SANEI V Programme

GROUNDWATER MARKETS IN WEST BENGAL, INDIA: EMERGENCE, EVOLUTION AND MARKET STRUCTURE

Revised Final Report

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1. Introduction

Over the last thirty years a rapid and radical transformation has occurred in the agricultural sector of the state of West Bengal, India. For at least the first two decades of this period, and to some extent even thereafter, the sectoral growth rate has been remarkably high and if one looks at the entire span of time, the fruits of change have been harvested by almost all groups: landless labourers, small and medium landholders, middlemen and traders. Today, in a broad statistical sense, a village in the agriculturally advanced areas of the state bears little resemblance to the same village thirty years ago. A way of life has been lost forever, perhaps on several counts for the better. Yet many areas remain outside the pale: life and living conditions have remained largely unchanged, as the agricultural metamorphosis that transformed the agricultural heartland has not taken place in these regions.

Why has this metamorphosis occurred at all and further, why has it taken place in some areas and not in others? Explanations have been partial at best. The most widely publicized of these, land reforms in the form of limited land redistribution and the establishment and enforcement of tenancy rights, laudable as they are for their re-distributive effects, may have had little direct impact on growth largely because the quantum of land involved is a small fraction of the total agricultural area of the state.[1] A largely underemphasized, and sometimes disparagingly rejected, explanation is the positive role of the state machinery (including both government line departments and Panchayats) in providing irrigation, electricity and agricultural extension services to foster the adoption of the new agricultural (HYV) technology and the spread of cultivation both in the Rabi season as well as in the summer. While the quality of service provided by the state owned facilities have been erratic and often unreliable in places, their large direct role, at least in the early years of the transformation, is perhaps undeniable. This research is based on the conceit that these usual explanations completely ignore the role of private investment in groundwater extraction mechanisms and the concomitant emergence of markets for provision of groundwater for irrigation in driving the process of technology adoption in the state. It is our view that this ubiquitous phenomenon has been almost completely neglected both

[1] See Banerjee, Gertler and Ghatak (2002) for a very compelling incentive based argument that the establishment of tenancy rights may have had a significant impact on agricultural growth in West Bengal; and Bardhan and Mukherjee (2004) for estimates of the area covered by the land reforms programmes.

at the official and at the academic levels in the state.[2] As we see it, the agricultural transformation occurred essentially because the new agricultural technology was success fully adopted on a large scale across most parts of the state. Further cultivation of summer (boro) paddy in the post monsoon season expanded rapidly after the introduction of HYV seeds and the spread of irrigation facilities. As we shall see in a subsequent section, the area under boro paddy has expanded rapidly in the last thirty years and in West Bengal, the area under cultivation of this crop is second only to the area under cultivation of Khariff (Aus and Aman Paddy).[3] Since cultivation of HYV paddy requires controlled irrigation, this would not have been possible without the expansion of reliable irrigation facilities. While a large part of the latter was provided by the Government, through the expansion of canal irrigation and minor irrigation facilities like deep tube wells (DTW), river lift irrigation schemes (RLI), cluster shallow tube wells (STW) and submersible pump tube wells (SMTW), etc. In many areas that are outside the command areas of the governmental irrigation facilities, private farmers invested in groundwater extraction devices. Further, even within the official command areas of the governmental irrigation facilities, such investment has taken place on a large scale to provide supplementary irrigation for Khariff paddy and irrigation for rabi and summer crops. It seems evident, therefore, that although agricultural change is more likely in areas where government irrigation is available private investment in groundwater extraction mechanisms and the emergence of markets for the supply of groundwater had a significant role in the spread of HYV technology and the spread of acreage under summer paddy.

The focus of this research is on this aspect of irrigation development. In particular, we study the patterns of evolution of private groundwater extraction in the state, the evolution of groundwater markets, the rise of seasonal land tenancy forms where farmers who own groundwater extraction devices rent in land in the command areas of their machines, instead of selling irrigation water to the land holders. A major finding is that in all the moujas[4] that we have surveyed owners of

[2] The Bureau of Applied Economics and Statistics, Government of West Bengal, Statistical Abstract 2001-2002 asserts that in "West Bengal irrigation is done mainly through Government Canals". Mukherjee (2004) is a good survey of the literature on the subject. A striking feature of the survey is that it reveals how little careful work has been done in this area in West Bengal.

[3] For official purposes Aus paddy is defined as monsoon paddy that is harvested on or before 31 October.

[4] A mouja is a land revenue unit used by the Census of India. In rural areas, a mouja may contain one or more villages. However, some large villages lie in more than one mouja. While residents of a mouja may own land outside the mouja, and non-residents may own land within it, it is reasonable to assume that for the most part

groundwater irrigation devices (barring very rare individuals) irrigate more land than they own within their command area. This means that they either sell water or rent in land in the command areas of their machines.

We also study market structures: prices, contracts and the possibility of tacit collusion among owners of water extraction devices. Careful empirical support of the hypothesis that collusive behaviour prevails, or of its negation, requires very intricate and time consuming surveys that involve much more time than we had at our disposal. What we have done is to set up a theoretical argument to explain how collusive behaviour may be sustained and then tested for the existence of such collusion sustaining behaviour in four villages. At the heart of the theoretical argument lies a startling empirical finding: all respondents we spoke to across the districts we studied agreed that owners of groundwater extraction devices tacitly or explicitly agreed upon the areas that they would service and while violations of agreements did occur at times such violation were limited in scope or disputes were resolved by the intervention of village and sometimes Panchayat leaders. Our respondents included not only cultivators who did not own groundwater extracting devices, but also a large proportion of owners of these devices, landless labourers who are not regular cultivators, panchayat members and ground level governmental staff.

Our study, largely empirical in nature, is based on large scale mouja level surveys across close to one thousand moujas in five districts of the state, complete enumeration household surveys in thirty odd moujas and "close in" market structure studies in four moujas.[5]We hope that our report will, at least partially, fill a major research gap in the study of groundwater markets in Eastern India and will lead to a more finely nuanced explanation of the agricultural transformation in West Bengal.

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residents of the mouja have most of their land within their home mouja. In our household level surveys we have dropped moujas where this assumption is grossly violated.

[5] We were hoping to be able to complete close in studies in several other villages across agro-climatic zones before writing up this report but the work has turned out to be much more difficult and time consuming than we had expected largely because of the sensitivity nature of the questions which require enormous confidence building effort to elicit "correct" responses. This work, however, is still being done and we hope to be able to include the findings in the final version of the paper.

The report is presented in several sections. In **Section 2** we provide a brief review of the pattern of evolution of agricultural activity in the state from 1960-61 to 2000-01. This allows us to identify the changes in cropping patterns both at the state and at a more disaggregated district level so that (a) we can identify the relative importance (in terms of area under cultivation) of different crops in the growth process; and (b) identify the districts where growth has been faster than others.[6] A major finding is that boro cultivation has increased rapidly in the state, but this growth has been uneven across districts. **Section 3** presents a bird's eye view of the salient features of the geography of the state. This provides a first cut explanation of the reasons behind the regional disparities in growth: regions where geo-physical conditions are such that cultivation of boro paddy is difficult, if not impossible, because of the lack of water, unfavourable temperatures and soil conditions remained outside the pale. It also signals that in such areas, private investment in groundwater irrigation may have been absent largely because the returns from such investment were low, and perhaps even negative. In **Section 4** we present case studies of five villages to highlight how cropping patterns and irrigation facilities evolved at the ground level in different agro-climatic zones, market access conditions, and under different patterns of government investment in irrigation and agro-electricity. We shall see how private investment in groundwater extraction devices and markets for the supply of groundwater emerged and evolved in these villages and how these patterns were linked to agro-climatic features and government investment. This section is important for two reasons: it (a) sets the groundwork for the large scale survey based studies that form the core of the report; and (b) provides an understanding of how things work on the ground in a transition process to complement the statistical and econometric findings. **Section 5** describes our methodology. In **Section 6** we begin our statistical study of private groundwater markets by describing the spatial pattern of spread of investment in groundwater extracting devices across the moujas we have surveyed and their role in agricultural activity. In particular, private groundwater extracting devices coexist with government irrigation facilities in many moujas. We describe the relative importance of government and private groundwater irrigation facilities in the cultivation of the most irrigation intensive crop in the state: summer paddy. In **Section 7** we present the results of the econometric analysis of the

[6] Strictly speaking, disaggregation at by agro-climatic zones would have been ideal since a district may contain several broad agro-climatic zones. This is not possible because Government data is collected and organized by administrative units as opposed to agro-climatic zones. We have tried to take care of this problem in our process of selection of districts and developmental blocks. Please see the Section 5.

survey data to see what factors explain the presence of private groundwater irrigation devices in a given mouja. The section also presents the results of our econometric analysis of the data to see what explains the fact that groundwater extractors have shifted from STWs to SMTWs in some moujas and not in others. In **Section 8** we look at contracts. The presence of privately owned groundwater extraction mechanisms does not guarantee that owners of such devices simply use them to irrigate their own land and sell water to other cultivators in the command areas of their devices. In many areas, owners of STWs and SMTWs prefer to rent in land in the command areas of their devices in some seasons. The section begins by presenting our findings related to this phenomenon to show that the presence of groundwater extraction devices does not imply the existence of a thriving market in groundwater in all cropping seasons. The next segment of this section presents survey data on the nature of contracts. The focus here is on prices charged and not on the timing of payments. To provide a deeper understanding we supplement this with our interview and close in fixed questionnaire survey based evidence on the timing of payments, hidden price cuts, default and mechanisms to prevent default. In **Section 9** we present our findings from the complete enumeration household surveys. In this section we try to see who buys water, who invests in groundwater extraction devices and who sells water. As in Section 8, the statistical evidence is complemented with evidence from free flowing interviews in several villages. In **Section 10** we study four moujas where boro cultivation occurs on a very large scale and irrigation is fully dependant on groundwater extraction using privately owned SMTWs.[7] In two of these villages sale of groundwater is the norm in the boro season. In the third, renting in land against a fixed fee in kind (paddy) by owners of SMTWs dominates sale of water. In the fourth village, the predominant feature is renting in land from landowners against the supply of water to the landowner. This is a variation on the fixed fee in kind for supply of water contract except for the fact that instead of paying in a quantity of the crop the payment is made by allowing the use of some land for the season. The objective here is to study in detail the nature of contracts, defaults and price-cutting. The larger objective is to study how agreements between owners of groundwater extraction mechanisms on pricing can be sustained in the face of myopic competitive pressures. A theoretical argument informs the empirical analysis that we carry out. Given space restrictions, we sketch the arguments that lie at the heart of the formal models and

[7] It would be useful to have similar information for villages where groundwater is extracted with STWs only, or by a combination of SMTWs and STWs.

extract the essential empirical clues that may support an assertion that owners of the SMTWs engage in collusive behaviour. **Section 11** is devoted to concluding remarks.

2. Evolution of Agricultural Activity in West Bengal: 1960-61 to 2000-01

Table 2.1 displays the area under some major crops in West Bengal from 1960-61 to 2000-01 except for the years1989-90, 1991-92 and 1992-93 for which data was not available. Some cash crops like tea have been left out because tea is cultivated primarily in Darjeeling district where the agro-climatic conditions are appropriate. Vegetables (other than potato) have also been left out because the area under these crops is still a very insignificant part of total area under cultivation. It is, however, worth noting that vegetable cultivation has expanded rapidly in recent years in the districts around Kolkata as well as in parts of Murshidabad and Jalpaiguri. Similar growth has occurred in commercial cultivation of flowers and fruits in regions that are well connected with Kolkata.

The most striking feature is that throughout this period, the area under the khariff aman paddy far exceeded that under any other crop. The area under Aus paddy increased up to the late nineteen seventies, fluctuated in the next decade and then fell sharply in the nineteen nineties. The area under wheat and boro paddy expanded in the nineteen sixties but the rate of growth was much larger in the former than in the latter. These trends appear to have continued throughout the next decade. In the next two decades, the area under boro cultivation increased sharply while that under wheat fell and then remained more or less stationary at a low level. In 1999-2000, the area under boro paddy was 31.5 percent of the total area under aus and aman paddy. Severe flooding in October 2000 destroyed a large part of the standing paddy crop in some districts in the southern part of the state so that even though the area under boro paddy was lower than in the previous year it was still around 35 percent of the area under the Khariff paddy crops (*aus* and *aman* paddy). It is interesting to note that in 1999-2000 the area under wheat was around seven percent of the area under monsoon paddy and the area under jute, which had the third largest coverage after monsoon paddy and boro paddy, was 13 percent of the area

Table 2.1: Area under (in '000 hectares) cultivation of major crops in West Bengal from 1960-61 to 2000-01

YEAR	AUS	AMAN	BORO	WHEAT	POTATO	JUTE	SUGAR CANE	PULSES	RAPE & MUSTARD	LIN SEED	TIL
1960-61	635.8	3935.9	33.1	34.6	58.6	291.5	40.1	774.3	88.6	44.2	3.8
1961-62	522.9	3868.8	29.8	45.8	57.5	463.1	34.4	764.5	115.5	50.6	4.3
1962-63	547.2	3874	23.7	48.9	66	434.7	31.2	732.5	95.3	45.4	4.9
1963-64	586.8	3920.1	24.4	54.9	65.6	446.1	32.6	764.6	87.1	42.6	5.6
1964-65	611.6	4036.9	22.5	40.8	71	456.6	41.1	787	103.4	43.9	5.8
1965-66	587.1	4033.5	30.1	41.2	82.1	403.6	39.3	771	98.4	39.3	8.2
1966-67	650.9	3970.2	27.6	55.2	75.8	423.4	29.5	787	107.4	35	8.2
1967-68	737.7	3921.9	54.8	79	78.5	496	26.7	704.6	111.9	35.6	8.5
1968-69	860.9	3887	90.9	128	70.9	268.7	31.1	747.4	118.5	36.7	8.1
1969-70	798.4	4117.6	106.3	206.8	59.6	437.5	39.2	704.7	104	38.1	8.9
1970-71	799.2	3969.9	186.5	360.2	65.1	407.1	38.3	669.5	108.2	43.6	10.3
1971-72	799.8	3887.4	304.2	422.4	72.8	461.1	33.9	597.1	107	53.9	14.2
1972-73	824.8	3981.7	262.9	368.2	75.7	367.3	32.5	545.6	95.5	36.9	11.1
1973-74	841.7	4048	325.1	330.1	80.5	418.5	30.8	659.7	122.6	56.4	14.9
1974-75	972	4107.1	340.4	421.8	86	370.2	29	682.3	102.7	63.5	25.9
1975-76	864.6	4241.1	320.7	565.3	112.8	334.7	29.3	727.2	95.3	66	33.3
1976-77	817.9	4148.7	237.9	515.2	115	440.6	29.5	619.4	72.2	43.1	33.4
1977-78	807.5	4308.5	308.7	484.4	126.1	478.6	31.4	564.4	96.6	60.2	52
1978-79	695.7	3627.8	441.9	521	161.4	537.9	32.1	561	110	68.3	56
1979-80	628	4022.9	253.8	505.9	108.4	504.3	29.3	559.3	115.6	52.6	56.1

Table 2.1 (continuation): Area under (in '000 hectares) cultivation of major crops in West Bengal from 1960-61 to 2000-01

YEAR	AUS	AMAN	BORO	WHEAT	POTATO	JUTE	SUGARCANE	PULSES	RAPE & MUSTARD	LIN SEED	TIL
1980-81	615.1	4214.6	346.5.	283	115.6	610.4	14.3	524.3	131.1	67.8	108.1
1981-82	695	4216.2	298.8	214	120.3	505.9	23	440.1	163.3	55.1	122.5
1982-83	635.5	3883.4	324.6	266.2	115.9	438.8	31.1	407.3	110.9	65.2	114.4
1983-84	721.4	4103.9	520.3	329.2	145.8	463.5	20.3	397.3	189.3	62.5	94.8
1984-85	631.4	4096.4	470.7	335.9	148.8	534.8	13.4	377.7	244.7	52.6	79.9
1985-86	483.1	4083.3	512.3	305.1	138.4	730.7	12.9	421	231.6	48.8	74.8
1986-87	637.4	4059.2	679.4	397.7	173.1	517.5	12.5	353.5	294.9	21.5	86.9
1987-88	616.2	4067.2	792.2	374.2	179.9	423.7	11	362.8	379.9	18.7	165.8
1988-89	720.6	4180.1	720.5	300.1	188.8	415.3	16.4	308.9	378.5	16.8	69.5
1989-90	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1990-91	610.3	4306.5	896.1	269.1	194.5	500.2	12.2	314	378.1	8.5	99.3
1991-92	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1992-93	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1993-94	539.6	4290.9	1045	306.9	230.9	475.2	10.3	269	380.9	12.3	114.8
1994-95	518.8	4210.6	1043.3	325.6	232.3	507.9	10.6	227.4	377.7	13.7	108.7
1995-96	510.5	4282.6	1160.1	337.8	255.9	515.8	17.2	212.7	327.5	15	115.3
1996-97	461.7	4282.4	1156.4	351.1	314.3	620.1	24.9	234.6	319.4	10.6	142.5
1997-98	423.1	4270.3	1206.9	367.4	284	641.6	25.8	221.9	327.1	16.5	127.9
1998-99	425	4028.6	1450.5	367.5	318.2	612.1	26.9	203.7	344.4	10.3	100.4
1999-2000	427.2	4248.9	1474.3	364.2	315.8	613.9	22.9	214.1	346	9.8	105.4
2000-01	394	3639.5	1401.8	426	299.7	613	21.6	274.5	436	11.9	107.2

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years.

under monsoon paddy. Another significant development is that over this period there has been an almost complete shift from traditional seed varieties to HYV seeds.[8]

The area under jute cultivation follows a rising cyclical trend. It has, however, been rising in the nineteen nineties in spite of the fact that jute fibre prices have not been particularly favourable in this period.[9] The area under pulses has declined monotonically over the period. In 1999-2000 the area under pulses was around 28 percent of the area under pulses in 1960-61. The area under rape and mustard fluctuated between 87, 000 hectares and 122.6 thousand hectares over the period 1960-61 to 1979-80. It rose sharply thereafter and stayed above 300, 000 hectares throughout the nineteen nineties. However, even in this period, there were sharp fluctuations in acreage under this crop. Figures for the area under other oilseeds (linseed and til) show a rising trend throughout the period 1960-61 to 2000-01. What is remarkable, however, is that after the mid nineteen eighties the area under linseed dropped sharply.

Overall, one finds some clear patterns. Summer paddy has emerged as the premier post-monsoon crop of the state especially after the mid nineteen eighties. The major rabi crops are wheat, pulses, mustard and rape, and potato. Further, yield rates have also risen over this period for all major crops as farmers shifted from traditional varieties to the high yielding varieties (Table 2.2). It is worth investigating whether these are secular patterns across the state.

Analysis of the data for the net-cropped area, cropping intensity, and area under different crops reveals that there are wide variations in the growth patterns across districts. In particular, expansion of cropping in the post monsoon season has been fairly rapid is many districts and practically stationary in others. Further, the timing of the “take-off” varies across districts. Table2.3 presents the figures for the net-cropped area in all the districts for selected years starting from 1960-61. Table2.4 presents the cropping intensity for each district over the same years.

The net cropped area has fluctuated within a narrow band for almost all districts over the period 1960-61 to 1999-2000. In some districts like Burdwan there is a slight declining

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[8] See Statistical Abstracts, Bureau of Applied Economics and Statistics, Government of West Bengal. Various Years.

[9] Field level investigations indicate that farmers grow the crop because the hard stem cores have important uses, e.g. kitchen fuel, material for constructing fences, and so fetch good prices. The revenue from sale of the stem core and the fibre makes jute cultivation profitable.

Table 2.2: Yield rates of different crops in West Bengal from 1960-61 to 2000-01 (in Kg. per hectare)

YEAR	AUS	AMAN	BORO	WHEAT	POTATO	JUTE	SUGARCANE	RAPE-MUSTARD	LINSEED
1960-61	813	1245	1139	743	9882	1236	5130	396	228
1961-62	759	1129	1101	751	12723	1313	5285	295	152
1962-63	751	1026	1131	626	12097	1299	4343	393	260
1963-64	843	1227	1189	596	8157	1330	4715	327	228
1964-65	985	1271	1204	684	11218	1437	4611	350	187
1965-66	802	1087	1226	825	10471	1000	4555	420	308
1966-67	814	1072	1449	821	8470	1222	4407	411	403
1967-68	819	1146	2018	900	8186	1398	4412	315	253
1968-69	846	1243	2441	2095	12097	891	5688	508	338
1969-70	813	1236	2979	2330	10195	1398	5758	421	273
1970-71	1139	1183	2871	2411	14281	1187	5418	330	303
1971-72	1208	1185	3070	2181	14558	1354	4888	325	263
1972-73	965	1052	2773	1869	12534	1329	5058	446	293
1973-74	827	1081	2243	1905	11991	1580	5282	361	250
1974-75	899	1172	2515	1984	15754	1268	5800	386	315
1975-76	908	1222	2806	2100	14322	1445	5846	412	265
1976-77	788	1106	3004	2040	14410	1418	6142	353	273
1977-78	931	1360	2857	2140	15152	1303	6073	443	322
1978-79	819	1335	2859	1916	15144	1380	5872	425	268
1979-80	844	1162	2680	1518	18400	1348	4905	462	262

Table 2.2: (continuation): Yield rates of different crops in West Bengal from 1960-61 to 2000-01

YEAR	AUS	AMAN	BORO	WHEAT	POTATO	JUTE	SUGARCANE	RAPE-MUSTARD	LINSEED
1980-81	937	1429	2497	1672	17057	1310	6057	605	286
1981-82	960	1045	2534	1819	16496	1591	6134	580	247
1982-83	891	900	2591	2274	20013	1552	5140	532	270
1983-84	966	1431	2557	2595	21008	1544	5044	597	300
1984-85	1046	1504	2698	2418	21071	1458	5752	670	278
1985-86	1119	1475	2786	2421	19930	1820	6312	706	266
1986-87	1114	1403	3030	1717	20469	1723	6069	600	314
1987-88	1064	1506	3142	1801	21048	1544	6281	876	270
1988-89	1486	1803	2708	2082	23033	1964	7095	864	383
1989-90	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1990-91	1485	1594	2973	1970	23046	1978	7069	889	215
1991-92	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1992-93	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1993-94	1683	1855	3102	2060	22533	2110	5274	769	290
1994-95	1615	1991	2888	2286	23925	2102		790	293
1995-96	1674	1778	2946	2147	24456	1978		700	284
1996-97	1680	2000	3119	2390	26956	2178		891	255
1997-98	1777	2088	2958	2206	20947	2119		767	255
1998-99	1743	1900	3393	2117	21023	2169		731	261
1999-2000	1938	1902	3031	2336	23689	2227		805	406
2000-01	1736	1979	3240	2485	25606	2182	67821	956	334

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years.

Note: Yield rates for Sugarcane from 1994-95 onwards are not reported because the figures reported in the Statistical abstract 2001-02 is clearly erroneous.

Table 2.3: Net cropped area (in '000 hectares) by district in selected years

	Years								
District	**1960-61**	**1965-66**	**1970-71**	**1975-76**	**1980-81**	**1985-86**	**1990-91**	**1995-96**	**2000-01**
Burdwan	498.1	491.7	456.2	487.27	471.12	462.68	460.25	465.69	477.49
Birbhum	343.7	340.6	340.8	338.05	341.85	323.63	343.39	311.52	337.52
Bankura	340.9	349.1	378.1	375.96	379.51	390.53	391.22	365.66	344.07
Midnapore	915.1	904.1	898.9	882.55	861.96	901.81	846.34	844.65	874.24
Howrah	100.7	91.7	77.5	99.74	96.74	89.38	84.81	85.6	87.04
Hooghly	238.2	239.7	213.6	229.88	234.39	226.32	221.8	227.84	230.54
24 Parganas-N	662	674.3	642.2	710.01	693.43	248.61	281.83	256.09	259.87
24 Parganas-S						381.62	398.88	398.07	378.29
Nadia	309	313.8	297.8	326.56	320.34	316.89	287.2	297.8	298.5
Murshidabad	413.4	411.6	396.8	424.87	426.8	414.93	404.57	407.19	393.04
Uttar Dinajpur	447	467.2	492.1	462.44	468.39	456.53	424.31	453.96	273.41
Dakshin Dinajpur									190.46
Maldah	282.2	286.4	279.3	286.38	283.89	287.74	254.55	283.52	222.91
Jalpaiguri	289.5	303.4	331.9	323.86	317.67	262.98	341.33	321.51	336.51
Darjeeling	98	100.2	103	44.26	45.73	128.06	137.56	145.83	136.88
Cooch Bihar	243.1	274.6	276	260.14	264.45	245.98	247.49	259.01	264.92
West Bengal	**5435.9**	**5525.3**	**5463.1**	**5560.63**	**5508.15**	**5474.39**	**5463.42**	**5461.93**	**5417.38**

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table 2.4: Cropping intensity by district in selected years

Cropping Intensity of different crops									
District	**1980-81**	**1985-86**	**1990-91**	**1995-96**	**1996-97**	**1997-98**	**1998-99**	**1999-00**	**2000-01**
Burdwan	145	153	162	166	171	178	189	191	165
Birbhum	132	137	144	157	143	143	152	156	136
Bankura	118	118	139	148	149	154	151	150	145
Midnapore	125	127	150	165	167	165	161	166	164
Howrah	134	169	203	184	204	234	212	206	190
Hooghly	158	175	203	216	227	218	220	220	172
24 Parganas-N	127	180	163	180	185	198	206	209	198
24 Parganas-S		123	128	128	126	134	142	148	142
Nadia	167	182	230	236	242	251	243	249	242
Murshidabad	159	172	183	190	195	196	206	210	192
Uttar Dinajpur	151	160	161	159	165	164	182	187	183
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	153	155	157
Maldah	140	140	192	163	152	153	153	156	206
Jalpaiguri	137	178	136	144	146	150	153	153	167
Darjeeling	n.a.	108	125	119	113	123	126	117	136
Cooch Bihar	158	176	184	191	201	202	201	203	192
Purulia	103	106	106	109	104	109	102	110	104
West Bengal	**139**	**147**	**159**	**164**	**165**	**169**	**171**	**174**	**168**

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

trend while, in Jalpaiguri, there is a rising trend. Cropping intensities have risen in all districts other than Purulia. A closer look at the Table reveals some interesting features. In 1960-61, the cropping intensity in Nadia and Murshidabad was significantly higher than in other districts and the cropping intensities in Burdwan, Birbhum, Bankura, and Midnapore were similar to that in Purulia. The terrain in the western parts of Burdwan, Birbhum, Bankura and Midnapore is similar to that in Purulia. However the eastern parts of these districts lie in the South Bengal Alluvial Plain. In the decade of the nineteen sixties these areas were largely monocropped.[10] Cropping intensities started rising in the nineteen seventies in these districts but the sharp jump occurred in some districts in the nineteen eighties and in most districts in the late nineteen eighties and early nineteen nineties. The next step is to look at the relative importance of various crops in the post monsoon season in different districts across time.

Tables 2.5 to2.10 present the figures for acreage under the major crops as a percentage of the net-cropped area in each district in selected years starting from 1960-61. Before 1970-71 the percentage of net cultivated area under summer paddy was insignificant. It started rising thereafter but area expansion was confined largely to a few districts – Burdwan, Midnapore, Hooghly and to a somewhat lesser extent in Howrah, Nadia and Malda – in the decade of the eighties. This general pattern changed somewhat in the next decade as cultivation expanded rapidly in Howrah, Nadia and North 24 Parganas, and especially so after the middle of the decade. In the decade of the 1990s, large scale Boro cultivation was taking place in Burdwan, Midnapore, Hooghly, Howrah, 24 Parganas (North), Nadia and Uttar Dinajpur. In 1998-99, 53.5 % of the net cultivated area in Burdwan was devoted to the cultivation of Boro paddy and 66.18% in Howrah. It was above 40% in Hooghly, 24 Parganas (North) and Nadia. In 24 Parganas (South), Birbhum, Bankura, Maldah, Dakshin Dinajpur and Cooch Bihar too the area under boro cultivation expanded significantly during this decade. The point is that except for Purulia, Jalpaiguri and the plains areas of Darjeeling districts boro cultivation became a major feature of agricultural activity in the 1980s and particularly so in the decade thereafter.

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[10] See section 2.

Overall, it appears from the district level data that at least from the mid nineteen eighties, cultivation of boro paddy has emerged as the most important agricultural activity after cultivation of rain-fed paddy in most districts. Clearly, this change has been driven by the relatively higher profitability from cultivation of summer paddy. The question then is: what explains the differences in percentage of net cultivated area under boro paddy across districts?

