Private Tubewell Development and Cropping Patterns in West Pakistan

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I. INTRODUCTION

One of the most significant phenomena in agricultural development in Pakistan has been the installation of private tubewells by the farmers of West Pakistan at an exceedingly fast rate during the Second Plan period. Installation of these tubewells has enabled the farmers to intensify irrigation and make important changes in cropping patterns in order to maximize the income from their crop production. In this article we present results of two surveys conducted recently on private tubewells and the cropping pattern followed by farmers in area where tubewells are being installed. The results of these surveys indicate that West Pakistan is likely to attain a rate of increase in agricultural production which will be unparalled in the history of agriculture. To achieve and maintain such a rate of increase, however, considerable revision will be necessary in the programme for land, water and power development proposed for the next ten years and that included in the Third Five Year Plan.

In Sections II and III of this paper, we present the results of our survey on the number of tubewells and the cost of installation and operation of tubewells in different parts of the former Punjab. In Section IV are presented the results of our survey on the cropping patterns and other characteristics of the tubewell and non-tubewell farmers. A summary and the conclusions of the

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Mr. Mohammad Ghaffar, a Research Assistant in the Institute, carried the burden of interviewing tubewell and non-tubewell farmers all over the former Punjab and spent 6 months continuously in the villages. He and Mr. N. H. Nizami, a Staff Economist in the Institute, helped the author in compilation and tabulation of the data.

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paper are given in Section V where some policy issues arising out of this study are also raised.

An estimate of the likely increases in crop production during the Third Plan period, on the basis of results of this survey, is being prepared. This will be presented along with the agricultural production targets proposed by the Planning Commission in a subsequent issue of this *Review*.

II. TUBEWELL INSTALLATION IN WEST PAKISTAN

The average yield of crops in the irrigated areas of West Pakistan is much lower than the yields obtained in the irrigated areas in other countries under similar conditions. One basic cause of this is that much less irrigation water is available than is required for consumptive use of crops. One cusec of water is generally supplied for 350 acres in West Pakistan, compared to 70 acres or less in the United States of America and other countries under similar climatic conditions [14, p. 22]. The most important improvement in the agriculture of West Pakistan can, therefore, be expected from the use of additional water on the lands presently irrigated with inadequate water supplies.

Government Tubewells

Under the plains of the former Punjab and Bahawalpur lies a vast reservoir of water which can be used to store and supply additional water by tubewell pumping. The former Punjab Government installed 20 tubewells between 1938 and 1940 in an area close to Shalimar Gardens for irrigation purposes [2, p. 50]. The next big schemes for pumping groundwater were the Rasul Project and the Central Tubewell Project under which about 1,500 tubewells were installed in the Rechna and Chaj Doabs between 1944 and 1953 with a view to lowering the watertable and providing additional water for irrigation [2, pp. 50-53]. More recently, the West Pakistan Water and Power Development Authority (WAPDA) has installed about 2,000 tubewells in Salinity Control and Reclamation Project Number One (SCARP 1) in the Rechna Doab [1, p. 261]. These tubewells were installed in 1959 and 1960 and commenced operation in 1961/62. About 400 additional tubewells have been installed in SCARP 2 area in the Chaj Doab between 1961/62 and 1963/64.

Private Tubewells

Hand pumps to draw water for domestic purposes have been used in Pakistan for more than one hundred years. Installation of tubewells for agricultural use is, however, of more recent origin. The Department of Agriculture has been helping the farmers in installing tubewells for the last thirty years. The Department undertakes the drilling of bore holes and installation of pipes and

strainers. The remaining work, *i.e.*, supply and installation of pump and engine and the construction of pump house, *etc.*, is done by the farmers themselves. Pipes and strainers may be purchased from the Department of Agriculture or from the local market. Private drillers have also been drilling wells for the last twenty-five years or so, but have entered this field in a big way during the last six years.

The Department of Agriculture, Punjab, had an Agricultural Engineering Section at the Agricultural College and Research Institute, Lyallpur, which installed about ten to twenty tubewells a year between 1939/40 and 1949/50. The *Annual Report* of the Department of Agriculture, Punjab, for the year ending June 1939, states the following:

> During the year 17 power-operated tubewells were completed and handed over to their owners . . . There is a constantly increasing demand for both large and small power-operated tubewells particularly where cheap hydro-electric power is available [18, p. 54].

It appears that both the Department of Agriculture and private drillers were installing some tubewells before 1938/39. However, complete records of these installations are not available. It is recorded that the Department of Agriculture installed 177 tubewells between 1938/39 and 1949/50 [11, pp. 1-2]. The number installed by the private drillers is not known.

The work of the Agriculture Engineering Section of the Department of Agriculture was expanded in 1950/51 and it installed 624 tubewells in the next four years. The rate of installation was further increased in 1959/60 and it exceeded 1,000 tubewells a year between 1961/62 and 1963/64.

Number of Private Tubewells According to Revenue Department

The Revenue Department published the figures of the number of tubewells in the former Punjab for the first time in 1953/54, when 990 tubewells were reported in existence [19, p. xix]. Out of these, the Department of Agriculture had installed 801 tubewells (177 *plus* 624). The remaining 189 tubewells were installed either by private drillers up to 1953/54 or by the Department of Agriculture prior to 1938/39. In any case, the rate of installation by private drillers prior to 1953/54 must have been very small.

The total number of tubewells as recorded by the Revenue Department for the Northern Zone of West Pakistan, the number of private tubewells installed by the Department of Agriculture and the estimated number installed by private drillers between 1953/54 and 1963/64 is given in Table I. The total number of tubewells increased from 1,200 in 1954/55 to 4,200 in 1959/60, showing an increase

of 3,000 tubewells during the First Plan period. The number further increased to 13,600 by 1963/64 showing an increase of over 9,400 during the first four years of the Second Plan period.

TABLE I

NUMBER OF PRIVATE TUBEWELLS INSTALLED BY THE DEPARTMENT OF AGRICULTURE AND BY PRIVATE DRILLERS IN THE NORTHERN ZONE OF WEST PAKISTAN, 1953/54 to 1963/64

Year (1)	Total number of private tubewells at the end of the year (2)	Total number installed during the year (3)	Number installed by the Department of Agriculture (4)	Number installed by private drillers (5)
1953/54	990	*n.a.*	*n.a.*	*n.a.*
1954/55	1,216	226	258	(a)
1955/56	1,495	279	307	(a)
1956/57	1,911	416	329	(a)
1957/58	2,168	257	371	(a)
1958/59	3,295	1,127	388	739
1959/60	4,214	919	489	430
1960/61	6,904	2,690	817	1,873
1961/62	9,757	2,853	1,040	1,813
1962/63	12,404	2,647	1,088	1,559
1963/64	13,646	1,202	1,410	(b)

Sources: Column (2): Director, Land Records, West Pakistan, Lahore.
Column (3): Calculated from Column (2).
Column (4): Letter from Director of Agricultural Engineering, West Pakistan.
Column (5): Column (3) *minus* Column (4) for year 1958/59 through 1962/63.

Notes: *a*) Differences between Column (3) and Column (4) before 1958/59 are judged to be too small to be of significance in view of the fact that the data in the two columns come from different sources.
b) Data for 1963/64 appear to be incomplete as far as the total number of tubewells shown in Column (2) is concerned.

A comparison of figures of Columns (4) and (5) of this table indicates that up to 1957/58, the total number of tubewells installed in any year was almost equal to the number installed by the Department of Agriculture. Thus, the Department of Agriculture installed 1,265 tubewells in the 4 years between 1954/55

and 1957/58. The revenue records showed an increase of only 1,178 tubewells in the same 4 years. The difference of 87 tubewells (1,265 *minus* 1,178) is probably due to the fact that it takes some time for the farmer to have his tubewell recorded with the Revenue Department. This number would probably be noted in the next year's revenue records. In any case, it seems that the private drilling trade did not install any significant number of tubewells up to 1957/58 but it entered the field in a big way after that.

Comparison of number of tubewells recorded by the Revenue Department in each district between 1953/54 and 1963/64, given in Appendix Table A-1, with the number installed by the Department of Agriculture given in Table A-2, shows that private drillers installed 730 tubewells in Gujranwala and Sialkot districts in 1958/59. In other districts, the number of tubewells installed in 1958/59 was almost equal to the number installed by the Department of Agriculture. The question naturally arises as to why private drillers entered the field of tubewell installation in such a large way in 1958/59 and in two districts only. The most probable explanation for this appears to be the provision of electricity to these two districts in 1958/59, which gave a great stimulus to the farmers in the installation of tubewells. As the Department of Agriculture had only a limited number of drilling rigs in these two districts, private drillers moved in. In the following year (1959/60), the entire installation of 430 tubewells by private concerns appears to have taken place again in the Gujranwala district (*cf.* Table A-1 and Table A-2).

The next big increase in the rate of installation of tubewells took place in 1960/61 when 1,873 tubewells were installed by private drillers (Column (5), Table I), compared to 817 by the Department of Agriculture (Column (4), Table I). An examination of statistics for different districts in Table A-I indicates that this increase took place mainly in Multan, Gujranwala and Montgomery districts. Emergence of private drillers in the Multan and Montgomery districts in 1960/61 seems to have followed the electric transmission and distribution facilities in these districts on the completion of the Multan Thermal Power Station in 1960. A major increase in installation of tubewells took place again in the next two years, 1961/62 and 1962/63, in the same four districts *viz.*, Multan, Montgomery, Gujranwala and Sialkot.

This evidence suggests strongly that the availability of electricity acted as a catalyst which led to a wave of private drilling.

A Complete Survey of Private Tubewells

The Pakistan Institute of Development Economics carried out a small survey of private tubewells in a few villages in the former Punjab in March 1964. The

results of this survey were published in an earlier issue of this *Review* [3, pp. 233-243]. While carrying out that survey the author found that in a large number of cases the tubewell farmers were paying the usual charges for canal water and were not getting any rebate for irrigation by tubewell water[1]. The obvious implication of this was that these tubewells were not recorded by the Irrigation and Revenue Departments. The author, therefore, considered the desirability of carrying out a survey or a complete census of the tubewells in the former Punjab with the help of the Department of Agriculture. The question was discussed with the Director of Agriculture, Lahore. He readily agreed to the proposal and directed his staff to help the author in the proposed survey.

The survey was conducted in the summer of 1964 in each village of sixteen districts in the Northern Zone of West Pakistan. These districts were selected because they had large areas underlain with non-saline groundwater where the farmers were installing tubewells for irrigation. The survey was carried out through the District Agricultural Officers. The actual count of tubewells was made by the Field Assistants in each village in their Unions and their work was supervised by Agricultural Assistants, most of whom are graduates in agriculture. The author made extensive tours of the villages of these districts when the survey was being done.

The results of the survey are summarized in Table II and shown graphically in the map, where the number of tubewells in each Union is represented by the number of dots. The Union Council boundaries are not shown on the map in order to avoid congestion. A rough estimate of the number of tubewells in other districts has also been prepared and included in Table II. There were in all, in the middle of 1964, 24,000 private tubewells in the Northern Zone and about 25,000 tubewells in the whole of West Pakistan. Out of these, about 6,600 tubewells were installed by the farmers in the year 1963/64, 6,400 in the Northern Zone and 200 in the Southern Zone.

There are two main areas of concentration of tubewells. One of these is in the Multan and Montgomery districts where electricity was supplied in 1960/61. These two districts had 9,200 tubewells by the middle of 1964. The second is in Gujranwala and Sialkot districts where electricity was supplied in 1958/59. These two districts had 6,700 tubewells at the time of the survey. Other important

[1] In canal-irrigated areas, the government levies charges for the supply of canal water to the farmers. If a farmer does not use canal water, he should not be required to pay for the canal water.

