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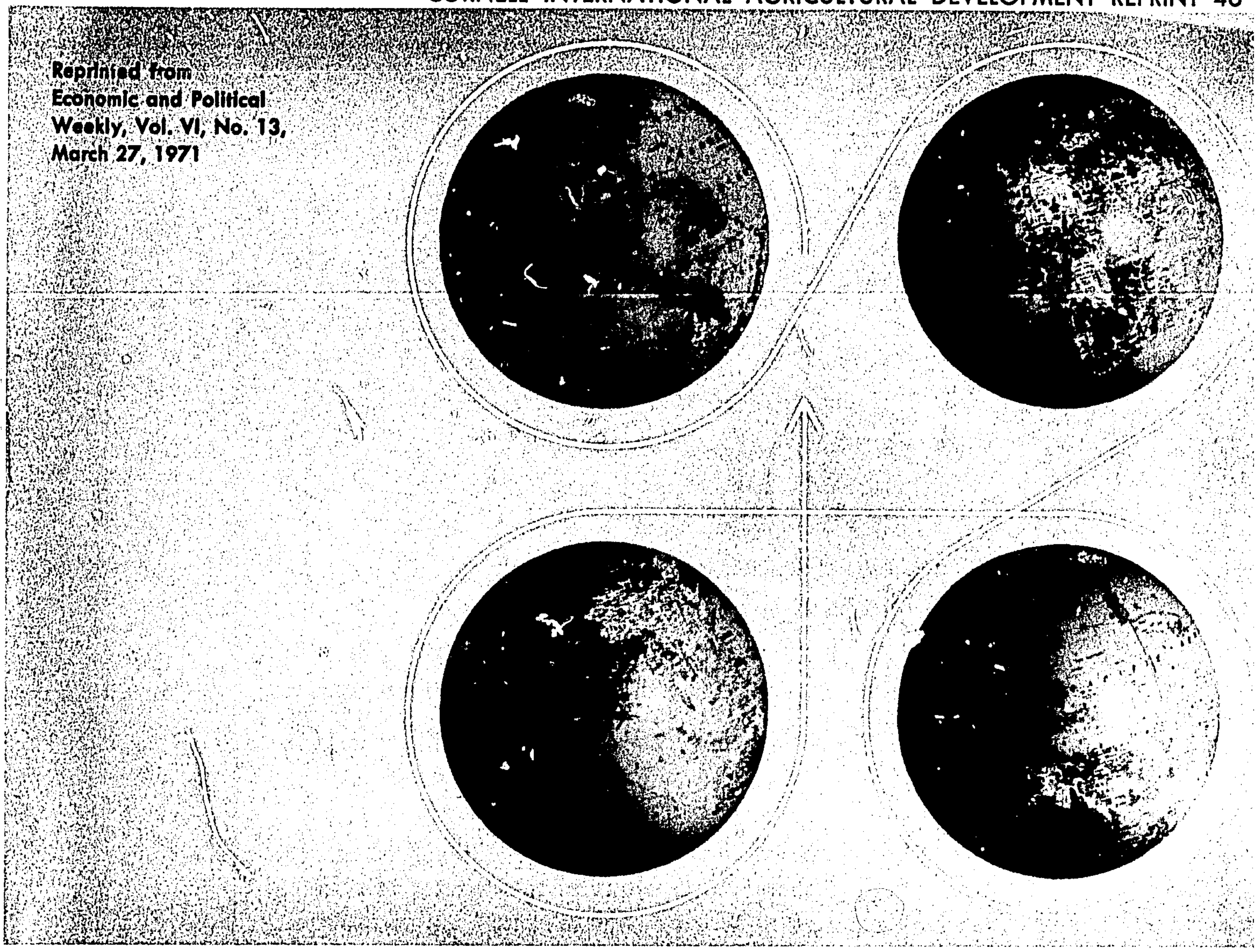

Dilemma of State Tube Wells

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DILEMMA OF STATE TUBE WELL

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In the area studied in western Uttar Pradesh the Capital cost of state tube wells is seven and a half times as high per unit of pumping capacity as that of the private tube wells. There is thus economic pressure to spread out the overhead costs by achieving high rates of utilisation. State tube wells operate much closer to engineering capacity than do the private tube wells. They pump twice the volume of water and irrigate three times the hectarage per unit of pumping capacity of the private tube wells. But such rates result in increased breakdowns and the consequent unreliability of water supplies.