Cultivation of Boro paddy requires controlled irrigation because the crop is extremely moisture sensitive. Further, boro paddy is a very water intensive crop. It requires about four times as much water per hectare as wheat and much more than either oilseeds or pulses.[11] An explanation of the pattern of evolution of boro cultivation crucially hinges on the availability and evolution of irrigation facilities over this period.[12]

In the early part of the transition to boro cultivation, state owned canals; deep tube-wells, river lift irrigation schemes etc. were the main sources of irrigation for cultivation of boro paddy. Over time farmers installed STWs and later on submersible pump tube-well systems to draw groundwater. This investment took place mainly in areas where irrigation from government sources was either unavailable or erratic.[13] In many areas, including those near the tail ends of canals where irrigation water is completely unavailable in the summer, private groundwater extraction is the sole dependable means of irrigation for boro paddy.[14] A similar problem exists in many areas where river lift

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[11] This explains the differences in prices charged for irrigation for the different crops. See section 2.

[12] Jalpaiguri and perhaps parts of the plains areas of Darjeeling district are exceptions because the explanation may lie elsewhere. In these areas temperatures are too low for germination of the paddy seeds in the months when boro is transplanted in the other districts so that the boro cultivation season in these areas begins much later. However, the soil is acidic and this leads to fixation of soil nutrients. This is one possible reason for the lower productivity of boro paddy in these areas and hence of the apathy of farmers towards cultivation of boro paddy.

[13] See section 2.

[14] In Manteswar Block of Burdwan district, for example, water has not been available for irrigation of boro paddy for a long time in most moujas that lie within the official command areas of canals. Owners of submersible tube-well pump-sets often use the canals for transport of the groundwater across the mouja. Cases like this are fairly widespread and so there may be reason to suspect an upward bias in official estimates of the area under canal irrigation in the boro season. However, it is worth noting that in many moujas lying in the head areas of the canals, water is officially provided in alternate years but farmers draw water from them every year. In many moujas in the Kanksa and Galsi I blocks of Burdwan district that lie in the head areas of the canals that are supposed to deliver water to moujas in Manteswar block, such activity may be the norm. In effect then, it is difficult to tell whether official estimates of canal-irrigated

irrigation systems or deep tube-wells were installed and operated by different departments of the state government. Bad maintenance and bureaucratic delays together with the non-availability of operational staff in critical periods during the cropping season have often made these sources of irrigation unreliable.[15]

An explanation for the inter-regional variation in the extent of boro cultivation emerges from this. Given paddy prices, boro cultivation is most profitable in areas where water is cheap. Thus, in the command areas of reliable government funded irrigation schemes like canals, deep tube-wells etc., where the price that people pay for water is low, and boro cultivation is widespread. Outside such areas, the cost of water is typically significantly higher and varies with the nature of the soil, the state of the aquifer, the gradient of the land, energy prices and the availability of electricity for running the pump sets.

The degree of porosity of the soil determines the number of times water has to be supplied to a plot over the cropping season. In areas where the soil has high clay content, the total amount of water required is lower than in areas where the soil is lighter. The depth of the water Table determines the cost of investment in the water extraction device. In areas where the water Table is low, or falls sharply over the summer months, the cost of boring and pipes can be quite high. In areas where one has to bore through hard rock to reach the water Table, the cost of boring is prohibitive given current technology.[16] In areas where the gradient is relatively high, water requirement is higher on the upper slopes than on the bottom. Part of the reason is that the soil (typically) on the upper slopes tends to be lighter than the soil further down. Another reason is that the water supplied to the plots on the upper slopes tends to seep down towards the plots on the lower slopes. In the first phase of expansion of private groundwater extraction, machines

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areas are under or over estimates of actual figures. Our own studies indicate that this problem exists in Birbhum district as well.

[15] In recent years, a move by the government to formally hand over the operation and maintenance to local beneficiary committees appears to be yielding positive results. In many areas where there are no government funded irrigation sources, recourse to private groundwater irrigation was the only option available to farmers who wanted to cultivate boro paddy.

[16] This problem exists in Purulia district and in the western parts of Bankura, Birbhum, Burdwan and Midnapore districts as well.

were typically run using diesel as fuel. As electrical connections were extended to areas where it had not been available before, owners of groundwater extraction devices switched to electrically operated machines. Further, availability of electricity appears to have led to a spurt in investment in new shallow tube wells and submersible pump set tube wells as the cost of installation of electricity operated equipment was significantly lower than the cost of diesel operated machines and also because operating costs were much lower. In West Bengal, the fixed fee electricity charges for irrigation have been low for a long time. Over the last few years, these have been raised but default is quite widespread.[17]With this in mind, one can provide tentative explanations for (i) the variation in the extent of boro cultivation and (ii) the differences in the "take-off" periods across districts. As an illustration, we take a closer look at the two districts in West Bengal.

Canal irrigation was introduced in Burdwan district before independence. There was a rapid expansion of the command area of the canal system in the post independence period as new canals were built and sub-canals were extended further. However, large areas have remained outside the canal command zone and, in practice, the supply of water from the canal system is erratic and often completely unavailable in a significant section of the canal command area. Deep tube wells were introduced on a large scale in the nineteen seventies together with river lift irrigation schemes. However, the total command area of these schemes is much smaller than that of the canal system. In much of the eastern part of the district, private farmers installed shallow tube wells and later submersible pump tube wells. In the early phase, such investment was often partially supported by subsidies from the government and low cost bank loans. For the most part, however, such investment appears to be funded with personal savings and private borrowing from friends, relatives, sellers of equipment, and informal sector lenders.

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[17] Electricity operated pump sets are cheaper than the diesel run sets. However, recently, connection charges have risen sharply as farmers have to pay for the cost of the additional electrical poles and wires required to connect their machines to closest point from which electricity supply is available. This acts as a deterrent to switchovers in many cases.

Kanksa Block is located in the western part of Burdwan district. The river Damodar bound the geographical area of the block on the north by the river Ajay, and on the south. Both the rivers are flood prone. Kanksa in a sense is the boundary between of the rich fertile alluvial lands of the eastern part of the district and the gravely soils that lie further west. The fertile lands on the southern end of the block are irrigated by water from the Damodar Valley Corporation canal system. As one moves northward, the soil is less fertile and especially so in the western part where the soil is often lateritic. In between are pockets of alluvial soil where some cultivation is possible. In these, the dependence of cultivation on groundwater irrigation is clearly evident. In the moujas where the soil is lateritic, there is little cultivation and investment on groundwater extraction mechanisms is rare. In the area west of this block, cultivation of summer paddy is uncommon, limited largely by the availability of water for irrigation. This is one reason why the area under boro paddy as proportion of the net cultivated area in Burdwan is lower than that in Hooghly. If one were to compare this proportion for the less barren areas of Burdwan with the corresponding proportion for Hooghly, the former would exceed the latter by a significant margin.

Galsi I block has some of the most fertile soils in the district. This is a traditional paddy-growing zone and today the cropping pattern is typically paddy followed by paddy. Much of the agricultural area in the block has access to canal irrigation, but even here the dependence on groundwater irrigation is apparent. In many moujas, all the cultivable land does not lie within the command area of a canal. In others, canal water is available for irrigation of boro paddy in alternate years. In these moujas, groundwater is used for cultivation in the areas where canal irrigation is not available or in the “off” years. In a sense, canal irrigation may have served to induce investment in groundwater extraction mechanisms on a large scale in the neighbourhoods of canal command areas for two reasons. First, canal irrigation serves to convince farmers that if controlled irrigation is available then boro cultivation is profitable. Second, flood irrigation using canal water often helps to recharge aquifers so that groundwater extraction costs are low in these neighbourhoods because the water Tables remain high even in the peak summer months.

The story in Kalna I Block is somewhat different. Kalna I Block is located in the eastern part of the district. To the east is the river Bhagirathi. The soil in the block is alluvial and ranges mainly between clay loam and clay and the principal cropping system is paddy followed by paddy. Vegetables including potato are cultivated in several moujas though the scale varies with the nature of the soil. river lift irrigation systems and DTWs provide irrigation for boro cultivation in several moujas and canal irrigation is available in some. For the most part, however, boro cultivation is heavily dependent on groundwater extraction using electrically operated submersible pump sets.[18] Diesel run pump sets are used in areas where electricity is unavailable.

Manteswar block is a near perfect example of the role of private investment in private investment on groundwater extraction devices in supporting the expansion of boro cultivation in the state. Most moujas have little or no access to irrigation from sources installed by the state. In the first phase of expansion of boro cultivation, diesel powered shallow tube well pump sets were installed by farmers, and from around 1989 there was a rapid and almost universal shift to submersible pump sets as water levels fell. In many areas the introduction of electricity helped to accelerate the pace of change.

We turn next to Murshidabad district to highlight how rising paddy prices induced the rapid expansion of boro cultivation in areas that were traditionally wheat-growing regions in the winter season.[19] The main rivers running through Murshidabad district are Padma, Bhagirathi, Bhairab, Babla, Dwaraka, Kuiya, Brahmani and Mayurakshi. The river Bhagirathi runs from north to south through the centre of the district and the river Padma along the eastern boundary with Bangladesh. There are several large low-lying wetlands in the district that are flooded in the monsoon.

[18] See section 2.

[19] A similar phenomenon occured in many areas across the state. As paddy prices rose, farmers started cultivating summer paddy on plots that were previously viewed as not being very useful for paddy cultivation. In some areas summer paddy replaced other crops while in others the crop was cultivated on plots that were traditionally left fallow after the monsoon.

The soil characteristics of the district vary across regions. East of the Bhagirathi River we have the *Bagri* soil area. This area consists mainly of the riverine tract of the Bhagirathi. It has light alluvial soil with comparatively light soil texture. The typical Bagri soils are loam and sandy loam. To the west of the river we have the *Rahr* soil area. This Rahr area is contiguous to Birbhum, but like eastern Birbhum, it is not Rahr in the true sense of the word.[20] It is substantially a continuation of the sub-Vindhyan region of laterite clay and calcerious nodules. The land is high and slightly undulating with a gentle downward slope from west to east. The soil is comparatively heavy, greyish or reddish in colour, and is mixed with lime and iron oxide. Generically, Rahr soils are clay and clay loam[21] [22].

Khariff paddy is cultivated in approximately 70 percent of the available agricultural land during the monsoon season with a predominance of HYVs Jute is cultivated on 25 percent of the land during the same period. In the post monsoon season, the main crops are summer paddy (30 percent of the net cultivated area) and wheat (around 30 percent of the net cultivated area). There is also a significant area under mustard cultivation. The main boro and wheat growing areas are Lalbagh, Berhampore and Kandi subdivisions. Analysis of the data for the years 1990-91 to 1999-2000 reveals a sharply rising trend in the area under boro cultivation and a roughly stationary trend in wheat area across subdivisions.

Groundwater irrigation has played a major role in agricultural activity in the district for several decades. In the decade of the 1970s there were large-scale governmental programmes for introduction of private groundwater irrigation by shallow pump-sets as part of the programme to extend the green revolution technology in paddy and wheat. What triggered off the rapid expansion of groundwater extraction was perhaps the rapid rise in paddy prices in the late nineteen eighties and much of the next decade.

[20] Rahr means an area where nothing grows.

[21] The main crops in the Rahr area are jute, paddy, wheat, oilseeds, pulses, sugarcane, vegetables and spices. Fruits like mango, litchee, jackfruit, banana, guava, papaya, etc are grown on a large scale. The main crops in Rahr area are paddy and potato. Oilseeds and vegetables are grown through out the year.

[22] The soil around Farakka is peculiar: it is clay with very heavy grain sand. Around Kandi we have low-lying clay.

Boro (Summer paddy) cultivation occurred primarily in the Rahr areas where the soils are heavier and have higher water retention capacity. The spread pattern of boro cultivation changed abruptly in the 1990s. Cultivation spread rapidly in the Bagri area in eastern part of the district as rising paddy prices made boro cultivation very profitable. Farmers found it profitable to invest in shallow tube well pump sets as paddy prices rose and we see the emergence and rapid expansion of private shallow tube well irrigation in this decade.[23] By the end of the decade, in all the blocks of Murshidabad district (except for the Lalgola block and Bharatpur II block), the area under private groundwater irrigation was larger than the area under all other sources taken together. In most blocks, this difference was quite large.

The studies of Burdwan and Murshidabad districts presented above only serve to illustrate some patterns. Careful studies of other districts, we believe, will reinforce the general observations made in this section.[24]

[23] Use of groundwater is high in wheat and winter vegetable cultivation. The average water requirement for wheat is 18 acre inch and for boro is 70 acre inch. One can get very good quality drinking water at a depth of 60 feet in many areas of the district and groundwater draw down is not a serious problem in almost all parts of the district.

[24] A word of caution is in order. Econometric analysis of data collected in the last few years is unlikely to reveal the impact of soil conditions on the spread of boro cultivation and investment in STWs or SMTWs because at the height of the boro craze, all types of land were used for cultivation of the crop using groundwater. Even with rising diesel prices and falling paddy prices there is still no sign of a serious roll back in the area under this crop.

Table 2.5: Area under Boro as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	.48	.59	6.82	16.60	19.93	21.07	25.83	37.99	46.03
Birbhum	.41	.53	1.20	3.67	6.93	5.78	10.8	21.48	15.23
Bankura	.23	.29	.42	1.28	1.47	3.71	10.5	15.53	11.42
Midnapore	.97	.35	6.11	8.26	5.55	11.54	23.24	26.46	30.64
Howrah	.10	.87	13.55	9.93	6.62	25.96	54.24	53.86	55.60
Hooghly	1.34	.75	16.57	22.49	24.28	21.96	31.15	42.79	38.56
24 Parganas-N	.08	.16	3.27	4.20	4.94	20.15	27.35	35.18	41.98
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	3.8	9.88	13.03	22.07
Nadia	.26	.64	1.38	3.46	8.40	17.99	32.76	35.86	49.49
Murshidabad	.80	.80	1.79	3.6	5.3	8.97	13.71	18.37	27.60
Uttar Dinajpur	.09	.28	.57	1.86	1.26	3.24	12.66	18.11	33.8
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	19.64
Maldah	3.97	3.67	4.69	7.47	7.78	10.53	21.96	22.33	31.85
Jalpaiguri	0	0	.03	0	0.03	0.04	0.21	1.03	1.99
Darjeeling	0	0	.10	0	N.A	N.A	0.15	0.07	0.29
Cooch Bihar	.04	.11	.14	.31	0.037	0.16	3.11	6.68	10.72
Purulia	0	.04	.07	.29	0.066	0.06	.86	0.77	0.32
West Bengal	.61	.54	3.41	5.77	6.29	9.36	16.4	21.24	25.88

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table 2.6: Area under Wheat as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	.50	.77	5.68	7.98	2.21	2.1	.59	.88	1.32
Birbhum	1.63	2.33	22.83	19.17	6	5.50	4.13	6.1	7.97
Bankura	.91	.66	2.17	9.39	2.69	3.1	1.99	1.83	2.56
Midnapore	.01	.02	1.22	3.55	1.02	1.1	.66	1.88	1.55
Howrah	0	0	6.45	5.11	.83	1	.12	.93	1.15
Hooghly	.13	.13	10.63	11.66	2.73	2.43	.36	.04	.69
24 Parganas-N	.02	.07	2.34	3.55	1.3	2.45	3.16	2.81	5.23
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	.18	.15	.05	.84
Nadia	1.33	0	14.91	20.39	13.73	17.58	14.45	15.71	20.23
Murshidabad	3.07	3.91	25.6	25.89	20.31	22.80	22.79	27.92	34.47
Uttar Dinajpur	.16	.17	14.02	13.36	7.9	8.45	6.6	7.86	13.71
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	5.35
Maldah	.89	.80	7.27	13.06	8.66	9.14	14.77	15.73	22.16
Jalpaiguri	.17	.30	.27	7.26	2.77	3.73	3.10	6.34	7.90
Darjeeling	.51	.4	.49	5.87	3.28	1.01	2.69	1.85	2.41
Cooch Bihar	.74	.62	2.57	8.23	4.76	5.69	5.49	6.99	9.51
Purulia	.04	.07	.32	4.73	0.56	.62	.36	1.42	.93
West Bengal	.64	.75	6.59	10.17	5.14	5.57	4.92	6.18	7.86

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table 2.7: Area under Jute as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	1.37	1.99	2.81	1.89	3.67	4.32	2.98	2.19	2.20
Birbhum	.06	.03	.09	.09	0.09	0.28	0.06	0.10	0.03
Bankura	.15	.40	.26	.21	0.50	0.31	0.10	0.08	0.12
Midnapore	.92	1.47	1.31	1.35	2.50	2.16	1.18	1.15	0.88
Howrah	4.27	5.34	4.9	2.21	6.41	5.59	4.13	3.85	7.81
Hooghly	9.99	14.35	12.55	7.26	15.06	17.50	14.16	10.09	12.97
24 Parganas-N	3.85	7.31	4.98	5.31	1.67	20.15	13.23	14.92	21.47
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	0.89	0.43	0.25	0.47
Nadia	9.68	17.5	21.05	20.24	36.68	51.69	40.60	38.21	43.65
Murshidabad	11.56	12.59	17.41	11.44	19.54	30	26.15	30.80	35.87
Uttar Dinajpur	10.02	13.06	12.48	10.75	18.19	23.52	10.82	10.22	21.58
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	7.93
Maldah	7.3	6.32	8.38	6.29	11.09	15.39	10.80	8.22	10.77
Jalpaiguri	12.26	14.96	12.68	9.02	17.47	26.58	11.89	11.75	13.16
Darjeeling	2.45	4.29	3.2	4.52	10.28	3.90	2.69	1.1	1.61
Cooch Bihar	16.70	19.92	20.47	16.26	28.51	30.94	25.01	31.58	31.74
Purulia	.16	.07	.04	0	N.A	N.A	N.A	N.A	N.A
West Bengal	5.36	7.30	7.45	16.02	11.08	13.35	9.15	9.44	11.31

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table2.8: Area under Potato as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	2.27	3.29	3.2	4.58	5.20	5.90	8.26	50.46	8.82
Birbhum	1.6	2	1.47	2.25	1.99	1.95	2.36	3.02	3.79
Bankura	.59	.63	.74	1.3	1.79	1.97	4.96	5.63	6.25
Midnapore	.61	1.16	1.11	1.7	1.81	2.43	3.97	6.54	6.91
Howrah	.89	2.29	2.5	3.01	1.96	3.47	4.24	5.72	10.57
Hooghly	6.93	10.26	7.49	9.92	14.08	17.81	26.28	35.95	34.96
24 Parganas-N	.32	.58	.36	.73	.69	2.05	1.21	1.37	3.27
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	.24	.28	.30	1
Nadia	.1	.19	.07	.83	.62	.66	.66	.87	1.17
Murshidabad	.8	.97	.68	1.37	1.62	1.49	1.56	1.72	2.26
Uttar Dinajpur	.87	.64	.65	1.77	1.05	1.38	1.01	1.45	2.45
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	2.52
Maldah	.32	.21	.25	.66	.39	.52	.59	.63	1.08
Jalpaiguri	.76	.53	.36	1.17	.38	.91	1.20	3.45	4.25
Darjeeling	12.55	4.29	2.43	8.81	10.06	2.97	3.05	3.36	5.19
Cooch Bihar	.62	.55	.62	1.61	.45	1.26	2.14	3.32	4.61
Purulia	.04	.07	.11	.49	.10	.12	.42	.47	.29
West Bengal	1.08	1.49	1.19	2.03	2.10	2.53	3.56	4.69	5.53

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table 2.9: Area under Total Pulses as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	9.84	6.47	6.3	6.98	3.61	2.85	.61	.34	1.13
Birbhum	14.2	12.36	11.38	14.02	8.45	6.30	2.50	3.85	5.98
Bankura	3.7	2.89	3.39	3.17	2.08	1.59	.69	.82	.38
Midnapore	9.69	10.64	6.67	8.33	6.45	4.65	2.62	2.02	2.38
Howrah	22.05	6.98	8.65	13.84	16.13	16.78	5.31	.70	.46
Hooghly	11.71	7.3	7.3	5.39	3.58	2.83	.36	.26	.65
24 Parganas-N	10.95	12.03	8.7	9.63	7.21	7.32	5.54	2.89	4.96
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	6.81	3.03	1.36	2.30
Nadia	49.03	50.10	43.52	40.79	31.53	22.28	25.70	15.31	19.10
Murshidabad	35.24	36.30	35.76	31.8	25.52	23.14	13.10	10.27	15.09
Uttar Dinajpur	6.89	7.49	8.47	11.66	8.63	6.48	5.33	4.27	3.33
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	2.15
Maldah	29.27	35.27	34.51	30.8	19.76	15.22	23.26	10.05	16.19
Jalpaiguri	2.69	2.24	1.18	3.49	2.49	2.74	1.44	.78	1.96
Darjeeling	.92	1.5	1.07	3.39	3.06	.78	.73	1.30	1.39
Cooch Bihar	5.02	4.48	3.44	7.11	3.06	3.17	3.80	3.67	3.96
Purulia	8.27	8.16	9.57	7.78	5.66	5.23	6.17	4.67	6
West Bengal	14.24	13.95	12.25	13.08	9.52	7.69	5.75	3.89	5.07

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

Table 2.10: Area under Rape & Mustard as a percentage of net cultivated area by district (selected years)

District	1960-61	1965-66	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01
Burdwan	.44	.51	.75	.62	4.31	7.61	11.39	7.06	10.32
Birbhum	.12	.15	.56	.62	3.10	8.47	13.72	6.52	10.58
Bankura	.44	.49	.5	.82	1.05	2.66	4.93	3.28	4.04
Midnapore	.33	.37	.41	.32	.34	.86	2.41	3.97	2.87
Howrah	.20	.11	.26	.3	.10	.90	2.95	1.52	1.95
Hooghly	.46	.33	1.31	1	1.37	3.80	5.23	3.60	5.51
24 Parganas-N	.54	1.07	1.68	.8	1.56	7.48	10.79	9.57	15.51
24 Parganas-S	N.A	N.A	N.A	N.A	N.A	.42	.80	.50	.61
Nadia	2.98	4.62	3.34	2.79	5.56	8.58	16.43	21.99	27.34
Murshidabad	2.37	3.11	3.18	2.92	4.05	7.25	12.83	11.44	16.54
Uttar Dinajpur	5.66	5.69	4.65	4.95	4.04	8.41	11.74	10.71	12.55
Dakshin Dinajpur	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	11.71
Maldah	4.96	4.92	4.58	4.92	3.52	4.55	10.84	5.33	15.61
Jalpaiguri	2.63	1.68	2.68	2.32	1.95	2.59	2.17	2.64	2.47
Darjeeling	1.12	1.30	.78	1.58	.87	.47	.95	.14	.07
Cooch Bihar	3.62	2.48	2.93	2.96	2.95	1.83	2.02	2.90	3.06
Purulia	.31	.40	.54	.52	.17	.15	.30	.24	.16
West Bengal	1.63	1.78	1.98	1.71	2.38	4.23	6.92	6	8.05

Source: Statistical Abstract, Bureau of Applied Economics & Statistics, Government of West Bengal, various years

3. Geography

The state of West Bengal has several distinct physiographic zones ranging from the Himalayan hilly zones in the north to the coastal areas in the south. Goswami (1995) groups the entire area of the state into five broad physiographic zones.

- The North Bengal Hill Zone consisting of parts of Darjeeling District.
- The North Bengal Alluvial Plain and Fan Zone consisting of the Districts of Jalpaiguri, Cooch Bihar, North Dinajpur, South Dinajpur, Malda and parts of Darjeeling District.
- The South Bengal Alluvial Plain consisting of the Eastern parts of Birbhum, Bankura, Midnapore, Burdwan districts and the districts of Howrah, Hugli, Nadia and Murshidabad. Except for their coastal regions, the Districts of South and North 24 Parganas are also within this zone.
- The coastal plain comprising of the coastal areas of Midnapore, South 24 Parganas and North 24 Parganas Districts.
- The Western Bengal Undulating Upland consisting of the western parts of Birbhum, Bankura, Midnapore Districts and all of Purulia District. The western part of Burdwan has similar soil characteristics.

Mishra (1994) divides the year into four seasons: Winter (December to February), summer (March to May), monsoon (June to September) and retreating monsoon (October and November). These roughly correspond to the three principal agricultural seasons: summer with pre-Khariff, Monsoon with Khariff and retreating monsoon and winter with Rabi.[25] The annual rainfall is generally quite high but varies significantly across the state. Annual rainfall in the drier parts of the western districts is around 130 mm, while that in the south facing slopes of the Himalayan hills in Darjeeling and Jalpaiguri districts it can range from 400mm to 500mm. Further, much of the annual precipitation is confined to

[25] One has to be a bit careful here. Temperatures differences may be quite significant across physiographic zones so that the correspondence of crops to calendar months stated above may not be very accurate for all zones. For example, boro planting and harvest in Jalpaiguri district occurs much later than in Barddhaman.

the five months from June to October (80-90 percent) and the rest is distributed over the remaining five months. There are several large and small rivers running through the state. Some like the rivers Ganga, Bhagirathi, Rupnarayan and Teesta transport large volumes of water throughout the year while others are primarily seasonal and carry large volumes of water only during the monsoon.

Most of the precipitated water is wasted as runoff through the torrential rivers that feed the perennial rivers. In the northern part of the state, part of the precipitation, however, finds its way into the local underground aquifers through fissures and joints in the hard rock terrain and spreads southwards through hydrologically continuous aquifers. The North Bengal Hill Zone and the North Bengal Alluvial Plain and Fan Zone serves as a groundwater recharge zone for the deeper aquifers lying further south. South of the river Ganga, the eastern segment of the Western Bengal Undulating Upland serves as the recharge zone for the deeper aquifers lying to the east. In Murshidabad and Nadia districts, across the river Bhagirathi, a 150 meter deep granular sediment occurs from the surface downwards. Here the groundwater occurs under unconfined condition and the region serves as the recharge zone for the aquifers lying to the south.[26] [27]

[26] This paragraph is based on Mishra (1994) and Goswami (1995).

[27] Todd (2001) provides a comprehensive and easily understandable introduction to groundwater hydrogeology.

4. Village Case Studies

In this section we present case studies of moujas. The first mouja is in Nadia District. The story of this mouja reveals the impact of state investment in groundwater irrigation on cropping patterns and on private investment in irrigation. In a more general sense, it provides an example of the role of successful state intervention in irrigation in fostering agricultural growth and in inducing "copy-cat" private investment in irrigation where the state owned irrigation facilities are unavailable. The next two moujas are located in Burdwan district: Bhadai mouja is located in Manteswar Block and Banagram Mouja is located in the laeteritic areas of Kanksa Block. The fourth mouja is located in Birbhum district on the southern bank of the river Mayurakshi. The Mayurakshi is a wide relatively shallow river that is almost dry throughout the year and floods every monsoon. The subsoil geology is peculiar in this area and the depth of the water Table fluctuates widely within very small neighbourhoods. This mouja is interesting because a few SMTWs are the only sources of irrigation for a relatively large area and command areas of the existing devices are unusually high. The geology of the area appears to be impeding entry of new groundwater extracting devices.

4.1 Hossainpur

Hossainpur is located in the South Eastern part of Nadia District, fairly close to the Indian border with Bangladesh. Nadia has a history of diversified cropping and Hossainpur is no exception. Unlike Bardhaman district, which lies to the west across the Bhagirathi River, or parts of Murshidabad district, which lies to the north, farmers in Nadia have not faced water stress caused by declining groundwater levels. Public investment in irrigation facilities in the late sixties, together with aggressive state funded extension, led to a rapid expansion of acreage under HYV summer paddy. This is one of the villages where the state's role in promoting adoption of HYV summer paddy in the early part of the decade of the nineteen-seventies and in sustaining it over the later years through the provision of cheap irrigation is clearly manifest. It also highlights the demonstrative role of public groundwater based irrigation in promoting private investment in mechanised groundwater extraction devices for irrigation by farmers.

Hossainpur mouja has two villages: Hossainpur and Durgapur. It is located about 75 kilometers North-East of Kolkata. It is connected both by roads and railway to Ranaghat, the closest large town, which lies about 10-11 km to the west. The net cultivated area of the mouja in 2002-03 was around 165 hectares. A metalled road runs east to west through Hossainpur village and the land slopes downward gently on both sides of the road. The soil on the high grounds around the road is loamy and at the bottom of the incline is largely clay. In between lie the tracts of clay loam soil. The land on the northern fringe of the mouja is also relatively high, and on these too the soil is loamy. Overall, around 60 percent of the agricultural land has loamy soil and the rest varies between clay loam and loam. This means that for the most part, the moisture retention capacity of the soil is relatively high and the soil is ideal for the cultivation of a variety of crops. In the areas where the soil is heavier, the land is ideal for paddy cultivation. Up to around 1970, the main rain-fed crops were paddy, including the broadcast *aus* paddy, and jute. Even today, villagers refer to the high grounds as the *aus* land. The mouja has several tanks. These provided irrigation water for the main *rabi* crops: pulses and mustard.

In 2003-04, the area under boro paddy was around 75 hectares and that under wheat was around 6 hectares. In the Khariff season, HYV seeds have replaced the traditional varieties and oilseeds, pulses, vegetables (khariff and rabi) fruits and flowers are grown on a much larger scale than before. In 2003-04, pulses were cultivated on 10 hectares of land and mustard on another 8 hectares. A remarkable change in the cropping pattern is the rise in the cultivation of perishable crops like vegetables, bananas and flowers that today are cultivated on around 33 hectares. The expansion of vegetable, banana and flower cultivation is partially explained by the fact that the urban markets of Kolkata are within easy reach. This, however, is not a complete explanation because much of Burdwan district has similar access to Kolkata but there cropping patterns are not as diversified. The difference lies perhaps in the nature of the soil (loam) and the agricultural traditions of the Nadia and the region in general.