TABLE II

ACTUAL NUMBER OF PRIVATE TUBEWELLS INSTALLED BY THE FARMERS IN EACH DISTRICT OF THE FORMER PUNJAB AND BAHAWALPUR AND ESTIMATED NUMBER OF PRIVATE TUBEWELLS IN OTHER PARTS OF WEST PAKISTAN

Name of the district (1)	Total number of tubewells installed upto middle of 1964 (2)	Total electric tubewells (3)	Total diesel tubewells (4)	No. installed in the year 1963/64 (5)
A. Northern Zone				
Gujrat	719	299	420	274
Sargodha	352	181	171	109
Lyallpur[a]	1,063	291	772	301
Jhang	1,540	448	1,092	304
Mianwali	228	107	121	60
Sialkot	2,458	434	2,024	503
Gujranwala[b]	4,234	1,270	2,964	1,170
Sheikhupura[c]	460	117	343	125
Lahore	1,607	856	751	504
Montgomery	4,055	1,175	2,880	1,049
Multan	5,148	624	4,524	1,345
Muzaffargarh	443	—	443	142
D.G. Khan	220	—	220	40
Bahawalpur	398	26	372	122
Bahawalnagar	273	3	270	87
Rahimyar Khan	443	9	434	177
Sub-total Punjab & Bahawalpur	23,641	5,840	17,801	6,312
N-W.F.P. (estimated)	359	310	49	88
Total Northern Zone	24,000	6,150	17,950	6,400
B. Southern Zone (estimated)	1,000	50	950	200
Total private tubewells (estimated)	25,000	6,200	18,800	6,600

Source: Survey conducted by PIDE.

a) Excludes Jaranwala tehsil which falls in SCARP 1.

b) Excludes Hafizabad tehsil which falls in SCARP 1, but includes Ferozwala tehsil of Sheikhupura district.

c) Estimated number of private tubewells in Sangla Hill and Sheikhupura tehsils of Sheikhupura district, Hafizabad tehsil of Gujranwala district and Jaranwala tehsil of Lyallpur district. Major part of these tehsils is included in SCARP 1 area.

districts are Lahore, Jhang and Lyallpur, which had 4,200 tubewells. Parts of these districts have also been supplied with electricity, which seems to have encouraged the installation of tubewells in these districts. Thus, these 7 districts accounted for 20,000 tubewells out of 24,000 tubewells in the Northern Zone of West Pakistan and 25,000 tubewells in the whole of West Pakistan.

Although provision of electricity seems to have been the principal cause of rapid increase in the installation of tubewells in the Gujranwala, Sialkot, Multan and Montgomery districts, it will be seen from Columns (3) and (4) of Table II that the majority of the tubewells in all these districts are run with diesel engines. The position seems to have developed somewhat in the following way. Provision of electricity enabled some farmers to make good profits from the installation of tubewells. When these installations demonstrated the profitability of tubewells, others even when they could not get electric connections, drilled wells and installed diesel engines. It was, thus, demonstrated that good profits were possible even with diesel engines. More farmers then began to install diesel engine tubewells and the number increased rapidly.

The map also shows the influence of groundwater quality on the installation of tubewells by the farmers. Most of the tubewells are concentrated in areas having less than 1000 parts per million (ppm) of dissolved solids. These are located mainly in upper parts of the *doabs* where rainfall is high and along the rivers where the river water during the high floods season contributes to the groundwater recharge. The number of tubewells decreases with increasing distance from the area of recharge and active circulation. There are, however, many tubewells in areas having 1000 to 3000 ppm of dissolved salts and even in areas having more then 3000 ppm of dissolved salts. We did not study these tubewells in detail. However, here the influence of canal seepage on the quality of water may be important. The salinity lines shown in the map refer to the total dissolved salts in the groundwater between 100 feet and 450 feet below ground surface [6, p. 51]. The water in the upper 100 feet is diluted with seepage from canal water and contains much less salt. It is this water which is mainly pumped by tubewells installed by the farmers. Furthermore, these tubewells are reported to be worked very sparingly. These are used only to meet the critical needs of crops during canal closures, particularly in the sowing and maturing periods and not for increasing the intensity of cropping.

Comparison With Revenue Records

If the number of tubewells installed during 1963/64 is deducted from the total number of tubewells, we can get an estimate of the total number of tubewells at the end of 1962/63. This comes to 17,600 tubewells for the Northern Zone (24,000 *minus* 6,400). The corresponding figure in the revenue records at the end of 1962/63 was 12,400 tubewells (Table I). The revenue records, therefore, appear to have underestimated the total number of tubewells in 1962/63 by 5,200 or about 42 per cent. At the end of 1963/64, our survey showed the number of tubewells to be 10,354 higher than that in the revenue records (24,000 *minus* 13,646). The number in our survey was thus 76 per cent higher than that in the revenue records. The major differences were in the districts of Multan (1,733), Gujranwala (1,710), Montgomery (1,457), Lahore (1,180), Sialkot (1,036) and Jhang (770). These districts accounted for a difference of 7,886 between the revenue records and results of our survey. In our survey we came across a large number of tubewells in these districts where the farmers were paying the full canal water charges for areas irrigated jointly from canal and tubewell water. No concession was given for the use of tubewell water. It appears that these tubewells were not recorded in the revenue papers. This may be explained as follows.

When a farmer uses tubewell water along with the canal water, he pays the full charges for canal water. Such a tubewell will not be recorded in the revenue papers. When a tubewell owner digs a separate watercourse for the use of tubewell water and does not apply any canal water to the area served by the tubewell, he still pays the full charges for canal water but becomes eligible for a 25 per cent rebate. Such a tubewell is recorded in the revenue papers, but a number of farmers with whom we discussed this question, considered the procedure for getting this concession as too cumbersome and therefore did not avail of this concession. It appears that after the introduction of electricity the income from tubewells in relation to the concession became so large that most farmers ignored the concession. Their tubewells were, therefore, not recorded by the Revenue Department. In 1963/64, the Revenue Department appears to have recorded only a small fraction of the additional tubewells installed during the year.

Comparison With WAPDA Records

Whereas our survey showed the number of private tubewells to be much higher than that recorded by the Revenue Department, the number of electric tubewells recorded by WAPDA is higher than that recorded in our survey. It will be seen from Table II that out of 25,000 tubewells in West Pakistan, there were 18,800 diesel tubewells and 6,200 electric tubewells at the end of 1963/64.

TABLE III

NUMBER OF GOVERNMENT AND PRIVATE AGRICULTURAL TUBEWELLS CONNECTIONS BY WAPDA IN VARIOUS DISTRICTS OF WEST PAKISTAN AT THE END OF 1963/64

District (1)	Number of tubewells		
	Private (2)	Government (3)	Total (4)
A. Punjab & Bahawalpur Area			
1. Campbellpur	133	*nil*	133
2. Rawalpindi	14	*nil*	14
3. Jhelum	16	*nil*	16
4. Gujrat	512	*nil*	512
5. Mianwali	164	*nil*	164
6. Sargodha	678	163[a]	841
7. Lyallpur	242	278[b]	520
8. Jhang	590	32	622
9. Lahore	1,943	*nil*	1,943
10. Gujranwala	146	515	661
11. Sheikhupura	208	2,837[c]	3,045
12. Sialkot	458	*nil*	458
13. Muzaffargarh	2	*nil*	2
14. Multan	1,196	*nil*	1,196
15. Montgomery	1,896	*nil*	1,896
16. Bahawalpur	37	*nil*	37
17. Bahawalnagar	27	*nil*	27
18. Rahimyar Khan	1	*nil*	1
Sub-Total A	8,263	3,825	12,088
B. N-W.F.P. Area			
1. Peshawar	539	*nil*	539
2. Mardan	347	*nil*	347
3. Kohat	196	*nil*	196
4. D.I. Khan	230	*nil*	230
5. Hazara	12	*nil*	12
6. Bannu	4	*nil*	4
7. Malakand	26	*nil*	26
8. Saidusharif	17	*nil*	17
Sub-Total B	1,371	*nil*	1,371
C. Sind Area	60	*nil*	60
TOTAL (A + B + C)	9,694	3,825	13,519

Source: Operational Manager, Electricity, WAPDA, through the courtesy of S. Munawar Ali, Director General, Planning and Investigations, WAPDA, Lahore, with his letter dated March 8, 1965.

Notes: *a*) Tubewells in SCARP 2 area.

b) Tubewells in SCARP 1 area.

c) Include 971 tubewells in SCARP 1 area. There are reported to be 1,400 tubewells under Rasul Tubewell Scheme by S.E. Tubewell Investigation Circle, Moghalpura, of which no record could be traced from Operational Manager's Office, Electricity, WAPDA. They are looking into this.

Out of this, 17,800 diesel tubewells and 5,840 electric tubewells were in the Punjab and Bahawalpur. However, WAPDA is reported to have given 9,694 electric connections for private agricultural tubewells and 3,825 electric connections for agricultural tubewells in West Pakistan up to June 1964 (Table III). In the Punjab and Bahawalpur, the number of electric connections given by WAPDA for private agricultural tubewells was 8,263 (Column (2), Table III) against 5,840 found in our survey (Column (3), Table II). The main differences were in the Gujrat, Sargodha, Lahore Montgomery and Multan districts. The differences suggest that city and cantonment tubewells used for domestic drinking water purposes and for lawns and gardens attached to houses are included in the list of agricultural tubewells by WAPDA. If these are deducted from the number compiled by WAPDA, the actual number of private agricultural tubewells to which electric connections have been given comes more in line with the number found in our survey. Even then it is possible that the total number of electric tubewells is more than 6,200 and that total of all tubewells is probably larger than 25,000 found in our survey (Table II).

Comparative Role of Agriculture Department and Private Drilling Concerns

As previously stated the total number of tubewells installed by the farmers in the Northern Zone in 1963/64 was 6,400. Out of these the Department of Agriculture installed 1,410 tubewells[2]. The remaining 4,990 tubewells must, therefore, have been installed by the farmers with the help of private drilling concerns. Thus starting with an insignificant number of tubewells installed prior to 1957/58, the private drillers installed about 5,000 tubewells in 1963/64.

The total number of tubewells recorded by the Revenue Department and the number of tubewells installed by private drillers between 1958/59 and 1962/63 as shown in Table I is probably not correct as the Revenue Department underestimated the total number in 1962/63 and 1963/64 by as much as 42 and 76 per cent respectively. However, as explained on page 4, it appears that the number recorded up to 1957/58 was probably correct. A better (rough) estimate of the tubewells after 1958/59 may be made on the assumption that the revenue records underestimated the total number by 10 per cent in 1959/60, 15 per cent in 1960/61, 25 per cent in 1961/62, 42 per cent in 1962/63 and 76 per cent in 1963/64. The total number of tubewells as adjusted on this basis and the probable number of tubewells installed by the private drillers is shown in

[2] Out of 1,410 tubewells, 1,369 tubewells were installed by the Agricultural Engineers, Lyallpur and Bahawalpur and 41 by the Agricultural Engineers, D.I. Khan and Peshawar. This information was supplied to the author by the Director, Agricultural Engineering, Lyallpur, in January 1965 and by the Superintending Engineer, Agricultural Machinery Organization, Peshawar, in February 1965.

Table IV. Thus, the number installed by private drillers increased from practically nil in 1957/58 to about 850 in 1959/60 and about 4,400 in 1962/63 and to about 5,000 in 1963/64. The private drillers got a big boost in business in 1960/61,

TABLE IV

ADJUSTED NUMBER OF TOTAL TUBEWELLS, NUMBER INSTALLED BY THE AGRICULTURE DEPARTMENT AND NUMBER INSTALLED BY PRIVATE DRILLERS IN NORTHERN ZONE OF WEST PAKISTAN

Year	Total number of private tubewells		Total number installed during the year	Number installed by the Agriculture Department	Number installed by private drillers
	As per revenue records	Adjusted			
1959/60	4,214	4,635	1,340	489	851
1960/61	6,904	7,940	3,305	817	2,488
1961/62	9,757	12,200	4,260	1,040	3,220
1962/63	12,404	17,600	5,400	1,088	4,312
1963/64	13,646	24,000	6,400	1,410	4,990

after the Multan Thermal Station began to supply some electricity for tubewells. They have made great progress since then. The contribution of private drilling concerns at present far exceeds that of the Department of Agriculture. The Pakistan Institute of Development Economics is now engaged in a survey of private drilling concerns in the former Punjab and Bahawalpur. The results of this survey will be reported in a subsequent issue of this *Review*. Preliminary results of this survey indicate that a larger number of drilling concerns have entered the field in the last two to three years. This lends some support to the increases shown in the above figures of tubewells installed by private drilling concerns.

The private drilling concerns appear to be capable of increasing their capacity very rapidly and should be able to install all the tubewells required by the farmers in the coming years without much difficulty.

The Department of Agriculture had 150 drilling rigs up to 1963 [16, p. 80.] With these they installed 1,620 tubewells in 1963/64. Additional drilling rigs have been imported in 1963/64 and 1964/65. The Department of Agriculture now has 304 hand-drilling rigs and 18 power rigs [21, p. 33]. These are expected to be in commission throughout the Third Plan period. Each hand-drilling rig and power

rig installs 11 and 9 tubewells respectively in a year[3]. On this basis, the presently available 304 hand-drilling rigs and 18 power rigs will install 3,500 tubewells in a year throughout the Third Plan period[4] [21, p. 33]. The Department of Agriculture has put up a proposal for the acquisition of 300 additional hand-operated drilling rigs and 10 additional power rigs for the Third Plan period [22, p. 3]. In order to expedite drilling operations and to enable the farmers to install their tubewells as rapidly as possible, provision for additional rigs should be included in the Third Plan. This additional equipment will increase the capacity of Department of Agriculture drilling in the Third Plan period, with a lag, to an annual rate of about 6,800. By the time this equipment comes into use, private drillers may very well have achieved a similar capacity.