In situations of traditional crop patterns, traditional varieties, and low levels of fertiliser use, such unreliability is not costly—though it does tend to discourage input such as the introduction of high-yielding varieties and high levels of fertiliser use. Given the comparative costs, pricing systems, crop patterns, and yields shown in the following survey, a change in the operation of state tube wells to resemble the operation of private tube wells would result in substantially decreased revenues to the state tube wells but it would greatly increase returns to society as a whole.

There were, in 1969, over 9,000 state tube wells in Uttar Pradesh alone, representing a capital investment of over Rs 72 crores. There is substantial potential to increase the returns to that already sunk cost, and more state tube wells may be provided in the future for small farmers.

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Yet state tube well programmes have been subject to much criticism. It is generally agreed that, compared to private tube wells, state wells have a high capital cost per unit of delivery capacity, greater uncertainty of water supply, and consequently lower production benefits. State tube wells, therefore, have incurred substantial financial losses.

Yet it should be remembered that state tube wells tap a deeper water resource than private tube wells. Their higher cost may, therefore, be justified in the future. But questions which remain to be answered are: (a) what is the optimal manner for management of state tube wells; and (b) with optimal management, can the state tube wells today provide a return on capital competitive with other sources of water, including private tube wells.

Useful Lessons

Useful lessons for operation of state tube wells may be drawn from comparison of costs, returns, and mode of operation between private tube wells and other well irrigation. The data for this comparison were drawn from a sample of 141 farms in Aligarh District, Uttar Pradesh, randomly drawn from three classifications by size of farm, and four classifications by types of wells.[1] Each farm in the sample was irrigated entirely from one source. The basic data are for 1966-67, but they are supplemented from a brief re-survey conducted in 1968-69.

State tube wells in the sample had twice the delivery capacity of the private tube wells, but, contrary to common criticism, they operated nearly three times as many hours per year (Table 1). Thus the state tube wells operated much closer to engineering capacity than did the private wells: they pumped twice the volume of water and irrigated three times the acreage per unit of pumping capacity.[2]

Unfortunately, the capital costs of the state tube wells were fifteen times as large as those of the private tube wells and seven and a half times as large per cusec of delivery capacity (Table 2). Thus, even with much higher rates of use, the cost per unit of water pumped was still 50 percent higher for the state tube wells than it was for the private tube wells. The dilemma for the state tube wells, therefore, was that while the high capital costs forced attempts to achieve high rates of utilisation, these high rates of utilisation in turn led to increased uncertainty of supply and hence to much lower returns to water.

Table 1: Physical Features of State and Private Tube Wells

Items	Units	State Tube Well	Private Tube Well
Depth of well	metres	60	20
Delivery capacity per hour	cubic metres	145	68*
Running hours per year	hours	4,000	1,500
Water delivered per year	100 cubic metres	5,650	1,030
Area irrigated per well	hectares	135	20

* Measurement techniques for the private tube wells may have resulted in an upward bias in the discharge rates perhaps by as much as 5 to 10 percent.

Source: Study of an 86 farms sample from Aligarh District, 1966-67.

water from the state tube well was very attractive compared to that from the traditional Persian wheel or the charsa. The latter supplied water at, respectively, over twice and nearly four times the cost by the state tube well. However, the state tube wells charged the cultivator a highly subsidised price for water, Rs 18.00 per 1,000 cubic metres. Including the normal tip to the tube well operator of about Rs 6 per 1,000 cubic metres, the charge to the cultivator was slightly more than the average cost of private tube well water and slightly less than the charge to purchasers for private tube well water. Adjustments, for what discrepancies in the records suggest were no charges for as much as 25 percent of the state tube well water delivered, brought the rate well below even the cost of private tube well water.

On most small farms using private tube wells, the water was purchased at an average cost of about Rs30 per 1,000 cubic metres. Owners of private tube wells sold to other farmers an average of 30 percent of the water pumped. Despite the somewhat higher cost to them, cultivators expressed a strong preference for purchasing private tube well water over state tube well water because the lower percentage of capacity operation and the more decentralised administration allowed higher returns per unit of water delivered.

Table 2: Comparative Costs for Four Types of Wells

(cost in rupees)

Items	State Tube Well	Private Tube Well	Persian Wheel	Charsa
Initial investment:*				
(a) Equipment	38,300	3,000	600	115
(b) Civil works	38,200	2,100	1,200	1,200
Total	76,500	5,100	1,800	1,315
Annual Costs:				
(a) Fixed costs**	10,711	1,010	294	213
(b) Variable costs***	7,980	1,272	433	820
Total	18,691	2,282	727	1,033
Cost of water per 1,000 cubic metres	33	22	75	120
Depreciation rate assumed for equipment (percent)	5	10	15	50
Proportion of fixed costs to total costs (percent)	57	43	41	20
Number of farms in sample	36	50	41	14

* Excludes cost of electric connections for both state and private tube wells.