In 1968, the government installed a deep tube well (DTW), but cultivation using groundwater in the post monsoon season began in 1970 because people believed that use of groundwater would ruin the land. To induce use of groundwater from the DTW, the government provided free water and seeds. Major flooding in 1971 led to severe damage of the standing Khariff paddy crop and the residents, faced with a serious shortage of food grains, cultivated wheat on a fairly large scale in the *rabi* season that followed. This may have helped reduce fears about cultivation of cereals in the post monsoon season because from 1972-73 cultivation of summer paddy (*boro* paddy) expanded rapidly. In 1971-72 the area under wheat cultivation was around 4 hectares and that under summer paddy was less than 2 hectares. By 1973 the latter had increased to around 7 hectares. From 1972, there was a sharp drop in the cultivation of mustard and pulses. These crops were replaced by cultivation of wheat and vegetables. There was no conflict between summer paddy and wheat cultivation since *boro* was cultivated using groundwater from the DTW on the lower lying clay and clay loam fields. Traditionally, these fields were used for the cultivation of paddy in the monsoon season and were left fallow in the post monsoon period. These fallow lands were used for grazing cattle from mid January till mid June when the monsoon arrived. Wheat was cultivated on the relatively higher areas. By 1977-78 the area under wheat cultivation had declined from a high of around 20 hectares to less than 3 hectares. Local farmers claim that the reason was that the profits from wheat cultivation were declining. What probably happened was that profits from cultivation of vegetables, flowers and fruit like banana were rising so that land on which wheat was grown was used to cultivate these crops.

In 1974, cluster shallow tube-wells and mini-deep (submersible pump) tube wells were introduced in the mouja under a CADC project scheme. This project was completed by 1980. Today most of the land in the mouja is irrigated by water from one of the state funded groundwater irrigation schemes. In the areas that lie outside the command areas of these schemes, farmers have installed shallow tube-well pump-sets (STW). Unlike the government funded machines, which run on electricity, these machines are often diesel operated. In these areas, markets have emerged for supply of groundwater: owners of STWs sell the water they extract from the aquifers to farmers who cultivate land in the neighbourhood of their wells. Often, they rent in the land for a season and pay the landowner in cash or in kind. Contractual forms for the supply of water vary depending upon the crop. At present, the charge is Rs 40 per hour of water supply for vegetables and Rs. 6000 to Rs. 7500 per hectare for supply of water for the entire season for *boro* paddy. Plots that have higher clay content in the soil require lower levels of water supply during the season than the ones with lighter soil. This is one reason for the difference in the rates charged for seasonal contracts. Another reason could be that the nature of competition among water sellers differs at different locations within the same mouja.

Beneficiary committees manage the DTW and the CADC shallow and submersible pump tube-wells. In June 2003, the West Bengal State Electricity Board (WBSEB) raised charges for supply of electricity and, thereafter, the rates charged by the committees for the supply of water were increased. Even though these rates are significantly higher than the rates charged the year before, they are much lower than the rates charged by the private suppliers of water. The charge for supply of water for the entire season is Rs. 2015 per hectare for Boro paddy; Rs. 504 per hectare for aman paddy and wheat; Rs. 378 per hectare for mustard; Rs. 250 per hectare for pulse; and Rs. 865 per hectare for vegetables. The year before, these charges were less than one third of the current rates.

In the next subsection we look at a mouja in Burdwan District where, as in Hossainpur, the last thirty years have witnessed a rapid change in the pattern of agricultural activity. There are two remarkable differences: first, there is very little crop diversification and second, the investment in irrigation facilities is fully private.

4.2 Bhadai

Bhadai mouja is located in Manteswar Block of Bardhaman District. This region has heavier soils with higher water retention capacity. Traditionally, this is a paddy growing area. Bhadai is located about a kilometer off the road that links Bardhhaman and Nabadwip. The closest market town is Kusumgram, which is located about six kilometers to the east. The village is situated on the higher ground where the soil is of the more porous sandy loam type. To the north, west and east of the main village, the ground slopes sharply downwards into the relatively flat loam and clay areas that constitute the main agricultural area of the mouja, and then slopes upward towards the high grounds of the adjoining moujas. The mouja is bounded on its western side by the river Khari. Local residents claim that the river is dying largely because groundwater levels have fallen along its entire course so that the lateral flow of groundwater that used to feed the stream has dropped over the years. To the south, the soil is sandy loam and the fields are at the same level as the village. The total agricultural area of the mouja is around 120 hectares of which 40 percent has sandy loam soil, 10 percent has loamy soil and the rest is clay. Almost all of the agricultural land is used for the cultivation of khariff paddy during the monsoon. Supplementary irrigation is provided by lifting water from tanks, the river and mainly by the private STW and SMTWs that are located in the mouja. After the monsoon season, the main crop is summer paddy. In 2003-04 the area under this crop was around 94 hectares. Oilseeds and pulses were cultivated in the high grounds around the village, but the area under these crops hovered around 10 to 12 hectares. The area under wheat and potatoes was less than 10 hectares.

Up to the end of the nineteen sixties, and to a great extent for several years thereafter, the fields of the village lay empty from late January till early June. Agricultural activity began in late May with the planting of broadcast *aus* paddy in the low-lying lands near the river. Transplantation of *aman* paddy began in early July and continued through late August. In the low-lying areas around the river, *khesari*, a type of pulse, was intercropped with the *aman* paddy. The *aus* paddy crop was harvested in the month of September. Harvest of the *Aman* paddy crop began in mid December and continued till late January. Over the next few months, ponds were drained and desilted. The silt was spread on the surrounding land.

In the late nineteen-sixties boro cultivation was introduced in the village. Public investment in extension of summer paddy cultivation was limited to providing subsidized fertilizers and diesel pump-sets. A sub-canal of the Damodar Valley Corporation's (DVC) canal network runs through Sijni mouja, which adjoins Bhadai, and a DTW was installed there by the state government around 1973-74. Water from these sources does not reach the agricultural lands of Bhadai mouja. The first three persons, who cultivated boro paddy in the village, planted the Taichun variety of paddy on plots located near the river. Irrigation was provided by lifting water from the river Khari using diesel operated pump-sets provided by the government at subsidized prices. The Taichun variety of paddy was prone to pest attacks and in the early nineteen-seventies a new variety, IR8, was introduced. By the late nineteen-seventies, the river had started drying up and given the scale of boro cultivation along its banks, it was no longer a reliable source of irrigation for boro paddy. Two of the early adopters of boro paddy in the mouja, perhaps inspired by the success of boro cultivation using groundwater in the neighbouring Sijni mouja, installed STWs in 1974. Installation of diesel STWs peaked in the late nineteen seventies and the last STW was installed in 1985. From the beginning, STW owners were primarily interested in renting in land in the command areas of their machines during the boro season. The sale of water was largely done in the khariff and rabi seasons. However, sale of water to other cultivators did occur and may have increased as farming households with smaller amounts of land and other resources started entering the business. In many cases, the money received by the owner of the STW as advance payment for the supply of water during the boro season, was used to finance his own cultivation.

Around 1983-84, the government installed electrical lines and electrical connections were given to STWs located near the river. The diesel STWs in this area were replaced by electrically operated machines around this time. By the mid nineteen-eighties, the pattern of cultivation in the mouja had changed dramatically: summer paddy cultivation had become a regular and important part of agricultural activity. The expansion of cultivation of summer paddy not only in the mouja, but also in much of Manteswar and its adjoining blocks during this period, led to a fall in the groundwater level in the post monsoon months. In many areas, STWs could no longer be relied upon to provide an adequate supply of water in the critical months of April and May. Groundwater levels had declined to a great extent by the late nineteen eighties and STW owners had to dig deep pits into which the STWs were lowered to draw the groundwater. The walls of these unlined pits often collapsed causing damage to the machines, and sometimes, fatal injuries. The first electrically operated SMTW was introduced in Bhadai Mouja in 1984. Within a few years, all the electrically operated STWs were replaced by submersible pump-sets and five of the existing diesel operated STWs were replaced by diesel run submersible pump-sets. Around 1991-93 there was a rapid increase in the number of submersible pump-sets installed in the mouja. Many of the new investors were small landowners who were attracted by the high profits that could be earned from investment in groundwater extraction mechanisms if the paddy prices remained at the current levels. In March 2004 there were17 of which 7 are diesel operated. Low voltage problems forced owners of the electrically operated machines to maintain back-up generators or to rent them in critical phases of the cropping season.

Apart from this, a new technology for extracting groundwater is becoming popular. A 5hp pump is placed at the base of a lined dug well like structure and is driven by a 5 or 10hp diesel operated machine placed on the surface with the aid of a drive belt. The cost of installation of these devices is around Rs. 30,000 which is less than half the installation cost of a diesel operated SMTW. Operating costs are also half that of an SMTW and local cultivators tell us that the level of performance of these machines is at least as good as that of SMTWs. In March 2004 there were 5 such devices in operation in the mouja of which the oldest was installed three years ago.

In 2003-04, the rates charged for the supply of water in the boro season were Rs. 7,500 per hectare (Electric SMTW), Rs. 12,000 (Diesel SMTW and the new devices). What is interesting is that even though the operational costs of these new machines are about half that of the diesel SMTWs the rates are the same leading to the suspicion that rates are fixed by collusive agreements between sellers. What is important is that renting in land by the owners of groundwater extracting devices far outweighs water sale. The rental rate for land during the boro season was 1200 kg. per hectare irrespective of land quality [28] [29].

[28] A plot that requires twice as much fertilizer as another commands the same rate as the superior plot.

[29] A resident of the village who owns one of the newer devices agreed that he charged the same rate as diesel SMTW owners because he wanted to rent in land rather than sell water. He agreed that water rates were fixed so as to induce landowners to rent out the land for the season. Casual conversations across moujas where land renting dominates water sale often lead to the same assertion. We are unsure about the validity of the claim largely because land renting dominates water sale in many moujas with electric

For supplementary irrigation in the khariff season, the rate for sale of water is Rs. 1500 per hectare irrespective of the type of machine used. In this season water sale far outweighs renting in land by the owners of groundwater extraction devices. There is a consensus of opinions that owners of groundwater extraction devices tacitly divide up "service" areas and rarely encroach upon the areas of others. Over the years, however, as new entrants installed SMTWs, command areas were reallocated among neighbouring machines to avoid inefficient price wars or other forms of violence. Incumbents for the most part allowed entrants to operate in part of their command areas. In this particular mouja political tensions are particularly high -- simple disputes can lead to politically polarized aggressive behaviour -- so the panchayat and local politicians often have to intervene to settle disputes over entry of new SMTWs.

4.3 Bangram

Bangram is a small mouja located to the south of the flood prone river Ajay that forms a boundary between Burdwan and Birbhum districts. Access to this village is difficult through a road that runs off the Panagarh-Moregram highway, a few kilometers south of the river. The road passes through vast stretches of rough, empty terrain where the soil is red and coarse, and villages are few and far between. Much of the land in the mouja is under forest cover and virtually no cultivation occurs here. Cultivation takes place in those areas where the soil is relatively fertile and less porous, and water is available. The mouja has a total area of about 98 hectares but only about 14 hectares is cultivable. Of the 14 hectares, 60 percent is laterite and the rest is sandy loam with a high sand content. The water Table is very low and even in the months immediately after the monsoon, groundwater is available at 105 feet. There are no government funded irrigation schemes in the mouja, and the residents view attempts at extraction of groundwater for cultivation as futile and foolish exercises. Most residents would not have been able to afford the expenditure in any case.

SMTWs where the water rates are relatively low by general standards. In any case we have not been able to come up with a foolproof test to accept or reject this hypothesis

Virtually no cultivation occurs in the mouja where the 70 odd SC and ST and a few families belonging to other castes eke out a living by cultivating land in neighbouring moujas where soil conditions are better and STWs are used for irrigation. Many of these families had land in nearby Masna mouja where the soil was sandy loam and groundwater levels were high. The floods in October 2000 deposited large amounts of sand in Masna mouja and today half of the old cultivable area is covered with a deep layer of sand.

While Banagram mouja has some extreme features it is not pathological. We present this example simply to show that in areas where soil and groundwater conditions are similar the reasons for non-occurrence of the agrarian transformation are clear. In vast areas of Western Birbhum, Burdwan, Bankura, Midnapore and Purulia districts where soil conditions are similar, groundwater levels are very low, or hard rock impedes the search for groundwater both by the state and by private farmers, life is not very different. We also very deliberately selected a mouja close to a relatively large river to highlight the fact that proximity to rivers does not guarantee the existence of private groundwater extraction: soil and other geo-physical features matter.[30]

4.4 Shaktipur

Shaktipur is located in the north-eastern part of Suri I Block of Birbhum district. The river Mayurakshi runs along its northern periphery. The land across the river lies in Mohammad Bazaar Block. The terrain here is undulating and soil types vary widely. Near the river the soil is sandy loam with a high sand content. The sand content declines as one moves southwards on to higher ground. Further south and to the southwest lie the low lying fertile clay and loamy soil areas that constitute the primary paddy growing areas of the mouja. The Mayurakshi, like the river Ajay, is flood prone. In October 2000 heavy flooding led to the deposition of a deep layer of sand along the low lying north-eastern edge of the mouja. Large tracts of fertile cultivable land were turned to barren sand flats overnight. Along the south-eastern part of the mouja lies a large wetland (*beel*) whose

[30] This assertion is supported by our econometric findings as we shall see in Section 7.

total area is about 80 hectares. A sub canal runs west to east along a raised spine down the centre of the mouja and turns northward toward the river near the mouja's eastern edge. No water is available from this canal even in the khariff season and SMTW owners use it for the transport of groundwater during the boro season.

The subsoil geology in this mouja is peculiar and acts as a physical entry barrier for new groundwater extraction devices. All the six SMTWs that are located in this mouja [31] lie clustered in a small area in the north-eastern fringe by the river. The water Table in this mouja is very low and lies at depths well over a hundred feet from the surface. The depth of the water Table fluctuates widely across the mouja. What makes things worse is that in many areas in the mouja, investors prospecting for water were confronted by a peculiar spongy soil lying at depths of about 120 feet through which they were unable to bore further.

The agricultural area of the mouja today is about a hundred hectares of which a significant portion is highland that is not suitable for the cultivation of summer paddy or any other crop that requires irrigation because water cannot be transported there from the SMTWs. There are several large tanks in the mouja that are used to irrigate the rabi crops and to provide supplementary irrigation in the khariff season. In 2003-04 around 35 hectares were used for boro cultivation[32] and another thirty five for the cultivation of potato, sugarcane, mustard and other oilseeds (*til*), wheat and sundry vegetables.

Between 1978 and 1982 the government provided STWs on a loan-cum-subsidy scheme to local farmers and in 1985 eight STWs were provided by the local panchayat under a loan-cum-subsidy scheme. Most of these were abandoned within a few years. Local farmers recall that even in the period 1985-89 summer paddy was cultivated on around 3 hectares of land. From 1990 as paddy prices rose, boro cultivation expanded. The first SMTW was installed in 1990 and water was transported southward along a field channel

[31] Two of these six are used to irrigate lands lying in the neighbouring Parsimulia mouja which does not have any STWs or SMTWs

[32] Local residents claim that the area under boro paddy has declined in the mouja. This is clearly true in the adjoining mouja because the SMTWs that supplied water there did not operate this season as (according to local residents) their owners anticipated some difficulties with the State Electricity Board.

to the sub-canal through which the canal flowed eastward. The second SMTW was installed within a few years on a plot west of the first SMTW and was used primarily to supply water to the owner's own plots and those of other cultivators that lie on the western part of the mouja, north of the canal. Two other SMTWs were installed thereafter, the last in 2002. Interestingly, the third SMTW was installed by the person who had installed the first SMTW in the mouja, and the last one by the other SMTW owner. These four electrically operated and completely privately funded[33] SMTWs are the only sources of irrigation in the mouja other than the tanks and the beel. Around the mid nineteen nineties, SMTW owners installed permanent channels for the transportation of water across the mouja. The first SMTW owner built a raised drain that allows him to use the gravitational flow to transport water across the canal and into the areas further south. The second SMTW owner installed underground pipes that allow him to transport water to the canal.[34] Around this time a major reallocation of command areas took place between the two households as they exchanged delivery areas. The family of the first SMTW owner now supplies water in the northern part of the mouja and in the southern part across the canal. The second SMTW owner now supplies water all along the western part of the mouja above the canal (and to some extent below it) and along a band around the canal along its entire length. In the summer of 2004, the family of the first SMTW owner supplied water to around 21 hectares of land and the other SMTW owner to the rest. The SMTW owners own a fair proportion of the land irrigated by these SMTWs the way the command areas were reallocated was determined partially by the location of these plots. The rest of the water was sold at prices ranging from Rs. 4100 to Rs 4350 per hectare depending on the distance of the plot from the SMTW. It is worth noting that in Shaktipur mouja water sale has always been a part of the activity of SMTW owners and the practice of renting in land by them is virtually, if not completely, absent.

[33] Both the families have relatively large landholdings and at least one has business interests that

[34] The soil in the zone lying between the canal and the SMTW is relatively porous and seepage losses are high. This is a major reason for installing the pipe. The installation of the pipe may have also served as a credible signal that this SMTW owner was thinking about expanding his domain of operation., perhaps at his competitor's expense.

4.5 General observations

Till the late nineteen seventies, much of the agricultural land of the state was mono-cropped. Rabi cultivation occurred in areas where some amount of water was available for irrigation from rivers and tanks, and around the low-lying areas known as *beels* that flooded during the monsoon and retained the accumulated water for several months thereafter. In many flood-prone low-lying areas in the state, paddy cultivation on a large scale started only after the introduction of HYV summer paddy. In the years before the introduction of HYV summer paddy, long stem local varieties were cultivated in flood prone areas and in many areas where flood problems were particularly acute, e.g. the beel areas of Haskhali block of Nadia District, elderly residents can recall the cultivation of floating rice. In other flood prone areas like the parts of Krishnanagar I block of Nadia district lying along the river Jalangi, cultivation of rabi crops was the principal agricultural activity.

The introduction of irrigation facilities for the post monsoon crops created the environment for expansion of area under cultivation for both the rabi crops and the more water intensive crops like wheat and summer paddy. The story of Hossainpur mouja highlights the role of state funded investment in irrigation on the expansion of post monsoon cultivation. It also indicates that the success of these schemes may have induced the sharp rise in investment on private groundwater irrigation facilities in areas where water was not available from the state owned schemes. Studies of moujas that lie within and or near the command areas of state run canal and river lift irrigation schemes yield similar findings. A plausible conclusion then is that governmental investment in irrigation facilities, including the promotion of groundwater extraction for agricultural use by subsidizing investment on private shallow tube-wells and pump sets, may have had a large role in fomenting the rapid diffusion of private investment in groundwater irrigation across the state.

The stories of Bhadai and Shaktipur moujas capture the experiences of moujas where direct public investment in irrigation facilities has been limited or imperfect. It highlights the role of private investment in irrigation facilities and the emergence of markets for water extracted from underground aquifers. This is important because this aspect of irrigation in West Bengal has been largely ignored or downplayed in official or academic discussions on the subject of agrarian change in the state. For us, the story of the agricultural metamorphosis in West Bengal over the last three decades is inextricably linked with private investment in groundwater extraction mechanisms and the emergence and evolution of groundwater markets. The stories of Bhadai, Bangram and Shaktipur moujas also introduce some complications that may be missed by researchers who work on smaller scales: variations in geophysical conditions within relatively small geographical areas can lead to significant variations in the intensity of investment in groundwater extraction mechanisms and in the patterns of competition among STW and SMTW owners. There remains one question to which we do not have an answer: why are the rates for supply of water in Shaktipur mouja relatively low[35] despite that fact that there are only two water sellers? One answer could be that the sellers have coordinated on a price that discourages attempts to enter the market; another could be that social pressures discourage them from charging prices that would be seen as being "unfair".

[35] See Section 4.2.

5. Methodology

To study groundwater markets in the state, the first step, we believe, is to identify the areas where groundwater serves as a source of irrigation. The next step is to classify these areas in accordance with the importance of this source of irrigation among all sources. The third step is to identify areas where groundwater markets exist. The final step is to select and study a sample of villages to answer the kinds of questions that are of interest to us but which cannot be answered by using secondary data.

I. Assembly of data related to surface irrigation and groundwater irrigation in West Bengal from:

1. Published government data and data collected by non-governmental organizations and individual researchers.

2. Interviews with governmental functionaries and Panchayat Members.

3. Large scale field surveys across various districts of West Bengal.

II. Development of theoretical models to generate testable hypotheses that will be empirically tested using the data collected. The econometric methods that will be used to explain choices between different options by buyers / sellers are logit or tobit which are appropriate for the qualitative and dichotomous dependent variables. The tobit or logit regression will further be combined with conventional regression to analyse the problem in greater detail. In order to find out the right econometric model we tried with alternative model specifications. The regressions exercises can be divided into two broad groups – **mouja level regressions** and **household level regressions**. As already mentioned all the regression exercises are done with our survey data. For mouja level we surveyed 992 moujas and complete enumeration household surveys were conducted in thirty moujas spread across agro-climatic zones. Out of these 992 moujas we could use 886 observation units because the data for the remaining 110 units were found to be either incomplete or found to be reported with suspicious values for some of the variables. A total of 10229 household units were enumerated in the 30 moujas of which we could use 6995 observations for econometric exercises spread in 18 moujas. The household data for the remaining 12 moujas could not be used as the corresponding mouja level survey data were not available for the reasons stated before, or because the corresponding moujas were not surveyed. But we utilized household data on all the moujas for the general discussions. However, it may be noted that the apparent problem associated with a small set of moujas for household survey is overcome with a very large number of observations on households spread across different regions of West Bengal.

The objective of the econometric exercise centres around one primary theme:
Why does private investment in groundwater extraction mechanisms occur in some regions and not in others? Even when it exists in a particular region, investment by different households depends upon household specific factors. The most appropriate dependent variable for our purpose is the existence or non-existence of private investment in groundwater extraction at the mouja level and whether a household unit invests in groundwater extraction mechanism or not. Thus the dependent variable is best captured as a qualitative variable. Thus *probit* or *logit* regressions are the most appropriate method for our case. As the cumulative normal distribution and the logistic distribution[36] are very close to each other except at the tails, we are not likely to get very different results with either of them[37]. Throughout this study we have used logit regressions. In addition we also estimated some of the econometric models by OLS methods with an appropriate dependent variable.

We briefly describe the regression methodology of qualitative dependent variables. Consider a dependent variable y, which takes a value 1 if the event of importance occurs and 0 otherwise. The assumption that y is binary is a simplification. In the probit and

[36] For probit model the disturbance term is assumed to be normal while it is assumed to be logistic for the logit model.
[37] But the estimates of regression coefficients β_j s from the two methods are not directly comparable, because the logistic distribution has a variation $\pi^2/3$. Hence the estimates of β_j s obtained from the logit model have to be multiplied by $3^{1/2}/\pi$ to be comparable to the estimates obtained from the probit model. Amemiya (1981) suggested logit estimates be multiplied by 0.625 instead of $3^{1/2}/\pi$ as this transformation gives a better approximation. However, in the case of conditional probability the model estimates vary.

logit methodology it is assumed that there is an underlying response variable y_i^* which is defined by the econometric relation:

$$y_i^* = \beta' x_i + u_i \tag{1}$$

where y_i^* is unobservable and x_i is the vector of explanatory variables for i [th.] observation. The econometrician observes a dummy variable y, defined by:

$$\begin{aligned} y_i &= 1 \text{ if } y_i^* > 0 \\ &= 0 \text{ otherwise.} \end{aligned} \tag{2}$$

In this case $\beta' x_i$ is not $E(y_i | x_i)$ but $(y_i^* | x_i)$. From (1) and (2) we get

$P(y_i = 1) = P(u_i > -\beta' x_i) = 1 - F(-\beta' x_i)$ where F is the cumulative distribution function for u_i. Thus the likelihood function is

$$L = \prod_{y_i=0} F(-\beta' x_i) \prod_{y_i=1} \left[1 - F(-\beta' x_i)\right] \tag{3}$$

The functional form for F in (3) will depend upon the distribution of u_i. In the case of probit model we assume that $u_i \sim N(0, 1)$, iid. Thus,

$$F(-\beta' x_i) = \int_{-\infty}^{-\beta' x_i} \frac{1}{(2\pi)^{1/2}} \exp\left(-\frac{t^2}{2}\right) dt\,.$$

If u_i is assumed to have a logistic distribution, the resultant model is logit. In this case,

$$F(-\beta' x_i) = \frac{\exp(-\beta' x_i)}{1 + \exp(-\beta' x_i)} = \frac{1}{1 + \exp(\beta' x_i)}\,.$$

The maximization of the likelihood function in (3) is achieved by any standard numerical optimisation technique. We used the Newton-Raphson method. We do not describe the OLS technique here, as it is quite well known.

III. Indirect establishment of the presence of tacit collusion through a study of methods used to support tacit collusion in a manner similar in spirit to that used by Genesove and Mullin (2001). This will require detailed interviews of sellers, buyers and non-participants in the groundwater markets village by village.

6. Patterns of Private Investment in Groundwater Extraction: Variations across space

In this section we present a largely descriptive analysis of the geographical spread of privately owned STWs and SMTWs, and their importance as sources of irrigation in different cropping seasons, on the basis of our survey. As we saw in Section 2, cultivation of Khariff paddy is the most important (in terms of area under cultivation) agricultural activity in West Bengal and that there has been a large scale shift away from traditional varieties to HYV seeds and technology. It follows then that the availability of supplementary irrigation facilities to tide over phases of scarce rainfall during critical stages in the cropping season is of great importance. In the post monsoon season, cultivation of wheat, vegetables and summer paddy require large doses of controlled irrigation unlike other rabi crops like oilseeds and pulses. Thus the current levels of cultivation of the water intensive crops like summer paddy are possible only because of the availability of water from the state and privately owned irrigation facilities.

Table 6.1 presents the block wise distribution of moujas in our survey area where Khariff paddy, summer paddy and wheat are cultivated. Since our survey covered a very large proportion of moujas within each block that we studied, the data very closely reflects the pattern of cultivation of these crops in these blocks. The Table shows that all three crops are cultivated in a very large proportion of the moujas surveyed. What the Table does not show is the relative importance of these crops (in terms of the area under cultivation as a proportion of the cultivable area) in these moujas. Our survey shows that in almost all the moujas, khariff paddy is cultivated in a very high proportion of the cultivable area and except for some blocks – Beldanga I, Muraroi I – wheat is cultivated in less than 10 percent of the cultivable area in these moujas.

Table 6.2 takes a closer look at the scale of boro cultivation in the moujas in our sample. At the lower end are blocks like Dhupguri in Jalpaiguri district, Muraroi I in the north-western part of Birbhum district and Suri I in the west-central part of the same district, where less than 20 percent of the cultivable area is used for boro cultivation in

Table 6.1: Block-wise distribution of moujas by crop cultivation: Khariff Paddy, Summer Paddy and Wheat

Block	No. of moujas in Sample	Number of moujas where		
		Khariff Paddy is cultivated	Summer Paddy is cultivated	Wheat is cultivated
Kalna-I	81	81	80	49
Kanksa	36	36	30	33
Galsi-I	60	60	59	53
Manteswar	83	83	83	63
Beldanga-I	53	53	48	53
Ranaghat-II	116	116	116	110
Krishnanagar-I	94	94	94	93
Suri-I	108	107	64	101
Suri-II	78	78	76	78
Sainthia	172	172	149	165
Muraroi-I	84	84	54	83
Dhupguri	27	27	26	27
Total	**992**	**991**	**879**	**908**

Source: Survey data

Table 6.2: Area under summer paddy cultivation as a percentage of net cultivated area by block

Block	Area under Summer Paddy cultivation as a percentage of net cultivated area										
	No. of Boro cultivated moujas	**0-10 %**	**11- 20 %**	**21- 30 %**	**31- 40 %**	**41- 50 %**	**51- 60 %**	**61-70 %**	**71- 80 %**	**81- 90 %**	**91- 100 %**
Kalna-I	80	13	6	20	21	9	3	6	2	0	0
Kanksa	30	11	4	1	5	2	2	2	1	1	1
Galsi-I	59	0	0	1	0	5	1	2	7	12	31
Manteswar	83	0	0	4	6	10	7	12	19	12	13
Beldanga-I	48	7	9	12	8	7	3	2	0	0	0
Ranaghat-II	116	1	1	16	34	28	21	6	4	5	0
Krishnanagar-I	94	1	8	11	27	21	8	9	4	3	2
Suri-I	64	29	19	6	1	2	3	2	1	1	0
Suri-II	76	5	5	17	4	6	11	12	10	5	1
Sainthia	149	31	30	23	15	12	11	8	8	9	2
Muraroi-I	54	27	13	4	3	2	3	1	1	0	0
Dhupguri	26	20	5	0	1	0	0	0	0	0	0
Total	**879**	**145**	**100**	**115**	**125**	**104**	**73**	**62**	**57**	**48**	**50**

Source: Survey data

most moujas and in a large number of moujas summer paddy is not cultivated. At the other end are Galsi I and Manteswar blocks of Burdwan district where the crop is cultivated in more than 60 percent of the cultivable area in most moujas. It is worth noting (we shall see this in greater detail a bit later) that in Galsi I block, reliable and adequate canal irrigation is available in most moujas, and in Manteswar block, boro cultivation is possible largely because of the high level of private investment in groundwater extraction devices. In between these two extremes lie blocks like Ranaghat II and Krishnanagar I of Nadia district, and Suri II and Sainthia blocks of Birbhum district, where summer paddy is cultivated in 20 to 60 percent of the cultivable area in most moujas. Overall, however, boro paddy is cultivated on less than 50 percent of the cultivable area in 67 percent of the 879 moujas in our sample in which this crop is grown.