III. COST OF INSTALLATION AND OPERATION OF PRIVATE TUBEWELLS

For estimating the cost of installation and working expenses of tubewells, we selected about 200 tubewells distributed over 100 villages in 50 Union areas in the non-saline groundwater areas of Multan, Montgomery, Gujranwala, Sheikhupura, Sialkot, Gujrat, Jhang and Sargodha. We did not select any tubewells in the saline groundwater areas for this purpose. Furthermore, due to limitation of trained staff and time and attitude of many of the farmers, it was not possible to take a random sample. Some of the farmers refused to give information on such items as operating expenses, electricity used and hours worked. We had no alternative but to leave them and select other farmers who were prepared to supply this information. This may have introduced bias into the results. However, the size of the sample was sufficiently large and its distribution over different parts of the former Punjab was quite wide, so that a fairly good sample of the tubewell farmers in the non-saline groundwater areas was selected.

Cost of Installation

The average cost of installing a tubewell came to about 8,700 rupees per well in the whole of the former Punjab and Bahawalpur. It varied from an average of 12,000 rupees for diesel engine tubewells in the Multan and Montgomery districts to an average of about 5,400 rupees for electric tubewells in the Gujranwala and Sialkot districts. Most of these tubewells were of 6 inches diameter. The details of the cost of installation of tubewells in Multan

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[3] One hand-drilling rig drills on an average one tubewell in one month or about 11 tubewells in a year. The power rig are used in the mountainous areas, hence their outturn is less than that of hand rigs which are used in the plains.

[4] In the shorter run, on the basis of only slightly increased drilling capacity of the Department of Agriculture (but particularly of the private drilling concerns) we may expect some 8,000 to 9,000 tubewells to be installed in 1964/65 compared to 6,600 in 1963/64. This will increase the total number of tubewells at the end of the Second Plan period to about 33,000 to 34,000.

and Montgomery districts and for Gujranwala and Sialkot districts are given in Appendix Table B-1 and are summarized in Table V. The difference in cost between different districts is mainly due to the depth of watertable and availability of suitable water-bearing sand. In the Gujranwala and Sialkot districts the watertable is high, averaging about 10 feet in depth. These two districts had about 34,000 open surface wells distributed throughout the cultivated area which were used for irrigation before the installation of tubewells. The farmers have installed most of their tubewells in these open surface irrigation wells. Furthermore, these two districts are in the upper parts of the Rechna Doab and, therefore, have a greater proportion of medium and coarse sands. The strainer does not have to be very long in these districts to give an adequate discharge. The length of the strainer averages about 70 feet only. Since the watertable is high, the lining pipe is also not very long and averages about 40 feet only. The wells are fitted with an engine or motor of 14 to 18 horse power. The average cost of electric motor-driven tubewells in these districts is about 5,400 rupees while that of diesel engine tubewells is about 8,500 rupees per well.

TABLE V

COST OF INSTALLATION OF A DIESEL AND ELECTRIC TUBEWELL IN DIFFERENT DISTRICTS

Cost	Multan & Montgomery districts		Gujranwala & Sialkot districts	
	Diesel tubewell	Electric tubewell	Diesel tubewell	Electric tubewell
Cost of tubewell exclusive of engine or motor	6,250	6,250	3,360	3,360
Cost of engine or motor	5,750	2,550	5,140	2,040
Total cost	12,000	8,800	8,500	5,400

Source: Appendix Table B-1.

In the Multan and Montgomery districts on the other hand, the watertable is deeper, averaging about 25 feet. Although there are some 38,000 open surface wells in these two districts, these wells are concentrated mainly in non-perennial areas[5]. In the perennial areas the farmers have to dig wells about 25 feet deep so that the centrifugal pump can be fixed close to the surface of the groundwater. The lining pipe has also to be longer, the average length being about 80 feet. The strainer is also of greater length, being about 105 feet. The motor or engine also must be of greater horse power. For these reasons the cost

[5] Canals flowing all the year round and fed from a permanent barrage or diversion dam spanning the source river are called perennial canals. Those which run during the summer months only when there is more water in the rivers are called non-perennial.

of installation of tubewells is high in these districts and averages about 8,800 rupees per well for electric tubewells and about 12,000 rupees per well for diesel tubewells.

Overall average cost for the 4 districts combined comes to about 8,700 rupees per tubewell. The average cost of electric tubewells is about 7,100 rupees and those of diesel engine tubewells is about 10,300 rupees per well[6].

Discharge of Private Tubewells

The discharge of private tubewells was estimated by comparing it with the discharge of the canal outlet. The method of calculating the discharge is explained in Appendix C.

The average discharge of the tubewells in various districts is given in Table VI. The average of the tubewells in the Multan, Montgomery, Gujranwala and Sialkot districts varies between 1.12 and 1.24 cusecs. The average for Gujrat district is less and that for Jhang district is more. The weighted mean for the 6 districts comes to 1.19 cusecs. As these districts account for about 72 per cent of all tubewells, we have used this figure as the average for the whole province.

Water Pumped by Tubewells

The number of hours worked by tubewells in the non-saline groundwater areas in different districts varied between 1,900 and 2,600 hours a year, as shown in Table VI. On the average the tubewells worked for 2,350 hours during

TABLE VI

WORKING HOURS AND DISCHARGE OF TUBEWELLS

District	Average number of hours worked in 1963/64	Average area irrigated in 12 hours	Estimated average discharge at the field	Estimated average discharge at the tubewell head[a]
(1)	(2)	(3)	(4)	(5)
	(*hours*)	(*acres*)	(*cusecs*)	(*cusecs*)
Multan	2,250	4.70	1.18	1.24
Montgomery	2,560	4.25	1.06	1.12
Gujranwala	2,260	5.55	1.16[b]	1.22
Sialkot	2,470	5.50	1.15[b]	1.21
Gujrat	1,920	3.35	0.70[b]	0.74
Jhang	2,410	5.17	1.29	1.36
Overall weighted average	**2,350**	**4.89**	**1.13**	**1.19**

Source: Survey conducted by PIDE.

Notes: *a*) It is assumed that 5 per cent of the water is lost in the watercourse between the tubewell and the fields irrigated.

b) It is assumed that the depth of the irrigation or delta of water is 2½ acre inches per acre in the Gujranwala, Sialkot and Gujrat districts where tubewells are used mostly for rice irrigation. For other districts the depth of water for one irrigation is assumed as 3 acre inches per acre.

[6] Harza Engineering Company estimated the average cost of a private electric tubewell as 7,090 rupees and that of a private diesel tubewell as 9,100 rupees. *See* [10a, p.9]. We came across this report after our report had been finalized and sent to press.

1963/64. Thus, if we assume the average discharge of the tubewells to have been 1.19 cusecs, the tubewells pumped about 233 acrefeet of water per well. Out of this about 220 acrefeet was delivered in the fields, the balance being lost in the watercourse. According to limited enquiries made by us after the main survey was over, it appears that in the saline groundwater areas the tubewells work much less time and pump much less water. On a rough calculation, out of the 25,000 tubewells in West Pakistan about 20,000 are located in the non-saline groundwater areas. These would have pumped about 4.7 million acrefeet (MAF) of water during 1963/64 out of which about 4.4 MAF was delivered in the fields.

By the end of the Second Plan period (mid-1965), the number of tubewells in West Pakistan is expected to increase to about 33,000 out of which about 28,000 may be in the non-saline groundwater areas. These tubewells will pump about 6.5 MAF of water in 1964/65. If we include 2.5 MAF of water likely to be pumped by WAPDA tubewells, the total pumping will be about 9.0 MAF, out of which about 8.5 MAF will be delivered in the fields. This would mean a 14 per cent addition to the 60 MAF of river water likely to be delivered by canals at the fields in West Pakistan in 1964/65.

Annual Working Expenses of Tubewells

The annual working expenses of diesel and electric tubewells for the *i*) Multan and Montgomery districts and *ii*) Gujranwala and Sialkot districts are shown in Appendix Table B-2. To the annual working expenses have been added the depreciation and interest charges. These are calculated on the assumption that life of the tubewell including pipes, strainers, pumps and other materials, is ten years and that of the motor and engine is fifteen years. Interest is calculated at the rate of 8 per cent per year on the average value of the tubewells. Some of the farmers were able to borrow funds at 6 per cent rate of interest from the Agricultural Development Bank (ADB), but their number was relatively small. We consider that 6 per cent rate of interest is low as a measure of opportunity cost and have, therefore, used 8 per cent in our calculations. According to Mahbubul Haq: "It would seem that a shadow price of capital between 8 to 10 per cent would be . . . appropriate . . ." [7, p. 47].

A summary of the total annual cost is given in Table VII. For the Gujranwala and Sialkot districts the annual operating cost of diesel tubewells is about 4,700 rupees and of electric tubewells about 2,700 rupees. Annual operating cost of electric tubewells is thus about 2,000 rupees less. The cost per acrefoot of water pumped is about 19 rupees from diesel tubewells and 14 rupees from electric tubewells. The cost per hour is 2.0 rupees for diesel tubewells and 1.2 rupees for electric tubewells.

TABLE VII

ANNUAL COST OF OPERATION OF A DIESEL AND ELECTRIC TUBEWELL IN DIFFERENT DISTRICTS

Cost	Multan & Montgomery districts		Gujranwala & Sialkot districts	
	Diesel tubewells	Electric tubewells	Diesel tubewells	Electric tubewells
Annual operating cost	4,670	2,750	3,720	2,040
Interest and depreciation	1,490	1,150	1,020	700
Total annual cost	**6,160**	**3,900**	**4,740**	**2,740**
Cost per acrefoot of water	24.0	18.1	19.3	14.3
Cost per hour worked	2.6	1.7	2.0	1.2

Source: Appendix Table B-2.

In the Multan and Montgomery districts the average cost of operation of a diesel tubewell comes to about 6,200 rupees during the year. This is equal to 24 rupees per acrefoot of water pumped or 2.6 rupees per hour worked[7]. Working of the electric tubewells costs about 3,900 rupees per year which is 2,300 rupees less than that of diesel tubewells. This cost is equal to about 18 rupees per acrefoot of water pumped or 1.7 rupees per hour of tubewell run.

For all the 4 districts combined, the cost of pumping water from diesel tubewells comes to 21.8 rupees per acrefoot of water. For the electric tubewells the cost comes to 16.4 rupees per acrefoot of water. The cost of pumping water from diesel tubewells is, thus, 33 per cent higher than that from electric tubewells.

Canal water charges are very low compared to cost of pumping water from tubewells. Water rates vary with the crop grown. For the Lower Chenab Canal in the former Punjab, the water rates for different crops are given in Column (2) of Table VIII. In order to estimate the cost per acrefoot of water, we have prepared a rough estimate of the amount of water used by each crop. This is given in Column (3) and the cost per acrefoot of water is worked out in Column (4).

7 The Department of Agriculture has estimated the cost of pumping water from diesel tubewells as 2.25 rupees per hour or 27 rupees per acrefoot for one cusec capacity tubewell [12, p. 13].

TABLE VIII

CANAL WATER CHARGES FOR DIFFERENT CROPS

Crop	Water rate per acre cropped	Estimated water use	Water rate per acre-foot of water
(1)	(2)	(3)	(4)
	(rupees)	*(acrefeet)*	*(rupees)*
Sugarcane	21.6	4.4	4.9
Rice	10.4	3.8	2.7
Cotton	10.4	2.2	4.7
Maize	6.4	1.6	4.0
Wheat	6.4	1.1	5.8
Oilseeds	8.0	0.6	13.3
Gram	4.8	0.8	6.0

Sources: Column (2) from [27, p. 138-140].
Column (3): Our estimates.
Column (4): Col. (2) ÷ Col. (3).

Canal water rates vary from 4.8 rupees to 21.6 rupees per acre cropped or between 2.7 and 13.3 rupees per acrefoot of canal water delivered as compared to 16.4 rupees per acrefoot of water pumped from electric tubewells and 21.8 rupees per acrefoot of water pumped from diesel tubewells.

Sale and Purchase of Tubewell Water

In almost all villages visited by us, water was sold by the tubewell farmers to neighbouring cultivators. In villages where there was only one tubewell, water was usually sold at 4 to 5 rupees per hour. Where more tubewells were installed, water was usually sold at about 3.0 to 3.5 rupees per hour from diesel tubewells and about 2.5 to 3.0 rupees per hour from electric tubewells. In some villages the water was sold at 8 rupees per acre irrigated. As it took about 2.5 to 2.8 hours for one acre to be irrigated, this rate was equal to about 2.8 to 3.2 rupees per hour.

In the Gujranwala and Sialkot districts, the value of water sold was usually realized in the form of a share of the crop produce. Rice was the most commonly grown crop on the tubewell water in these districts. For this crop, the

usual practice was to charge one-third of the gross produce as the cost of tubewell water. For all other crops, one-fourth of the gross produce was charged. Charges were high in the case of rice because it required much more water as compared to other crops.