** Includes interest charged at 10 percent for all types of wells as well as depreciation at rates shown.

*** Market prices used for all inputs including labour.

Source: Study of 141 farms in Aligarh District, 1966-67.

Returns to Water

In order to estimate returns to water, comparison of sources of water is made with respect to crop pattern, yield, input use, and return. It is assumed throughout this analysis that, differences in these factors associated with different water sources reflect the variation in cost and certainty of water supply. The importance of certainty of supply is much greater for the new high-yielding varieties than for the traditional varieties. Nevertheless, there is an important bias if the difference with respect to use of high-yielding varieties or other inputs and practices is due to differences in propensity to innovate among the users of the various water sources.

In 1966-67, i.e., shortly after the high-yielding varieties were introduced, as well as two years later, a much higher proportion of wheat area irrigated from private tube wells was planted with high-yielding varieties compared to what area irrigated from state tube wells (Table 3). Experience on land irrigated from state tube wells was comparable with experience on land irrigated from Persian wheels.

Table 3: Percentage of Area Planted with Different Varieties of Wheat According to Source of Irrigation

	Percent of Total Area by Source of Irrigation									
	State Tube Well		Private Tube Well		Persian Wheel		Charsa		Average of All Farms	
	'66-67	'68-69	'66-67	'68-69	'66-67	'68-69	'66-67	'68-69	'66-67	'68-69
Wheat variety										
Desi	90	29	59	11	85	34	100	98	72	20
K-68	*	12	18	19	7	12	0	2	12	16
Dwarf	10	-	23	-	8	-	0	-	16	-
Red dwarf	-	25	-	18	-	21	-	0	-	20
White dwarf	-	34	-	52	-	33	-	0	-	44
Area (hectares)	40	56	116	174	35	48	11	5	202	283

* Less than one percent.
Source: Study of 141 farms in Aligarh District, 1966-67 and 1968-69.

Hybrid bajra, not as successful a crop as dwarf wheat, was grown almost exclusively on farms irrigated from private tube wells but it was only grown on seven percent of the total bajra area in 1966-67 and eight percent in 1968-69. Hybrid maize was also almost exclusively grown on farms with private tube wells. It occupied 29 percent of the maize area on those farms in 1966-67 and only nine percent in 1968-69.

In general, farms using private tube well water followed more intensive crop patterns than did the others. The pattern on the state tube well irrigated farms was very similar to that on farms irrigated from Persian wheels. Farms irrigated by charsa followed the least intensive crop patterns. More specifically, the private tube well farms grew more bajra and American cotton than did farms irrigated from other sources. The private tube well farms thus took advantage of the possibility of well-timed pre-monsoon irrigation. For the same reason, 50 percent more land grew peas, which also required early irrigation to facilitate planting after a kharif crop. These farms had much less fallow land in kharif; grew more pure crops and less of the more drought-tolerant mixtures, and had three times the proportion of area in perennial crops (Table 4).

The charsa irrigated farms had the costliest least readily available water, and so grew no dwarf wheat varieties of hybrid bajra. Instead, they raised a high proportion of bajra and wheat mixtures and crops such as arhar which do not require irrigation. Farms irrigated by state tube wells and by Persian wheels resemble each other in their cropping patterns which fall between the patterns followed on farms where charsa and private tube well methods of irrigation are used.

Farms were divided into categories of small (0.5 to 3.0 hectares), medium (3.1 to 8.0 hectares), and large (8.7 to 18.0 hectares). There appeared to be no significant difference in cropping pattern between small and medium size farms with a given irrigation source. It was notable that, within the private tube well category, small farms were not less progressive than the larger holdings from which they generally purchased water. In fact, these small farms appeared much more progressive than the small farms using state tube well water, for, they had 80 percent of their wheat hectarage under improved varieties in

1968-69 whereas the small, state tube well irrigated farms had less than 60 percent. The small, charsa irrigated farms did not use improved varieties.