Tables 6.3-6.5 provide a rough idea of the importance of private groundwater irrigation in the cultivation of Khariff paddy, wheat and summer paddy. Privately owned STWs and SMTWs are used to provide supplementary irrigation in the Khariff season in 49 percent of the 991 moujas where khariff paddy is cultivated. The role of these devices is larger during the rabi season and in the summer. Privately owned STWs and SMTWs are used for irrigation of summer paddy in 77 percent of the 879 moujas where summer paddy is cultivated; and for irrigation of the wheat crop in 66 percent of the 908 moujas where wheat is grown. A closer inspection of these Tables reveals some important details. The number of moujas where only STWs are used exceeds the number of moujas where SMTWs are used (exclusively and in conjunction with STWs). However, the difference is not particularly large. This indicates that in a fairly large proportion of moujas in our sample, groundwater levels may already be below the critical level where STWs can be used to provide reliable and adequate irrigation in the critical peak summer months, and in the moujas where the two types of devices are both in use, groundwater levels may be falling below these critical levels at least in the late summer. In this last class of moujas, we may be observing the transition from STWs

Table 6.3: Block-wise distribution of moujas where Private Groundwater irrigation is available for Khariff Paddy cultivation

Block	Number of moujas where			
	Only private STWs are used	**Only private SMTWS are used**	**Both are used**	**Total**
Kalna-I	9	41	15	65
Kanksa	6	0	0	6
Galsi-I	14	0	1	15
Manteswar	2	33	21	56
Beldanga-I	42	1	7	50
Ranaghat-II	109	1	2	112
Krishnanagar-I	91	1	1	93
Suri-I	11	4	0	15
Suri-II	2	0	1	3
Sainthia	11	14	35	60
Muraroi-I	0	0	0	0
Dhupguri	7	0	0	7
Total	**304**	**95**	**83**	**482**

Source: Survey data

Note: A mouja where private STWs or SMTWs pump sets are used may or may not have sources of irrigation owned by the government. The word "only" is used in column 2 to indicate that SMTWs are not used in these moujas and in column 3 to indicate that STWs are not used in these moujas.

Table 6.4: Block-wise distribution of moujas where private groundwater irrigation is available for Wheat cultivation

Block	Number of moujas where			
	Only private STWs are used	**Only private SMTWs are used**	**Both are used**	**Total**
Kalna-I	5	17	3	25
Kanksa	18	0	0	18
Galsi-I	35	0	1	36
Manteswar	4	23	4	31
Beldanga-I	47	0	6	53
Ranaghat-II	104	1	3	108
Krishnanagar-I	91	0	1	92
Suri-I	17	13	2	32
Suri-II	15	4	4	23
Sainthia	41	41	30	112
Muraroi-I	13	26	9	48
Dhupguri	26	0	0	26
Total	**416**	**125**	**63**	**604**

Source: Survey data

Note: A mouja where private STWs or SMTWs pump sets are used may or may not have sources of irrigation owned by the government. The word "only" is used in column 2 to indicate that SMTWs are not used in these moujas; and in column 3 to indicate that STWs are not used in these moujas.

Table 6.5: Block-wise distribution of moujas where Private Groundwater irrigation is available for Summer Paddy cultivation

Block	Number of moujas where			
	Only private STWs are used	Only private SMTWs are used	Both are used	Total
Kalna-I	12	42	10	64
Kanksa	19	0	1	20
Galsi-I	26	0	3	29
Manteswar	1	43	31	75
Beldanga-I	37	3	6	46
Ranaghat-II	110	1	3	114
Krishnanagar-I	92	0	1	93
Suri-I	17	5	2	24
Suri-II	22	2	8	32
Sainthia	21	53	45	119
Muraroi-I	8	29	10	47
Dhupguri	17	0	0	17
Total	**382**	**178**	**120**	**680**

Source: Survey data

Note: A mouja where private STWs or SMTWs pump sets are used may or may not have sources of irrigation owned by the government. The word “only” is used in column 2 to indicate that SMTWs are not used in these moujas; and in column 3 to indicate that STWs are not used in these moujas to SMTWs.[38] There is also the possibility – as in parts of Birbhum district – that large variations in water table depths within the same mouja may explain the coexistence of both types of devices in the same mouja. Our survey indicates, however, that we are indeed largely observing a transition in technology in these moujas as STWs become increasingly unreliable due to falling water tables.[39]

The second thing that one can observe from Tables 6.3 and 6.5 is that in some blocks the number of moujas where STWs and SMTWs are used for irrigation increases as we move from the khariff season to the summer. In blocks like Galsi I and Suri II that lie near the head reaches of canal systems, adequate water is available for supplementary irrigation in most moujas.[40] In some parts of these blocks, however, sufficient water may not be available in the summer and so cultivators use STWs and SMTWs for irrigation during this season. On the other hand, blocks like Muaroi I and Manteswar are beset by the classic tail-end problem: canal water is available during the monsoon (at least in parts of the block) but the flow of water drops sharply in the rabi season and in the summer. Thus, cultivation in these parts of the year is almost fully dependent on groundwater extraction. Beldanga I, Krishnanagar I and Ranaghat II blocks are located in a geophysical region where groundwater recharge is high, and so STWs far outnumber SMTWs. State owned irrigation facilities are limited to DTWs, RLIs and cluster STWs, but the total command areas of these irrigation systems is small consequently, in these blocks, privately owned STWs are the primary sources of supplementary irrigation in the khariff season and for irrigation in the rabi season and in the summer in this blocks.

Dhupguri block in Jalpaiguri district has radically different geographical and hydro-geological features. The block is located in the Terai zone[41] where the soil moisture levels are high throughout the year and virtually no supplementary irrigation is required during

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[38] See Section 4.

[39] Notice that in Beldanga I (Murshidabad district), Ranaghat II and Krishnanagar I (Nadia district) use of SMTWs is virtually absent. The reason is that in these areas recharge is high and so the water tables in the different moujas do not fall below depths that are adequate for the use of STWs. See Section 3.

[40] In parts of some moujas, gradient problems prevent use of canal water for irrigation and so farmers use STWs or SMTWs for supplementary irrigation in the monsoon season.

[41] See Section 3.

the monsoon. In the rare instances when it is required, farmers use the numerous dug-wells and rivulets, or dig shallow pits that fill with water from the lateral flow of groundwater. Forests and tea gardens cover the northern and western parts of the block and even where there are no forests, the soil is often rocky. For the most part, the agriculturally advanced areas of the block lie to the south and the southeast. Vegetables and potatoes are grown in the rabi season and the presence of soil moisture close to the surface means that very little irrigation is required.[42] Very little wheat and boro paddy is cultivated in most areas in the block even though relatively little irrigation is needed.[43]

Massive levels of government and donor agency investment on minor irrigation development have been made in the district. This includes the provision of subsidised or free electricity connections; electric motors and pump-sets to groups of farmers who install bore wells set in a close cluster. Others have received subsidised diesel operated pump sets. In Dhupguri many farmers have their own bore wells and rent the services of diesel operated pump-sets and plastic delivery pipes to draw water from the aquifer. Cultivators who do not own bore wells, rent the services of pump sets and delivery pipes, and draw water from bores owned by others. For local residents, renting out the services of equipment is a thriving business in some areas. The point worth noting in this digression is that in Jalpaiguri district, diesel-run pump sets do not remain fixed at a given location during a cropping season. Only the electrically operated sets remain fixed to a particular location, and that too because the electrical connection for the device is placed at a fixed location. This is why the question: "do you purchase water for irrigation?" elicits the automatic negative answer. People here rent in the services of groundwater extraction machinery and delivery pipes. They do not buy water. In that sense it is true that, as local residents claim, water markets do not exist in Dhupguri. A little introspection leads to the conclusion that even in the southern districts, people

[42] We have not been able to measure the exact amount of irrigation water required for the cultivation of these crops but local farmers and experts seem to believe that the irrigation required per hectare for potato cultivation in Dhupguri is less than one third of the irrigation required in Burdwan and Hooghli. We have not been able to verify this claim.
[43] One reason could be the low yield rates of these crops due to the nature of the soil, which is mainly of the sandy loam type and is acidic in content. Further, the decomposition rate of organic materials is low due to low temperatures and high rainfall.

actually rent in the services of groundwater extraction devices since the water is a common property resource and is not
owned exclusively by the owner of the STW or SMTW. The only difference lies in the fact that in the southern districts the pump and its driving equipment generally remain fixed to a bore throughout a cropping season.

The next question that we ask is: how does the area under state owned irrigation facilities fare in comparison with the area under irrigation by privately owned groundwater extraction devices in the moujas we have surveyed? We focus on boro paddy for two reasons: first, in West Bengal, the acreage under summer paddy exceeds that under all crops other than khariff paddy; and second, the crop requires high doses of irrigation. Tables 6.6 through 6.10 present the relevant data from our survey of moujas. In Table 6.6 we present the block-wise distribution of moujas classified by the percentage of agricultural area under boro paddy cultivation that is irrigated by privately owned STWs and SMTWs. This provides a first cut impression of the importance of private groundwater irrigation in the cultivation of summer paddy given the area under cultivation of the crop.

Table 6.6 reveals that in several blocks – e.g. Galsi I, Suri I, Suri II and Sainthia – the number of moujas where privately owned STWs and SMTWs are used for cultivation of summer paddy is significantly lower than the total number of moujas where this crop is grown. A major reason is that in the four blocks listed above canals are fairly reliable sources of irrigation in the summer in most moujas where the crop is cultivated. Since little irrigation is available from the state owned irrigation sources in the summer in Manteswar, Kalna I, Beldanga I, Krishnanagar I and Ranaghat II blocks, privately owned STWs and SMTWs provide the required irrigation for boro paddy in most moujas in these blocks. What the Table does not tell us is how important is the role of private groundwater extraction in supporting the expansion of boro cultivation in the blocks and moujas we have studied. Privately owned groundwater extraction devices may be the only sources of irrigation in all moujas of a block. If at most 5 percent of the cultivable area in each mouja is devoted to the cultivation of boro paddy, it is probably incorrect to say that private investment in groundwater extraction has had a serious impact on the expansion of boro cultivation in the block. This provides the rationale for the analysis in the rest of this section.

Table 6.6: Block-wise distribution of moujas by percentage of area under private irrigation during Summer Paddy cultivation

Block	**Percentage of total Summer Paddy cultivated area under private irrigation**											
	No. of moujas where Summer Paddy is cultivated	**0-10 %**	**11- 20 %**	**21- 30 %**	**31- 40 %**	**41- 50 %**	**51- 60 %**	**61-70 %**	**71- 80 %**	**81- 90 %**	**91- 100 %**	**No. of moujas where private irrigation is used**
Kalna-I	80	13	15	2	5	2	3	4	3	4	13	64
Kanksa	30	2	1	2	1	1	2	0	2	1	8	20
Galsi-I	59	8	5	2	1	3	2	3	2	2	1	29
Manteswar	83	0	0	1	1	1	2	4	5	7	54	75
Beldanga-I	48	0	0	1	2	4	1	2	2	1	33	46
Ranaghat-II	116	1	1	4	6	13	12	14	11	5	47	114
Krishnanagar-I	94	1	0	1	2	8	5	6	11	15	44	93
Suri-I	64	3	2	2	1	2	2	3	2	1	6	24
Suri-II	76	12	7	2	2	1	1	1	2	3	1	32
Sainthia	149	4	2	1	5	4	2	4	8	2	87	119
Muraroi-I	54	0	0	0	0	1	0	1	5	0	40	47
Dhupguri	26	2	2	2	4	3	1	0	1	0	2	17
Total	**879**	**46**	**35**	**20**	**30**	**43**	**33**	**42**	**54**	**41**	**336**	**680**

Source: Survey data

Note: Private irrigation sources comprise of STWs and SMTWs only. Government irrigation sources may exist at those moujas.

Table 6.7: Block-wise distribution of moujas where summer paddy cultivation isdone using irrigation from government sources only

Block	Area under Boro cultivation as a percentage of net cultivated area in moujas											
	No. of moujas where Summer Paddy is cultivated	0-10 %	11- 20 %	21- 30 %	31- 40 %	41- 50 %	51- 60 %	61-70 %	71- 80 %	81- 90 %	91- 100 %	Total
Kalna-I	80	1	4	3	4	1	0	1	0	0	0	14*
Kanksa	30	2	1	0	2	1	1	1	0	1	1	10
Galsi-I	59	0	0	0	0	0	1	1	4	3	21	30
Manteswar	83	0	0	0	2	0	1	2	0	1	2	8
Beldanga-I	48	0	2	0	0	0	0	0	0	0	0	2
Ranaghat-II	116	0	0	0	1	0	1	0	0	0	0	2
Krishnanagar-I	94	0	0	0	0	0	0	0	0	0	1	1
Suri-I	64	15	6	4	1	2	1	2	1	1	0	33*
Suri-II	76	2	2	10	4	3	5	6	8	4	0	44
Sainthia	149	1	2	3	1	2	2	5	4	4	2	26*
Muraroi-I	54	2	0	0	0	0	0	0	0	0	0	2
Dhupguri	26	8	1	0	0	0	0	0	0	0	0	9
Total	**879**	**31**	**18**	**20**	**15**	**9**	**12**	**18**	**17**	**14**	**27**	**181**

Source: Survey data

Note: Kalna-1: At 2 moujas summer paddy is totally cultivated by lifting water from tank
Saithia: At 4 moujas summer paddy is totally cultivated by lifting water from tank
Suri-1: At 7 moujas summer paddy is totally cultivated by lifting water from tank
Muraroi-1**:** At 5 moujas summer paddy is totally cultivated by lifting water from tank

Table 6.8: Block wise distribution of moujas by area under Boro cultivation as a percentage of net cultivated area in moujas, where 1 percent to 30 percent of total Boro cultivated area is irrigated by privately owned STW and SMTW

Block	Area under Boro cultivation as a percentage of net cultivated area in moujas											
	No. of moujas where summer paddy is cultivated	1-10 %	11- 20 %	21- 30 %	31- 40 %	41- 50 %	51- 60 %	61-70 %	71- 80 %	81- 90 %	91- 100 %	Total
Kalna-I	80	5	2	8	9	4	0	1	1	0	0	30
Kanksa	30	2	0	1	0	0	0	1	1	0	0	5
Galsi-I	59	0	0	0	0	2	0	0	0	7	6	15
Manteswar	83	0	0	0	0	0	1	0	0	0	0	1
Beldanga-I	48	0	0	1	0	0	0	0	0	0	0	1
Ranaghat-II	116	0	0	1	1	2	0	1	1	0	0	6
Krishnanagar-I	94	0	0	1	1	0	0	0	0	0	0	2
Suri-I	64	1	4	1	0	0	1	0	0	0	0	7
Suri-II	76	0	1	5	0	3	3	6	2	1	0	21
Sainthia	149	1	1	0	0	0	2	2	0	1	0	7
Muraroi-I	54	0	0	0	0	0	0	0	0	0	0	0
Dhupguri	26	3	2	0	1	0	0	0	0	0	0	6
Total	**879**	**12**	**10**	**18**	**12**	**11**	**7**	**11**	**5**	**9**	**6**	**101**

Source: Survey data

Table 6.9: Block wise distribution of moujas by area under Boro cultivation as a percentage of net cultivated area in moujas, where 31 percent to 70 percent of total Boro cultivated area is irrigated by privately owned STW and SMTW

Block	Area under Boro cultivation as a percentage of net cultivated area in moujas											
	No. of moujas where summer paddy is cultivated	1-10 %	11- 20 %	21- 30 %	31- 40 %	41- 50 %	51- 60 %	61-70 %	71- 80 %	81- 90 %	91- 100 %	Total
Kalna-I	80	3	0	3	2	2	1	2	1	0	0	14
Kanksa	30	1	1	0	1	0	1	0	0	0	0	4
Galsi-I	59	0	0	1	0	2	0	1	2	2	1	9
Manteswar	83	0	0	2	1	0	0	0	0	2	3	8
Beldanga-I	48	2	0	3	2	2	0	0	0	0	0	9
Ranaghat-II	116	1	0	8	12	14	5	2	1	2	0	45
Krishnanagar-I	94	0	1	3	10	5	2	0	0	0	0	21
Suri-I	64	2	5	1	0	0	0	0	0	0	0	8
Suri-II	76	1	1	1	0	0	1	0	0	0	1	5
Sainthia	149	3	8	1	1	0	0	1	1	0	0	15
Muraroi-I	54	1	1	0	0	0	0	0	0	0	0	2
Dhupguri	26	6	2	0	0	0	0	0	0	0	0	8
Total	**879**	**20**	**19**	**23**	**29**	**25**	**10**	**6**	**5**	**6**	**5**	**148**

Source: Survey data

Table 6.10: Block wise distribution of moujas by area under Boro cultivation as a percentage of net cultivated area in moujas, where more than 70 percent of total Boro cultivated area is irrigated by privately owned STW and SMTW

Block	Area under Boro cultivation as a percentage of net cultivated area in moujas											
	No. of moujas where summer paddy is cultivated	1-10 %	11- 20 %	21- 30 %	31- 40 %	41- 50 %	51- 60 %	61-70 %	71- 80 %	81- 90 %	91- 100 %	Total
Kalna-I	80	4	0	5	6	2	1	2	0	0	0	20
Kanksa	30	6	2	0	2	1	0	0	0	0	0	11
Galsi-I	59	0	0	0	0	1	0	0	1	0	3	5
Manteswar	83	0	0	2	3	10	5	10	19	9	8	66
Beldanga-I	48	5	7	8	6	5	3	2	0	0	0	36
Ranaghat-II	116	0	1	7	20	12	15	3	2	3	0	63
Krishnanagar-I	94	1	7	7	16	16	6	9	4	3	1	70
Suri-I	64	5	3	0	0	0	1	0	0	0	0	9
Suri-II	76	2	1	1	0	0	2	0	0	0	0	6
Sainthia	149	22	19	19	13	10	7	0	3	4	0	97
Muraroi-I	54	19	12	4	3	2	3	1	1	0	0	45
Dhupguri	26	3	0	0	0	0	0	0	0	0	0	3
Total	**879**	**67**	**52**	**53**	**69**	**59**	**43**	**27**	**30**	**19**	**12**	**431**

Source: Survey data

Tables 6.7 through 6.10 present block-wise distributions of moujas *where summer paddy is cultivated* classified by the percentage of cultivable area in the mouja that is under boro paddy. Table 6.7 presents the data for the moujas where only state owned sources of irrigation are used for irrigation of the boro paddy crop. There are181 moujas in this set The Table shows that in Galsi I which is located near the head reach of the Damodar valley corporation's canal system, canals alone provide sufficient water to support a very high level of boro cultivation in around 50 percent of the moujas surveyed. In Suri I boro cultivation depends solely on irrigation from state owned sources of irrigation in 33 of the 64 moujas where summer paddy is cultivated. However, in almost two-thirds of these moujas, boro cultivation is done on less than 20 percent of the cultivable land. In seven other moujas, boro cultivation is done by lifting water from ponds, tanks and other water bodies. In these moujas only a very small fraction of the cultivable area is devoted to the crop. Only government owned sources of irrigation are used in 44 of the 76 moujas of Suri II block where boro paddy is cultivated. In more than 50 percent of these moujas, the crop is cultivated in more than half the cultivable area. In Sainthia, only state owned sources of irrigation are used in 26 of the 149 moujas where the crop is grown. In over 65 percent of these moujas the area under boro paddy is more than 50 percent of the cultivable area.

Suri I and Suri II are located at the head reach of the Mayurakshi Dam Canal System, whose source is the Tilpara barrage just outside Suri town. The canals in this system pass through Suri I, Suri II and Sainthia. While Sainthia and Suri II have similar soil characteristics, the western parts of Suri I block are arid and have little or no access to canal water. Sainthia, on the other hand, is a large block and distance from the canal head, at least partially, explains why cultivators depend solely on government irrigation in a relatively smaller number of moujas.[44]At the other extreme are the Muraroi I, Manteswar, Ranaghat II, Krishnanagar I and Beldanga blocks where state owned sources provide the only means of irrigation for boro cultivation in only a small percentage of moujas. Further, in the 7 moujas in Muraroi I block where the state provides the only

[44] Many moujas lie in the tail areas of the canal system and there are a large number of moujas that are not part of the canal command area.

means of irrigation for boro paddy, less than 10 percent of the cultivable area is devoted to boro paddy.

The next Table (Table 6.8) looks at moujas where privately owned STWs and SMTWs have a relatively small role in providing irrigation for boro paddy cultivation. In the 110 moujas in this set, privately owned STWs and SMTWs provide irrigation in up to 30 percent of the area under boro cultivation. The data shows that except for Galsi I block, the proportion of cultivable area under boro cultivation is low in most moujas in this group. Table 6.9 presents data for the moujas where privately owned STWs and SMTWs provide irrigation in 31 to 70 percent of the area under boro paddy. One can think of this as the set of moujas where (*given the area under boro paddy*) privately owned STWs and SMTWs have a moderate to high role in irrigation. There are 148 moujas in this set. It can be seen that 45 of the 116 moujas of Ranaghat II block where boro paddy is cultivated belong to this group. Within this group of 45 moujas, boro paddy is grown in more than 50 percent of the cultivable area in only 10 moujas. There are no canals in Ranaghat II block and government investment in irrigation facilities is limited to installation of DTWs, RLIs and cluster STWs and SMTWs. What the data shows is that the state's investment on irrigation facilities has not played a particularly great role in providing irrigation for cultivation of boro paddy. This picture is even bleaker in Krishnanagar I and Beldanga I blocks. The reason behind pointing this out in such detail is that these are some of the blocks where the state has put a lot of emphasis on the development of minor irrigation schemes. The data for Galsi I block also provides some food for thought. In 6 of the 9 moujas of the block that belong to this set, boro cultivation is done on more than 60 percent of the cultivable area. This is interesting because it seems to suggest a possible demonstrative effect of canal irrigation: in moujas where canal irrigation is available in only a part of the cultivable area, private farmers invested in groundwater extraction mechanisms to reap the benefits of cultivating the crop on the remaining land.

Table 6.10 looks at moujas where the privately owned STWs and SMTWs play a very large role in irrigation given the area under boro paddy. There are 431 moujas in this set, which is surprising given the spread of our survey area across agro-climatic zones. Notice first that only 5 moujas in Galsi I belong to this set (and 9 in the last), testifying to the fact that if effective and cheap government irrigation is available, then there is almost no need for private investment in groundwater extraction. In Sainthia, 97 moujas belong to this group, but in 60 of these boro cultivation occurs in less than 30 percent of the cultivable area. The data for Muraroi I reveal a similar picture. Manteswar lies at the other extreme. Out of the 83 moujas in Manteswar where boro paddy is cultivated, 66 belong to this set. Further, in 46 of these moujas more than 60 percent of the cultivable area is devoted to boro paddy. The data for Beldanga I, Krishnanagar I and Ranaghat II present a somewhat different picture. In these blocks, a large proportion of the moujas belong to the set in which privately owned STWs and SMTWs irrigate more than 70 percent of the area under boro paddy. However, in these moujas, the proportion of cultivable area under boro paddy lies in the 20 to 60 percent range in most moujas, and in 31 out of the 36 moujas in Beldanga I block, boro paddy is cultivated on less than 50 percent of the cultivable area. Crop diversification could be a reason for the pattern and extent of summer paddy cultivation in these areas. Our survey indicates that in the relevant moujas of Beldanga I block wheat, vegetables and mustard are grown on a fairly large scale in the period after the monsoon. In Krishnanagar I block, wheat and mustard are grown on a fairly large scale, and as we indicated in Section 3, both rabi vegetables and mustard are grown on a fairly large scale in Ranaghat II block during the same period.

In this section we have presented a description of the patterns of private investment in STWs and SMTWs across the blocks where we ran our surveys. In the process, we tried to develop some heuristic arguments to explain why one tends to see a greater role for private groundwater irrigation in the cultivation of boro paddy in some areas and a smaller role in others. We also saw that STWs are not used in many moujas, that in some moujas they co-exist with SMTWs, and that in many moujas STWs are the only type of mechanised private groundwater extraction devices in use. In the next section, we present the results of the econometric analysis of the survey data to see what factors explain the presence of private groundwater irrigation devices in a given mouja. The section also presents the results of our econometric analysis of the data to see what explains the fact that groundwater extractors have shifted from STWs to SMTWs in some moujas and not in others.

7. MOUJA LEVEL REGRESSION RESULTS

Our own field experience and analysis of the descriptive statistics in the previous sections helped us build up a tentative explanation of the existence of the private groundwater extraction mechanism. This led to the choice of the following regressors for the mouja level analysis:

BCULT% = proportion of land for boro (summer paddy) cultivation out of total cultivable land in the mouja,

BGSTW% = proportion of land irrigated for boro by govt. STW out of total land used for boro cultivation in the mouja,

BGSUB% = proportion of land irrigated from govt. SMTW out of total land used for boro cultivation in the mouja,

BCAN% = proportion of land irrigated by canal out of total land used for boro cultivation in the mouja,

BRLI% = proportion of land irrigated by RLI out of total land used for boro cultivation in the mouja,

BDTW% = proportion of land irrigated for boro by DTW out of total land used for boro cultivation in the mouja,

CAND3 = an exogenous dummy and takes a value one if canal irrigation exists and is regular and zero otherwise,

RLID3 = an exogenous dummy and takes a value one if RLI exists and is regular and zero otherwise,

CANAGE = age of the canal in the mouja (difference of 2004 and the date of completion of the canal),

RLIAGE = age of the RLI in the mouja (difference of 2004 and the date of installation of the RLI)[45],

DTWAGE = age of the DTW in the mouja (difference of 2004 and the date of installation of the DTW),

[45] If there exists more than one RLI then we take use the date of first installation for calculating RLIAGE. Similarly for DTW. For canals this problem does not arise for a mouja as there is not more than one canal in an individual mouja.

DIS = (CAND3 X 3 + RLID3 X 2 + DTW)/6, an index of the presence of total government irrigation where the weights are so chosen that canal gets highest weight as it covers largest area, then RLI and then DTW[46],

LOAM = proportion of loam land in total cultivable land of the mouja,

CLOCLA = proportion of clay and clay loam land in total cultivable land of the mouja,

SANDCLA = proportion of sandy clay land in total cultivable land of the mouja,

SANDLO = proportion of sandy loam in total cultivable land of the mouja,

HROCK = an exogenous dummy with a value of one if there exists hard rock in the mouja and zero otherwise,

LWL = an exogenous dummy with a value of one if low water level is stated to be a constraining factor for installing STW or SMTW in the mouja and zero otherwise,

CLLAY = an exogenous dummy with a value of one if clay layer is stated to be a constraining factor for installing STW or SMTW in the mouja and zero otherwise,

PORSOIL = proportion of porous soil in total cultivable land in the mouja,

ELECFLD = an exogenous dummy with a value one if there is complete or incomplete electrification in the agricultural field in the mouja and zero otherwise,

WLF03 = length in feet from ground that water is available in the mouja during mid February to mid March in 2003.

We have reported the estimated value of the coefficient for each regressor in the Tables along with the corresponding t-value within brackets. In the lower part of the Tables we have reported the relevant statistics for the regression diagnostics. For logit regressions, we report the value of the log likelihood function, LNL(UR), McFadden's pseudo R^2, [47] Chi-squared statistic for testing H_0:$\beta = 0$ (not including the constant),[48]. We also report the ratio of predicted '$y_i = 0$' to actual '$y_i = 0$', 0-PR/AC, the ratio of predicted '$y_i = 1$' to actual '$y_i = 1$', 1-PR/AC and the proportion of actual to predicted y_i, AC/PR. For the

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[46] We also calculated an unweighted measure, but in terms of performance there is not much difference.

[47] pse-R^2 = (1- ln L/ ln L_0) where ln L is LNL(UR) and ln L_0 is value of the log likelihood function with β=0)

[48] χ^2(df) = 2 (ln L – ln L_0) and df is the degrees of freedom

OLS regressions we report R^2, adjusted R^2, Adj R^2, Akaike information criteria,[49] and F value for the joint significance of the regressors, F-VALUE.

For the OLS regressions our dependent variable is the proportion of land irrigated by private STW and / or SMTW in total land cultivated in boro[50].