When land was occupied by tenants, the usual practice in the canal-irrigated areas was to share the produce on a fifty-fifty basis between the landlord and the tenant. Where the landlord had installed a tubewell in a canal-irrigated area he typically got 60 per cent of the produce and the tenant got 40 per cent. The additional 20 per cent by the landlord was assumed as the cost of operation of the tubewell. Where no canal water was available the landlord installing the tubewell typically got two-third of the produce and tenant got one-third.

IV. CROPPING PATTERNS AND OTHER CHARACTERISTICS OF TUBEWELL AND NON-TUBEWELL FARMERS IN THE FORMER PUNJAB

Cropping patterns and other characteristics were studied for the same tubewell farmers for whom details of cost of installation and cost of operation were studied and which have been reported in Section III. Crops grown by the owners of these tubewells during the year 1963/64 were recorded. An equal number of farmers not having tubewells in the same village and on the same canal outlets were selected for noting their cropping pattern for comparison with the tubewell farmers. An effort was made to select non-tubewell farmers who had the same kind of soil, exactly the same canal water supply and about the same size of holding. It was difficult, however, to get non-tubewell farmers who had the same size of holding as the tubewell farmers since the former usually had smaller size of holdings. Furthermore, most of the non-tubewell farmers purchased some tubewell water. Those farmers who purchased tubewell water equal to or more than 20 per cent of their canal water supply were not considered in calculating the cropping pattern of non-tubewell farmers.

The work of interviewing the farmers was done by one of the Research Assistants of the Pakistan Institute of Development Economics, who spent about 6 months in the tubewell villages of the former Punjab[8]. The Department of Agriculture deputed their field staff in the Montgomery and Gujranwala districts to help the Institute in this work. The results of the survey on the size of the tubewell and non-tubewell holdings, loans taken by the farmers for tubewell installation, bullock labour and manual labour used on tubewell and non-tubewell holdings and the cropping pattern followed by them are presented in this section.

[8] Mr. Mohammad Ghaffar, Research Assistant in the Agriculture Section in the Institute did this difficult task. But for his perseverance and hard work it would not have been possible to complete this study.

Size of Holdings and Tubewell Installation

Table IX shows the number of tubewells installed by farmers having different sizes of holdings in different districts of the Punjab. Out of 136 tubewells considered in this section, 101 had been installed by single farmers whereas 35 were installed jointly by 104 farmers, 2 to 4 farmers joining to install one tubewell. Thirty-one tubewells, or 23 per cent of the total, were installed by farmers having less than 25 acres each and 55 per cent of all tubewells were installed by farmers having less than 50 acres each. The remaining 45 per cent were installed by farmers having holdings of 50 acres and above.

Loans Taken for Tubewell Installation

Out of a total of 136 tubewell farmers only 24 farmers or 18 per cent of the total had borrowed any funds for installation of tubewells (Table X). The remaining 82 per cent had installed the tubewells with their own resources. For the farmers who obtained loans for tubewell installation the average amount of loan taken was about 9,500 rupees per farmer.

For the sake of comparison, it may be pointed out that the Agricultural Development Bank (ADB) has reported that it sanctioned and disbursed loans totalling 16.6 million rupees for the installation of 1,219 tubewells in the whole of West Pakistan in 1963/64 [15, p. 31]. The total number of tubewells installed during the year according to our survey was 6,600 (Table II). Thus, ADB figures imply that 20 per cent of all farmers who installed tubewells in West Pakistan in 1963/64 borrowed funds from the ADB compared to 18 per cent found in our survey. The average amount of loan issued by ADB was 13,600 rupees compared to 9,500 rupees for the farmers in our survey.

Bullocks and Men on Tubewell and Non-Tubewell Holdings

While making enquiries on the cropping pattern followed by tubewell and non-tubewell farmers, we noted the number of family workers working on the holding as well as the hired labourers employed on the holding. Similarly, the number of bullocks on each holding along with the area of the holding was recorded. These details are summarized in Table XI separately for the Multan and Montgomery districts and for the Gujranwala and Sialkot districts. In the Multan and Montgomery districts, the average size of tubewell holding was about 55 acres whereas that of non-tubewell holdings was about 28 acres. The number of bullocks kept on the average was 4.2 pairs on tubewell holdings and 2.2 pairs on non-tubewell holdings. The operated acreage per pair of bullocks was, there-

TABLE IX

NUMBER OF TUBEWELLS INSTALLED SINGLY AND JOINTLY BY FARMERS HAVING DIFFERENT SIZES OF HOLDING IN DIFFERENT DISTRICTS OF THE FORMER PUNJAB

District (1)	Size of holding: Below 25 acres (2)	25-50 acres (3)	50-150 acres (4)	Above 150 acres (5)	Total (6)
	Number of tubewells installed by single farmers				
Montgomery	3	2	4	1	10
Multan	2	7	17	3	29
Gujranwala[a]	4	7	11	1	23
Sialkot	5	5	2	*nil*	12
Gujrat	6	1	1	*nil*	8
Jhang	*nil*	5	9	1	15
Sargodha	1	1	1	1	4
Sub-Total	**21**	**28**	**45**	**7**	**101**
	Number of tubewells installed jointly (and number of farmers[b])				
Montgomery	2(6)	5(24)	3(6)	*nil*	10(36)
Multan	*nil*	3(8)	3(6)	*nil*	6(14)
Gujranwala[a]	4(13)	3(6)	1(2)	*nil*	8(21)
Sialkot	3(7)	1(2)	*nil*	*nil*	4(9)
Gujrat	1(6)	*nil*	*nil*	*nil*	1(6)
Jhang	*nil*	3(10)	1(3)	*nil*	4(13)
Sargohda	*nil*	1(2)	1(3)	*nil*	2(5)
	10(32)	**16(52)**	**9(20)**	*nil*	**35(104)**
Total number of tubewells	31	44	54	7	136
Total number of farmers	53	80	65	7	205
Percentage of tubewells in different size of holding	23	32	40	5	100
Percentage of farmers in different size of holding	26	39	32	3	100

Source : Survey conducted by PIDE.

Notes a) Actual number of tubewells studied in the Gujranwala district was 69 installed by single farmers and 24 installed by farmers jointly. As the size of holdings is smaller in Gujranwala district than in most other districts, only one-third of the number of tubewells studied is included in this table so as not to distort the picture for the whole province. In all other districts the sample size was in roughly the same proportion to total number of tubewells as the "deflated" Gujranwala sample is to that districts total

b) Figures in parentheses represent the number of farmers

TABLE X

LOANS TAKEN FOR INSTALLATION OF TUBEWELLS IN DIFFERENT DISTRICTS

District	Total number of farmers who installed tubewells	Number of farmers who got loans	Amount of loans taken
(1)	(2)	(3)	(4)
Multan	35	12	131,000
Montgomery	20	7	72,000
Gujranwala	31	5	26,000
Sialkot	16	*nil*	*nil*
Gujrat	9	*nil*	*nil*
Jhang	19	*nil*	*nil*
Sargodha	6	*nil*	*nil*
Total	136	24	229,000
Average amount of loan for farmers who actually obtained loans (Col. (4) ÷ Col. (3))			9,500
Average amount of loan on total number of farmers who installed tubewells (Col. (4)÷Col. (2))			1,700

Source: Survey conducted by PIDE.

fore, about the same in both cases (about 13 acres). However the area cropped per pair of bullocks was much higher (17.2 acres) in the case of tubewell farmers than in the case of non-tubewell farmers (12.7 acres). This means that installation of tubewells increased the efficiency of bullocks by more than 35 per cent. This is because the bullocks are underworked at present. They generally work for about 120 to 130 days in the canal-irrigated areas [5, p. 37]. With the installation of tubewells the farmers were able to work them for longer hours or for more days and thus covered more area. Similarly, the area cropped per man was 7.0 acres in the case of non-tubewell farmers and 10.3 acres on tubewell holdings. This means that output per man was higher by about 50 per cent on tube-

well holdings. In this calculation it is assumed that yield per acre remained the same. Actually, yield per acre on tubewell holdings was higher than that on non-tubewell holdings. Output per man, therefore, was more than 50 per cent higher on tubewell holdings compared to non-tubewell holdings.

In the Gujranwala and Sialkot districts, the area operated per pair of bullocks was about 10.5 acres on non-tubewell holdings and about 13.4 acres on tubewell

TABLE XI

AVERAGE SIZE OF HOLDING, AREA OPERATED PER PAIR OF BULLOCKS AND PER MAN ON TUBEWELL HOLDINGS AND NON-TUBEWELL HOLDINGS IN DIFFERENT DISTRICTS OF THE FORMER PUNJAB

Characteristics of holdings	Multan and Montgomery districts		Gujranwala and Sialkot districts	
	With tubewells	Without tubewells	With tubewells	Without tubewells
(1)	(2)	(3)	(4)	(5)
1. Holdings studied (number)	42	32	42	47
2. Pairs of bullocks per holding (number)	4.2	2.2	3.1	2.7
3. Workers per holding (number)	7.0	4.0	6.4	6.0
4. Average area operated per holding[a] (acres)	54.9	28.1	42.0	28.3
5. Average area cropped[b] per holding (acres)	72.1	27.9	63.5	35.6
6. Average area operated per pair of bullocks Row (4) ÷ Row (2), (acres)	13.1	12.8	13.4	10.5
7. Average area cropped per pair of bullocks Row (5) ÷ Row (2), (acres)	17.2	12.7	20.5	13.2
8. Average area operated per man, Row(4) ÷ Row (3), (acres)	7.8	7.0	6.6	4.7
9. Average area cropped per man, Row (5) ÷ Row (3), (acres)	10.3	7.0	9.9	6.0

Notes: *Source:* Survey conducted by PIDE.

a) Area operated is the actual area of the holding.

b) Area cropped represents the acres of crops raised on the holdings. This may be more or less than the area operated, depending upon the intensity of cropping.

holdings. However, the area cropped on tubewell holdings was about 20.5 acres per pair of bullocks compared to only 13.2 acres in the case of non-tubewell farmers indicating a much higher efficiency of bullock use on tubewell holdings. Area cropped per man was 6.0 acres in non-tubewell holdings and 9.9 acres in the case of tubewell holdings showing 65 per cent higher output per man even if it is assumed that the yield per acre remained constant. Actually, yield per acre also increased resulting in a still higher output per manual worker.

Tubewells and Fertilizer Use

Table XII shows the fertilizer used by tubewell and non-tubewell farmers during 1963/64. The tubewell farmers used on the average about 0.9 bags[9] of fertilizer when calculated on the basis of total area cropped. Not all the crops, however, received the fertilizer. The crops to which fertilizer was actually applied received on the average about 1.8 bags per acre.

The non-tubewell farmers, on the other hand, applied 0.4 bags per acre cropped on the basis of the entire holding or 1.4 bags per acre for the area to which fertilizer was actually applied.

The dose of fertilizer for the crops to which fertilizer was actually applied was, thus, about 30 per cent higher in the case of tubewell farmers. On the basis of total area cropped the tubewell farmers used more than twice the fertilizer as compared to non-tubewell farmers.

The farmers who have installed tubewells are progressive farmers and were probably using a higher quantity of fertilizer even before the installation of tubewells. But the influence of tubewells in modernization of the whole of agriculture needs to be stressed. When a farmer saves or borrows some 6 to 12 thousand rupees and installs a tubewell his whole outlook on agriculture as a business changes. He wants to grow more valuable crops, to apply fertilizer, and to use other modern inputs to increase his income. We will surmise this hypothesis further in the following pages.

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9 Nitrogen was the main fertilizer used. A bag contained 112 pounds of ammonium sulphate or 87 pounds of ammonium nitrate or 51 pounds of urea. Each of these contained about 23 pounds of nitrogen.

TABLE XII

FERTILIZER USE BY TUBEWELL AND NON-TUBEWELL FARMERS

Districts	Tubewell farmers				Non-Tubewell farmers			
	Number of farmers	Average area cropped	Average area to which fertilizer applied	Fertilizer applied	Number of farmers	Average area cropped	Average area to which fertilizer applied	Fertilizer applied
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		(.....*acres*.....)		(*bags*[a])		(.....*acres*.....)		(*bags*[a])
Multan	26	87	49	87	31	25	11	19
Montgomery	19	44	20	34	12	37	10	11
Gujranwala	29	73	20	26	32	45	11	13
Sialkot	15	46	26	63	15	16	3	6
Gujrat	9	23	11	13	8	11	*nil*	*nil*
Jhang	14	70	62	124	18	21	11	17
Sargodha	6	95	12	21	2	97	3	4
Total/average	118	65	31	56	118	30	9	13
Bags of fertilizer applied on the total area cropped				0.9				0.4
Bags of fertilizer on the area to which fertilizer was actually applied				1.8				1.4

Note: *Source:* Survey conducted by PIDE.

a) Each bag contained 112 pound of ammonium sulphate or 87 pounds of ammonium nitrate or 51 pounds of urea. Each of these had about 23 pounds of nitrogen.