Table 4: Percentage of Area Under Various Crops According to Source of Irrigation

Crops	Percent of Total Area by Source of Irrigation State Tube Well	Private Tube Well	Persian Wheel	Charsa	Average of All Farms
Kharif crops					
Bajra	11	18	7	9	13
Bajra mixtures	11	6	11	16	9
Maize	8	6	6	4	6
American cotton	*	3	2	*	2
Miscellaneous kharif crops	2	3	4	0	3
Kharif fallow	16	11	19	20	15
Rabi crops					
Wheat	14	20	12	10	16
Wheat mixtures	16	8	17	20	13
Peas	10	14	8	3	11
Arhar	7	1	6	10	4
Miscellaneous rabi crops	1	2	4	4	3
Rabi fallow	1	1	2	3	1
Zaid crops (Primarily Vegetables)	1	4	*	1	2
Perennial crops	2	3	2	*	2

* Less than one percent.
Source: Study of 141 farms in Aligarh District, 1966-67

In contrast to 1966-67, the small farms in 1968-69 planted a slightly lower percentage of their land with dwarf varieties than did the medium size farms. However, the differences were small, and were probably due to a desire on the part of all cultivators to grow enough of the higher quality desi varieties for home consumption, which would take a higher proportion of total wheat area on the smaller farms. This factor was of course insignificant as long as the area planted with the dwarf varieties was small.

For the same varieties grown, private tube well irrigated farms invariably had higher yields compared to farms irrigated from other sources (Table 5). This was so presumably because of the assured water supply as well as the consequent greater use of fertilisers. The yield advantage for these private tube well irrigated farms was consistently more than 20 percent. In addition, these farms planted a much higher percentage of their land with new high-yielding varieties.

Table 5: Average Yield of Selected Crops, by Source of Irrigation

(Quintals per hectare)

Crop	State Tube Well	Private Tube Well	Persian Wheel	Charsa	Average of All Farms
Bajra desi	7	10	9	7	9
Bajra hybrid	-	19	-	-	17
Maize desi	7	9	8	-	8
Maize hybrid	-	21	-	-	20
Wheat desi	13	16	15	12	15
Wheat K-68	-	24	-	-	23
Wheat dwarf	-	34	-	-	34
Wheat and gram	11	13	12	10	12
Barley	9	15	12	-	13
Barley and pea	9	13	11	10	11
Pea	6	10	8	-	8

Source: Study of 141 farms in Aligarh District, 1966-67.

The average yields on farms irrigated by Persian wheels were consistently higher than those on farms using state tube well water. This suggests that farmers using state tube wells do not get adequate water at the proper time, and that although the Persian wheel farmers have a high cost and low discharge of water they are at least able to irrigate their fields when they need to. Charsa farmers had the lowest yields of all, which indicates their high cost of water, the consequent need to use it sparingly, and their low use of fertiliser.

There were few significant differences in yields among size classes within the same irrigation system. The small farms had lower yields of desi wheat than did the medium and large farms, but on private tube well irrigated farms yields of dwarf wheat were substantially higher on small farms than on the medium and large farms. This may indicate that more care in supervision and management is needed for dwarf wheat — something which the small farmers can provide.

Farm Practices and Input Use

In general, a more reliable water supply encouraged use of high-yielding varieties — which in turn made it profitable to use more fertiliser. Even for the same varieties, private tube well farms used more fertiliser per acre than did state tube well farms, which in turn used somewhat more fertiliser than Persian wheel irrigated farms (Table 6). Farms irrigated with charsa used almost no fertiliser. Again, size of farm within a particular irrigation system made no significant difference to the relative quantity of fertiliser used.

As is to be expected, the quantity of water pumped per hectare is directly related to its cost and reliability. The state tube well farms were less frequently irrigated than were the three private systems. For any given crop, the quantity of water used was much greater in the private tube well systems than in the others. For example, for desi wheat crops the four systems used the following millimetres of water per hectare: private tube wells 485; state tube wells 356; Persian wheel 343; and charsa 347. Farmers using state tube wells and growing dwarf wheat were the more influential farmers with larger farms located near the wells; they were therefore able to provide an extra irrigation for their dwarf wheat. Nevertheless, they still used substantially less water per hectare of dwarf wheat than did the private tube well farmers.

Table 6: Nitrogen Used on Selected Crops by Source of Irrigation

(kg per hectare)

Crop	State Tube Well	Private Tube Well	Persian Wheel	Charsa	Average of All Farms
Bajra desi	2	7	2	2	5
Bajra hybrid	-	53	-	-	48
Maize desi	5	14	5	-	8
Maize hybrid	-	75	-	-	72
Wheat desi	9	26	5	4	14
Wheat K-68	-	56	-	-	52
Wheat dwarf	36	76	44	-	70
Peas	2	10	1	-	6

Source: Study of 141 farms in Aligarh District, 1966-67.