As some of the regressors are found to be (pair wise) highly correlated, to avoid the problem of multicollinearity we first looked at the correlation matrix of the regressors. The regressors for which the co-efficient of correlation has a high absolute value (0.4 and above)[51] were not used simultaneously. Regressors that are moderately correlated (absolute value of 0.2 or above) were used but we also reported the results of the regression analysis with the regression equation containing one of these variables only.

Table 7.1 presents the regression results for the dependent variable y_i with $y_i = 1$ if there exists STW or SMTW in the mouja and $y_i = 0$, otherwise. To investigate the role of government source of irrigation we used three sets of regressors. The first set of regressions in Table 7.1 uses the proportion of area irrigated by government sources in total boro cultivation (BGSTW%, BGSUB%, BRLI% and BDTW%). In the second set these regressors were replaced by exogenous dummies for the existence of different government sources of irrigation (CAND3, RLID3 and DTWD3). The third set is in terms of the ages of the different government sources of irrigation. We did not use the three sets of the regressors in a single equation for obvious reasons. However, DIS was reported to be non-significant in all the regressions to start with, hence we dropped it in the subsequent regressions.

The results reported in Table 7.1 do not seem to be robust. Though in many cases we find expected signs of the regressors as well as the right t-statistic for the significance level,

[49] AIC = -2(logL - K)/N.

[50] There is expected to be endogenity between the proportion of land irrigated by private STW and/ or SMTW in total land cultivated in boro and BCULT% or other regressors such as ELECFLD, LWL, WLF03 or soil type. This could have been avoided if we could use an appropriate instrument for our dependent variable. But we could not find some suitable instrument so that we were forced to use it.

[51] The correlation co-efficient between acreage under boro cultivation and the acreage under wheat was 0.67. Hence we used the acreage under boro only.

many coefficient values often change sign or a significant t-value becomes non-significant and vice-versa as we alter the combination of regressors. This prompted us to

Table7.1: Mouja level *logit* regression results

	SL NO. -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
REGRESSORS	CONSTANT	3.9 (7.2)	3.08 (7.3)	3.10 (7.4)	2.8 (7.7)	1.53 (8.3)	4.95(9.5)	4.491 (10.5)	4.42 (8.4)	4.63 (10.7)	2.4 (8.1)	2.31 (14.4)	4.71 (8.9)	4.86 (11.1)	2.75 (8.6)	2.81 (15.4)
	BCULT%	0.014 (2.42)	0.013 (2.7)	0.013 (2.74)	0.0125 (2.27)	0.035 (6.7)	-0.002 (-0.7)		0.0013 (0.3)		0.0003 (0.1)		0.002 (0.5)		0.001 (0.23)	
	BGSTW%	0.049 (1.5)			0.0436 (1.4)		0.019 (1.3)		0.036 (5.6)	0.038 (6.1)	0.026 (4.04)	0.027 (4.7)	0.04 (6.1)	0.041 (6.5)	0.03 (4.98)	0.03 (5.3)
	BGSUB%	-0.039 (-5.9)	0.023 (2.9)	0.028 (9.7)	-0.033 (-5.3)	-0.02 (-3.4)	-0.037 (-5.9)	-0.035 (-5.9)	-0.0341 (-5.6)	-0.036 (-5.8)	-0.024 (-4.1)	-0.025 (-4.3)	-0.038 (-5.8)	-0.0389 (-6.2)	-0.028 (-4.6)	-0.0281 (-4.9)
	BCAN%	-0.034 (-10.1)	-0.026 (-9.1)	-0.026 (-9.2)	-0.037 (-11.1)	-0.032 (-10.4)										
	BRLI%	-0.023 (-4.4)	0.49 (0.68)		-0.022 (-4.3)	-0.009 (-1.9)	-0.013 (-2.7)	-0.011 (-2.33)								
	BDTW%	0.049 (1.6)			0.051 (1.6)		0.033 (2.3)	0.048 (6.3)								
	CAND3								-0.68 (-2.8)	-0.74 (-3.3)	-0.75 (-3.3)	-0.82 (-3.8)				
	RLID3								0.52 (1.3)		0.699 (0.09)					
	DTWD3								0.44 (1.1)		0.84 (2.32)	0.82 (2.3)				
	CANAGE												-0.002 (-4.7)	-0.022 (-5.1)	-0.002 (-5.1)	-0.024 (-5.9)
	RLIAGE												-0.04 (-0.31)		0.013 (0.10)	
	DTWAGE												0.0001 (0.9)		0.0002 (0.12)	
	LOAM	-0.001 (-0.6)					-0.001 (-0.6)		-0.001 (0.5)				-0.007 (-0.5)			
	CLOCLA	0.002 (0.55)			0.004 (1.1)		-0.003 (-0.9)		-0.028 (-0.8)		-0.17 (-0.5)		-0.0002 (-0.5)		-0.64 (-0.19)	
	SANDCLA	-0.001 (-0.4)					-0.0001 (-0.01)		-0.0004 (-0.35)				-0.24 (-0.16)			
	HROCK	-1.14 (-4.2)	-1.09 (4.7)	-1.08 (-4.6)	-1.23 (-4.5)	-1.3 (-6.1)	-1.48 (-6.2)	-0.33 (-6.1)	-1.41 (-5.7)	-1.41 (-6.4)	-0.002 (-6.8)	-1.57 (-7.4)	-1.34 (-5.04)	-1.4 (-6.3)	-1.51 (-6.3)	-1.6 (-7.5)
	LWL	-0.086 (0.32)			-0.095 (-0.35)		-0.007 (-0.03)		0.056 (0.24)		0.11 (0.5)		0.15 (0.6)		0.18 (0.8)	
	CLLAY	0.004 (0.01)			-0.12 (-0.23)		-0.42 (-0.9)		-0.39 (-0.9)		-0.66 (-1.6)		-0.4 (-0.91)		-0.69 (-1.6)	
	PORSOIL	-0.71 (-1.34)			-0.73 (-1.4)		-0.79 (-1.69)		-0.95 (-2.03)	-0.88 (-1.9)	-1.10 (-2.4)	-1.16 (-2.67)	-0.98 (-2.1)	-0.992 (-2.23)	-1.09 (-2.42)	-1.24 (-2.9)
	ELECFLD	-0.51 (-2.84)	-0.38 (-2.33)	-0.38 (-2.34)			-1.04 (-6.1)	-1.036 (-6.3)	-0.89 (-5.1)	-0.98 (-5.7)			-0.88 (-5.1)	-0.93 (-5.6)		
	WLF03	0.0026 (0.54)			0.001 (0.28)		-0.002 (-0.5)		-0.036 (-0.08)		-0.003 (-0.65)		-0.002 (-0.4)		-0.004 (-0.9)	
	LNL(UR)	-257.82	-303.41	-303.67	-262.49	-325.3	-323.16	-327.48	-323.01	-325.75	-338.74	-341.94	-314.92	-316.68	-330.19	-334.51
STATISTICS	pse-R^2	0.435	0.336	0.335	0.425	0.288	.0.292	0.283	0.293	0.287	0.258	0.251	0.310	0.360	0.277	0.266
	χ^2(df)	397.57 (15)	306.39 (6)	305.89 (5)	388.23 (12)	262.61 (5)	266.89 (14)	258.26 (5)	267.19 (15)	261.71 (6)	235.74 (12)	229.33 (6)	283.38 (15)	279.86 (6)	252.83 (12)	244.20 (5)
	0-PR/AC	175/187	155/187	154/187	191/187	98/187	119/187	100/187	128/187	126/187	136/187	148/187	145/187	141/187	130/187	138/187
	1-PR/AC	711/699	731/699	732/699	695/699	788/699	767/699	786/699	758/699	760/699	750/699	738/699	741/699	745/699	756/699	748/699
	AC/PR	782/886	770/886	769/886	770/886	719/886	750/886	741/886	747/886	751/886	737/886	739/886	750/886	752/886	729/886	727/8886

test for outlier values using the *hat matrix a la* Belsley, Welsh and Kuh (1980)[52]. A total of 251 observations were found to be outliers. After dropping them we repeated the regression exercises. The results are reported in Table 7.2. The corresponding OLS regressions are reported in Tables 7.3 and 7.4 where the latter reports the results without outliers. In both the cases we checked for heteroscedasticity using Breusch and Pagan test. The null of heteroscedasticity is rejected. Further we repeated the regression exercises dropping several observations from the beginning, from the end and from the middle. This is done to avoid any possible undetected multicollinearity resulting in parameter instability. These exercises did not yield instability of parameter values. Hence we can conclude safely that the regression results so reported are robust.

Table7.2 and 7.4 indicate that BCULT% and BGSTW% do not affect private investment in STW or SMTW. The existence of large coverage of major government irrigation, such as canal, RLI or even government submersible, negatively affects private investment in irrigation. This is true for OLS regressions also. But DTW is non-significant in any form in logit regressions. However, it is significant in the OLS regressions (Tables 7.3 and 7.4). Thus the major irrigation like canal is always robust.

Regarding types of soil[53] the regression results are nor very clear, either in terms of expected sign or in terms of level of significance or both. LOAM is only marginally negative significant (see column 5 of Table 7.2). Though PORSOIL is negative significant in some of the equations of Table 7.1, it becomes altogether non-significant in Table 7.2 Only SANDCLA is found to be with an expected positive sign (columns 7 through 16 in Table 7.2), but becomes non-significant in columns 1 through 5. The pattern is similar in OLS regressions also.

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[52] The leverage value is defined as $h_{ii} = X_i^{'} (X^{'}X)^{-1} X_i$ where $V(e_i)=\sigma^2 (1-h_{ii})$. Belsley, Welsh and Kuh suggested that if $h_{ii} > 2K/N$, where K is the number of parameters to be estimated and N the number of observations, then this signals that the i th. observation point is worthy of attention,. To obtain them we require hat matrix, i.e. the projection matrix into the column space of X, $H = X^{'} (X^{'}X)^{-1} X$.

[53] SANDLO and CLOCLA are highly negatively correlated with a correlation co-efficient of –0.74, hence we used only CLOCLA.

Table 7.2: Mouja level *logit* regression results (without outliers)

	SL NO. -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
REGRESSORS	**CONSTANT**	4.89 (7.2)	5.23 (8.5)	5.01 (10.3)	4.89 (8.7)	5.57 (8.9)	5.27 (10.2)	6.3 (7.77)	6.3 (8.7)	5.47 (7.5)	5.62 (8.8)	5.62 (7.6)	5.97 (8.8)	7.5 (8.6)	6.8 (9.6)	6.98 (8.5)	7.2 (8.6)
	BCULT%	0.79 (1.1)															
	BGSTW%																
	BGSUB%	-0.10 (-2.65)	-0.098 (-2.6)	-0.12 (-2.86)	-0.09 (-2.5)	-0.09 (-2.5)	-0.10 (-2.7)	-0.05 (-1.3)		-0.046 (-1.23)		0.05 (-1.29)		-0.09 (-2.3)	-0.095 (-2.49)	-0.094 (2.29)	-0.096 (-2.3)
	BCAN%	-0.05 (-9.1)	-0.05 (-9.3)	-0.052 (-9.6)	-0.051 (-9.4)	-0.05 (-9.4)	-0.052 (-9.8)										
	BRLI%	-0.004 (-4.6)	-0.041 (-4.6)	-0.038 (-4.5)	-0.41 (-4.7)	-0.043 (-4.9)	-0.039 (-4.9)										
	BDTW%																
	CAND3							-0.9 (-3.1)	-1.1 (-3.5)	-1.07 (-3.6)	-1.23 (-4.3)	-1.08 (-3.6)	-1.1 (-3.8)				
	RLID3							0.26 (0.4)		0.19 (0.34)		0.29 (0.5)					
	DTWD3							0.89 (1.4)		0.89 (1.41)		0.82 (1.28)					
	CANAGE													-0.05 (-5.7)	-0.53 (-6.5)	-0.051 (-5.9)	-0.051 (-5.9)
	RLIAGE													-0.02 (-1.2)		-0.022 (-1.2)	-0.193 (-1.1)
	DTWAGE													0.26 (0.1)		0.0045 (0.19)	0.002 (0.1)
	LOAM					-0.014 (-1.9)						0.001 (0.1)					0.0003 (0.05)
	CLOCLA	-0.002 (-0.51)	-0.29 (-0.5)					-0.010 (-2.1)	-0.12 (-2.4)					-0.007 (-1.4)			
	SANDCLA	0.54 (0.3)	0.0052 (0.3)		0.45 (0.3)	0.002 (0.09)		0.04 (2.5)	0.039 (2.2)	0.05 (2.9)	0.05 (2.86)	0.05 (3.0)	0.05 (3.1)	0.034 (2.003)	0.038 (2.35)	0.038 (2.29)	0.0398 (2.32)
	SANDLO				0.01 (1.7)					0.008 (1.63)						0.005 (1.1)	
	HROCK	-1.46 (-3.4)	-1.61 (-3.9)	-1.18 (-3.3)	-1.72 (-4.0)	-1.55 (-3.8)	-1.39 (-3.6)	-1.6 (-4.5)	-1.4 (-4.13)	-1.54 (-4.4)	-1.08 (-3.5)	-1.4 (-4.2)	-1.4 (-4.3)	-1.3 (-3.4)	-0.93 (-2.98)	-1.24 (-3.3)	-1.16 (-3.18)
	LWL	-0.66 (-1.5)	-0.78 (-1.9)		-0.71 (-1.7)	-0.90 (-2.2)	-0.67 (-1.7)	-0.63 (-1.9)		-0.64 (-1.9)		-0.74 (-2.2)	-0.7 (-2.4)	-0.33 (-0.8)		-0.3 (-0.8)	-0.37 (-1.03)
	CLLAY	-0.60 (-0.9)	-0.62 (-0.9)			-0.67 (-1.0)				-0.99 (-1.9)		-1.06 (-1.99)	-1.1 (-2.1)	-0.79 (-1.4)		-0.81 (-1.43)	-0.85 (-1.5)
	PORSOIL																
	ELECFLD							-1.3 (-5.1)	-1.4 (-5.6)	-1.28 (-4.9)	-1.35 (-5.6)	-1.3 (-5.1)	-1.3 (-5.4)	-1.25 (-4.9)	-1.26 (-5.3)	-1.24 (-4.9)	-1.24 (-5.0)
	WLF03	0.008 (0.96)	0.0071 (0.8)			0.008 (0.98)		0.001 (0.1)		0.001 (0.1)		0.002 (0.3)		-0.003 (-0.4)		-0.003 (-0.4)	-0.002 (-0.29)
STATISTICS	**LNL(UR)**	-114.32	-114.97	-117.84	-113.67	-113.41	-116.36	-173.33	-178.64	-174.16	-181.71	-175.53	-177.22	-154.18	-157.28	-154.63	-155.21
	pse-R^2	0.521	0.518	0.506	0.523	0.525	0.512	0.273	0.251	0.270	0.238	0.264	0.257	0.354	0.341	0.352	0.349
	χ^2(df)	248.39 (10)	247.09 (9)	241.36 (4)	249.70 (9)	250.22 (9)	244.31 (5)	130.38 (11)	119.76 (5)	128.13 (11)	113-62 (4)	125.98 (11)	122.60 (6)	168.67 (11)	162.47 (5)	167.81 (11)	166.62 (11)
	0-PR/AC	83/79	84/79	93/79	86/79	84/79	71/79	34/79	37/79	38/79	29/79	38/79	37/79	54/79	41/79	48/79	51/79
	1-PR/AC	552/556	551/556	442/556	549/556	551/556	564/556	601/556	598/556	597/556	606/556	597/556	598/556	581/556	594/556	587/556	584/556
	AC/PR	589/635	588/635	589/635	590/635	584/635	581/635	572/635	579/635	569/635	565/635	567/635	565/635	568/635	563/635	570/635	567/635

Table7.3: Mouja level OLS regression results

	SL NO. -->	1	2	3	4	5	6	7	8
REGRESSORS	**CONSTANT**	96.21 (61.3)	94.9 (68.8)	94.84 (68.7)	119.74 (23.5)	113.18 (23.12)	113.26 (23.12)	122.72 (24.5)	117.40 (24.4)
	BCULT%								
	BGSTW%	-1.2 (-12.7)	-1.11 (-12.6)	-1.11 (-12.6)	-0.61 (-3.3)	-0.57 (-3.1)	-0.57 (-3.03)	-0.83 (-4.5)	-0.81 (-4.4)
	BGSUB%	0.91 (-12.8)	-0.94 (-13.2)	-0.94 (-13.2)	0.80 (-5.3)	-0.88 (-5.8)	-0.88 (-5.8)	-0.89 (-6.0)	-0.97 (-6.6)
	BCAN%	-0.92 (-52.3)	-0.93 (-52.9)	-0.93 (-53.1)					
	BRLI%	-0.94 (-29.7)	-0.94 (-29.8)	-0.94 (-29.7)					
	BDTW%	-0.61 (-13.8)	-0.62 (-13.9)	-0.62 (-13.9)					
	CAND3				-25.04 (-7.8)	-26.7 (-8.31)	-26.8 (-8.3)		
	RLID3				-33.4 (-8.19)	-33.45 (-8.1)	-33.38 (-8.09)		
	DTWD3				-13.26 (-4.1)	-14.8 (-4.5)	-14.93 (-4.5)		
	CANAGE							-0.56 (-10.0)	-0.59 (-10.7)
	RLIAGE							-1.26 (-9.2)	-1.27 (-9.2)
	DTWAGE							-0.46 (-4.4)	-0.51 (-5.0)
	LOAM			0.31 (0.51)			0.321 (0.25)		0.44 (0.35)
	CLOCLA	-0.04 (-1.8)			-0.17 (-3.9)			-0.15 (-3.4)	
	SANDCLA	-0.42 (-0.8)	-0.57 (-0.8)	-0.639 (-1.02)	-0.79 (0.07)	0.143 (0.1)	-0.47 (-0.35)	0.001 (0.17)	-0.002 (-0.17)
	SANDLO		0.13 (0.23)			-0.56 (-0.47)			
	HROCK	-6.1 (-3.4)	-5.76 (-3.2)	-5.76 (-3.24)	-21.66 (-5.8)	-20.25 (-5.4)	-20.38 (-5.3)	-20.03 (-5.4)	-18.8 (-5.1)
	LWL	-2.35 (-1.8)	-2.68 (-2.04)	-2.681 (-2.052)	0.51 (0.02)	-1.52 (-0.54)	-1.14 (-0.5)	2.03 (0.74)	0.93 (0.34)
	CLLAY	-4.45 (-1.6)	-5.76 (-2.04)	-5.3 (-1.9)	-14.65 (-2.52)	-18.21 (-3.13)	-18.54 (-3.19)	-19.19 (-3.39)	-22.7 (-4.02)
	PORSOIL	-10.8 (-3.3)	-10.19 (-1.91)	-10.11 (-3.12)	-20.35 (-2.98)	-18.3 (-2.65)	-18.06 (-2.6)	-22.43 (-3.37)	-20.48 (-3.1)
	ELECFLD				-13.74 (-7.4)	-13.58 (-7.5)	-13.62 (-7.29)	-12.57 (-6.96)	-12.38 (-6.8)
	WLF03	-0.10 (-0.33)	-0.10 (0.32)	-0.103 (-0.32)	-0.38 (-0.56)	-0.33 (-0.47)	-0.36 (-0.5)	-0.59 (-0.89)	-0.06 (-0.9)
STATISTIC	**LnL(UR)**	2958.34	-2959.93	-2959.83	-3487.5	-3495.26	-3495.34	-3469.57	-3475.39
	R^2	0.85	0.85	0.85	0.337	0.322	0.322	0.3694	0.359
	Adj R^2	0.85	0.85	0.85	0.324	0.309	0.309	0.358	0.347
	AIC	8.37	8.4	8.37	9.86	9.89	9.89	9.81	9.83
	F- VALUE	330.71	328.97	329.09	27.18	25.44	25.42	31.63	29.98

Table 7.4: Mouja level OLS regression results (without outliers)

	SL NO. -->	1	2	3	4	5	6	7	8	9	10	11	12
REGRESSORS	**CONSTANT**	97.56 (52.9)	98.81 (60.0)	95.88 (62.4)	95.001 (55.7)	105.235 (19.2)	119.29 (21.78)	113.42 (20.8)	110.109 (19.9)	124.307 (23.2)	120.147 (22.4)	116.040 (21.4)	118.85 (22.3)
	BCULT%	0.32 (1.5)											
	BGSTW%	-0.98 (-8.1)	-0.98 (-8.1)	-0.97 (-8.0)	-0.98 (-8.1)	-0.534 (-1.9)	-0.67 (-2.37)	-0.64 (-2.3)	-0.673 (-2.4)	-0.875 (-3.2)	-0.86 (-3.1)	-0.888 (-3.2)	-1.107 (-3.9)
	BGSUB%	-1.2 (-6.6)	-1.21 (-6.6)	-1.225 (-6.6)	-1.25 (-6.8)	-1.03 (-2.4)	-0.974 (-2.28)	-1.022 (-2.4)	-1.06 (-2.5)	-1.09 (-2.6)	-1.151 (-2.7)	-1.170 (-2.8)	-1.467 (-3.5)
	BCAN%	-0.96 (-55.9)	-0.95 (-56.3)	-0.957 (-56.6)	-0.95 (-56.3)								
	BRLI%	0.95 (-26.5)	-0.959 (-26.6)	0.964 (-26.6)	0.954 (-26.4)	-0.729 (-8.6)							
	BDTW%	0.89 (-17.4)	-0.89 (-17.3)	-0.89 (-17.2)	-0.91 (-17.4)	-0.50 (-4.1)							
	CAND3						-27.398 (-8.0)	-28.7 (-8.6)	-27.65 (-8.2)				
	RLID3						-30.69 (-6.7)	-30.775 (-6.7)	-29.94 (-6.5)				
	DTWD3						-14.19 (-4.04)	-14.94 (-4.2)	-15.73 (-4.5)				
	CANAGE									-0.62 (-10.6)	-0.644 (-11.1)	-0.631 (10.9)	-0.548 (-9.5)
	RLIAGE									-1.12 (-7.6)	-1.11 (-7.6)	-1.108 (-7.4)	-1.063 (-7.2)
	DTWAGE									-0.052 (-4.7)	-0.55 (-4.9)	-0.559 (-5.1)	
	LOAM				0.467 (1.7)	0.23 (3.52)			0.141 (2.2)			0.131 (2.1)	
	CLOCLA	-0.06 (-2.9)	-0.06 (-2.6)				-0.13 (-2.6)			-0.111 (-2.3)			-0.136 (-2.8)
	SANDCLA	0.18 (-3.5)	-0.18 (-3.7)		-0.134 (-2.8)	0.414 (3.6)	0.27 (2.43)	0.360 (3.2)	0.41 (-3.7)	0.133 (1.2)	0.198 (1.8)	0.249 (2.3)	0.166 (0.1)
	SANDLO			0.03 (1.2)				-0.27 (0.5)			0.26 (0.05)		
	HROCK	-6.6 (-3.7)	-7.29 (-4.2)	-6.9 (-3.9)	-6.57 (-3.8)	25.31 (-6.3)	20.49 (-5.1)	-19.3 (-4.8)	-18.78 (-4.7)	-16.36 (-4.1)	-14.94 (-3.7)	-14.64 (-3.7)	-14.606 (-3.6)
	LWL	0.48 (-0.4)	-0.6 (-0.47)	-1.13 (-0.8)	-0.97 (-0.8)	-2.11 (-0.7)	0.266 (0.01)	-1.12 (-0.4)	0.41 (-0.1)	3.864 (1.3)	2.70 (0.9)	3.458 (1.2)	5.653 (1.9)
	CLLAY	-5.07 (-1.8)	-5.44(- 1.8)	-5.9 (-2.05)	-6 (-2.09)	-23.95 (-3.5)	-17.908 (-2.7)	-19.4 (-2.9)	-18.91 (-2.8)	-17.868 (-2.8)	-19.6 (-2.9)	-18.558 (-2.8)	-17.161 (-2.6)
	PORSOIL	4.56 (0.3)	4.62 (0.3)	5.33 (0.4)	4.73 (0.33)	30.92 (0.926)	25.189 (0.7)	26.02 (0.8)	25.64 (0.8)	19.46 (0.6)	19.633 (0.6)	19.748 (0.6)	23.136 (0.7)
	ELECFLD					-15.113 (-7.7)	-13.72 (-7.1)	-13.70 (-7.0)	-140.10 (-7.2)	-13.154 (-6.9)	-13.161 (-6.9)	-13.45 (-7.1)	-12.19 (-6.4)
	WLF03	0.006 (0.17)	0.004 (0.12)	0.003 (0.1)	0.009 (0.3)	-0.858 (-1.1)	-.100 (-1.3)	-0.100 (0.2)	-0.818 (-1.0)	-0.105 (-1.4)	-0.104 (-1.3)	-0.885 (-1.1)	-0.135 (0.1)
statistic	LnL(UR)	- 2578.26	- 2579.42	- 2582.223	- 2581.57	- 3127.09	- 3114.69	- 3118.08	- 3115.79	- 3094.69	- 3097.41	- 3095.17	- 3105.84
	R^2	0.872	0.872	0.871	0.8712	0.282	0.309	0.301	0.307	0.353	0.348	0.350	0.3281
	Adj R^2	0.87	0.869	0.868	0.869	0.268	0.295	0.287	0.292	0.337	0.332	0.367	0.315
	AIC	8.16	8.165	8.174	8.172	9.89	9.854	9.865	9.858	9.791	9.8	9.793	9.82
	F- VALUE	326.78	353.11	349.55	350.37	320.32	21.38	20.64	21.13	25.87	25.24	25.76	25.31

The fact that types of soil have no role in private investment in STW or SMTW can be explained in the following terms. We are observing the spread of private investment in STW or SMTW at some advanced stage of its evolutionary path. Possibly in the initial years soil types were important determinants. For example, higher water retention capacity of clay or clay loam positively affected the investment pattern in the respective areas. On the other hand, porosity of soil with lower water retention capacity is non-conducive to private investment in ground water extraction. As boro prices rose, lands that were previously not considered suitable for paddy cultivation began to be used. It is possible that the regression is not picking up the effect of differences in soil characteristics because we are looking at cross section data in a much later phase of transition.

Among other geo-physical characteristics, presence of hard rock in the moujas negatively affects private investment in groundwater irrigation. The result also holds in the OLS regressions. It is also very robust whether we exclude outliers or not, even co-efficient estimates remain almost same. But the co-efficient estimate of low water level as a constraining factor, LWL, though sometimes appear with an expected negative sign (and significant) is not robust. This is possibly because of the fact that LWL may be a constraining factor for STWs, but if the water Table is low then *ceteris paribus* private investment in groundwater extraction takes place through SMTWs. The co-efficient estimate of WLF03 also shows similar pattern.[54] Contrary to common sense the presence of clay layer (CLLAY) does not affect emergence of STW or SMTW in a mouja as revealed by the non-significant co-efficient estimates. However, in the OLS regressions when we investigate the effect on the spread of private irrigation in boro, CLLAY has a negative significant co-efficient. This is because of the fact that CLLAY is a constraining factor for installation of STW or SMTW, so its presence reduces installation of STWs or SMTWs and as a result proportion of area irrigated by STW or SMTW decreases. Thus in the OLS regression it has negative and significant co-efficient estimate. But in the case of logit regression the presence of CLLAY does not altogether exclude installation of STW

[54] We have data for depths of water table for the years 1993, 1998 and 2003. Since these are pair wise correlated with a high degree of correlation, we used the data for 2003.

or SMTW in the mouja. Even with the presence of CLLAY there might exist STW or SMTW.

Electrification of the agricultural fields, ELECFLD is negative significant in both the logit as well as OLS regressions. This result is robust, independent of whether we exclude outlier observations or not. This result appears to fly in the face of an existing consensus of opinion that introduction of electricity leads to an increase in private investment on groundwater extraction devices and so has to be interpreted very carefully. For the OLS regressions our dependent variable is the proportion of land irrigated by private STW and / or SMTW in total land cultivated in boro. What the corresponding econometric result says is that the availability of electricity in the agricultural fields is a significant explanatory variable but the association between the proportion of area under boro paddy that is irrigated by private irrigation sources and the presence of electricity in the mouja is negative. To see why this result makes sense, consider first the moujas where the proportion is low. In these moujas, the primary sources of irrigation are government canals and to other state owned devices like DTWs, RLIs, cluster STWs etc. In such areas, the availability of electricity may have little or no encouraging effect on private investment in groundwater extraction devices either because available state owned sources provide sufficient water for the irrigation of boro paddy in much of the agricultural area as in Galsi I block, or as geophysical conditions are such that investment in groundwater extraction devices is unprofitable as in Suri I block. In the areas where the proportion of total area under boro paddy that is irrigated by privately owned groundwater extraction devices is high, soil and other geophysical conditions are such that investment in groundwater extraction devices was profitable at least during the period when paddy prices were high and diesel prices were lower. In Krishnanagar I and Ranaghat II blocks of Nadia district, and Beldanga I block of Murshidabad District, where the proportion of agricultural area under boro paddy is very high, state owned sources of irrigation has little or no role. In these areas, the number of moujas where only diesel operated STWs and SMTWs are in operation far outnumber the number of moujas where operated devices exist so that the association between availability of electricity and proportion of area under boro paddy that is cultivated with water from privately owned sources is quite likely to be negative. Further, in these blocks, as in Manteswar block of

Burdwan district, the introduction of electricity in a mouja had little or no impact on the area under cultivation of boro paddy. For the most part, existing diesel operated machines were converted to use electricity and where new machines were installed, the command areas were reallocated to accommodate the new entrants.

