. However, at the position Ph/Ah the owner will make excess profits because the price is above the average cost. (Normal profit, i.e. the opportunity cost of capital and management effort is already included in the AC and AVC cost.)

3. Conversely, if the price per acre is lower than Pe, say Ps, then the operator will not cover his costs, including normal profit. Between Ps and Pe he will continue to operate because he will at least cover his variable costs. Below Ps he will not operate at all and he will close his tubewell. (Technically Ps is the Shutdown Price.)

4. Above Pe, in the region of excess profits, it is attractive to other entrepreneurs to enter the irrigation industry. Below Pe those already in the industry will be trying to liquidate their fixed costs and stop operation. Above Pe,

increasing numbers of operators will drive the price per acre down. Below Pe, a reduction in industry capacity will drive it up.

5. The position Pe/Ae, where the MC curve cuts the AC curve, therefore represents the industry equilibrium: i.e. that point at which tubewell owners (more correctly the marginal owner) make normal profits only. None will be making a loss and so closing down but equally none will be making excess profits sufficient to attract entrepreneurs to set up new tubewells.

This point EP, for Equilibrium Point or more tellingly Entry Point, where an entrepreneur decides whether or not to 'enter' the industry, is the critical determinant of both price and the average area irrigated per unit of tubewell equipment. As the figure shows, an increase in the fixed cost would move the Average Cost curve, and with it EP, up and to the right along the MC curve, leading to an increased price and a higher average irrigated area.

There are a number of points that arise from this model. First, the extent to which an increase in the fixed cost raises price and the extent to which it raises the irrigated area per unit of equipment depend on the slope of the MC curve. If variable and marginal costs are increasing slowly, then MC will be flat and the majority of any increase in fixed cost will be recovered through an increase in the area per unit. Price will not increase by much. Conversely, if MC is steep then price will rise sharply and the area per unit will not change greatly.

As mentioned at the beginning, it is widely believed that tubewell irrigation equipment is not being used to its technical capacity. This should mean that area can be expanded cheaply and the slope of MC will thus be small. Nevertheless the evidence on land class discussed in Section 2.3 suggests that there are technical barriers to greater irrigated areas which may be

expensive to overcome. Section 2.2 indicates that transaction and supervision costs are significant and they too may increase quickly as area grows. For both these reasons MC may be steep.

This raises crucial questions about the value of subsidies on tubewell equipment since such subsidies reduce the fixed cost. This means that they have a direct effect on the irrigated area per unit of equipment, i.e. on performance. As the model shows, the size of that effect depends on the slope of the MC curve which is determined by the technical and socio-economic constraints to area expansion. If the MC curve is flat, area per unit of equipment can be expanded cheaply. Subsidies would, therefore, be counter productive since they would encourage excessive investment in irrigation equipment without making the price of water significantly cheaper or inducing any expansion in the total area irrigated.

If, on the other hand, the MC curve is steep, subsidy may be a more useful means to support farmers and the resulting inefficiency in the use of irrigation equipment may be taken as an acceptable cost which must be borne in order to provide that support. It might also be valid to argue that some degree of inefficiency is worthwhile if it ensures a genuinely competitive water market. There are significant equity benefits. More entrepreneurs, especially those with relatively little capital, gain access to the market and hot competition is a defence against monopoly or cartel practices that might be used against the farmers.

Despite the evidence in Sections 2.2 and 2.3 that there are significant constraints to unit area expansion, the intensity of competition between tubewells indicates that the tubewell industry as a whole is currently operating in an area where the MC curve is flat. That is to say that a reduction in subsidy is likely to induce an improvement in unit performance and a reduction in the number of tubewell units in operation without any significant increase in the cost of water to the consumer.

3. CHOICE OF TECHNOLOGY

For irrigation in Bangladesh there are two choices to be made. First it has to be decided whether surface water is to be used, by means of gravity fed or LLP schemes, or whether some form of tubewell development of the groundwater is more suitable. The second decision concerns which type of tubewell to adopt: DTW, STW or HTW. It is this second choice, and in particular the choice between DTW and STW that is considered here. The widespread evidence of competition between STW and DTW indicates that there are several areas where one or other technology is inappropriate, since DTW are more expensive and should only be installed where STW are unable to access sufficient water. Both types should not be operating in one area. Some means to assess which is the correct technology in a given area is required.

This might seem a relatively straightforward matter, decided merely on the balance between the available groundwater and the land to be irrigated. Where there is sufficient water at depths accessible to the cheaper technology, STW, for it to irrigate all the available land then that must be preferred. Where it is only by the use of DTW that enough water can be reached to ensure that all the land can be irrigated then that is the technology to use. There have been variations on this theme whereby, for example, STW zones are declared to be those where 90% of the land can be irrigated from shallow aquifers. Otherwise the area is a DTW zone. Despite the variations, this same basic line of thought has underlain all attempts to plan groundwater development to date.