The only significant difference in the amount of water used per hectare among different sizes of farms occurred in the Persian wheel and charsa irrigated farms. In both cases, the small farms used about 25 percent more water per hectare than the medium size farms. This apparently resulted from greater surplus on the small farms of bullock and human labour available for the arduous task of lifting water. The small farms using private tube well water used about 10 percent less water per hectare than the medium size farms, presumably reflecting a somewhat higher cost of water to them.

The different water sources, crop varieties, and levels of input, suggested the possibility of a number of contrasts in physical response and economic returns to water and other inputs. Data were analysed by individual plots on each farm with respect to a large number of factors which influence yield. Many equations were fitted using different forms, variables, and groupings of the data. Linear functions were in general found to fit best, but particular care has to be taken in extrapolating results. The correlation co-efficients were invariably very low, although similar to those normally encountered in unaveraged plot observations under farm conditions. Despite the limitations, a number of useful points can be derived from this analysis.

First, the response to increments of water and associated inputs was much higher for the new high-yielding varieties than for desi varieties. For example, the water co-efficient for dwarf wheat was nearly four times as large as for desi wheat. Likewise, the co-efficient for water in the case of hybrid bajra was nearly five times as large as that for desi bajra.

Secondly, the response to increments of water and associated inputs appeared somewhat greater on private tube well irrigated farms than on other farms. The higher response to private tube well irrigation probably reflected the better control and timeliness of water application.

In most cases, the response co-efficient for nitrogen was not statistically significant. Nevertheless, a high co-efficient for desi wheat suggested high returns for further increments of nitrogen from the low levels currently applied. Similarly the low response to nitrogen, shown by the linear function for dwarf wheat on private tube well irrigated farms, suggested that at the high levels of application on those farms and with existing practices the returns to nitrogen had been pushed very low. This implied that farmers applying nitrogen at the higher levels might reduce their applications in the future.

In a similar analysis, each farm was used as an observation, and total value of output was related to various variables, including water and nitrogen. Both linear and logarithmic functions were fitted with the linear functions consistently giving a better fit. The marginal returns from some of these equations are presented in Table 7, which includes ratios of marginal returns to cost of water and nitrogen. The returns are not only to the stated input but also to all other inputs associated with it. Thus the 'net' return to the one input would be lower than the figure shown.

A relatively low co-efficient for nitrogen in the private tube well equation was consistent with the already very high rates of nitrogen used on these farms. Successively higher co-efficients for the state tube well, Persian wheel and charsa farms were consistent with the successively smaller amounts of fertiliser used on these groups of farms. Thus, despite the greater cost of or poorer control of water on these sets of farms, at their current margins they would profit much more from more fertiliser application than would the private tube well farms. It would appear, however, not to be profitable for these groups to raise their rates of application of nitrogen as high as the private tube well farms.

Table 7: Marginal Return Associated with Nitrogen and Water, by Source of Irrigation

Source of Irrigation	Marginal Returns To		Ratio of Marginal Returns to Costs*	
	Nitrogen (rupees per kg)	Water (rupees per cubic metre)	Nitrogen	Water
State tube well	19	.06	8:1	2:1
Private tube well	10	.10	4:1	4:1
Persian wheel	30	-	12:1	-
Charsa	35	.03	14:1	1:1

* Costs of water are as stated in Table 2: cost of nitrogen in Rs 2.50/kg.

Source: Study of 141 farms in Aligarh District, 1966-67

The co-efficient for water was highest on the private tube well farms despite the fact that they used the greatest quantity of water per hectare. The combination of reliable supply, substantial use of high yielding varieties, and high levels of other inputs thus appeared to have maintained the returns to water even at high levels of use. Conversely, charsa irrigated farms, emphasising crops unresponsive to high levels of water input and deficient in other inputs, did not respond well to more water within that context.[3] Thus, private tube wells provided large quantities of low cost water thereby inducing a number of complementary changes in cropping patterns, crop varieties, and input use. These served to increase not only the amount of water that was profitable to use, but also production and farm incomes.

The ratios of costs to returns, shown in Table 7, confirm this analysis. The net returns, of course, were not as attractive as they appear because nitrogen and water serve in the Table as proxies for other inputs including other nutrients, each of which had its own costs.