This has an important implication from policy perspective. It shows that electrification of agricultural fields may not go hand in hand with private investment in ground water extraction mechanism, in fact it can go in the opposite direction as our study shows. The electrification of agricultural fields should be targeted keeping other factors in mind.

8. Contracts

In this section we look at the nature and pattern of contracts entered into by owners of groundwater extraction devices and the people who own or operate land but do not own the water extraction devices. This section is based on the mouja level survey data, field investigations based on free flowing interviews, and close-in household level surveys based on structured questionnaires.

Studies of water markets typically focus on water sales. Our investigations reveal that in some areas and cropping seasons, sale of water may be a small part of the activities of owners of STWs and SMTWs. In particular, owners of STWs and SMTWs may be more interested in renting in land in the command areas of their water extraction devices during some seasons and in selling water in other seasons. Our mouja level surveys indicate that in the khariff season, sale of water on an hourly basis is the norm. In some moujas, buyers and sellers enter into seasonal contracts. An interesting pattern can be observed here. In the blocks where the source of irrigation is primarily private STWs, hourly contracts are the norm, and in the blocks where SMTWs are the main sources of irrigation, fixed fee contracts predominate. However in many areas, where the STWs and SMTWs run on electricity, water is supplied without charge. There are several reasons for this. First, the fixed fee nature of electricity charges implies that the marginal cost of supplying water is zero.[55]Second, owners of STWs and SMTWs live in small village societies, where *supplying water to save a crop* is often seen as a humanitarian gesture.[56]Third, supplying water free of charge in the Khariff season may be a way of providing indirect price cuts to clients who purchase water in the boro season.[57]

[55] Our field investigations reveal that people who *use* the water often supply the labour required. Typically, the owner of the STW/SMTW hands over the keys to the machine shed to the cultivators who return these after drawing the water.

[56] Owners of diesel operated machines often allow others to use their machines free of charge as long as the user pays for the fuel and supplies the labour.

[57] In Murulia mouja in Manteswar block, these hidden price cuts are no longer hidden. The pervasiveness of the practice has made it virtually obligatory for SMTW owners to offer this service if they want to retain clients. What appears to irritate the SMTW owners most is that the users expect them to supply the labour required to ensure that proper irrigation is done on their plots.

In the rabi season, water sale is the norm except in Ranaghat II and Krishnanagar I blocks of Nadia district where the cultivation of rabi crops is a major agricultural activity.[58]For the most part, however, sale of water for the irrigation of rabi crops like vegetables, oilseeds, pulses and wheat is the overwhelming practice. There are several reasons for this. First, in most moujas the area under vegetables, wheat and pulses is relatively small. Pulses, oilseeds and wheat are cultivated for the most part by landholders for their own use and the small surpluses of the crops are sold. Vegetable cultivation is labour intensive and requires much more monitoring than other crops. This means that for the most part, vegetables are cultivated in small plots for domestic use or by people who have greater access to household labour. In Nadia, where commercial production of rabi crops occurs on a larger scale, things are somewhat different.

The overall picture is more complex once one looks at the pattern of contracts in the boro season. Table 8.1 presents a block wise distribution of moujas classified by the relative importance of water sale and renting in of land as a general practice in the mouja. The picture is complex and interesting because it is difficult to see why in several blocks sale of water appears to be the dominant practice in most moujas and in others renting in of land by STW and SMTW is predominant. What this indicates, however, is that within a mouja, the size of the market for groundwater varies across cropping seasons not only because of the variations in areas under cultivation and variations in irrigation requirements of different crops, but also because of variations in the nature of preferences of the owners of STWs and SMTWs over contracts (selling water or renting in land) across cropping seasons.[59] [60]

The next two sets of Tables provide more detailed information about contracts and prices for purchase and sale of water. Since, for the most part, water markets and markets for renting land are most active in the summer (boro paddy cultivation) we focus in on contracts in this season. Our investigations indicate that (by and large) in each mouja

[58] See Section 2.
[59] We hope that future research will unravel this mystery.
[60] Our studies and those by Shah and Raju, Fujita and Hossain, Meinzen-Dick, Webster, and others show that contract forms can differ across regions and across crops.

there is a typical contract. This means that for the most part, local respondents report a particular contract as being the prevailing contract. This does not mean that other contracts do not exist in the mouja. In moujas where the contract specifies a fixed monetary payment per hectare of irrigation the normal payment pattern typically requires part advance payment and part payment during the cropping season or after harvest. While the amount that will be paid in at these times is specified in the contract, variations in actual payment patterns are mostly tolerated. Even if full payment is not made before the next year's boro crop is planted, debt renegotiations do occur, and in extreme cases, some debt forgiveness takes place. Our field investigations in thirty moujas across five districts indicate that the number of such cases is limited.[61] Another variation is a discount that is given for full payment in advance. A third type of variation is the implicit assurance of free irrigation during the Khariff season. A fourth type of variation is caused by differences in soil or other characteristics that lead to differences in irrigation requirements. In many moujas, rates differ for plots in the "high" and "low" plots. Other variations exist, but our impression is that the scale at which deviations from the "official" contract occurs in a mouja depends to a large extent on the nature of competition in the mouja.

Table 8.2 to Table 8.7 present the block-wise distribution moujas classified by the dominant water sale contract form that prevails in each mouja. It is important to bear in mind the caveats introduced in the last paragraph while reading the rest of this section. Table 8.2 presents the data for the moujas where all STWs are run on diesel. These moujas may or may not have SMTWs or other sources of irrigation. Similarly, Table 8.3 presents the data for the moujas where all STWs are run on electricity. Table 8.4 presents data for moujas where both types of STWs are in use. Tables 8.5 to 8.7 present the corresponding data for moujas where SMTWs are in use. In all the Tables, the number of moujas in which we were unable to identify a particular contract as the "normal" contract

[61] This assertion is based on conversations with STW and SMTW owners as well as buyers of water. The usual complaint made by STW owners is that they have to work very hard to recover their dues, but even they agree that only a few buyers cause problems. A major reason behind the relatively easy recovery of dues is that threats to default and enter into contracts with other sellers are countered by the sharing of information on default among neighbouring sellers and refusal to serve a buyer who has defaulted elsewhere. These practices are supported by the usual strategic threats that are commonplace in the theory of repeated games.

Table 8.1: Distribution of moujas by relative importance of sale of water over renting in of land by STW/SMTW owners in the Boro season

Block	Number of moujas where Summer Paddy is cultivated	Number of moujas where private STWs & SMTWs are used	Yes	No	Indifferent
Kalna-I	80	64	45	6	13
Kanksa	30	20	13	3	4
Galsi-I	59	29	13	5	11
Manteswar	83	75	7	33	35
Beldanga-I	48	46	42	0	4
Ranaghat-II	116	114	40	14	60
Krishnanagar-I	94	93	71	0	22
Suri-I	64	24	16	3	5
Suri-II	76	32	14	13	5
Sainthia	149	119	93	6	20
Muraroi-I	54	47	37	6	4
Dhupguri	26	17	3	4	10
Total	**879**	**680**	**394**	**93**	**193**

Source: Survey data

Note: Yes- water selling more prevalent, No- rent in land more prevalent, Indifferent- equal share

Table 8.2:Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private STW (diesel) owners

Block	Number of moujas where only private STWs (diesel) are used	Number of moujas where boro is cultivated by only private STW (diesel)	Fixed fee (Cash)	Fixed fee (Crop)	Hourly contract (Rupees/Hour)	Mixed	Unclear
Kalna-I	24	20	1	0	16	0	3
Kanksa	23	18	0	0	17	0	1
Galsi-I	50	28	0	0	28	0	0
Manteswar	39	32	31	0	0	0	1
Beldanga-I	28	20	1	18	1	0	0
Ranaghat-II	35	33	4	0	25	1	3
Krishnanagar-I	26	25	0	0	25	0	0
Suri-I	20	11	0	0	6	0	5
Suri-II	30	26	10	0	3	0	13
Sainthia	40	21	8	0	6	0	7
Muraroi-I	20	17	0	12	4	0	1
Dhupguri	18	13	0	0	11	0	2
Total	**353**	**264**	**55**	**30**	**142**	**1**	**36**

Source: Survey data

Note: A mouja where private STWs (diesel) are used may or may not have private SMTW or other sources of irrigation owned by the government. The word "only" is used in column 2 & column 3 to indicate that electric private STWs are not used.

Table 8.3: Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private STW (electric) owners

Block	Number of moujas where only private STW (electric) are used	Number of moujas where boro is cultivated by only private STW (electric)	Fixed fee (Cash)	Fixed fee (Crop)	Hourly contract (Rupees/Hour)	Mixed	Unclear
Kalna-I	1	1	0	0	1	0	0
Kanksa	1	1	1	0	0	0	0
Galsi-I	0	0	0	0	0	0	0
Manteswar	0	0	0	0	0	0	0
Beldanga-I	3	3	3	0	0	0	0
Ranaghat-II	0	0	0	0	0	0	0
Krishnanagar-I	1	1	0	0	1	0	0
Suri-I	7	5	4	0	1	0	0
Suri-II	2	2	2	0	0	0	0
Sainthia	26	25	23	1	1	0	0
Muraroi-I	2	1	0	1	0	0	0
Dhupguri	0	0	0	0	0	0	0
Total	**43**	**39**	**33**	**2**	**4**	**0**	**0**

Source: Survey data

Note: A mouja where private STWs (electric) are used may or may not have private submersibles pump sets or other sources of irrigation owned by the government. The word "only" is used in column 2 & column 3 to indicate that diesel private STWs are not used.

Table 8.4: Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private STW (diesel & electric) owners

Block	Number of moujas where only private STWs (diesel & electric) are used	Number of moujas where boro is cultivated by private STW (diesel & electric)	Fixed fee (Cash)		Fixed fee (Crop)		Hourly contract (Rupees/Hour)		Mixed		Unclear	
			D	E	D	E	D	E	D	E	D	E
Kalna-I	1	1	0	0	0	0	0	0	0	0	1	1
Kanksa	1	1	0	0	1	0	0	0	0	0	0	1
Galsi-I	1	1	0	0	0	0	1	0	0	0	0	1
Manteswar	0	0	0	0	0	0	0	0	0	0	0	0
Beldanga-I	22	20	0	13	18	3	0	0	0	3	2	1
Ranaghat-II	81	80	19	27	0	0	50	35	10	12	1	6
Krishnanagar-I	67	67	0	16	0	0	67	50	0	0	0	1
Suri-I	3	3	1	2	0	0	1	1	0	0	1	0
Suri-II	2	2	1	1	0	0	0	0	0	0	1	1
Sainthia	24	20	13	17	0	0	1	1	2	2	4	0
Muraroi-I	0	0	0	0	0	0	0	0	0	0	0	0
Dhupguri	8	4	0	0	0	0	2	2	0	0	2	2
Total	**210**	**199**	**34**	**76**	**19**	**3**	**122**	**89**	**12**	**17**	**12**	**14**

Source: Survey data

Note: A mouja where private STWs (diesel & electric) are used may or may not have private submersibles pump sets or other sources of irrigation owned by the government.

Table 8.5: Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private SMTW (diesel) owners

Block	Number of moujas where only private SMTWs (diesel) are used	Number of moujas where boro is cultivated by private SMTW (diesel)	Fixed fee (Cash)	Fixed fee (Crop)	Hourly contract (Rupees/ Hour)	Mixed	Unclear
Kalna-I	16	15	2	0	5	0	8
Kanksa	0	0	0	0	0	0	0
Galsi-I	3	2	0	0	1	0	1
Manteswar	18	16	14	0	0	0	2
Beldanga-I	0	0	0	0	0	0	0
Ranaghat-II	0	0	0	0	0	0	0
Krishnanagar-I	0	0	0	0	0	0	0
Suri-I	1	3	1	0	0	0	2
Suri-II	1	1	0	0	0	0	1
Sainthia	10	9	4	0	1	0	4
Muraroi-I	13	11	1	7	2	0	1
Dhupguri	0	0	0	0	0	0	0
Total	**62**	**57**	**22**	**7**	**9**	**0**	**19**

Source: Survey data

Table 8.6: Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private SMTW (electric) owners

Block	Number of moujas where only private SMTWs (electric) are used	Number of moujas where boro is cultivated by private SMTW (electric)	Fixed fee (Cash)	Fixed fee (Crop)	Hourly contract (Rupees/ Hour)	Mixed	Unclear
Kalna-I	33	30	27	0	1	0	2
Kanksa	1	1	0	0	1	0	0
Galsi-I	1	1	0	0	1	0	0
Manteswar	22	20	20	0	0	0	0
Beldanga-I	9	9	0	0	0	4	5
Ranaghat-II	5	4	2	0	1	0	1
Krishnanagar-I	1	1	0	0	1	0	0
Suri-I	4	4	3	0	0	0	1
Suri-II	9	9	8	0	0	0	1
Sainthia	86	86	73	1	3	3	6
Muraroi-I	25	25	24	1	0	0	0
Dhupguri	0	0	0	0	0	0	0
Total	**196**	**190**	**157**	**2**	**8**	**7**	**16**

Source: Survey data

Table 8.7: Block-wise distribution of moujas on the basis of different contracts in boro season offered by the private SMTW (diesel & electric) owners

Block	Number of moujas where only private SMTWs (diesel & electric) are used	Number of moujas where boro is cultivated by private SMTW (diesel & electric)	Fixed fee (Cash)		Fixed fee (Crop)		Hourly contract (Rupees/ Hour)		Mixed		Unclear	
			D	E	D	E	D	E	D	E	D	E
Kalna-1	7	7	2	3	0	0	2	0	0	0	3	4
Kanksa	0	0	0	0	0	0	0	0	0	0	0	0
Galsi-1	0	0	0	0	0	0	0	0	0	0	0	0
Manteswar	40	38	35	38	0	0	0	0	0	0	3	0
Beldanga-1	0	0	0	0	0	0	0	0	0	0	0	0
Ranaghat-II	0	0	0	0	0	0	0	0	0	0	0	0
Krishnanagar-1	0	0	0	0	0	0	0	0	0	0	0	0
Suri-1	0	0	0	0	0	0	0	0	0	0	0	0
Suri-II	0	0	0	0	0	0	0	0	0	0	0	0
Saithia	3	3	0	2	0	0	1	0	0	0	2	1
Muraroi	4	3	1	2	1	0	0	0	0	0	1	1
Dhupguri	0	0	0	0	0	0	0	0	0	0	0	0
Total	**54**	**51**	**38**	**45**	**1**	**0**	**3**	**0**	**0**	**0**	**9**	**6**

Source: Survey data

Note: A mouja where private SMTWs (diesel & electric) are used may or may not have private STW pump sets or other sources of irrigation owned by the government.

is recorded in the last column.

Overall, in moujas where only diesel run STWs are used for irrigation (and electric STWs are not) the total number of moujas where hourly contracts for purchase of water from STWs are "normal" exceeds the total number of moujas where fixed fees are the norm. A closer look at the data (Table 8.2) reveals that except for Manteswar, Beldanga I, and to some extent Muraroi I blocks, this pattern is true of all the blocks surveyed in our study. If we look at the data for the moujas where STWs are run on electricity only (Table 8.3), fixed fee contracts clearly are predominant. However, except for Sainthia block, such moujas are rare. The number of moujas where both types of STWs are in use for the irrigation of boro paddy is larger, with the main concentration in four blocks: Beldanga I, Ranaghat II, Krishnanagar I and Sainthia. Hourly contracts are clearly predominant in the two blocks of Nadia district: Ranaghat II and Krishnanagar I. In Beldanga I and Sainthia, fixed fee contracts predominate.

The picture changes once we look at the contracts for supply of water from SMTWs. In the 47 moujas where all the SMTWs are run on diesel (Table 8.5) – concentrated mainly in Manteswar, Sainthia and Muraroi I – fixed fee contracts are the norm. Further, in most of these, the contract stipulates a payment in cash. In the 187 moujas where all the SMTWs are run on electricity (Table 8.6) fixed fee contracts that require payment in cash far outstrips the number of moujas where other types of contracts prevail. This pattern is repeated in the next Table (Table 8.7) where we look at moujas where SMTWs are run on diesel co-exist with SMTWs that are run on electricity. It is worth noting that, in a broad sense, in the blocks where fixed fee contracts dominate, they dominate for all types of equipment, and that the converse is also true leading to the conjecture that the nature of the contract (fixed fee or hourly rate) has more to do with the region than the equipment being used. Why this should be so is beyond us at this stage of our research. A likely explanation would be that there are differences in transactions costs across regions that make fixed fee contracts superior to hourly rate contracts in some regions and the other way around in other regions. This is an interesting area of research that we hope to explore in future[62].

The next set of Tables (Tables 8.8 to8.13) presents data on prices. It is important at this stage to mention that in many areas where hourly rates prevail for supply of water from diesel run STWs, the contract is specified as a cost of diesel plus a cash amount. Typically, the amount of diesel that has to be provided is 1 litre per hour of supply although buyers often pay for this in cash. We have reported the total cash price. This means that the prices we record are valid for the period October 2003 to February 2004 when these surveys were conducted and may have changed during the last boro cultivation period as diesel prices rose.[63] A second observation that we think is important is that in all the moujas where contracts for supply of water from SMTWs stipulate payment in cash for both diesel and electricity run machines, the price is at least as high for supply from diesel run machines as it is for supply from electrically operated machines. In most cases the charge is significantly higher. Tables 8.8 through 8.11 present the data on hourly contracts.

Table 8.12 presents the distribution of rates for supply of water from diesel run STWs in the moujas where contracts are of the fixed-fee-in-cash variety.[64] There are four blocks where such contracts are to be found: Manteswar and Beldanga I, Suri II and Sainthia. The lowest rates prevail in Sainthia and Suri II and the rates are clearly the highest in Manteswar.[65] Table 8.13 presents the corresponding figures for supply of water from electrically operated STWs in the moujas where contracts are of the fixed-fee-in-cash variety. In the blocks where such contracts are to be found, rates appear to be lowest in Sainthia. Table 8.14 and Table 8.15 present the corresponding data for supply of water

[62] We wish to thank Professor T. N. Srinivasan for pointing this out.

[63] These validity dates are true for all types of equipment and contract forms. The only difference is that fixed fee contracts are negotiated before the season begins and are not renegotiated in that season if fuel prices rise. New rates are set before the next cropping season.

[64] We include rates from all the moujas where STWs are used for the irrigation of boro paddy and do not distinguish between moujas where either electricity or diesel run machines are used exclusively, and moujas where the two types co-exist.

[65] The rates are much higher in Manteswar in spite of the fact that, broadly speaking, the water retention capacity of the soil is probably the highest here and therefore the irrigation requirement is lower here than in the other blocks.

from SMTWs. The average rates are still the highest in Manteswar although the “normal” rates that are charged for supply of water from electrically operated machines are dispersed more widely in this block than in the other blocks. What possible explanations

Table 8.8: Block-wise distribution of moujas on the basis of hourly contracts in boro season offered by the private STW (diesel) owners

Block	Rupees/ Hour				
	21-30	**31-40**	**41-50**	**51-60**	**61-70**
Kalna-1	0	0	8	8	0
Kanksa	0	7	7	3	0
Galsi-1	0	17	12	0	0
Manteswar	0	0	0	0	0
Beldanga-1	0	1	0	0	0
Ranaghat-II	4	68	3	0	0
Krishnanagar-1	7	85	0	0	0
Suri-1	0	1	6	0	0
Suri-II	0	0	3	0	0
Saithia	0	1	6	0	0
Muraroi-1	0	0	0	0	4
Dhupguri	0	0	5	4	4
Total	**11**	**180**	**50**	**15**	**8**

Source: Survey data

Note: A mouja where private STWs (diesel) are used may or may not have private STW (electric)

Table 8.9: Block-wise distribution of moujas on the basis of hourly contracts in boro season offered by the private STW (electric) owners

Block	Rupees/Hour				
	21-30	**31-40**	**41-50**	**51-60**	**61-70**
Kalna-1	0	0	0	1	0
Kanksa	0	0	0	0	0
Galsi-1	0	0	0	0	0
Manteswar	0	0	0	0	0
Beldanga-1	0	0	0	0	0
Ranaghat-II	33	2	0	0	0
Krishnanagar-1	43	8	0	0	0
Suri-1	0	1	1	0	0
Suri-II	0	0	0	0	0
Saithia	0	1	1	0	0
Muraroi-1	0	0	0	0	0
Dhupguri	0	0	2	0	0
Total	**76**	**12**	**4**	**1**	**0**

Source: Survey data

Note: A mouja where private STWs (electric) are used may or may not have private STW (diesel)

Table 8.10: Block-wise distribution of moujas on the basis of hourly contracts in boro season offered by the private SMTW (diesel) owners

Block	Rupees/Hour						
	21-30	**31-40**	**41-50**	**51-60**	**61-70**	**71-80**	**81-90**
Kalna-1	0	0	0	0	0	4	3
Kanksa	0	0	0	0	0	0	0
Galsi-1	0	0	1	0	0	0	0
Manteswar	0	0	0	0	0	0	0
Beldanga-1	0	0	0	0	0	0	0
Ranaghat-II	0	0	0	0	0	0	0
Krishnanagar-1	0	0	0	0	0	0	0
Suri-1	0	0	0	0	0	0	0
Suri-II	0	0	0	0	0	0	0
Saithia	1	0	0	1	0	0	0
Muraroi-1	0	0	0	0	2	0	0
Dhupguri	0	0	0	0	0	0	0
Total	**1**	**0**	**1**	**1**	**2**	**4**	**3**

Source: Survey data
Note: A mouja where private SMTWs (diesel) are used may or may not have SMTW electric)

Table 8.11: Block-wise distribution of moujas on the basis of hourly contracts in boro season offered by the private SMTW (electric) owners

Block	Rupees/Hour							
	21-30	**31-40**	**41-50**	**51-60**	**61-70**	**71-80**	**81-90**	**91-100**
Kalna-1	0	0	1	0	0	0	0	0
Kanksa	1	0	0	0	0	0	0	0
Galsi-1	0	0	1	0	0	0	0	0
Manteswar	0	0	0	0	0	0	0	0
Beldanga-1	0	0	0	0	0	0	0	0
Ranaghat-II	1	0	0	0	0	0	0	0
Krishnanagar-1	1	0	0	0	0	0	0	0
Suri-1	0	0	0	0	0	0	0	0
Suri-II	0	0	0	0	0	0	0	0
Saithia	1	0	0	2	0	0	0	0
Muraroi-1	0	0	0	0	0	0	0	0
Dhupguri	0	0	0	0	0	0	0	0
Total	**4**	**0**	**2**	**2**	**0**	**0**	**0**	**0**

Source: Survey data

Note: A mouja where private SMTWs (electric) are used may or may not have SMTW (diesel)

Table 8.12: Block-wise distribution of moujas on the basis of fixed fee (Cash) contracts in boro season offered by the private STW (diesel) owners

Block	Rupees/ Hectare									
	2500-3750	**3751-5000**	**5001-6250**	**6251-7500**	**7501-8750**	**8751-10000**	**10001-11250**	**11251-12500**	**12501-13750**	**13751-1500**
Kalna-1	0	0	0	0	0	0	1	0	0	0
Kanksa	0	0	0	0	0	0	0	0	0	0
Galsi-1	0	0	0	0	0	0	0	0	0	0
Manteswar	0	0	0	6	1	10	8	2	3	1
Beldanga-1	0	0	0	0	1	0	0	0	0	0
Ranaghat-II	0	0	2	21	0	0	0	0	0	0
Krishnanagar-1	0	0	0	0	0	0	0	0	0	0
Suri-1	0	1	0	0	0	0	0	0	0	0
Suri-II	0	10	1	0	0	0	0	0	0	0
Saithia	13	1	5	2	0	0	0	0	0	0
Muraroi-1	0	0	0	0	0	0	0	0	0	0
Dhupguri	0	0	0	0	0	0	0	0	0	0
Total	**13**	**12**	**8**	**29**	**2**	**10**	**9**	**2**	**3**	**1**

Source: Survey data

Note: A mouja where private STWs (diesel) are used may or may not have private STW (electric)

Table 8.13: Block-wise distribution of moujas on the basis of fixed fee (Cash) contracts in boro season offered STW (electric) by the private owners

Block	Rupees/Hectare									
	2500-3750	3751-5000	5001-6250	6251-7500	7501-8750	8751-10000	10001-11250	11251-12500	12501-13750	13751-1500
Kalna-1	0	0	0	0	0	0	0	0	0	0
Kanksa	0	0	0	1	0	0	0	0	0	0
Galsi-1	0	0	0	0	0	0	0	0	0	0
Manteswar	0	0	0	0	0	0	0	0	0	0
Beldanga-1	0	1	15	0	0	0	0	0	0	0
Ranaghat-II	0	0	24	3	0	0	0	0	0	0
Krishnanagar-1	0	5	7	4	0	0	0	0	0	0
Suri-1	6	0	0	0	0	0	0	0	0	0
Suri-II	0	3	0	0	0	0	0	0	0	0
Saithia	20	17	3	0	0	0	0	0	0	0
Muraroi-1	0	0	0	0	0	0	0	0	0	0
Dhupguri	0	0	0	0	0	0	0	0	0	0
Total	**26**	**26**	**49**	**8**	**0**	**0**	**0**	**0**	**0**	**0**

Source: Survey data

Note: A mouja where private STWs (electric) are used may or may not have private STW (diesel)

Table 8.14: Block-wise distribution of moujas on the basis of fixed fee (Cash) contracts in boro season offered SMTW (diesel) by the private owners

Block	Rupees/Hectare									
	2500-3750	**3751-5000**	**5001-6250**	**6251-7500**	**7501-8750**	**8751-10000**	**10001-11250**	**11251-12500**	**12501-13750**	**13751-1500**
Kalna-1	0	4	0	0	0	0	0	0	0	0
Kanksa	0	0	0	0	0	0	0	0	0	0
Galsi-1	0	0	0	0	0	0	0	0	0	0
Manteswar	0	0	0	1	1	8	30	5	3	1
Beldanga-1	0	0	0	0	0	0	0	0	0	0
Ranaghat-II	0	0	0	0	0	0	0	0	0	0
Krishnanagar-1	0	0	0	0	0	0	0	0	0	0
Suri-1	0	1	0	0	0	0	0	0	0	0
Suri-II	0	0	0	0	0	0	0	0	0	0
Saithia	0	4	0	0	0	0	0	0	0	0
Muraroi-1	0	0	1	0	0	0	0	0	0	0
Dhupguri	0	1	0	0	0	0	0	0	0	0
Total	**0**	**10**	**1**	**1**	**1**	**8**	**30**	**5**	**3**	**1**

Source: Survey data

Note: A mouja where private SMTWs (diesel) are used may or may not have SMTW (electric)

Table 8.15: Block-wise distribution of moujas on the basis of fixed fee (Cash) contracts in boro season offered SMTW (electric) by the private owners

Block	Rupees/Hectare									
	2500-3750	**3751-5000**	**5001-6250**	**6251-7500**	**7501-8750**	**8751-10000**	**10001-11250**	**11251-12500**	**12501-13750**	**13751-1500**
Kalna-1	4	21	0	2	2	0	1	0	0	0
Kanksa	0	0	0	0	0	0	0	0	0	0
Galsi-1	0	0	0	0	0	0	0	0	0	0
Manteswar	2	4	22	22	0	7	1	0	0	0
Beldanga-1	0	0	0	0	0	0	0	0	0	0
Ranaghat-II	0	0	2	0	0	0	0	0	0	0
Krishnanagar-1	0	0	0	0	0	0	0	0	0	0
Suri-1	0	3	0	0	0	0	0	0	0	0
Suri-II	5	3	0	0	0	0	0	0	0	0
Saithia	17	49	9	0	0	0	0	0	0	0
Muraroi-1	0	21	5	0	0	0	0	0	0	0
Dhupguri	0	0	0	0	0	0	0	0	0	0
Total	**28**	**101**	**38**	**24**	**2**	**7**	**2**	**0**	**0**	**0**

Source: Survey data

Note: A mouja where private SMTWs (electric) are used may or may not have SMTW (diesel)

can one find for his pattern? One set of reasons revolves around differences in geo-physical features that lead to differences in the number of irrigations that has to be delivered per week to a plot. Clearly this is higher in areas where the soil is more porous and so leeching losses are higher, and in areas where temperatures are higher leading to faster rates of evaporation. Differences in the quality of the aquifers (degree of saturation) should also matter. Our survey shows that water retention capacity is higher in Manteswar (where the soil has a high clay and clay loam bias and temperatures are roughly the same in the summer) as say in Suri II and Sainthia. We have no definite and reliable evidence on the quality of the aquifers but casual empiricism indicates that the number hours of irrigation required per hectare is usually lower in Manteswar than in Suri II and Sainthia. One begins to suspect that collusion among water sellers may be higher among water sellers in the moujas in Manteswar once one observes that renting in land occurs much more frequently in this block than in other blocks where we find fixed fee contracts.[66] Tables 8.16 through 8.19 present the data for the fixed fee contracts where payment is in quantities of crop.[67]

[66] See footnote 29.
[67] Payment has to be made immediately after the harvest of the crop.