Cropping Patterns of Tubewell and Non-Tubewell Farmers

Table XIII shows the area under each crop as a percentage of the area of the total holding of the tubewell farmers and of the non-tubewell farmers. In the Multan and Montgomery districts, the non-tubewell farmers had an average cropping intensity[10] of about 99 per cent (Column (2)). In the same villages, the farmers who had installed tubewells had a cropping intensity of about 131 per cent (Column (3)). In other words, they had about 32 per

[10] Cropping intensity is defined as the percentage of the area of the holding cropped in either *kharif* or *rabi* season. For example, a farmer who grows crops on 45 per cent of his holding in *kharif*, and 60 per cent of the holding in *rabi*, has a cropping intensity of 105 per cent. If the land is completely sown to crops, both in *kharif* and *rabi*, there is 200 per cent intensity.

cent higher intensity of cropping compared to non-tubewell farmers. On their holdings the area under *kharif* crops was 67.6 per cent compared to 49.0 per cent for non-tubewell farmers. And their area under *rabi* crops was 63.5 per cent compared to 50.2 per cent for non-tubewell farmers. This reflects the fact that tubewell farmers have a larger area under *kharif* crops than under *rabi* crops, whereas the opposite is the case for non-tubewell farmers. The main difference was in the area under cotton, fruits and vegetables in the *kharif* season and wheat and fodder in the *rabi* season. On the other hand, their area under sugarcane, maize and gram was (proportionately) less than that of non-tubewell farmers.

In the Gujranwala district, the intensity of cropping was about 115 per cent in the case of non-tubewell farmers and about 146 per cent in the case of tube-

TABLE XIII

CROPPING PATTERNS FOLLOWED BY TUBEWELL FARMERS AND NON-TUBEWELL FARMERS IN THE MULTAN AND MONTGOMERY DISTRICTS AND GUJRANWALA DISTRICT

Crop	Multan and Montgomery districts		Gujranwala district	
	Non-tubewell farmers	Tubewell farmers	Non-tubewell farmers	Tubewell farmers
(1)	(2)	(3)	(4)	(5)
	Per cent of the area under each crop			
Cotton	27.5	38.2	2.7	1.8
Rice	0.2	0.7	36.0	62.2
Sugarcane	3.5	2.8	5.8	6.5
Maize	3.1	1.9	2.5	0.8
Kharif fodder	12.3	12.6	10.7	10.8
Fruits	1.6	7.9	0.7	2.7
Vegetables	0.2	2.5	0.9	1.1
Other *kharif* crops	0.6	1.0	1.1	1.1
Total *kharif*	49.0	67.6	60.4	87.0
Wheat	33.9	35.8	32.3	31.7
Oilseeds	0.7	1.1	2.1	1.2
Gram	1.5	1.2	3.5	2.2
Rabi fodders	11.9	14.1	14.1	18.9
Fruits	1.6	7.9	0.7	2.6
Vegetables	0.3	2.0	0.4	1.5
Other *rabi*	0·3	1.4	1.4	0.9
Total *rabi*	50.2	63.5	54.4	59.0
Grand total	99.2	131.1	114.8	146.0

Source: Survey conducted by PIDE.

well farmers. The main difference (27 per cent) was in the area under *kharif* crops and only a small difference (5 per cent) in the area under *rabi* crops. Almost the whole of the difference in the *kharif* season was in the area under rice, while in the *rabi* season the main difference was in the area under fodder.

Cropping Pattern Derived From Revenue Records

The cropping pattern determined in our survey is in line with the cropping patterns that may be calculated from the area under crops as reported by the Revenue Department and compiled by the West Pakistan Bureau of Statistics [23]. We have calculated the percentage of area under each crop from the records of Bureau of Statistics for *rabi* 1962/63 and *kharif* 1963 for the Multan, Montgomery and Gujranwala districts. The Bureau of Statistics classifies the area under each crop into irrigated and un-irrigated. The irrigated area is further classified as irrigated from *i*) canals, *ii*) wells, *iii*) tubewells, *iv*) canals *plus* wells, *v*) canals *plus* tubewells, and *vi*) other sources. We have taken their figures of total irrigated area and compared it with area irrigated from tubewells and canals *plus* tubewells.

Data for Multan and Montgomery districts are given in Table XIV whereas that for the Gujranwala district are given in Table XV. Columns (2) and (3) of these tables give the actual area under each crop as copied from the records of the Bureau of Statistics. Columns (4) and (5) show the percentage of composition of the crops taking the total cropped area to be 100 per cent. Three things come out clearly from these tables:

a) With the installation of tubewells, the proportion of area under *kharif* crops increased, whereas that under *rabi* crops decreased.

b) The proportion of area under cotton increased in the Multan and Montgomery districts, whereas the proportion of area under rice increased in the Gujranwala district.

c) The proportion of area under all other crops decreased except in the case of fruits and vegetables in the Multan and Montgomery districts.

Cropping patterns shown in Table XIV and XV for the total irrigated area are comparable to the non-tubewell farmers in our survey, as both have an intensity of cropping of about 100 per cent on the total area. The results for area irrigated from tubewells and canals *plus* tubewells are, however, not comparable with the cropping pattern of tubewell farmers in our survey because we recorded the area of the holdings and were, thus, able to calculate the intensity of cropping on the basis of area of the holdings studied. The records of the

TABLE XIV

TOTAL IRRIGATED CROPPED AREA, CROPS IRRIGATED FROM TUBEWELLS AND CANALS PLUS TUBEWELLS AND THE COMPOSITION OF CROPS IN THE MULTAN AND MONTGOMERY DISTRICT

Crops	Actual area under crops		Composition of crops	
	Total irrigated area	Area irrigated from tubewells and canal plus tubewells	Total irrigated area	Area irrigated from tubewells and canals plus tubewells
(1)	(2)	(3)	(4)	(5)
	(..... *'00' acres*.....)		(.....*per cent*.....)	
Kharif 1963				
Cotton	11553	1504	23.2	33.6
Rice	1505	88	3.0	2.0
Sugarcane	1497	115	3.0	2.6
Maize	781	66	1.6	1.5
Kharif fodder	5210	367	10.5	8.2
Fruits and vegetables	357	71	0.7	1.6
Other *kharif* crops	1931	97	3.9	2.2
Total *kharif*	22834	2308	45.9	51.7
Rabi 1962/63				
Wheat	17136	1524	34.5	34.1
Oilseeds	1184	103	2.4	2.3
Gram	1906	65	3.8	1.5
Rabi fodder	5565	386	11.2	8.6
Fruits and vegetable	616	68	1.3	1.5
Other *rabi* crops	455	13	0.9	0.3
Total *rabi*	26862	2159	54.1	48.3
Grand total	49696	4467	100.0	100.0

Sources: *i*) Cols. (2) and (3) from Bureau of Statistics [23].
ii) Cols. (4) and (5) calculated from Cols. (2) and (3).

TABLE XV

TOTAL IRRIGATED CROPPED AREA, CROPS IRRIGATED FROM TUBEWELLS AND CANALS PLUS TUBEWELLS AND THE COMPOSITION OF CROPS IN THE GUJRANWALA DISTRICT

Crops	Actual area under crops		Composition of crops	
	Total irrigated area	Area irrigated from tubewells and canals plus tubewells	Total irrigated area	Area irrigated from tubewells and canals plus tubewells
(1)	(2)	(3)	(4)	(5)
	(.....'00' acres.....)		(..... per cent.....)	
Kharif 1963				
Cotton	335	52	3.4	2.0
Rice	3758	1361	38.1	51.6
Sugarcane	370	73	3.7	2.8
Maize	102	80	1.0	0.5
Kharif fodder	310	52	3.1	2.0
Fruits and vegetables	44	7	0.4	0.2
Other *kharif* crops	467	15	5.0	3.1
Total *kharif*	5386	1640	54.7	62.2
Rabi 1962/63				
Wheat	2599	566	26.4	21.4
Oilseeds	201	29	2.0	1.1
Gram	167	41	1.7	1.6
Rabi fodder	1329	323	13.4	12.2
Fruits and vegetables	67	12	0.7	0.4
Other *rabi* crops	106	28	1.1	1.1
Total *rabi*	4469	999	45.3	37.8
Grand total	9855	2639	100.0	100.0

Sources : i) Columns (2) and (3) from Bureau of Statistics [23].
ii) Columns (4) and (5) calculated from Columns (2) and (3).

Bureau of Statistics do not give the total area of holding and, therefore, we cannot calculate the total intensity of cropping. We have assumed in this paper that tubewell farmers in the whole district had the same intensity of cropping as the tubewell farmers in our survey and have recalculated the area under each crop on this basis. The results are shown in Table XVI for the Multan and Montgomery districts and in Table XVII for the Gujranwala district. The results of our survey are also repeated in these tables for the sake of comparison.

The following conclusions emerge from an examination of these tables.

i) For the total area irrigated, the proportion of *kharif* crops was less than that of *rabi* crops for the whole of the Multan and Montgomery districts (Table XVI, Column (3)), as well for the non-tubewell farmers selected in our survey (Table XVI, Column (2)).

ii) For the area irrigated from tubewells and canals *plus* tubewells, the percentage of area under *kharif* crops was higher than that under *rabi* crops for the whole of these two districts as well for tubewell farmers selected in our survey.

iii) For the Gujranwala district, the proportion of area under *kharif* crops was higher than that under *rabi* crops for the whole district (Table XVII, Column (3)) as well as for non-tubewell farmers in our survey (Table XVII, Column (2)). For the area irrigated from tubewells and canals *plus* tubewells, however, the area under *kharif* crops was much higher than that under *rabi* crops. In these areas the intensity of cropping in the *kharif* season reached as high as 87 to 90 per cent compared with about 55 to 60 per cent in the *rabi* season.

iv) In the Multan and Montgomery districts the area under cotton was about 25 per cent for total irrigated area and for non-tubewell farmers in our survey. For area irrigated from tubewells and canals *plus* tubewells, the area under cotton was about 40 per cent.

v) In the Gujranwala district, the area under rice was about 40 per cent for the total irrigated area and for non-tubewell farmers in our survey and about 60 to 75 per cent in areas where tubewells were installed.

vi) In the Multan and Montgomery districts the area under fruits and vegetables, wheat, and *rabi* fodders was much higher where tubewells were installed. In the Gujranwala district the area under *rabi* fodders was considerably higher but the area under wheat was only slightly higher where tubewells were installed compared to the total irrigated area.

vii) The area under other crops such as sugarcane, maize, other *kharif* crops, gram, and other *rabi* crops was either the same or slightly less in tubewell irrigated areas than in the total irrigated area.

TABLE XVI

CROPPING PATTERN OF SELECTED FARMERS (PIDE SURVEY) AND WHOLE DISTRICT (BUREAU OF STATISTIC RECORDS) FOR TOTAL IRRIGATED AREA AND AREA IRRIGATED FROM TUBEWELLS AND CANAL PLUS TUBEWELLS IN THE MULTAN AND MONTGOMERY DISTRICTS

Crop	Total irrigated area		Area irrigated from tubewells and canals plus tubewells	
	Selected farmers (PIDE survey)	Montgomery and Multan districts (Bureau of Statistics)	Selected farmers (PIDE survey)	Montgomery and Multan districts (Bureau of Statistics)
(1)	(2)	(3)	(4)	(5)
	(*per cent*)			
Cotton	27.5	23.0	38.2	44.0
Rice	0.2	3.0	0.7	2.6
Sugarcane	3.5	3.0	2.8	3.4
Maize	3.1	1.6	1.9	2.0
Kharif fodder	12.3	10.4	12.6	10.8
Fruits	1.6	0.5	7.9	1.6
Vegetable	0.2	0.2	2.5	0.5
Other *kharif*	0.6	3.8	1.0	2.9
Total *kharif*	49.0	45.5	67.6	67.8
Wheat	33.9	34.2	35.8	44.8
Oilseeds	0.7	2.4	1.1	3.8
Gram	1.5	3.8	1.2	2.0
Rabi fodder	11.9	11.1	14.1	11.3
Fruits	1.6	0.5	7.9	0.8
Vegetables	0.3	0.8	2.0	1.2
Other *rabi*	0.3	0.9	1.4	—
Total *rabi*	50.2	53.7	63.5	63.3
Grand total	99.2	99.2	131.1	131.1

Sources: i) Columns (2) and (4) from Table XIII, Columns (2) and (3).
ii) Column (3) is calculated from Table XIV, Column (4) multiplied by 99.2 per cent.
iii) Column (5) is calculated from Table XIV, Column (5) multiplied by 131.1 per cent.