Gross and Net Returns per Hectare

Differences in gross returns per hectare reflected differences in cropping patterns and yields. The private tube well irrigated farms produced over twice the value of output per hectare as did the charsa irrigated farms and over 80 percent more value of output per hectare than did the state tube well farms. If we net out the cost of nitrogen and water, we widen the gap between the private tube well and the two traditional systems because of the very high cost of water calculated for the latter. The differences in these "net" income figures, provide a measure of the return in changing from one irrigation system to another (Table 8). By these calculations, farmers with Persian wheel and state tube wells benefited about as much when they shifted to a private tube well system, but there was no advantage for Persian wheel farmers who changed to state tube wells.

Table 8: Differences in Net Income per Hectare Associated with Different Sources of Irrigation

(Rupees per hectare)

Change from	Change to	Increase in Net Income*
State tube well	private tube well	790
Persian wheel	state tube well	(-) 50
Persian wheel	private tube well	740
Charsa	state tube well	250
Charsa	persian well	300
Charsa	private tube well	1,040

* Net income is defined as total production at market prices minus the cost of nitrogen and water. Nitrogen is taken as Rs 2.50 per kg; water at the costs shown in Table 2. Practically all other costs are land, family labour, or hired labour. The advantage of private tube wells over state tube wells would be Rs 90 less if market charges were used rather than costs. Likewise there would be no difference between state tube wells and Persian wheels. The gross returns per hectare for state tube wells, private tube wells, Persian wheel, and charsa were, respectively, Rs 1070, 1900, 1200 and 900; the 'net' returns were respectively, Rs 910, 1700, 960 and 600.

If we take from Table 8 the figure of the difference in net income of Rs 740 per hectare between a Persian wheel and a private tube well, multiplied by the four hectares of a model farm, the total capital cost of Rs 5,000 to Rs 6,000 is earned in about two years. By the same calculation, the charsa farmer could earn his capital investment in a private tube well in less than a year and a half.

If we take a more conservative estimate, by multiplying the average volume of water pumped by a private tube well (5,600 cubic metres per hectare) times the difference in pumping cost between a Persian wheel and a private tube well (Rs 53 per 1,000 cubic metres), we find a saving of Rs 295 per hectare or nearly Rs 1,200 for a model size farm of 4 hectares and hence a recovery of capital in four to six years. By the same calculations, the charsa farmer would recover his capital in two to three years in a switch to a private tube well.

These high benefits, derived from use of the private tube well compared to the state tube well, are based on the assumption that factors such as greater reliability, timeliness, and availability of water are responsible for the differences in crop composition, input use — and, hence, in returns. The underlying problem of state tube wells is their extremely high capital cost per unit of delivery capacity. Much of their unreliability stems from efforts to spread that capital cost over a large volume of water pumped, thereby favouring the irrigation of large acreages at the cost of good timing. To increase returns to farmers will probably necessitate a reduction in the area irrigated and less total water pumped per unit of delivery capacity (as is the case for the private tube wells). This in turn will raise the per unit cost of the water. More timely availability might make state tube wells sufficiently attractive so that their charge could be increased to equal the charge on private tube wells. But that charge may decline to average total cost, which in turn is not much higher than the present state tube well charge plus bakshish. Thus the gross income to the state from tube wells may well fall if they are operated to provide maximum net social returns. Of course, farmers could afford to meet the full cost of this water, given the potential benefits, but they would be reluctant if the much cheaper private tube wells were available.

Table 9 shows the number of wells required to irrigate 135 hectares (the average area irrigated by one state tube well) by each of the four systems. The capital requirements are similar for the state tube well and Persian wheel. The gross value of output is also similar for the two systems. In contrast, the capital investment in the private tube wells is less than half as great and the gross value of output is over 50 percent larger than for the other two systems. It is obvious that investment returns are much greater to private tube wells given the past capital-cost relationships. There is, however, already a large sunk cost in state tube wells and hence it is relevant to question how to increase their efficiency.

Table 9: Capital Investment and Gross Value of Output per 135 Hectares under Average Conditions for Each Well System

Source of Irrigation	Number of Wells to Irrigate 135 Hectares	Capital Investment for 135 Hectares (thousand Rs)	Gross Value of Output (thousand Rs)
State tube well	1	77	144
Private tube well	6.7	34	258
Persian wheel	40	72	162
Charsa	40	53	122

Source: Study of 141 farms in Aligarh District, 1966-67.