Table 8.16: Block-wise distribution of moujas on the basis of fixed fee (crop) contracts in boro season offered by private STW (diesel) owners

Block	**Kg./ Hectare**		
	300-700	**701-1100**	**1001-1500**
Kalna-1	0	0	1
Kanksa	0	0	0
Galsi-1	0	0	0
Manteswar	0	0	0
Beldanga-1	0	31	5
Ranaghat-II	0	0	0
Krishnanagar-1	0	0	0
Suri-1	0	0	0
Suri-II	0	0	0
Saithia	0	0	0
Muraroi-1	8	4	0
Dhupguri	0	0	0
Total	**8**	**35**	**6**

Source: Survey data

Note: A mouja where private STWs (diesel) are used may or may not have private STW (electric).

Table 8.17: Block-wise distribution of moujas on the basis of fixed fee (crop) contracts in boro season offered by private STW (electric) owners

Block	Kg./Hectare		
	300-700	**701-1100**	**1001-1500**
Kalna-1	0	0	0
Kanksa	0	0	0
Galsi-1	0	0	0
Manteswar	0	0	0
Beldanga-1	0	0	3
Ranaghat-II	0	0	0
Krishnanagar-1	0	0	0
Suri-1	0	0	0
Suri-II	0	0	0
Saithia	0	0	1
Muraroi-1	1	0	0
Dhupguri	0	0	0
Total	**1**	**0**	**4**

Source: Survey data

Note: A mouja where private STWs (electric) are used may or may not have private STW (diesel).

Table 8.18: Block-wise distribution of moujas on the basis of fixed fee (crop) contracts in boro season offered by private SMTW (diesel) owners

Block	Kg./Hectare		
	300-700	**701-1100**	**1001-1500**
Kalna-1	0	0	0
Kanksa	0	0	0
Galsi-1	0	0	0
Manteswar	0	0	0
Beldanga-1	0	0	0
Ranaghat-II	0	0	0
Krishnanagar-1	0	0	0
Suri-1	0	0	0
Suri-II	0	0	0
Saithia	0	0	0
Muraroi-1	1	7	0
Dhupguri	0	0	0
Total	**1**	**7**	**0**

Source: Survey data

Note: A mouja where private SMTWs (diesel) are used may or may not have SMTW (electric)

Table 8.19: Block-wise distribution of moujas on the basis of fixed fee (crop) contracts in boro season offered by private SMTW (electric) owners

Block	**Kg./Hectare**		
	300-700kg.	**701-1100kg.**	**1001-1500 kg.**
Kalna-1	0	0	0
Kanksa	0	0	0
Galsi-1	0	0	0
Manteswar	0	0	0
Beldanga-1	0	0	0
Ranaghat-II	0	0	0
Krishnanagar-1	0	0	0
Suri-1	0	0	0
Suri-II	0	0	0
Saithia	0	0	1
Muraroi-1	1	0	0
Dhupguri	0	0	0
Total	**1**	**0**	**1**

Source: Survey data

Note: A mouja where private SMTWs (electric) are used may or may not have SMTW (diesel)

9. Household behaviour: results of household level surveys

In this section we take a closer look at some basic questions. What types of households buy water? What types of households invest in water extraction devices? It is important to keep in mind two very basic features of the pattern of land holding in West Bengal that are perhaps in many ways the basic reasons for the existence of water markets in this part of the world. First, land holdings are typically very small and a very large percentage of households in a West Bengal do not own agricultural land. Second, land holdings are fragmented and often the plots owned by a family may lie in different parts of the mouja (or even outside the) where the family lives. These features imply that a large number of households may not have the money or the access to credit that will allow them to invest in groundwater extraction equipment, and that the families who own such equipment may not have enough land in the command areas of their machines. Thus it is fairly common practice for two owners of STWs or SMTWs to irrigate each other's plots, often under a pure barter arrangement.

9.1 Descriptive statistics

Table 9.1 presents data on the number of households classified by the size class of holdings in all the moujas where we ran our household level surveys. A word of caution is imperative. It is extremely difficult to ascertain the exact amount of land a family owns on the basis of surveys. Even though we repeatedly cross checked the responses we received by talking to other supposedly well informed local residents, particularly because we were interested in the relationship between the size of landholding and ownership of groundwater extraction devices, we are not absolutely certain that our data is completely accurate.[68] Tables 9.2 through 9.4 present data on the number of households in each mouja who cultivate Khariff paddy, rabi crops and summer paddy. It appears from our data that more landless households cultivate khariff paddy than the summer paddy. This is plausible because the cost of cultivation of boro paddy is higher than the cost of cultivation of khariff paddy once one excludes labour costs. Table 9.5 presents

[68] Our view is that landless agricultural labourers are often very good sources of information on landholding

Table 9.1: Number of households of different classes by moujas

Block	Mouja	Landless	Marginal	Small	Medium
Kalna-I	Keshabpur	63	69	9	7
	Choughuria	219	101	20	21
Galsi-I	Dharampur	171	367	81	57
Memari-I	Boror	380	272	21	20
	Birshimul	108	137	15	11
Manteswar	Kusumgram	1339	440	41	36
	Bhadai	135	68	12	8
	Paschim Kharampur	29	167	21	11
	Banui	57	172	35	9
	Murulia	80	89	18	10
Beldanga-I	Paluighata	190	134	6	5
	Maheshpur	459	186	13	5
Berhampur	Nealishpara	206	76	6	4
	Paschim Gopinathpur	104	25	0	0
	Koriagachhi	64	108	8	6
Ranaghat-II	Hosenpur	265	284	20	14
	Ujirpukuria	248	243	34	6
Krishnanagar-I	Pakurgachhi	396	291	21	9
	Haranagar	412	365	52	12
Suri-I	Dolgobindopur	19	35	9	5
	Parshimulia	76	70	11	5
	Saktipur	78	46	7	6
	Kamardangal	21	124	28	7
Suri-II	Maipur	63	190	21	16
Sainthia	Bhabanipur	113	56	17	10
	Kusumdihi	123	79	24	11
Muraroi-II	Kalikapur	263	261	14	10
Dhupguri	Purbamagurmari	137	127	26	8
	Dambari	122	288	39	18
	Uttar kathulia	126	410	61	22

Source: Survey data

Note:

Classification of household	Size of land ownership (x)
Landless	X = 0
Marginal	0< x ≤1 hectare
Small	1 hectare < x ≤2 hectare
Medium	X > 2 hectare

Table 9.2: Mouja wise distribution of cultivated households: Khariff Paddy

Block	Mouja	Landless	Marginal	Small	Medium
Kalna-I	Keshabpur	9	66	9	7
	Choughuria	36	99	20	21
Galsi-I	Dharampur	0	353	79	57
Memari-I	Boror	33	128	12	20
	Birshimul	93	262	21	11
Manteswar	Kusumgram	16	404	42	36
	Bhadai	17	64	12	7
	Paschim Kharampur	6	157	18	10
	Banui	2	151	34	9
	Murulia	2	86	18	11
Beldanga-I	Paluighata	32	129	16	5
	Maheshpur	20	173	13	5
Berhampur	Nealishpara	10	58	6	4
	Paschim Gopinathpur	10	18	0	0
	Koriagachhi	31	97	8	6
Ranaghat-II	Hosenpur	13	245	20	14
	Ujirpukuria	27	211	34	6
Krishnanagar-I	Pakurgachhi	7	274	21	9
	Haranagar	14	285	50	12
Suri-I	Dolgobindopur	8	35	9	5
	Parshimulia	26	68	11	5
	Saktipur	24	42	7	6
	Kamardangal	0	124	28	7
Suri-II	Maipur	0	180	20	16
Sainthia	Bhabanipur	7	56	17	10
	Kusumdihi	3	65	22	10
Muraroi-II	Kalikapur	7	239	13	9
Dhupguri	Purbamagurmari	1	36	20	8
	Dambari	0	276	37	18
	Uttar kathulia	0	372	61	22

Source: Survey data

Table 9.3: Total number of cultivators of different classes in Rabi season

Block	Mouja	Landless	Marginal	Small	Medium
Kalna-I	Keshabpur	6	60	9	7
	Choughuria	42	74	20	20
Galsi-I	Dharampur	0	66	38	45
Memari-I	Boror	22	99	10	10
	Birshimul	59	165	21	20
Manteswar	Kusumgram	0	25	7	10
	Bhadai	15	44	8	6
	Paschim Kharampur	3	63	11	8
	Banui	6	99	30	8
	Murulia	0	23	15	9
Beldanga-I	Paluighata	31	58	6	5
	Maheshpur	20	167	12	4
Berhampur	Nealishpara	13	30	6	4
	Paschim Gopinathpur	7	22	0	0
	Koriagachhi	31	86	8	6
Ranaghat-II	Hosenpur	9	178	19	14
	Ujirpukuria	19	153	34	6
Krishnanagar-I	Pakurgachhi	7	244	20	9
	Haranagar	12	237	49	12
Suri-I	Dolgobindopur	8	30	9	5
	Parshimulia	32	65	11	5
	Saktipur	18	39	7	5
	Kamardangal	0	58	28	7
Suri-II	Maipur	1	126	20	13
Sainthia	Bhabanipur	6	55	17	10
	Kusumdihi	13	46	20	10
Muraroi-II	Kalikapur	58	161	13	9
Dhupguri	Purbamagurmari	1	125	26	8
	Dambari	1	212	38	18
	Uttar kathulia	0	299	61	22

Source: Survey data

Table 9.4: Total number of cultivators of different classes in Boro season

Block	Mouja	Landless	Marginal	Small	Medium
Kalna-I	Keshabpur	7	54	9	7
	Choughuria	25	77	18	20
Galsi-I	Dharampur	0	352	78	57
Memari-I	Boror	31	87	12	11
	Birshimul	82	244	20	20
Manteswar	Kusumgram	36	315	50	22
	Bhadai	13	49	8	7
	Paschim Kharampur	5	56	8	5
	Banui	5	35	9	5
	Murulia	7	87	15	11
Beldanga-I	Paluighata	3	14	2	5
	Maheshpur	20	164	13	4
Berhampur	Nealishpara	7	45	2	3
	Paschim Gopinathpur	0	22	0	0
	Koriagachhi	0	28	5	5
Ranaghat-II	Hosenpur	25	267	20	13
	Ujirpukuria	29	186	34	6
Krishnanagar-I	Pakurgachhi	7	276	21	9
	Haranagar	4	275	50	12
Suri-I	Dolgobindopur	8	35	9	5
	Parshimulia	34	57	11	5
	Saktipur	23	40	7	6
	Kamardangal	0	124	28	11
Suri-II	Maipur	23	178	21	14
Sainthia	Bhabanipur	8	46	16	10
	Kusumdihi	33	62	22	10
Muraroi-II	Kalikapur	79	190	9	9
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	77	15	10
	Uttar kathulia	0	4	3	3

Source: Survey data

Table 9.5: Availability of irrigation facilities by source

Block	Mouja	Different sources of irrigation										
		Tank	Kandar	RLI	DTW	G STW	G. SM	Pvt STW	Pvt SM	Canal	Co STW	Co SM
Kalna-I	Keshabpur	Y	N	Y	N	N	N	N	Y	N	N	Y
	Choughuria	Y	N	N	N	N	N	N	Y	N	N	Y
Galsi-I	Dharampur	Y	N	N	N	N	N	Y	N	Y	N	N
Memari-I	Boror	Y	N	Y	N	N	N	Y	N	Y	N	N
	Birshimul	Y	N	Y	Y	N	N	N	Y	Y	N	N
Manteswar	Kusumgram	Y	N	N	Y	N	N	N	Y	Y	N	N
	Bhadai	Y	N	N	N	N	N	N	Y	Y	N	N
	Paschim Kharampur	Y	N	N	Y	N	N	Y	Y	Y	N	N
	Banui	Y	N	N	N	N	N	N	Y	Y	N	N
	Murulia	Y	N	N	N	N	N	N	Y	N	N	N
Beldanga-I	Paluighata	Y	N	Y	N	N	N	Y	N	N	N	N
	Maheshpur	Y	N	N	N	N	N	Y	Y	N	N	N
Berhampur	Nealishpara	Y	N	N	Y	N	N	Y	N	N	N	N
	Paschim Gopinathpur	Y	N	N	N	N	N	Y	N	N	N	N
	Koriagachhi	Y	N	N	N	Y	Y	Y	N	N	N	N
Ranaghat-II	Hosenpur	Y	N	N	Y	Y	Y	Y	N	N	N	N
	Ujirpukuria	Y	Y	N	Y	N	N	Y	N	N	N	N
Krishnanagar-I	Pakurgachhi	Y	N	Y	Y	N	N	Y	N	N	N	N
	Haranagar	Y	N	Y	N	N	N	Y	N	N	N	N
Suri-I	Dolgobindopur	Y	N	N	N	N	N	Y	N	Y	N	N
	Parshimulia	Y	N	N	N	N	N	N	Y	Y	N	N
	Saktipur	Y	N	N	N	N	N	N	Y	Y	N	N
	Kamardangal	Y	Y	N	N	N	N	Y	N	Y	N	N
Suri-II	Maipur	Y	N	N	N	N	N	N	Y	Y	N	N
Sainthia	Bhabanipur	Y	N	N	N	N	N	Y	Y	N	N	N
	Kusumdihi	Y	N	N	N	N	N	Y	Y	N	N	N
Muraroi-II	Kalikapur	Y	N	N	N	N	N	Y	Y	Y	N	N
Dhupguri	Purbamagurmari	Y	N	N	N	N	N	Y	N	N	N	N
	Dambari	Y	N	Y	N	N	N	Y	N	N	Y	N
	Uttar Kathulia	Y	N	Y	N	N	N	Y	N	N	Y	N

Source: Survey data.

data on the different sources of irrigation that are available in our survey moujas. The English word for *Kandar* is gully; and Co STW and Co SM designate co-operatively STWs and SMTWs that are owned by agricultural co-operatives. Either privately owned STWs or privately owned SMTWs exist in all these villages because the villages were selected from the class of all such moujas in each of the blocks. Tables 9.6 and 9.7 present data on the ownership of STWs and SMTWs in each mouja. For the most part, single households own STWs though some households own more than one such device. Joint ownership is more noticeable in the case of SMTWs simply because these are more expensive machines. At the peak of the boro paddy boom in the mid 1990s, many households that owned small amounts of land joined together to invest in these machines largely because of the profits they expected to make from selling water or from renting in land during the boro cultivation season. In Bhabanipur, several households that were previously part of one joint family, own SMTWs jointly because the large, consolidated plots of the joint family were divided among them and, therefore, their plots lie in single compact enclaves.

Tables 9.8 through 9.13 present the data on number of households in each size class of households who buy water from STW or SMTW owners in the khariff, rabi and boro seasons.

Table 9.6: Number of private STW owners by moujas

Block	Mouja	Private STW		
		Number of single owner	Number of joint owner	Number of owners who have more than 1
Kalna-I	Keshabpur	0	0	0
	Choughuria	0	0	0
Galsi-I	Dharampur	24	0	0
Memari-I	Boror	33	0	0
	Birshimul	0	0	0
Manteswar	Kusumgram	0	0	0
	Bhadai	0	0	0
	Paschim Kharampur	10	2	0
	Banui	0	0	0
	Murulia	0	0	0
Beldanga-I	Paluighata	7	0	1(2)
	Maheshpur	12	0	0
Berhampur	Nealishpara	5	0	0
	Paschim Gopinathpur	1	0	0
	Koriagachhi	21	7	0
Ranaghat-II	Hosenpur	32	0	1(3)
	Ujirpukuria	52	0	0
Krishnanagar-I	Pakurgachhi	88	0	2(2),1(3)
	Haranagar	121	0	3(2),1(3)
Suri-I	Dolgobindopur	5	0	0
	Parshimulia	0	0	0
	Saktipur	0	0	0
	Kamardangal	3	0	0
Suri-II	Maipur	0	0	0
Sainthia	Bhabanipur	12	0	0
	Kusumdihi	8	0	0
Muraroi-II	Kalikapur	43	5	0
Dhupguri	Purbamagurmari	31	0	0
	Dambari	54	0	0
	Uttar Kathulia	6	16	0

Source: Survey data

Note: Numbers within parentheses in the 3rd column represents total number of STW of the owner

Table 9.7: Number of private SMTW owners by moujas

Block	Mouja	Private SMTW		
		Number of single owner	Number of joint owner	Number of owners who have more than 1
Kalna-I	Keshabpur	1	0	0
	Choughuria	10	0	0
Galsi-I	Dharampur	1	0	0
Memari-I	Boror	0	0	0
	Birshimul	4	0	0
Manteswar	Kusumgram	36	0	3(2)
	Bhadai	14	2	1(2)
	Paschim Kharampur	8	5	3(2)
	Banui	12	8	0
	Murulia	10	13	0
Beldanga-I	Paluighata	0	0	0
	Maheshpur	6	0	0
Berhampur	Nealishpara	0	0	0
	Paschim Gopinathpur	0	0	0
	Koriagachhi	0	0	0
Ranaghat-II	Hosenpur	0	0	0
	Ujirpukuria	0	0	0
Krishnanagar-I	Pakurgachhi	0	0	0
	Haranagar	0	0	0
Suri-I	Dolgobindopur	0	0	0
	Parshimulia	2	0	0
	Saktipur	0	0	2(2)
	Kamardangal	0	0	0
Suri-II	Maipur	13	0	0
Sainthia	Bhabanipur	4	33	0
	Kusumdihi	3	0	0
Muraroi-II	Kalikapur	8	2	1(2)
Dhupguri	Purbamagurmari	0	0	0
	Dambari	0	0	0
	Uttar Kathulia	0	0	0

Source: Survey data

Note: Numbers within parentheses in the 3rd column represents total number of SMTW of the owner

Table 9.8: Number of cultivator of different class who buy water from STW for Khariff cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	0	0	0
	Choughuria	0	0	0	0
Galsi-I	Dharampur	0	10	3	6
Memari-I	Boror	0	6	0	0
	Birshimul	0	0	0	0
Manteswar	Kusumgram	0	0	0	0
	Bhadai	0	0	0	0
	Paschim Kharampur	0	0	0	0
	Banui	0	0	0	0
	Murulia	0	0	0	0
Beldanga-I	Paluighata	3	33	4	4
	Maheshpur	12	120	9	4
Berhampur	Nealishpara	0	5	1	0
	Paschim Gopinathpur	0	0	0	0
	Koriagachhi	23	81	8	3
Ranaghat-II	Hosenpur	2	40	7	8
	Ujirpukuria	20	189	30	5
Krishnanagar-I	Pakurgachhi	7	268	21	8
	Haranagar	11	252	46	10
Suri-I	Dolgobindopur	0	0	0	0
	Parshimulia	0	0	0	0
	Saktipur	0	0	0	0
	Kamardangal	0	0	0	0
Suri-II	Maipur	0	0	0	0
Sainthia	Bhabanipur	3	23	4	4
	Kusumdihi	0	3	4	5
Muraroi-II	Kalikapur	0	0	0	0
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	0	0	0
	Uttar kathulia	0	12	10	4

Source: Survey data

Table9.9: Number of cultivator of different class who buy water from Private STW for Rabi cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	0	0	0
	Choughuria	0	0	0	0
Galsi-I	Dharampur	0	36	26	31
Memari-I	Boror	12	82	15	15
	Birshimul	0	0	0	0
Manteswar	Kusumgram	0	0	0	0
	Bhadai	0	0	0	0
	Paschim Kharampur	0	6	3	0
	Banui	0	0	0	0
	Murulia	0	0	0	0
Beldanga-I	Paluighata	2	16	4	3
	Maheshpur	15	134	13	0
Berhampur	Nealishpara	0	4	1	0
	Paschim Gopinathpur	5	22	0	0
	Koriagachhi	18	64	8	2
Ranaghat-II	Hosenpur	4	32	7	7
	Ujirpukuria	18	131	28	4
Krishnanagar-I	Pakurgachhi	7	240	19	7
	Haranagar	9	220	49	10
Suri-I	Dolgobindopur	0	0	0	0
	Parshimulia	0	0	0	0
	Saktipur	0	0	0	0
	Kamardangal	0	44	28	5
Suri-II	Maipur	0	0	0	0
Sainthia	Bhabanipur	3	23	4	3
	Kusumdihi	3	14	7	6
Muraroi-II	Kalikapur	3	26	1	0
Dhupguri	Purbamagurmari	1	99	21	7
	Dambari	1	16	3	0
	Uttar kathulia	0	12	10	6

Source: Survey data

Table 9.10: Number of cultivator of different class who buy water from Private STW for Boro cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	0	0	0
	Choughuria	0	0	0	0
Galsi-I	Dharampur	0	117	26	19
Memari-I	Boror	10	43	4	8
	Birshimul	0	0	0	0
Manteswar	Kusumgram	0	0	0	0
	Bhadai	0	0	0	0
	Paschim Kharampur	1	17	3	3
	Banui	0	0	0	0
	Murulia	0	0	0	0
Beldanga-I	Paluighata	0	1	2	0
	Maheshpur	4	74	4	0
Berhampur	Nealishpara	0	4	0	0
	Paschim Gopinathpur	0	0	0	0
	Koriagachhi	0	15	4	0
Ranaghat-II	Hosenpur	3	33	8	7
	Ujirpukuria	23	159	28	4
Krishnanagar-I	Pakurgachhi	7	273	21	7
	Haranagar	2	144	23	8
Suri-I	Dolgobindopur	0	3	0	2
	Parshimulia	0	0	0	0
	Saktipur	0	0	0	0
	Kamardangal	0	0	0	0
Suri-II	Maipur	0	0	0	0
Sainthia	Bhabanipur	3	23	4	3
	Kusumdihi	5	19	10	8
Muraroi-II	Kalikapur	45	151	8	5
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	6	0	0
	Uttar Kathulia	0	2	1	0

Source: Survey data

Table 9.11: Number of cultivator of different class who buy water from private SMTW for Khariff cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	13	3	7
	Choughuria	36	41	13	23
Galsi-I	Dharampur	0	0	1	0
Memari-I	Boror	0	0	0	0
	Birshimul	44	49	7	4
Manteswar	Kusumgram	3	2	1	4
	Bhadai	6	10	2	0
	Paschim Kharampur	0	4	0	0
	Banui	0	0	0	0
	Murulia	2	85	18	9
Beldanga-I	Paluighata	0	0	0	0
	Maheshpur	13	94	10	3
Berhampur	Nealishpara	0	0	0	0
	Paschim Gopinathpur	0	0	0	0
	Koriagachhi	0	0	0	0
Ranaghat-II	Hosenpur	0	0	0	0
	Ujirpukuria	0	0	0	0
Krishnanagar-I	Pakurgachhi	0	0	0	0
	Haranagar	0	0	0	0
Suri-I	Dolgobindopur	0	0	0	0
	Parshimulia	4	17	1	2
	Saktipur	14	22	5	1
	Kamardangal	0	0	0	0
Suri-II	Maipur	0	4	0	3
Saithia	Bhabanipur	5	37	17	8
	Kusumdihi	0	3	1	3
Muraroi-II	Kalikapur	5	214	13	6
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	0	0	0
	Uttar kathulia	0	0	0	0

Source: Survey data

Table 9.12: Number of cultivators of different class who buy water from Private SMTW for Rabi cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	13	2	3
	Choughuria	34	40	13	13
Galsi-I	Dharampur	0	0	0	0
Memari-I	Boror	0	0	0	0
	Birshimul	35	64	6	6
Manteswar	Kusumgram	0	9	5	8
	Bhadai	2	10	2	3
	Paschim Kharampur	0	25	4	4
	Banui	0	0	0	0
	Murulia	0	0	0	0
Beldanga-I	Paluighata	0	0	0	0
	Maheshpur	7	38	3	2
Berhampur	Nealishpara	0	0	0	0
	Paschim Gopinathpur	0	0	0	0
	Koriagachhi	0	0	0	0
Ranaghat-II	Hosenpur	0	0	0	0
	Ujirpukuria	0	0	0	0
Krishnanagar-I	Pakurgachhi	0	0	0	0
	Haranagar	0	0	0	0
Suri-I	Dolgobindopur	0	0	0	0
	Parshimulia	19	36	8	2
	Saktipur	17	33	7	2
	Kamardangal	0	0	0	0
Suri-II	Maipur	1	111	20	12
Saithia	Bhabanipur	4	37	17	10
	Kusumdihi	6	19	14	0
Muraroi-II	Kalikapur	21	149	13	9
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	0	0	0
	Uttar kathulia	0	0	0	0

Source: Survey data

Table 9.13: Number of cultivator of different class who buy water from Private SMTW for Boro cultivation

Block	Mouja	Landless	Marginal	Small	Semi medium
Kalna-I	Keshabpur	0	11	4	5
	Choughuria	25	22	12	14
Galsi-I	Dharampur	0	0	0	0
Memari-I	Boror	0	0	0	0
	Birshimul	34	25	7	5
Manteswar	Kusumgram	34	302	29	23
	Bhadai	13	36	8	6
	Paschim Kharampur	3	36	5	3
	Banui	5	35	8	3
	Murulia	7	88	18	10
Beldanga-I	Paluighata	0	0	0	0
	Maheshpur	14	93	10	2
Berhampur	Nealishpara	0	0	0	0
	Paschim Gopinathpur	0	0	0	0
	Koriagachhi	0	0	0	0
Ranaghat-II	Hosenpur	0	0	0	0
	Ujirpukuria	0	0	0	0
Krishnanagar-I	Pakurgachhi	0	0	0	0
	Haranagar	0	0	0	0
Suri-I	Dolgobindopur	0	0	0	0
	Parshimulia	20	36	7	3
	Saktipur	21	39	6	5
	Kamardangal	0	0	0	0
Suri-II	Maipur	23	179	21	12
Sainthia	Bhabanipur	6	25	16	9
	Kusumdihi	19	37	15	3
Muraroi-II	Kalikapur	46	78	3	3
Dhupguri	Purbamagurmari	0	0	0	0
	Dambari	0	0	0	0
	Uttar kathulia	0	0	0	0

Source: Survey data

9.2. Regression Results

For the households we did only logit regressions. The dependent variable, y_i is defined as $y_i = 1$ if the household invests in STW or SMTW and $y_i = 0$, otherwise. In this case we regressed y_i on household characteristics along with mouja characteristics. Naturally mouja characteristics remain fixed for the households living in a particular mouja. In addition to the relevant variables for moujas we define the following variables specific to households.

LAND = total land cultivated by the households,

FLYSZ = family size of the household,

LNDPRHD = land per adult member of the household,

FPRISOINS = an exogenous dummy with a value one if farming is the primary source of income for the household and zero otherwise,

LSECSOINC = an exogenous dummy with a value one if labour is the secondary source when farming is the primary source of income for the household and zero otherwise,

BRENTIN = an exogenous dummy with a value one if the household rents in land in boro and zero otherwise,

BRENTOUT = an exogenous dummy with a value one if the household rents in land in boro and zero otherwise,

WTSELL = an exogenous dummy with a value one if the household sells water,

BGWTBUY = an exogenous dummy with a value one if the household buys water from government sources,

Here land means the total land that the household cultivates, including land under share tenancy. It would have been a better if we had separate data on own land and land as sharecropper. But in the absence of the disaggregation we had to work with total land cultivated by the households[69].

[69] The households are very sensitive to their true land holding and often misreport though they are not so secretive about actual cultivation.

Table 9.14 gives the regression results. After testing for outliers we dropped 667 observations and re-estimated the regression equations. The results remain by and large similar for mouja features except for ELECFLD. It is positive and significant in most of the cases as revealed by Table 9.15. This is an expected result but apparently contradicts the results of Section 7 for mouja level regressions where we found a negative and significant coefficient estimate of ELECFLD, both in logit and OLS regressions. However, one should be careful when comparing two results. In Section 7 we were working with mouja level data that are spread over different agro climatic zones – from agriculturally less intensive to highly intensive areas. So the presence of electricity in fields does not help installation of STW or SMTW if the moujas have wrong geo-physical characteristics or if sufficient water is available from state owned sources.. On the other hand absence of electricity in fields is not a hindrance if the other geo-physical characteristics are right. In the latter case diesel operated STWs or SMTWs are installed and the moujas are also agriculturally intensive For the household level studies we chose thirty moujas where the level of agricultural activity is high. Thus these areas have right geo-physical characteristics or have adequate water from canals etc. Our logit regression result says that the probability that a household will invest in groundwater extraction devices increase with the availability of electricity. In areas where the quantum of water available from canals is inadequate, electrification turns out to be an added advantage. Hence the presence of electricity acts as a positive factor in determining the probability that a household level will invest in a STWs or SMTWs. What the result does not say is that availability of electricity will increase the area under cultivation of boro paddy as farmers invest in new STWs or SMTWs.