There are two problems with this approach. The first is that STW equipment is easily moved and very large quantities are now available so that the enforcement of zoning is difficult. The high degree of competition in the tubewell water market, which has already been discussed, reflects the failure of zoning.

However, the second problem is much more difficult, and that is how to actually draw the boundaries between one zone and the next and decide which is suitable for STW and which is not. It is for a start, hard to assess the available groundwater accurately enough for these purposes. Even more complex is the calculation of water required to irrigate the available land and hence decide whether STW alone will suffice or some recourse to DTW will be necessary.

Most planning models define the water requirement using standard crop evapotranspiration calculations combined with assessments of soil permeability and other factors. As already mentioned, this represents the biological optimum water requirement which does not necessarily equal the economic optimum or the most profitable level of irrigation for the farmer. The use of this biological optimum to indicate the maximum allowable level of groundwater extraction is the safe, conservative approach to determining the total level of extractive capacity since it guarantees enough water for all users. Unfortunately it can lead to the wrong conclusion when used to determine the choice of technology.

This needs some explanation. Take, for example, a discrete area of land with its own unique groundwater resource. At the maximum, STW can extract enough water to irrigate 60% of the land to the full crop water requirement, the biological optimum. In order to irrigate the whole area to the same level DTW will be necessary. However, the marginal cost of water is such that, in fact, farmers find that the marginal yield increment at the biological optimum is too low. They only apply, therefore, 60% of the estimated full crop water requirement, at which level the value of the marginal yield justifies the cost of pumping. This means that STW can, at the levels of water use farmers will choose, actually irrigate the whole area. The introduction of DTW will, therefore, only result in heavy subsidy costs and probably, since the marginal cost of DTW water is likely to be higher than for STW even after subsidy, a reduction in yield

since farmers will cut their water applications back even further.

It is worth emphasising that these considerations are much more important i tubewell irrigation, where the marginal costs in fuel etc are high, than they would be in a gravity fed irrigation scheme where the marginal costs are low and farmers' water applications will come close to the full crop water requirement. Many of the techniques used to assess water requirements were developed for gravity fed schemes and insufficient adjustment is sometimes made for crucial differences in the character of tubewell irrigation.

To sum up, it is possible, indeed likely, that farmers will apply less water than the maximum crop water requirement. As a result the cheaper STW technology has a bigger role to play than that suggested in planning models based on maximum water requirements.

Time is a complicating factor. The life of a STW is roughly half that of a DTW. Since it inevitably takes several years to build up to a level of 100% irrigation, there will be a long period in which STW are perfectly viable even in an area where DTW are, in the long run, the only choice. Take the example area once again and accept that STW can only irrigate 60%. Any STW that is installed more than five years before the 60% level is reached is likely to be profitable since it can be used to full capacity for all that time. Indeed, there will not be any violent cut off when the critical level is reached. Instead there will be a more or less gentle decline in the amount of water available to STW as DTW start to extract more. Many STW will continue to be profitable for some time after the 60% level is breached and DTW are introduced. There may even be some areas where STW are always viable even at 100% development.