Administrative Problems of State Tube Wells

The length of time it takes to obtain repairs to state tube wells is greater than for private tube wells. A heavy burden of paper work on overseers and supervisors, the many formalities to be completed before repairs can be undertaken, and the lack of readily available spare parts were all cited as major causes of delay. The fact that state tube wells operate at much closer to capacity compounds the problem of delay because of their small reserve capacity. Thus, both the likelihood and the burden of a breakdown is much greater for state tube wells than for private ones.

Under the present system, the tube well operator tends not to come from the village where the well is located and is consequently frequently absent. Frequent claims of favouritism and corruption arise. Transformer thefts are a common problem for state tube wells relative to private tube wells, presumably because of less careful supervision. Thus, most important to improvement of the administration of the state tube wells is a system whereby the state tube well operator devotes himself effectively to efficient operation of the well.

It should be feasible to hire the tube well operator from the village where the well is situated, to provide a training programme which would facilitate his operation of the well, particularly with respect to mechanical repairs, and to train him in improved agricultural practices. The tube well operator could then devote himself to keeping the well in operation and making minor repairs. He could also encourage cultivators using the well to take up improved cultivation practices which would make more effective use of the water.

It would probably make sense to institutionalise the present <u>bakshish</u> system for the tube well operator by paying a commission on water pumped. This would give incentive to the tube well operator to keep the pump operating so that it could be used whenever cultivators want water. It would also give him an incentive to help cultivators obtain the information needed to shift to more intensive cropping patterns which would use more water as well as to diversify cropping patterns so that water would be in demand in the slack seasons.

The problems of mismanagement are further compounded by the <u>thokbandi</u> system by which each farmer receives water in rotation. On the one hand favoritism may break the system. On the other hand, in case of breakdown, a farmer who misses his turn must wait all the way around to another turn, which may lose him the benefits of an intensive but water sensitive farming system.

The basic dilemma of the state tube wells has its roots in the high capital costs. If the wells do not operate at a high percentage of capacity the cost per unit of water is high. But, at high operating rates, the reliability of the water supply is reduced, farmers dare not follow intensive, high-input cropping patterns — and so, the returns to water are reduced. Efforts to raise returns will raise costs, and vice versa.

In cases of traditional crop varieties the dilemma hardly arose because diminishing marginal returns to each crop tended to give higher returns by spreading water widely. The new high-yielding varieties generally are profitable only when accompanied by a high level of fertiliser input and a large, reliable supply of water. The cost of failure to receive water when needed is much greater for the high-yielding varieties than for the desi varieties. A low level of utilisation of water capacity, as in the case of the private tube well, provides a much more assured water supply, particularly if breakdowns and power failures are frequent.

The state tube wells in the sample irrigated about 135 hectares of land per well during the rabi season and a somewhat smaller area during the kharif season. The private tube wells, with about half the delivery capacity per well of the state tube wells, irrigated an average of 20 hectares during the rabi season. If the state tube wells had irrigated a comparable area relative to their delivery capacity, they would have handled 40 hectares, or less than a third of the current area.

It is by no means certain that the private tube wells are making optimal use of the pumping capacity available to them. The most economic way of operating might be to cover somewhat larger areas per unit of pumping capacity. On the other hand, since there is a well developed market for sale of water, it is quite possible that the private tube wells are operating optimally.

In any case, the large difference in returns to use of water between the state and private tube wells is surely substantially attributable to the greater degree of certainty and the better timing of the availability of water from the private tube wells. If 40 hectares were irrigated by a state tube well and the average holding size was four hectares, it would take only 10 farmers to use the total supply of water. Even assuming that the state tube well served cultivators with smaller than average holdings, we might have a maximum of about 20 cultivators per state tube well. Fewer farmers per well would greatly facilitate improved administration of the well which would, in turn, lead to increased timeliness and certainty of water as well as to reduced cost of operation. A reduced area irrigated per well would also lower the cost of provision and maintenance of channels and reduce the water losses caused by the long distances water must be carried in channels.

The primary disadvantage of reducing the area irrigated per well is the reduction in revenue to the tube well. This could be more than balanced by an increase in net returns to cultivators as a result of a switch to high-yielding varieties and more intensive cropping patterns. The financial dilemma becomes clear from the following figures which are based on averages from the Aligarh survey. A state tube well irrigating 135 hectares with 4,000 cubic metres per hectare and charging Rs 14 per 1,000 cubic metres has a revenue of Rs 7,560. If in emulation of private tube wells, the coverage is reduced to 40 hectares, water use is raised to 5,600 cubic metres per hectare and the charge still is Rs 14 per 1,000 cubic metres, the revenue drops over half to Rs 3,136.