Comparison With Harza Intensity of Cropping

In the above analysis it was assumed that tubewell farmers in the whole of Multan, Montgomery and Gujranwala districts had the same intensity of cropping as that found for the tubewell farmers in our survey in these districts. It may be mentioned that similar results would be obtained if any other intensity of cropping is assumed for the areas where tubewells are installed. For example, Harza Engineering Company International propose an intensity of cropping of 60 per cent in *kharif* and 80 per cent in *rabi* or a total of 140 per cent in areas where tubewells are to be installed [9, p. 30][11].

TABLE XVIII

PERCENTAGE AREA UNDER MAJOR CROPS ASSUMING INTENSITY OF CROPPING TO BE 140 PER CENT BASED ON RECORDS OF BUREAU OF STATISTICS FOR AREAS IRRIGATED FROM TUBEWELLS AND CANALS PLUS TUBEWELLS

Crop (1)	Multan and Montgomery district (2)	Gujranwala district (3)
	(.....*per cent*.....)	
Cotton	47.0	2.8
Rice	2.8	72.2
Other *kharif* crops	21.6	12.1
Total *kharif*	72.4	87.1
Wheat	47.7	30.0
Rabi fodder	12.0	17.1
Other *rabi* crops	7.9	5.8
Total *rabi*	67.6	52.9
Grand total	140.0	140.0

Sources: i) Column (2) calculated from Table XIV, Column (5).
ii) Column (3) calculated from Table XV, Column (5).

[11] Actually, Harza Engineering Company International gives the intensity of cropping as 150 per cent, but they count the 10 per cent area under sugarcane twice, once in the *kharif* season and once in the *rabi* season. In line with the practice in the Revenue and Agriculture Departments, we count the area under sugarcane only once. Therefore, Harza's intensity of cropping comparable to the figures in our tables is 140 per cent.

For an intensity of 140 per cent, the area under each crop can be calculated from the records of the Bureau of Statistics for areas served by tubewells and canals plus tubewells in the Multan, Montgomery and Gujranwala districts. This has been done in Table XVIII. In the preparation of this table we have multiplied the area shown against each crop in Column (5) of Table XIV and Column (5) of Table XV with 140 per cent. The results show that in the Multan and Montgomery districts, for 140 per cent intensity of cropping, the area under cotton will increase to 47 per cent of the area of the holdings and the total *kharif* acreage will increase to over 72 per cent. The *rabi* acreage will, however, be limited to below 68 per cent. In the Gujranwala district, the area under rice will increase to over 72 per cent and that under all *kharif* crops to about 87 per cent. The area under *rabi* crops will be limited to about 53 per cent. These results are very similar to the results found in our survey but are quite inconsistent with Harza's proposal of 60 per cent intensity in *kharif* and 80 per cent intensity in *rabi*.

Comparison With Intensity of Cropping in SCARP 1

Our results in the previous sections are based on a cross-section study of tubewell and non-tubewell farmers. In the Salinity Control and Reclamation Project Number One (SCARP 1) results are available for 12 scheme areas covering 1.14 million acres for the years 1962/63 and 1963/64. These results are presented in Table XIX. Columns (1) to (5) of this table show the actual area irrigated in *rabi* and *kharif* during the last two years and are taken from Appendix VI of *Salinity Control and Reclamation Project One (SCARP 1) Progress Report* for the period October 1963 to September 1964 [25]. Column (6) of Table XIX shows the percentage increase in the irrigated area in *rabi* 1963/64 over *rabi* 1962/63, whereas Column (7) shows the percentage increase in *kharif* 1964 over *kharif* 1963. In 6 schemes out of 12, the area under *rabi* crops in 1963/64 increased, whereas in the remaining 6 schemes it actually decreased. On the whole, there was an increase of about 1 per cent only in *rabi* 1963/64 compared to the previous year. On the other hand, there was an increase of about 18 per cent in the area under *kharif* crops in 1964 compared to 1963.

The very small increase in the *rabi* acreage was in spite of the fact that the farmers had access to all the water that they needed, but they did not use the water. In the *kharif* season they did and substantially increased the area cropped. This lends support to the results of our study.

It may be pointed out that when the operation of tubewells in SCARP 1 area started in 1961/62, there was at first a large increase in the area under *rabi* crops during the first two years. This was because parts of the SCARP 1 area were not getting much canal water in the *rabi* season. This is borne out by the

fact that total intensity of cropping in the *rabi* season in 6 schemes areas in SCARP 1 for which records are available for preoperation period was 34.6 per cent[12]. Comparable intensity in the lower Chenab Canal as a whole was 55.5 per cent [27, p. 108]. Thus, when the farmers got tubewell water they increased

TABLE XIX

COMPARATIVE IRRIGATION FIGURES OF RABI AND KHARIF 1962/63 AND 1963/64 IN SALINITY CONTROL AND RECLAMATION PROJECT NUMBER ONE (SCARP 1)

Scheme	1962/63		1963/64		Percentage increase or decrease in 1963/64 over 1962/63	
	Rabi 1962/63	*Kharif* 1963	*Rabi* 1963/64	*Kharif* 1964	*Rabi*	*Kharif*
(1)	(2)	(3)	(4)	(5)	Col. (4) ÷ Col. (2) (6)	Col. (5) ÷ Col. (3) (7)
	(.....*hundred acres*.....)				(.....*Per cent*.....)	
1. Harse Sheikh	166	111	155	134	—7	21
2. Beranwala	508	332	518	414	2	26
3. Hafizabad	682	616	693	774	2	26
4. Khangah Dogran	521	533	586	564	13	6
5. Sangla Hill	665	581	675	644	2	11
6. Shahkot	1326	999	1318	1186	—1	19
7. Shadman	339	324	297	363	—12	12
8. Zafarwal	1326	1022	1336	1254	1	23
Sub-total (1) to (8)	5533	4518	5578	5333	1	18
9. Chuharkana	57	48	51	49	—11	2
10. Chichakimallian	23	38	11	35	—52	—8
11. Pindi Bhatian	55	24	34	28	—36	17
12. Jaranwala	554	454	623	557	13	23
Sub-total (9) to (12)	687	564	719	669	5	19
Total (1) to (12)	6220	5082	6297	6002	1	18
Per cent of culturable area of 1,411 thousand acres	54.5	44.5	55.2	52.6		

Sources: i) Columns (2) to (5) from [25].
ii) Columns (6) and (7) calculated from Column (2) to (5).

[12] These 6 schemes were Harse Shaikh, Beranwala, Hafizabad, Khangah Dogran, Sangla Hill and Shadman areas. Total culturable area of these schemes was 581 thousand acres. Area under *rabi* crops before operation of tubewells was 201 thousand acres (34.6 per cent) and that under *kharif* crops was 219 thousand acres (37.6 per cent). Similar figures for other 6 schemes of SCARP 1 are not available.

their *rabi* intensity in the first two years till it reached 54.5 per cent in 1962/63 (Table XIX, last row). After that there was very little increase in the area under *rabi* crops. However, the area under *kharif* crops increased from 44.5 per cent of the culturable area in 1963 to 52.6 per cent in 1964. Results of our survey indicate that the area under *kharif* crops may be expected to increase substantially during the next few years whereas area under *rabi* crops may not increase to the same extent.

Income and Expenditure of Tubewell and Non-Tubewell Farmers and Net Income Due to Tubewell

According to the Department of Agriculture, each private tubewell will serve about 150 acres of canal-irrigated area [21, p. 65]. The present intensity of cropping, according to the Department of Agriculture, is 100 per cent in the former Punjab and Bahawalpur and about 60 per cent in the former Sind and N-W.F.P. With the installation of tubewells these intensities will increase to about 150 per cent in the former Punjab and Bahawalpur and to about 120 per cent in former Sind and N-W.F.P. [21, p. 60]. According to our estimates each tubewell will serve only about 100 acres and not 150 acres in the canal-irrigated areas of the former Punjab and Bahawalpur. Our estimate is prepared as follows:

The present canal water supply provides about 1.8 acrefeet per acre at the heads of the watercourses [8, p. II-5]. The water requirements of crops for a 140 per cent intensity of cropping are estimated to vary from 2.98 acrefeet per acre to about 4.72 acrefeet per acre in different canal systems in the former Punjab [8, p. II-9]. The overall average for the Punjab canals comes to about 4.0 acrefeet per acre. The deficiency in canal water supply is, thus, about 2.2 acrefeet per acre (4.0—1.8). As one private tubewell pumps about 220 acrefeet of water in a year, it will cover about 100 acres of canal-irrigated area.

On the basis of the present cropping patterns followed by the farmers in the whole irrigated area in Multan and Montgomery districts (Table XVI), the present yields of crops as reported by the Department of Agriculture for the irrigated areas in these two districts, and the prevailing harvest prices as reported by the Director of Land Records, we have prepared an estimate of the gross income for a 100-acre non-tubewell farm in these two districts. Similarly, on the basis of cropping patterns followed by the tubewell farmers in these two districts, the higher yields expected from the use of additional water on existing crops and increase in crop acreage expected with the installation of tubewells (Table XVI), an estimate of the gross income for a tubewell farmer operating a 100- acre farm has been prepared. These estimates are shown in Table XX.

While we were able to get reliable information on the area under each crop on tubewell holdings and on non-tubewell holdings, we could not do so for the yield of crops. We did not have the time or the resources to have the crops harvested in our presence and did not make an effort to get accurate information from the farmers on the yields obtained by them. Therefore, for non-tubewell farmers, we have used the average yields of irrigated crops as reported by the Department of Agriculture for the Multan and Montgomery districts. For tubewell farmers, we have prepared an estimate of the yield per acre on the assumption that each crop will get about 30 to 40 per cent additional water from tubewells and that this, with a small amount of additional fertilizer will increase the yield by about 20 to 30 per cent. Increases in yield will be different for different crops. In our survey, the tubewell farmers used, on the average, 0.9 bags of fertilizer per acre for the entire area cropped, compared with 0.4 bags per acre used by non-tubewell farmers. With the use of the 30 to 40 per cent additional water and 0.5 bags per acre of additional fertilizer, we have assumed the following additional acre yields on tubewell holdings in the non-saline groundwater areas of the Multan and Montgomery districts:

Crop	Increase in yield	
	(maunds per acre)	Per cent
Cotton	3.0	30
Rice	2.5	25
Sugarcane (*Gur*)	8.0	21
Maize	3.0	22
Wheat	3.0	22
Fruits and vegetables	15.0	21
Oilseeds	1.3	20
Gram	1.6	20

TABLE XX

INCREASE IN THE INCOME BY INSTALLATION OF A TUBEWELL ON A 100-ACRE FARM IN COTTON GROWING AREAS IN THE PUNJAB

Crop	Without tubewell					With tubewell			
	Area	Yield per acre	Production	Price per maund	Value	Area	Yield per acre	Production	Value
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(acre)	*(maunds)*			*(rupees)*	*(acre)*	*(maunds)*		*(rupees)*
Cotton	25	10.0	250	31.0	7,750	43	13.0	559	17,329
Rice	2	10.0	20	20.0	400	3	12.5	38	760
Sugarcane	4	38.0	152	16.5	2,508	4	46.0	184	3,036
Maize	2	13.5	27	13.5	365	2	16.5	33	446
Kharif fodder	11				1,760[a]	11			2,200[b]
Fruits and vegetables	1	70.0	70	11.0	770	3	85.0	255	2,805
Other *kharif* crops	2	6.0	12	12.0	144	2	7.5	15	180
Total kharif	**47**				**13,697**	**68**			**26,754**
Wheat	34	13.6	462	14.0	6,468	43	16.6	714	9,996
Oilseeds	2	6.5	13	23.0	299	3	7.8	23	529
Gram	4	8.0	32	14.4	461	2	9.6	19	274
Rabi fodder	11				2,200[a]	12			3,000[b]
Fruits and vegetables	1	70.0	70	11.0	770	3	85.0	255	2,805
Other *rabi* crops	1	6.0	6	18.0	108	1	8.0	8	144
Total rabi	**53**				**10,306**	**64**			**16,748**
Grand Total	**100**				**24,003**	**132**			**43,502**

Share of the landlord at 50 per cent of gross produce	12,000	at 60 per cent of gross produce	26,100
Less expenses of the landlord (one-half of land revenue, water rate, *etc.*)	2,000		2,600
Net share of landlord before deducting annual operating cost of tubewell	10,000		23,500
Annual operating cost of the tubewell	*nil*		6.160
Net income after deducting annual cost of tubewell	10,000		17,340
Income due to tubewell	*nil*		7,340

Source: See text.

Notes: *a*) No data on price of fodder in the rural areas are available. Harza use a price of one rupee per maund [10, p.48]. In the absence of market for fodder in the rural areas, we are using a lower price of 160 rupees per acre for *kharif* fodder (about 0.64 rupees per maund) and 200 rupees per acre for *rabi* fodder (about 0.50 rupees per maund).

b) Yield and value assumed to be 25 per cent higher on tubewell holdings.

With the availability of additional water supply, yields are now limited by the amount of fertilizer available. If more fertilizer was available, much higher yields would be possible in the non-saline groundwater areas.