FIGURE. 4

A MODEL OF MIXED TECHNOLOGY DEVELOPMENT

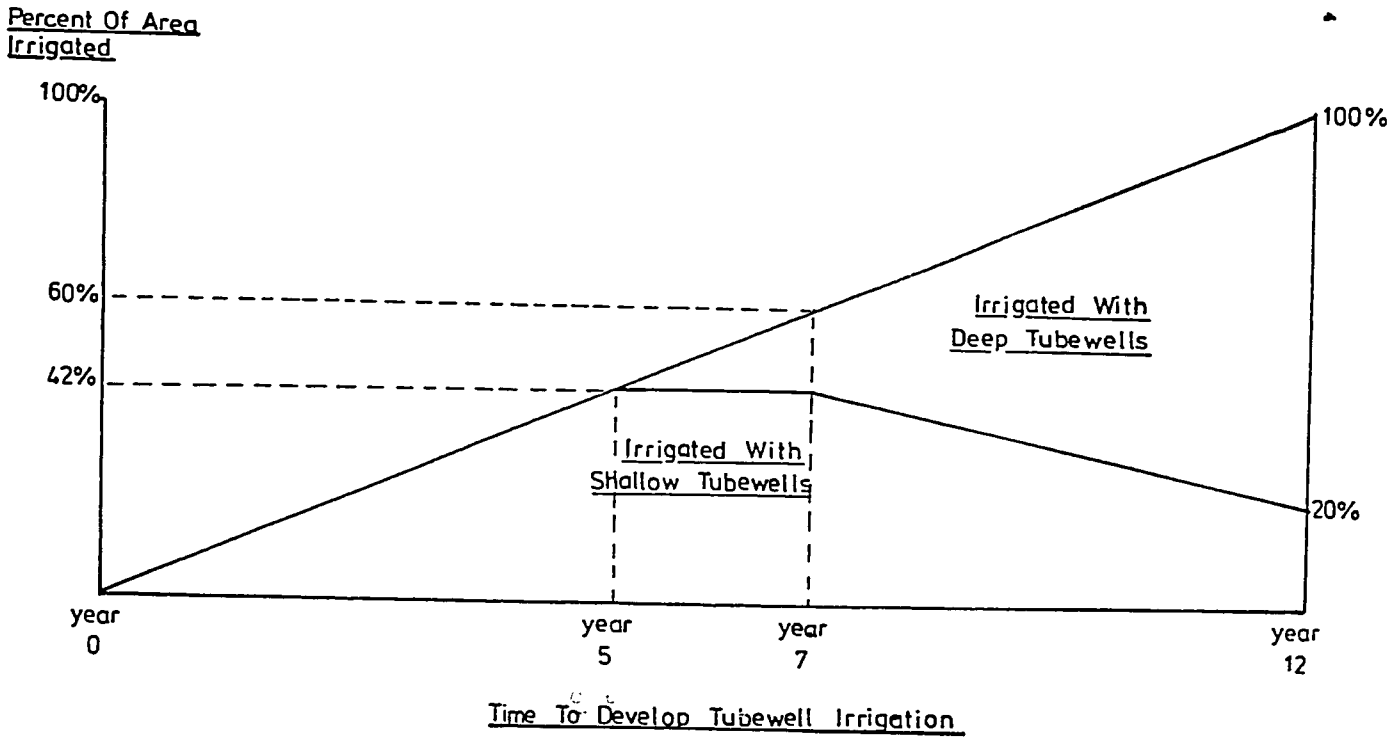


Figure 4 illustrates a very simple model indicating the ideal pattern of development over time. In the early stages any STW installed are likely to have more than enough time to pay back their investment costs before the water runs out. By year five, however, the deadline of 60% irrigation is only two years away and STW development should stop. DTW will be introduced then, to continue the expansion. Later on, as STW reach the end of their lives, DTW will start to take over land which was first irrigated with the smaller equipment. The area irrigated by STW will thus fall back to a base level of 20% at which they remain viable even when full development is achieved.

To make the model more realistic, many factors such as equipment life, payback periods and interest rates would have to be considered, even where the technical characteristics of the groundwater availability and the crop water requirements are fully understood. The most important factor of all, however, is the ability of the farming community to absorb irrigation capacity. This will determine the length of the development period. Over a long development, STW may be viable up to a level close to the 60% cut off. If the development is quick, on the other hand, few STW will have long enough to repay the capital invested and DTW will be introduced early.

This seems very academic and it might be suggested that a relatively broad approach to planning is all that is necessary or indeed possible. This is not so because of the risk of major over-expenditure on either one or other technology. If STW expansion goes too far, then many wells will go dry before they have paid back the investment made. If DTW are introduced too early, an unnecessary subsidy cost will be incurred.

To conclude, the vital requirement for a resolution of the technology choice is an understanding of the relative economic performance of both types of equipment, especially the viable life of each, and an accurate estimate of the economic level of irrigation water to apply. It may be emphasised that where the

conclusion is doubtful, the decision should probably go to STW. These are much cheaper and more flexible and they have a shorter pay back period.

For these reasons, STW are to some extent, self-regulating. Where high extraction starts to drive the water level out of the reach of STW, it will be relatively easy for some of the operators to liquidate their investment and move their equipment elsewhere so that extraction is brought back into balance with supply. Careful monitoring in predominantly STW areas would allow a relatively timely decision on whether to start the introduction of DTW and when. This would be preferable to endeavouring to accelerate the pace of development by anticipating the moment for DTW. The costs of this approach, in subsidies and wasted resources, would be high.

4. CONCLUSION

This paper has raised a number of different points, some more closely related than others. There is nevertheless one underlying theme. That is to highlight the need for a full understanding of the technical and economic characteristics of tubewell irrigation at the micro or farmer level, before major planning decisions are made:

i. Social factors are not as large a barrier to the efficient use of irrigation equipment as is sometimes believed. However the transactions cost of managing irrigation by large groups of small farmers is significant.

ii. The net incremental cropped area for the whole year is the true measure of tubewell performance, not the area irrigated alone which ignores the way irrigation affects the non-irrigated crop, a significant opportunity cost.

iii. Tubewell performance is strongly affected by land class, i.e. by the combination of soils and topography. Efforts to improve performance must be specifically designed to suit each area.

vi. Subsidies on equipment are directly reflected in excessive competition in the irrigation market and consequently, poor per unit performance.

v. In many areas a choice has to be made between STW and DTW. Because of the large difference in cost between them the choice must be correct but it involves a complex set of factors that will be very difficult to estimate accurately. The best approach may be to give the lead to the cheaper technology, STW, and ensure by careful monitoring that the moment for a change over to DTW is not missed.

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