If we assume, however, that increased reliability of the water supply raises the average state tube well's 'net' income to that of the average private tube well, as in Table 8, then the income becomes Rs 31,600, i.e., Rs 790 added farm income per hectare times 40 hectares. Since so much more revenue could be generated, it would be natural to charge farmers a higher price for the water. It would require a charge of Rs 34 per 1,000 cubic metres to match the revenue from the initial system, which is only a small part of the net gain and still less than half the cost of Persian wheel water. But it is still 50 percent more than the cost of private tube well water and 10 percent more than the current market price of private tube well water. Thus, as long as aquifers are such that shallow depth private wells are possible, the high capital cost of state tube wells will either have to be partially written off or a means found to reduce their capital costs.

It is quite possible that a combination of highly effective maintenance and a first-class system of water allocation, coordinated with a carefully developed cropping system, would allow much fuller use of state tube wells than presumed above. On the other hand, less efficient operation and maintenance for state than for private wells may make optimal coverage even less than the 40 hectares suggested.

In the sample of farms studied and within the same irrigation supply system, farmers with small holdings (0.5 to 3.0 hectares) were at least as progressive as those with larger holdings in their use of high-yielding varieties, in their application of purchased inputs such as fertiliser, and in their adherence to intensive cropping patterns. In addition, there was a well developed system of sale of private tube well water. The sale price was about 30 percent above average total cost, but it was low relative to returns, and the supply was apparently completely reliable. Further expansion of private tube wells should bring the price down further and serve the small farmer even better.

The problem of the small farmer is shown in Table 10. When farm size increases, gross value of output per permanent farm worker increases, indicating the more complete employment which a larger farm can provide. This contrast is much greater among farms irrigated with private tube wells because the Persian wheel and charsa require proportionately more labour to pump more water as evidenced by the greater quantity of water used per hectare on small farms than on medium ones within these irrigation systems. In the case of state tube wells, the degree of intensification is not as great, thus the income spread between small and medium farms is not as great. Medium size farms have over twice the gross of small farms within the private tube category; a slightly <u>lower</u> gross within the charsa category; about 50 percent higher within the Persian wheel category; and 80 percent higher within the state tube well category. The medium farms average 130 percent larger in area than the small ones. Thus introduction of private tube well water increases gross income of small farm operators but also further widens the income gap between themselves and those with larger farms.

The Table shows again the limited improvement provided by the state tube wells. Small farms with state tube well water actually have lower gross incomes than small farms with Persian wheel water; on medium size farms the gross income per farm worker is the same. In contrast, small farms with private tube well water have 10 percent higher gross income than those with Persian wheel irrigation. In the category of medium size farms the private tube well farms have gross incomes per permanent farm worker nearly 50 percent higher than the Persian wheel farms.

Table 10: Gross Value of Output per Permanent Farm Worker, by Size of Farm and Source of Irrigation

Source of Irrigation	Size of Farm		
	Small	Medium	Large
	(Rupees/permanent worker)		
State tube well	1,600	2,900	–
Private tube wel	2,100	4,300	6,100
Persian wheel	1,900	2,900	–
Charsa	1,900	1,800	–

Source: Study of 141 Farms in Aligarh District, 1966-67.

If state tube wells are to serve small farmers, they must not only provide water as reliably as the private tube wells, but methods must be found to intensify farm production to provide more employment. This may call for even greater reductions in the area to be irrigated per well. In any case, it requires careful farm management research especially on resource utilisation on small farms and their relation to irrigation.

NOTES

1. The data for this analysis are drawn from a joint research project of the Agricultural Experiment Station, UP Agricultural University and the Department of Agricultural Economics, Cornell University. It is reported in detail in T. V. Moorti, "A Comparative Study of Well Irrigation in Aligarh District, India", Occasional Paper Number 29, Department of Agricultural Economics, Cornell University — US AID Research Project, March 1970.

   For an exposition of this and other concepts of capacity utilisation see: Uma J. Lele, "Modernisation of the Rice Milling Industry: Lessons from Past Performance", Economic and Political Weekly, Volume V, Number 28, July 11, 1970, p. 1081.

3 For similar evidence of the interaction of high-yielding varieties and irrigation source see: Vishnoo Prasad Shukla, "An Economic Analysis of Farm Resource Use, Jabalpur District, Madhya Pradesh, India, 1967-68", Occasional Paper Number 26, Department of Agricultural Economics, Cornell University — US AID Prices Research Project, January 1970.