Present yields of crops are shown in Column (3) of Table XX, and our estimates of the per acre yields on tubewell holdings are given in Column (8) of Table XX. On the basis of these figures, the gross income for the non-tubewell farmer comes to 24,000 rupees from 100 acres or 240 rupees per acre. The gross income from a 100-acre tubewell holding raising 132 acres of crop comes to 43,500 rupees. This is equal to about 330 rupees per acre cropped.

In the absence of adequate data on cost of production of crops in recent years, we have used in this study, the difference between the rent or share of crop produce received by a tubewell farmer compared to a non-tubewell farmer in calculating the net income due to tubewell. As stated on page 19, the general practice in the canal-irrigated areas is to share the produce between the landlord and the tenant on a fifty-fifty basis. When a landlord installs a tubewell in a canal-irrigated area, he gets 60 per cent of the produce and the tenant gets 40 per cent.

In our calculations on the above basis, the share of the landlord who does not have a tubewell comes to 12,000 rupees for a 100-acre farm in the Multan and Montgomery districts. Out of this, the landlord pays one-half of the land revenue and water rate and one-half of the cost of fertilizer, improved seed and payment to village artisans. These changes come to about 20 rupees per acre or about 2,000 rupees for the total area[13]. The net share of the landlord, thus, comes to 10,000 rupees for the farm or 100 rupees per acre. This is quite consistant with the cash rent prevailing in these two districts which is about 100 rupees per acre in villages not too close to the towns.

For a farmer who has installed a tubewell, the share of the produce comes to 26,100 rupees which is 60 per cent of the gross produce. After deducting charges for land revenue, water rates, improved seed, fertilizer, *etc.*, the net share of the landlord comes to 23,500 rupees or 178 rupees per acre cropped. Out of this he has to bear the cost of operation of the tubewell. The annual cost of operation of a diesel tubewell including interest and depreciation in these districts

[13]Gill estimated the gross share of a landlord in the Lyallpur district in 1953/54, as 118.38 rupees per acre, share of expenditure of the landlord on land revenue, improved seed, *etc.*, as 20.86 rupees per acre and net income of the landlord as 97.52 rupees per acre [5, p.6]. For peasant proprietors the gross income, expenditure and net income per acre in the Lyallpur district in 1953/54 were estimated as 230.68 rupees, 97.29 rupees and 133.39 rupees respectively in the same study [5, p. 25]. Expenditure in this case, however, did not include value of family labour, interest and depreciation on bullocks and implements and value of farm-yard manure. Gill imputed a sum of 48.75 rupees per acre as the value of these items. When these are deducted the net income would be reduced to 84.64 rupees per acre.

TABLE XXI

INCREASE IN THE INCOME BY INSTALLATION OF A TUBEWELL ON A 100-ACRE FARM IN RICE-GROWING AREAS IN THE PUNJAB

Crop	Without tubewell					With tubewell			
	Area	Yield per acre	Production	Price per maund	Value	Area	Yield per acre	Production	Value
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(*acre*)	(*maunds*)		(*rupees*)		(*acre*)	(*maunds*)		(*rupees*)
Cotton	4	8.0	32	30.0	960	3	9.3	28	840
Rice	42	11.0	462	25.0	11,550	72	13.8	944	24,850
Sugarcane	4	30.0	120	16.5	1,980	4	36.0	144	2,376
Maize	1	11.0	11	13.5	150	1	13.0	13	175
Kharif fodder	5				600[a]	5			720[b]
Fruits and vegetables	1	60.0	60	11.0	660	2	70.0	140	1,540
Other *kharif* crops	5	6.0	30	12.0	360	3	7.5	22	264
Total kharif	**62**				**16,260**	**90**			**30,765**
Wheat	31	10.5	326	14.0	4,564	32	12.5	400	5,600
Oilseeds	2	5.0	10	23.0	230	2	6.0	12	276
Gram	2	7.0	14	14.4	202	2	8.0	16	230
Rabi fodder	15				3,000[a]	17			4,080
Fruits and vegetables	1	60.0	60	10.0	660	2	70.0	140	1,540
Other *rabi* crops	1	6.0	6	18.0	108	1	7.0	7	126
Total rabi	**52**				**8,764**	**56**			**11,852**
Grand Total	**114**				**25,024**	**146**			**42,617**
Share of the landlord at 50 per cent of gross produce					12,500	at 60 per cent of gross produce			25,570
Less expenses of landlord on land revenue, water rate, *etc.*					2,300				2,920
Net share of landlord before deducting annual operating cost of tubewell					10,200				22,650
Annual operating cost of a diesel tubewell					*nil*				4,740
Net income after deducting annual cost of tubewell					10,200				17,910
Income due to tubewell					*nil*				7,710

Source: See text.

Notes: a) *See* note *a)* under Table XX. In the rice-growing areas demand for fodder in the villages is much less than that in cotton-growing areas in the *kharif* season. We are, therefore, using a price of 120 rupees per acre for *kharif* fodder. For *rabi* fodder the price assumed is the same as that in cotton-growing area, namely, 200 rupees per acre.

b) Yield and value assumed to be 20 per cent higher on tubewell holdings.

comes to 6,160 rupees. Deducting this from the share of the landlord, the net share of the tubewell landlord comes to 17,340 rupees compared with 10,000 rupees for the non-tubewell landlord. The net income due to tubewell is, thus, 7,340 rupees which means that the landlord recovers more than the full cost of the diesel tubewell (12,000 rupees) in 2 years.

The cost of installation of an electric tubewell is 8,800 rupees (Table V) and the cost of operation of the same is 3,900 rupees for a year (Table VII). The net income of farmer having an electric tubewell, thus, comes to 19,600 (*i.e.*, 23,500—3,900) rupees and income due to tubewell as 9,600 rupees. This means that a 100-acre farmer installing an electric tubewell recovers his full cost within one year.

Similar estimates for gross and net income for a 100-acre farm in the Gujranwala district are shown in Table XXI. The net share of produce of a non-tubewell landlord growing 114 acres of crops on a 100-acre farm comes to 10,200 rupees or 90 rupees per acre cropped. An increase of 25 per cent in the yield of rice and 10 to 20 per cent in the yield of other crops has been assumed on tubewell holdings. On this basis the share of tubewell farmer growing 146 acres of crops on a 100-acre farm comes to 22,650 rupees or 155 rupees per acre from a similar area. After deducting the annual operating cost of 4,740 rupees for the diesel tubewell, the net income of the landlord comes to 17,910 rupees and income due to tubewell 7,710 rupees. This means that the cost of installation of 8,500 rupees for a diesel tubewell in the Gujranwala district (Table V) is realized in just over one year. The cost of an electric tubewell is realized in less than one year.

Income due to Tubewells from Different Sizes of Holding

In the above calculations the size of the holding was assumed to be 100 acres. Actually, farmers having all sizes of holding from below 25 acres to above 100 acres are installing tubewells (Table IX). We have, therefore, prepared an estimate of the gross income and net income for a 50-acre and a 25-acre tubewell holding in the Multan and Montgomery districts and in the Gujranwala district. This is given in Table XXII. In preparing this table it is assumed that 50 per cent of the water on a 50-acre holding and 75 per cent on a 25-acre holding is sold to neighbouring cultivators.

For a 50-acre tubewell holding, the net income due to tubewells varies between 4,100 and 4,400 rupees for a diesel tubewell. For an electric tubewell it comes to about 5,700 rupees (Row 8, Table XXII). The diesel tubewell owner, thus, recovers his cost in 3 years in the Multan and Montgomery districts and in 2 years in the Gujranwala district. The cost of the electric tubewell is recovered in less than 2 years in Multan and Montgomery districts and in less than one year in the Gujranwala district.

TABLE XXII

GROSS AND NET INCOME AND INCOME DUE TO TUBEWELL ON A 50-ACRE AND 25-ACRE HOLDING IN THE MULTAN, MONTGOMERY AND GUJRANWALA DISTRICTS

Holding	Multan and Montgomery districts			Gujranwala district		
	Without tubewell	With diesel tubewell	With electric tubewell	Without tubewell	With diesel tubewell	With electric tubewell
(1)	(2)	(3)	(4)	(5)	(6)	(7)
50-Acre Holding						
(1) Area cropped	50	66	66	57	73	73
(2) Net share of landlord per acre cropped	100	178	178	90	155	155
(3) Total share of landlord	5,000	11,750	11,750	5,100	11,320	11,320
(4) Income from sale of water[a]	*nil*	3,450	2,870	*nil*	2,870	2,300
(5) Total income from farming and sale of tubewell water	5,000	15,250	14,620	5,100	14,190	13,620
(6) Annual operating cost of tubewell[b]	*nil*	6,160	3,900	*nil*	4,740	2,740
(7) Net income after deducting operating cost	5,000	9,090	10,720	5,100	9,450	10,880
(8) Net income due to tubewell	*nil*	4,090	5,720	*nil*	4,350	5,780
25-Acre Holding						
(9) Area cropped	25	35	35	29	39	39
(10) Net share of the landlord per acre cropped	100	178	178	90	155	155
(11) Total share of landlord	2,500	6,230	6,230	2,600	6,050	6,050
(12) Income from sale of water[c]	*nil*	5,190	4,330	*nil*	4,330	3,460
(13) Total income from farming and sale of water	2,500	11,420	10,560	2,600	10,380	9,510
(14) Annual operating cost[b]	*nil*	6,160	3,900	*nil*	4,740	2,740
(15) Net income	2,500	5,260	6,660	2,600	5,640	6,770
(16) Net income due to tubewell	*nil*	2,760	4,160	*nil*	3,040	4,170

Source: See text.

Notes: a) Sale of 1,150 hours of water at 3.0 rupees per hour from diesel tubewells and 2.5 rupees per hour from electric tubewells in the Multan and Montgomery districts and at 2.5 rupees and 2.0 rupees per hour from diesel and electric tubewells respectively in the Gujranwala district.

b) From Table VII.

c) Sale of 1,730 hours of water at rates shown in note *a)* above.

For a 25-acre farmer, the net income due to tubewell varies between 2,800 and 3,000 rupees for diesel tubewell. For electric tubewell it comes to about 4,200 rupees (Row 16, Table XXII). For such small holdings the Multan and Montgomery farmers recover their cost in about 4 years for diesel tubewells and about 2 years for electric tubewells. In the Gujranwala district, the farmers recover their cost in less than 3 years for diesel tubewells and in less than 2 years for electric tubewells.

Very probably the smaller farmers having 25 acres or less will install tubewells of lower capacity. Although the cost of pumping per acrefoot of water will be higher from these tubewells, their capital cost for installation as well as total operating cost during the year would be lower. Therefore, they may recover their capital cost in less time than indicated in these calculations. However, we did not study enough of these smaller tubewells to give quantitative estimates.

It may be pointed out that the capital recovery capability estimated in this section is for the tubewells in the non-saline groundwater areas of the Multan, Montgomery and Gujranwala districts. We did not select any tubewells in the saline groundwater areas. The capital recovery capability of tubewells in the saline groundwater areas is likely to be very low and needs careful investigation.

V. CONCLUDING REMARKS

The evidence presented in this paper leads to five important inferences:

1) Provision of electricity to the rural areas of West Pakistan has been one of main causes of the rapid increase in tubewell installation in recent years. This appears to be due to the fact that cost of installation of an electric tubewell is about 3,000 rupees less than that of a diesel tubewell. Furthermore, the annual cost of pumping water from electric tubewells is about 2,000 rupees less than that from diesel tubewell. A very rapid development in tubewell installation may, therefore, be expected if electricity is made available to non-saline groundwater areas which cover some 12 million acres in the former Punjab and Bahawalpur.

2) Private tubewell drillers have rapidly moved wherever demand for tubewell drilling was created consequent upon the provision of electricity. Therefore, if electricity is extended to all the 12 million acres of non-saline groundwater areas during the Third Plan period, private drillers are likely to rapidly expand their drilling capacity and meet the full demand of the farmers for tubewell installation.

3) Additional water pumped from tubewells enables the farmers to get extremely high returns in non-saline groundwater areas. It enables them to

i) increase the depth of irrigation for existing crops,

ii) increase the intensity of cropping by eliminating fallowing and by double cropping,

iii) grow more valuable crops like cotton, rice, fruits and vegetables,

iv) increase the use of fertilizer,

v) increase the efficiency of bullock use, and

vi) increase the output per manual worker.

All these increases enable the farmers to realize the full cost of tubewell installation in a period of two to three years for diesel tubewells and in one to two years for electric tubewells.

4) One of the major conclusions of this study has been that the area under *kharif* crops has increased much more rapidly than the area under *rabi* crops wherever adequate water supply has become available with the installation of tubewells. The largest increase has taken place in the area under cotton and rice. Both of these are valuable foreign exchange earning crops. Government can assist this process further by making more water available in the *kharif* season by increasing the capacity of canals.

The water discharge of West Pakistan rivers generally begins to increase in April, culminating in high peaks in July and August after which the flow abruptly decreases reaching a low, but fairly constant, level from October to March. About 84 per cent of the annual river flow occurs during the six summer (*kharif*) months and only 16 per cent during the six winter (*rabi*) months. Nearly 44 per cent of the flow occurs during July and August [27, p. 85]. The river system of Pakistan is, thus, suited to a high *kharif* intensity and a low *rabi* intensity. The British engineers who designed the West Pakistan canal system, fixed the capacity of most canals to provide for a cropping intensity of about 25 to 30 per cent in *kharif* and 50 to 55 per cent in *rabi*. In this way most canals could be fed more or less evenly throughout the year. In order to make use of the extra summer river water supply, additional non-perennial canals were designed to convey water to some areas during the *kharif* season only. The present position is that the winter supply of the rivers is fully utilized in the perennial canals, but during summer, specially from mid-June to mid-September, the rivers carry surplus water over and above the capacity of both perennial and non-perennial canals. This water could not be used in the past because there was not enough water in the rivers during the sowing and maturing period of

additional *kharif* crops that could be given water from mid-June to mid-September. Now the tubewells can provide additional water during the sowing and maturing period of *kharif* crops. However, ultimately the pumping from tubewells will have to be limited to the amount of recharge from the surface. Therefore, if the more valuable foreign exchange earning *kharif* crops are to be grown on a larger and larger scale, the capacity of the canals will have to be increased to divert additional river water during the *kharif* season.

5) From our visit to the villages where tubewells are being installed we have formed an impression that tubewells already installed are having a powerful influence on the saving habits of neighbouring cultivators and most of them are planning to have their own tubewells. So far the only outlet which the farmers had for their savings was purchase of land or construction of houses. The price of land being extremely high, return on investment were low and there was less incentive for saving. Now for the first time the farmers have got a low cost investment opportunity which yields extremely high returns. Therefore, they are saving to have their own tubewells in increasing numbers. The less enterprizing farmers of the past are now becoming more enterprizing and a revolution in agriculture is taking place. The government can assist this revolution in agricultural development in West Pakistan by providing electric transmission lines to all the non-saline groundwater areas, making tubewell materials particularly lining pipes, and engines/motors available on credit and providing other ancillary facilities to the farmers.

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Appendix A:—PRIVATE TUBEWELLS

TABLE A-1

TOTAL NUMBER OF PRIVATE TUBEWELLS IN EACH DISTRICT ACCORDING TO REVENUE DEPARTMENT 1953/54 TO 1963/64

Total	1953/54	1954/55	1955/56	1956/57	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64
1. D.I. Khan	*n.a.*	*n.a.*	10	10	52	105	124	131	131	149	149
2. Bannu	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
3. Mardan	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
4. Hazara	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
5. Peshawar	*n.a.*	*n.a.*	6	6	6	6	6	6	7	7	8
6. Kohat	*n.a.*	*n.a.*	2	2	2	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
7. Campbellpur	11	2	1	1	1	1	1	1	1	*nil*	*nil*
8. Rawalpindi	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
9. Jhelum	5	3	3	3	3	3	5	3	4	7	8
10. Gujrat	8	9	22	69	102	102	112	159	177	198	250
11. Mianwali	17	19	19	19	19	19	20	28	28	37	72
12. Sargodha	57	77	77	77	105	106	106	85	89	157	156
13. Lyallpur	209	210	239	426	389	387	347	474	492	732	599
14. Jhang	105	135	180	178	192	256	403	648	671	738	770
15. Lahore	177	177	177	188	188	201	205	220	301	305	427
16. Gujranwala	96	119	130	143	183	550	1027	1437	1441	2222	2524
17. Sheikhupura	38	38	43	56	56	85	85	174	221	323	455
18. Sialkot	16	49	96	98	129	573	625	853	1215	1413	1422
19. D.G. Khan	13	39	32	37	45	51	58	82	86	93	93
20. Muzaffar Garh	7	9	9	10	47	47	48	50	60	60	118
21. Multan	50	50	87	224	221	261	289	1,313	2,159	2,859	3,415
22. Montgomery	181	280	339	339	392	493	700	1,027	2,194	2,494	2,598
23. Bahawalpur	*n.a.*	*n.a.*	*n.a.*	*n.a.*	11	24	28	94	188	198	154
24. Bahawalnagar	*n.a.*	*n.a.*	7	7	7	7	7	16	59	115	126
25. Rahimyarkhan	*n.a.*	*n.a.*	16	18	18	18	18	103	233	279	302
Total	**990**	**1,216**	**1,495**	**1,911**	**2,168**	**3,295**	**4,214**	**6,904**	**9,757**	**12,404**	**13,646**

Sources : *i*) 1953/54 to 1959/60. *from Season and Crop Reports.*

ii) 1960/61 to 1963/64 Information supplied by Director, Land Records, Lahore, with his letters of March 15, 1965 and April 9, 1965.

TABLE A-2

NUMBER OF PRIVATE TUBEWELLS INSTALLED BY THE DEPARTMENT OF AGRICULTURE IN EACH DISTRICT 1953/54 TO 1963/64

District	1953/54	1954/55	1955/56	1956/57	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64
1. D.I. Khan	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	32	30	34	36
2. Bannu	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	1	4	*nil*	1
3. Mardan	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	3	*nil*	*nil*	*nil*
4. Hazara	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	1	2	*nil*	*nil*	*nil*
5. Peshawar	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	2	7	6	3
6. Kohat	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	1
7. Campbellpur	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	4	*nil*	*nil*	1	*nil*
8. Rawalpindi	*nil*	1	*nil*	*nil*	*nil*	*nil*	1	1	3	*nil*	3
9. Jhelum	*nil*	*nil*	*nil*	*nil*	*nil*	1	3	*nil*	*nil*	*nil*	*nil*
10. Gujrat	7	10	10	11	1	4	31	24	22	24	24
11. Mianwali	2	8	4	7	7	6	7	10	22	46	77
12. Sargodha	6	15	12	8	7	7	23	13	24	26	24
13. Lyallpur	38	30	45	48	59	53	67	82	93	110	112
14. Jhang	33	35	32	15	46	37	32	63	110	95	127
15. Lahore	10	19	5	7	10	8	12	23	37	34	72
16. Gujranwala	16	25	27	56	47	43	52	68	61	62	89
17. Sheikhupura	9	7	10	11	17	15	17	32	24	32	40
18. Sialkot	14	28	40	42	60	36	36	54	58	63	106
19. D.G. Khan	9	11	10	7	7	10	7	33	46	44	51
20. Muzaffar Garh	3	4	8	4	5	8	11	28	51	70	47
21. Multan	30	17	40	41	39	45	57	132	194	206	260
22. Montgomery	15	29	47	45	48	70	94	152	177	149	165
23. Bahawalpur	27	19	17	27	18	45	34	19	25	22	39
24. Bahawalnagar								7	14	34	71
25. Rahimyarkhan								36	38	30	62
Total	**219**	**258**	**307**	**329**	**371**	**388**	**489**	**817**	**1,040**	**1,088**	**1,410**

Source: Statement supplied by the Director of Agricultural Engineering, Lyallpur, with his letter dated January 20, 1965, and Superintending Engineer, Agricultural Machinery Organization with his letter dated February 11, 1965.

Appendix: B COST OF INSTALLATION AND OPERATION OF PRIVATE TUBEWELLS

TABLE B-1

COST OF INSTALLATION OF DIESEL AND ELECTRIC TUBEWELLS IN DIFFERENT DISTRICTS OF THE PUNJAB

Item	Unit	Multan and Montgomery districts		Gujranwala and Sialkot districts		Overall average
		Qty.	Cost	Qty.	Cost	Cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			(rupees)		*(rupees)*	*(rupees)*
Well-digging	Feet	25	320	—	10	
Boring	Feet	155	560	105	270	
Lining pipe	Feet	80	1,180	40	360	
Strainer	Feet	105	700	70	490	
Pump			740		520	
Belt, pulley, bolts, valve, bearing, angle iron and other parts			630		350	
Bricks	Thousands	18	940	9	470	
Cement	Bags	22	230	12	140	
Labour and other items			950		750	
Sub-total			**6,250**		**3,360**	
Motor	H. P.	18	2,550	14	2,040	
Engine	H. P.	20	5,750	18	5,140	
Total cost of an electric tubewell			8,800		5,400	7,100
Total cost of a diesel tubewell			12,000		8,500	10,300
Overall average			10,400		7,000	8,700

Source: Survey conducted by PIDE.

TABLE B-2

ANNUAL WORKING EXPENSES AND COST PER ACREFOOT OF WATER PUMPED FROM DIESEL AND ELECTRIC TUBEWELLS IN DISTRICTS OF THE PUNJAB

Item	Montgomery and Multan districts			Gujranwala and Sialkot districts			Average of four districts
	Qty.	Rate	Value	Qty.	Rate	Value	Value
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Diesel Engine Tubewells			*(rupees)*			*(rupees)*	*(rupees)*
Diesel oil (drums)[a]	42	75	3,120	32	77	2,470	
Mobil oil (tins)	135	5	670	103	5	510	
Repair charges			440			320	
Pay of driver and other cost			440			420	
Sub-total:			**4,670**			**3,720**	
Depreciation on tubewell	6,250	10%	630	3,360	10%	340	
Depreciation on diesel engine	5,750	6.7%	380	5,140	6.7%	340	
Interest on average cost	6,000	8%	480	4,250	8%	340	
Total annual cost:			**6,160**			**4,740**	
Cost per acrefoot	256		24.0	245		19.3	21.8
Cost per hour	2,360		2.6	2,430		2.0	2.3
Electric Motor Tubewells							
Electricity used (kwh)	27,000	.08	2,150	20,500	.08	1,630	
Repair charges			420			310	
Other charges			180			100	
Sub-total:			**2,750**			**2,040**	
Depreciation on tubewell	6,250	10%	630	3,360	10%	340	
Depreciation on electric motor	2,550	6.7%	170	2,040	6.7%	140	
Interest on average cost	4,400	8%	350	2,700	8%	220	
Total annual cost:			**3,900**			**2,740**	
Cost per acrefoot	215		18.1	191		14.3	16.4
Cost per hour	2,350		1.7	2,200		1.2	1.5

Source: Survey conducted by PIDE.

Note: a) Drum contains 45 to 48 gallons.

Appendix C

METHOD USED IN CALCULATING THE DISCHARGE OF A PRIVATE TUBEWELL

The discharge of tubewells was calculated by comparing it with the discharge of canal outlet. The discharge of a canal outlet in the former Punjab is directly proportional to the area commanded by the outlet and is one cusec for every 350 acres of land commanded on most canal systems in the former Punjab. The following information was, therefore, obtained from each tubewell farmer and non-tubewell farmer for calculating the discharge of the tubewell:—

a) Total area of land commanded by the canal outlet.

b) The area of the holding and length of water turn (in hours) allotted to the tubewell (or non-tubewell) farmer.

c) Area irrigated by the canal outlet in 12 hours.

d) Area irrigated by the tubewell in 12 hours.

Let us assume that in a particular case:

a) the total area of all holdings on the canal outlet is 525 acres;

b) the tubewell farmer owns 50 acres of land and is allotted 16 hours of canal water every 7 days. Further that the non-tubewell farmer has 12½ acres and is allotted 4 hours of water supply after every 7 days;

c) that area irrigated by the canal outlet is 5½ to 6 acres in 12 hours; and

d) that area irrigated by tubewell is 4 acres in 12 hours.

Questions *b*) and *c*) were asked simply to check the area of the canal outlet and the discharge calculated for that area. In the above example, the tubewell farmer should get a water turn equal to $(50/525) \times (7 \times 24)$ hours $= 16$ hours. This is what he actually got. Therefore, the total area on the canal outlet is 525 acres. The discharge of an outlet commanding 525 acres would be 1.5 cusecs $(525 \div 350 \times 1)$. One cusec of water is equal to 2 acrefeet a day. Therefore, the above outlet will deliver 3 acrefeet in 24 hours or 18 acre-inches in 12 hours. One irrigation of a dry but previously irrigated field takes about 3 acres-inches of water [20, p. 167]. Therefore, the above outlet should irrigate about 6 acres of land located just near the outlet head in 12 hours. About 10 to 20 per cent of the water supply is lost in transit in the water course. Therefore, the area irrigated by the canal outlet at a distance from the outlet head would be about 5 to 5½ acres depending upon the distance from the outlet head. If this is the answer given by the tubewell and the non-tubewell farmers, we know that the discharge of the canal outlet is about 1.5 cusecs.

If the tubewell located on the same canal outlet irrigated about 4 acres in 12 hours against 5½ acres irrigated by the canal outlet, it would be reasonable to assume that the discharge of the tubewell was 1.1 cusecs against 1.5 cusecs of the canal outlet.