Taken together, the results in Section 7 and the result above lead to an important policy conclusion. If the policy target is to increase the area under cultivation of a particular crop that is constrained by the availability of irrigation, inducing private investment in STWs and SMTWs by providing electricity will work only if the areas where electricity is provided are either not already saturated with diesel operated machines or have the right geophysical conditions and low investment in groundwater extraction devices.

Otherwise, existing diesel operated machines will be converted to use electricity as a source of power as in the first case, or new machines will not be installed as unfavourable geophysical conditions will result in such investment being unprofitable.

Among other mouja level geo-physical characteristics, CLOCLA and HROCK act as deterrent for household investment in groundwater extraction. Among the household factors, land, family size, agriculture as the primary source of income positively affects household investment in groundwater irrigation. The presence of government irrigation in this case does not give robust result; the relevant variables (CAND3, RLID3, DTWD3 etc.) flip-flop in terms of the signs of the coefficients and/ or significance levels. The index of government irrigation, DIS is positive significant only in two regression equations, viz. columns 6 and 7 in Table 9.14. Farmers who rent out land in boro season have negative incentive to invest in STW or SMTW. LSECSOINC is non-significant in all the regressions, hence dropped later. This shows that marginal farmers who also work as farm labourer generally do not invest in groundwater extraction.

We also repeated the regression exercises with land size (LAND) replaced by the land per adult member of the family (LNDPRHD). This will take care of any heteroscedasticity due to size. The results are reported in Tables 9.16 and 9.17. In general the performance of the regression equations in terms of R^2 or Adj R^2 and other regression diagnostics are quite satisfactory.

Table 9.14: Identification of Potential Investors

	SL NO.-->	1	2	3	4	5	6	7
REGRESSORS	**CONST**	-3.014 (-15.1)	-2.99 (-24.0)	-4.36 (-20.3)	-3.09 (-15.7)	-4.27 (-16.9)	-3.22 (-15.9)	-4.46 (-17.4)
	LAND	0.173 (15.7)	0.173 (16.7)		0.17 (15.8)		0.184 (17.1)	
	FLYSZ			0.123 (4.8)		0.141 (5.3)		0.14 (5.4)
	FPRISOINC			2.343 (14.8)		2.348 (14.7)		2.45 (15.5)
	LSECSOINC							
	BRENTIN	0.144 (0.7)		-0.369 (-1.8)	0.348 (1.6)	-0.149 (-0.7)	0.302 (1.4)	-0.25 (-1.2)
	BRENTOUT	-0.70 (-2.3)	-0.71 (-2.4)	-0.092 (0.7)	-0.847 (-2.7)	-0.193 (-0.7)	-0.999 (-3.2)	-0.29 (-1.1)
	WTSELL	4.99 (21.3)	5.02 (21.8)	5.348 (21.4)	4.977 (20.1)	5.184 (20.1)	4.87 (20.2)	5.106 (20.4)
	BGWTBUY	0.064 (0.3)		0.759 (0.4)				
	CAND3				1.46 (5.9)	1.60 (6.5)		
	RLID3				1.364 (7.3)	1.436 (7.6)		
	DTWD3				0.473 (2.2)	0.235 (1.6)		
	DIS						1.224 (8.0)	1.225 (8.1)
	CLOCLA	-0.022 (-7.3)	-0.022 (-8.3)	-0.016 (-5.5)	-0.037 (-9.2)	-0.033 (-5.5)	-0.03 (-8.7)	-0.024 (-7.4)
	HROCK	-1.36 (-3.252)	-1.34 (-3.4)	-1.67 (-4.1)	-1.697 (-3.9)	-2.349 (-8.5)	-1.535 (-3.7)	-2.097 (-5.1)
	ELECFLD	0.669 (0.01)			-0.45 (-0.6)	-0.200 (-2.6)	-0.071 (-0.9)	-0.23 (-3.0)
STATISTICS	**LNL(UR)**	-894.53	-894.78	-875.84	-862.59	-836.51	-862.51	-841.56
	pse-R^2	0.452	0.452	0.463	0.472	0.487	0.472	0.484
	χ^2(df)	1475.25 (8)	1574.74 (5)	1512.63 (8)	1539.14 (10)	1591.292 (11)	1539.29 (8)	1581.18 (9)
	0-PR/ AC	6720/6559	6720/6559	6754/6559	6728/6559	6760/6559	6723/6559	6757/6559
	1-PR/ AC	275/436	275/436	241/436	267/436	235/436	272/436	238/436
	AC/PR	6740/6995	6740/6995	6754/6995	6734/6995	6542/6995	6737/6995	6743/6995

Table 9.15: Identification of Potential Investors (without outliers)

	SL NO.-->	1	2	3	4	5	6	7
REGRESSORS	CONST	-4.96 (25.7)	-3.73 (-15.8)	-4.1 (-14.7)	-4.84 (-21.5)	-3.92 (-14.7)	-3.65 (-15.6)	-3.98 (14.7)
	FLYSZ			0.16 (5.1)		0.18 (5.6)		0.18 (5.5)
	LAND	0.26 (14.9)	0.25 (14.8)		0.24 (14.4)		0.25 (15.2)	
	BRENTIN	0.39 (1.52)		0.14 (0.57)	0.4 (1.7)	0.22 (0.9)	0.402 (1.6)	0.26 (1.03)
	BRENTOUT	-0.94 (-2.3)	-0.73 (-1.8)	0.51 (1.38)	-0.7 (-1.7)	0.43 (1.1)	-0.64 (-1.5)	0.55 (1.5)
	WTSELL	4.53 (14.8)	4.73 (15.0)	5.17 (16.9)	4.4 (14.5)		4.74 (14.5)	5.31 (16.7)
	BGWTBUY	-0.84 (-2.6)	-0.17 (-0.5)	1.03 (3.7)				
	CAND3				-0.29 (-1.07)	2.32 (7.9)		
	RLID3				0.06 (0.3)	1.21 (5.4)		
	DTWD3				-0.51 (-2.2)	0.71 (2.7)		
	DIS						1.06 (5.0)	1.31 (5.75)
	CLOCLA	-0.03 (-2.3)	-0.02 (-6.6)	-0.02 (-2.0)		-0.04 (-8.9)	-0.03 (-7.9)	-0.03 (-7.63)
	HROCK	-0.09 (-0.15)	-1.27 (-2.1)	-1.33 (-2.0)	-0.25 (-0.4)	-1.31 (-2.2)	-1.46 (-2.3)	-1.2 (-2.08)
	ELECFLD	0.46 (4.8)	0.26 (2.6)	0.40 (4.14)	0.47 (4.84)	0.25 (2.6)	0.08 (0.84)	0.17 (1.99)
STATISTICS	LNL(UR)	-637.04	-616-23	-718.49	-637.74	-693.49	-603.59	-708.39
	Pse-R^2	0.374	0.394	0.294	0.373	0.318	0.407	0.303
	χ^2(df)	760.05 (8)	801.68 (7)	597.17 (8)	758.66 (9)	647.15 (10)	826.97 (8)	617.35 (8)
	0-PR/AC	6194/6079	6201/6079	6220/6079	6201/6079	6220/6079	6200/6079	6224/6079
	1-PR/AC	124/239	117/239	98/239	117/239	98/239	118/239	94/239
	AC/PR	6129/6318	6128/6318	6143/6318	6132/6318	6134/6318	6023/6318	6141/6318

Table 9.16: Identification of Potential Investors (adjusted for heteroscedasticity)

SL NO.-->		1	2	3	4	5	6
REGRESSORS	CONST	-3.03 (-15.2)	-3.11 (-24.0)	-3.09 (-15.8)	-3.15 (22.1)	-3.23 (-16.1)	-3.39 (-22.7)
	LNDPRHD	0.51 (14.7)	0.52 (15.5)	0.51 (14.4)	0.49 (14.3)	0.54 (15.3)	0.53 (15.3)
	LAND						
	FLYSZ						
	BRENTIN	0.13 (0.6)		0.33 (1.5)		0.28 (1.3)	
	BRENTOUT	-0.65 (-2.1)	-0.71 (-2.4)	-0.79 (-2.5)	-0.7 (-2.2)	-0.9 (-2.9)	-0.86 (-2.8)
	WTSELL	5.10 (22.1)	5.15 (22.6)	5.15 (21.1)	5.24 (21.5)	5.03 (21.2)	5.10 (21.8)
	BGWTBUY	0.29 (1.2)					
	D3			1.55 (6.4)	1.47 (6.0)		
	RLID3			1.25 (6.7)	1.05 (6.3)		
	DTWD3			0.31 (1.4)			
	DIS					1.08 (7.2)	1.03 (7.1)
	CLOCLA	-0.02 (-6.9)	-0.02 ()-7.2	-0.03 (-8.7)	-0.03 (-8.7)	-0.02 (-7.8)	-0.02 (-7.8)
	HARDRCK	-1.44 (-3.4)	-1.2 (-3.2)	-1.79 (-4.1)	-1.68 (-4.0)	-1.05 (-3.6)	-1.3 (-3.3)
	ELECFLD	-0.02 (-0.3)		-0.08 (-1.0)		-0.11 (-1.4)	
STATISTICS	LNL(UR)	-916.01	-917.28	-885.19	-888.59	-890.88	-893.03
	McFadden	0.439	0.438	0.458	0.456	0.454	0.453
	CHI-SQU(N)	1432.28 (8)	1429.75 (5)	1493.93 (10)	1487.11 (7)	1482.56 (8)	1478.24 (6)
	0:PRED/ ACTUAL	6730/6559	6727/6559	6735/6559	6378/6559	6734/6559	6734/6559
	1:PRED/ ACTUAL	265/436	268/436	260/436	257/436	261/436	261/436
	PROB:ACTUAL/PRED	6738/6995	6739/6995	6735/6995	6738/6995	6732/6995	6736/6995

Table 9.17: Identification of Potential Investors (adjusted for heteroscedasticity & without outliers)

	SL NO.-->	1	2	3	4	5
REGRESSORS	CONST	-4.88 (-25.7)	-4.97 (-29.7)	-4.75 (-21.6)	-3.63 (-15.7)	-3.58 (-22.7)
	LNDPRHD	0.67 (14.1)	0.64 (14.4)	0.63 (13.6)	0.67 (14.3)	0.66 (14.5)
	FLYSZ					
	LAND					
	BRENTIN	0.35 (1.35)		0.39 (1.51)	0.38 (1.5)	
	BRENTOUT	-0.998 (-2.43)	-0.88 (-2.13)	-0.73 (-1.8)	-0.7 (-1.6)	
	WTSELL	4.83 (16.1)	4.88 (16.5)	4.78 (15.8)	5.02 (15.8)	5.14 (16.3)
	BGWTBUY	-0.57 (-1.9)				
	CAND3			-0.20 (-0.8)		
	RLID3			0.02 (0.1)		
	DTWD3			-0.52 (-2.2)		
	DIS				0.94 (4.5)	1.02 (5.3)
	CLCLA	-002 (15.2)			-0.32 (-7.5)	-0.3 (-8.45)
	HROCK	0.028 (0.1)		-0.14 (-0.2)	-1.18 (-1.9)	
	ELECFLD	0.45 (4.7)	0.519 (6.3)	0.45 (4.7)	0.08 (0.9)	
STATISTICS	LNL(UR)	-656.32	-659.25	-655.33	-625.23	-631.61
	pse-R^2	0.355	0.352	0.356	0.385	0.379
	χ^2(df)	721.49 (7)	715.64 (4)	723.48 (9)	783.68 (8)	770.925 (4)
	0-PR/AC	6202/6079	6202/6079	6203/6079	6207/6079	6203/6079
	1-PR/AC	116/239	116/239	115/239	111/239	115/239
	AC/PR	6135/6318	6315/6318	6136/6318	6114/6318	6136/6318

10. Testing for collusion: A theoretical argument and some empirical evidence

Do owners of groundwater extraction devices engage in collusive practices? Opinions differ.[70] It seems reasonable to argue that if command areas of STWs or SMTWs overlap, then competition will drive down prices in the areas where the command areas overlap each other. Some might even drive this forward by arguing that in small societies it is difficult to openly discriminate among buyers whose plots lie in the overlap zone and those who can buy water from one of the water sellers only. In that case, competition among water sellers in the zone where their command areas overlap will lead to a drop in prices not only in this zone, but also in the areas where they have monopoly power over the buyers of water. For a formal proof of this argument, though in a different context, see Basu and Bell (1991). Across the moujas that we have studied, a commonly held view is that owners of groundwater extracting devices set prices by agreement among themselves and that profits from sale of water are high. The question that arises then is: how are water sellers able to ensure that people do not violate the agreements by providing hidden price cuts to attract buyers?

How does one arrive at an answer to the question with which we began this section? The standard approach is to compute the value of the Lerner Index[71] or at least to approximate this value when marginal costs are not available. There are a number of problems that make this approach less than compelling. First, the quality of the data collected may often be particularly unacceptable because respondents will typically tend to overstate costs. In section 8 we observed that in areas where contracts are on an hourly basis, pricing is based on an imputed value of the cost of diesel plus a mark-up. Our field investigations in the four moujas of Nadia district reveal that while STW owners charge for 1 litre of diesel per hour the actual requirement varies between 600 ml. to 800 ml. depending upon the vintage of the machine, its physical condition, pattern of maintenance, among other things. While local residents may have a fairly good idea about the fuel requirements of a

[70] See Webster (1999) and Wood (1999) for the view that water sellers extract a large part of the surplus and Fujita and Hossain (1995) for the view that competition among water sellers has driven profits down to zero.
[71] Lerner Index = (Price – Marginal Cost) / Price. See Tirole (1996) p. 66.

particular machine, and this may vary widely from the figure stated by the owner, it is difficult to be certain about the actual number. Second, there are serious difficulties involved in including the value of labour, especially if it is household labour, in estimates of marginal cost. Third, the Lerner index is a measure of the degree of monopoly. It does not tell us how oligopolists are able to enforce their collusive agreements on prices.

We adopt a different tack. The first step is to isolate machines and contracts where the difficulties connected with the estimation of marginal costs are low. The next step is to approximate the values of the Lerner indices. The third step is to see how (at least in theory) collusive agreements can be sustained. The final step is to see if the methods by which these agreements may be sustained are actually adopted.

It seems to us that it is best to focus upon the fixed fee contracts offered by owners of electrically operated STWs and SMTWs. The fixed fee specifies a price for the supply of water for the entire season for a particular area of land.[72] Further, since the owners of STWs and SMTWs pay a fixed fee for use of electricity, the cost of fuel for each additional bigha irrigated is zero. In fact, our studies indicate that all other costs incurred for irrigating *the additional bigha* are zero or very close to zero.[73]This means that the value of the Lerner Index is equal to one *irrespective of the price charged by the sellers*.

In the next few paragraphs we provide a sketch of a theoretical argument that indicates why collusive behaviour is theoretically possible if sellers interact with each other repeatedly over the years. It also explains how collusion can be sustained by setting up foolproof monitoring devices that help avoid inefficient price wars.

Consider the case of two water sellers whose SMTWs are located close to each other so that their technically feasible command areas partially overlap each other. This means that each water seller has two kinds of potential buyers: one type of buyer can buy water

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[72] The typical contract specifies the rate per *bigha*. The conversion rate from bigha to acre varies: in some places it is 0.33 acre per *bigha*, and 0.4 acre per *bigha* in others.

[73] In most cases, domestic labour is used to run the machines, ensure that field channels remain clear, etc. In the cases where labour is hired, the labour contract is a fixed fee for the entire package, which does not vary with small changes in the area irrigated by the STW or SMTW.

from both sellers because his plot lies in the zone where the command areas overlap each other: the other type of buyer can only buy water from a single seller because of the location of her plot. This means that in part of his command area the seller is a monopolist and in the rest he (she) is a duopolist. Assume for the sake of simplicity (and without loss of generality) that all the buyers have identical plots of land. This means that all buyers have the same surplus (revenue – cost) before payment of the charge for water. [74]Recall that the charge for water is a fixed fee for supply of an adequate quantity of water during the entire season.

Forget for the moment the social pressure story that was used to support the argument that sellers are unable to charge discriminatory prices. If discrimination is permissible, then in the plots where a seller is a monopolist, he (she) will -- at least in theory – be able to extract the entire surplus of the buyer of water through a fixed fee. The problem lies in the zone of competition. It is easy to see that in a single period story, myopic price competition will drive the price down to the marginal cost in this zone. Suppose that there is a (positive) fixed cost: the charge for electricity in this case. Then a number of possibilities emerge: either (a) the **total** profits of both sellers is positive, in which case they stay in the market; or (b) the **total** profits of both sellers is negative, and they stay out of the market; or (c) only one seller has non-negative profit in which case the other one closes down and the lone seller who operates his SMTW becomes a monopolist in his entire technically feasible command area. To drive home our basic point let us focus on the first case. We show next that if sellers are not myopic then they can do better.

Suppose sellers decide to divide up the zone of competition between themselves and each seller supplies water to the only those plots that lie in the area allocated to him in this agreement. Since, each seller is now a monopolist in the area allocated to him, he can charge the same fixed fee for supply of water as he charges the buyers in the zone where he is the only technically feasible supplier. Clearly, total profits will be higher in each period for both sellers if the collusive agreement can be sustained. The actual increase in profit per period depends on the division of the zone of competition. How the area will be

[74] This cost can include imputed costs of household labour, etc.

divided depends on the relative bargaining powers of the two sellers as also on their fall back options if the bargaining fails, but as long as each seller gets some share the argument goes through. If either seller "cheats" in any period and draws away his rival's customers then this sets off a price war in the zone of competition for ever after. This means that in each season after the season in which the cheating occurs, each seller's profit is equal to his myopic behaviour profit (described above). At the beginning of each season, each seller has to decide whether to cheat or to honour the agreement. The calculation is simple: if the gain from cheating in this season plus the discounted present value of the infinite stream of the one period game profits exceeds the present value of the future stream of profits he will earn if co-operation does not break down then he cheats. Otherwise, he honours the agreement. Since this is an interaction that is likely to continue for a long time, the future looks the same at the beginning of each season, and as long as the sellers are sufficiently patient and do not become increasingly impatient as they age, if honouring the agreement is the better option in the current period, it will remain the best option forever. The important element in this argument is that it specifies a device by which one can monitor cheating costlessly. If in one year I find that a person who had been buying water from me has started buying water from my competitor, I have a strong argument for claiming that my competitor has deviated from our agreement.

What is most interesting is that on the ground division of supply areas among sellers is commonplace and commonly accepted as a part of competitive strategy. In some places where price wars and other forms of violence have occurred, village meetings have been called to settle disputes and establish boundaries.[75] In all the moujas outside Jalpaiguri district where we ran our household surveys division of command areas is the norm. Minor deviations occur every year but these are tolerated as long as there is some "just" cause – the water seller's nephew married my daughter last winter, how can I refuse to buy water from him? – or if the violation is minor in nature. In order to arrive at more compelling evidence – over and above the information gleaned from talking to different

[75] This has happened in Murulia mouja in Manteswar. A political leader in Maipur told us that at the beginning of every boro season disputes arise over the setting up of field channels that he has to sort out. The location of the field channels effectively establishes the area where the water from an STW / SMTW can be delivered.

people in each village – we decided to run two specially designed fixed questionnaire surveys in for moujas where all the SMTWs in operation are run on electricity. One set of questionnaires was designed for the SMTW owners and the other for people who do not own SMTWs but "buy" water from them.[76] We surveyed all the SMTW owners in each village and a random sample of about 25 percent of the farmers who buy water or rent land to SMTW owners in each village. The four moujas we surveyed are: Bhadai and Murulia in Manteswar block; Saktipur in Suri I block; and Maipur in Suri II block.

Each SMTW owner was asked to provide a list of transactions for each year after the installation of his machine. These included expenditures, details of area irrigated in the boro season, the total area where water was sold, land was rented in, own land in the command area, etc. These respondents were also asked to indicate if they had faced incursions into their "established" supply areas and if so how this incursion took place. They were also asked how they responded to such actions. We also asked them if they had for some reason attempted to enter other "established" supply areas and if so why. We also asked them give us details of the incentives they used. We asked them to give us details of the responses to such actions by their competitors.

The overall results reveal a startling stationarity in the division of areas of operation. In rare instances, the area serviced by a particular supplier fell sharply. For the most part changes were marginal. What was more revealing is that attempts at veiled undercutting yielded few results as the targeted buyers simply used the better offer to re-negotiate their contracts with their current supplier. Such re-negotiations typically involved the provision of other services like free supply of water without charge in the khariff season -- which is largely costless for the seller because the electricity charge is a fixed fee for the whole year—free transport of the paddy from the field after harvest. In some cases, where land

[76] This part was in many ways the most difficult and sometimes dangerous part of our study. We began by targeting eight moujas, but four had to be dropped midstream because respondents refused to co-operate after we began to insist that details of transactions had to be backed by entries in their own diaries (many farmers keep notes of transactions in fairly copious detail). In those cases where farmers were either unwilling to allow us access to their diaries or did not have diaries we were forced to cross check as far as possible. This often led to difficulties.

is rented in by the SMTW owner higher rent offers were made, but this simply was used by the potential buyers to re-negotiate contracts.

The corresponding survey for the buyers of water / people who rent out land could only be conducted in three moujas.[77] In this survey we asked respondents to list all the plots they had owned or cultivated in the last ten years. For each plot we asked them to tell us the cropping pattern for each year they had cultivated the plot. If they had not cultivated the plot in a particular year, or in some season in a given year, we asked them if they had rented it out, and if so, whether or not the person renting in the plot was an SMTW owner. For plots where they cultivated summer paddy, we asked them if they had changed the source of supply from one SMTW to another in any year, and if so, why they had done this. In at least three of the four moujas, technically feasible command areas for most SMTWs are significantly larger than the area they actually irrigate because of the high density of installation of the machines. Remarkably stationary buyer-seller relationships, as well as the relationships between people who rent out land and the SMTW owners who rent in the land, over almost seven or eight years supports the findings from the survey of SMTW owners.

[77] Premature elections put a stop to our survey in Bhadai in early March 2004.

11. Conclusions

Perhaps the most important conclusion of our study is that private groundwater markets have played a much larger role in the rapid growth of the agricultural sector in West Bengal than has previously been recognized. The extent of spread of cultivation of summer paddy that we see today would not have been possible without private investment in groundwater extraction devices and the emergence and evolution of groundwater markets.

Our study of groundwater irrigation has covered all the major agro-climatic zones of the state except the hilly regions in the north. A general finding is that in a broad statistical sense groundwater markets exist wherever private individuals have invested in the water extraction equipment. We have been able to isolate the conditions under which such investment takes place, and these markets emerge, to a large extent. We have also been able to identify patterns in the nature of contracts both across cropping seasons and geographical zones. In general, wherever the hard rock lies close to the surface, investment in groundwater extraction is scarce. Further, the availability of reliable and adequate water from canals has acted as a deterrent to investment in these devices. In areas where the reliability of canal irrigation is low, private investment in groundwater extraction is to be found.

It is revealed by our study that mere electrification of agricultural fields may not be conducive to private investment in irrigation or may not enhance acreage of irrigated land from private sources if other geo-physical features are not right. The absence of electrification prompts the farmers to install diesel pump sets. However, the areas with right geo-physical conditions electrification raises the probability of private investment in irrigation as is revealed by household level regression analysis. These two results taken together help draw us a major policy directive towards the electrification programme. If the policy target is to increase the area under cultivation of a particular crop that is constrained by the availability of irrigation, inducing private investment by providing electricity will work only if the areas where electricity is provided are either not already saturated with diesel operated machines or have the right geophysical conditions and low investment in groundwater extraction devices. Otherwise, existing diesel operated machines will be converted to use electricity as a source of power as in the first case, or new machines will not be installed as unfavourable geophysical conditions will result in such investment being unprofitable.

Our study of investment patterns reveals that larger landowners are more likely to invest in the groundwater extraction devices. However, we also find that in many areas where SMTWs are in use, small landowners have often collectively invested in SMTWs. This trend was most pronounced in the mid nineteen nineties at the peak of the boro cultivation boom. A question for which we do not have a fully satisfactory answer is: Did the desire to increase the command area lead many people to shift from STWs to SMTWs? It is true that falling water levels contributed significantly to this trend, but we suspect that in many cases people with the capacity to invest in the more expensive SMTWs did this to eliminate competitors and further introduction of these devices may have forced other STW owners to install SMTWs. It would perhaps have been possible to answer this question had we been able to access the test well data from records of the State Water Investigation Directorate. Unfortunately, we realized at some stage in our research that the time and effort we were expending in accessing the data was not yielding any substantive results. We, therefore, decided to let this question remain unanswered.

Our study also reveals that the nature of contracts varies across crops and geographical areas. What it also reveals is that owners of groundwater extraction devices often prefer to rent in land rather than sell water. This adds an unexpected wrinkle to the usual water market story: even though a large number of STWs or SMTWs may exist in a mouja, the water market may or may not be very large simply because of the nature of preferences of the owners of these devices. We also found that there is geographical pattern in the direction of preferences. Unfortunately, we have not been able to arrive at an explanation for this observation.

A final question that we analyzed is of great importance. While it is true that private investment in groundwater extraction equipment has led to a rapid expansion of cultivation in the winter and summer, have owners of these devices colluded to extract monopolistic rents? The usual method is to compute the value of the Lerner index, but this is fraught with all types of complications as we note in section 10. In particular, it does not explain why collusion is sustainable. We demonstrate that collusion is indeed sustainable and further identify observable indicators that water sellers may use to establish that collusive agreements are being (or not being) adhered to by all parties. This allows the parties to avoid inefficient price wars that can lead to the break down of collusion. The startling empirical observation is that exactly this device is used in practice.

When we began this research, we were struck by the limited amount of published research in the area. The existing literature is also limited in the sense that it comprises essentially of studies of small numbers of villages. Our study is more widespread and often much deals with the issues at much greater depth. It is our hope that this study will be of use to future researchers and policy makers.

References

Amemiya, T. (1981): Qualitative Response Models: A Survey, *Journal of Economic Literature***,** 19, 4, 483-536.

Basu, K. and C. Bell (1991): Fragmented Duopoly: Theory and Application to Backward Agriculture, *Journal of Development Economics*, 36, 145-65.

Belsley, D. A., E. Kuh and R. E. Welsh (1980): Regression Diagnostics: Identifying Influential Data and Sources of Collinearity. New York: John Wiley & Sons.

Bornstein, S. and Shepard (1996): Dynamic Pricing in Retail Gasoline Market, *Rand Journal*, 27(3), 429-51.

Bresnehan, T. F. (1987): Competition and Collusion in the American Automobile Oligopoly: the 1955 price war, *Journal of Industrial Economics* (June), 457-82.

Deb Roy, A and T. Shah (2002): Socio Ecology of Groundwater Irrigation in India. Paper presented at IWMI-TATA Policy Research Program Annual Partners Meet 2002.

Dubash N. (1998): The "Instituted Process" of Groundwater Exchange in Gujarat, India. Paper presented at "Crossing Boundaries" Seventh Annual conference of the International Association for the Study of Common Property, Vancouver, British Columbia, Canada. June 10-14, 1998.

Ethison, G. (1994): Theories of Cartel Stability and the Joint Executive Committee, *Rand Journal*, (Spring), 37-57.

Fujita, K. and F. Hossain (1995): Role of the Groundwater Market in Agricultural Development and Income Distribution: A Case Study in a North-West Bangladesh Village, *The Developing Economies*, 33(4), 442-63.

Genesove, D. and W. Mullin (1998): Testing Static Oligopoly Models: Conduct and Cost in the Sugar Industry 1894-1914, *Rand Journal* (Summer), 29 (2), 355-77.

_________________________(2001): Narrative Evidence on the Dynamics of Collusion: the Sugar Institute Case, *American Economic Review* (June), 379-98.

Goswami, A. B. (1995), A critical study of water resources of West Bengal. Unpublished Ph. D. Thesis, Jadavpur University.

Jacoby, H., R. Murgai ands. U. Rehman (2001): Monopoly Power and Distribution in Fragmented Markets: The Case of Groundwater. Mimeo. Development Research Group, World Bank. Washington D.C.

Janakrajan, S. (1994): Trading Groundwater: A Source of Power and accumulation. In *Selling Water: Conceptual and Policy Debates Over Groundwater Markets in India*, ed. M. Moench. Gujarat, India: VIKSAT, Pacific Institute, Natural Heritage Institute.

Judge, G. G. et al. (1985): *Theory and Practice of Econometrics.* New York: John Wiley & Sons.

Kajisa K. and T. Sakurai (2001): Price Discrimination under Bilateral Bargaining with Multiple Modes of Contracts: A Study of Groundwater Markets in India. *FASID Discussion Paper Series 2001-02.*

Levenstein, M. C. (1997): Price Wars and the Stability of Collusion: A Study of the Pre-World War I Bromine Industry, *Journal of Industrial Economics* (June), 45(2), 117-37.

Maddala, G. S. (1983): *Limited Dependent and Qualitative Variables in Econometrics*. London: CUP.

Meinzen-Dick, R. (1996): Groundwater Markets in Pakistan: Participation and Productivity, *Research Report 105*, International Food Policy Research Institute, Washington D.C.

Mishra, S. (1994) An Assessment of Assured Rainfall in West Bengal, Calcutta. Department of Agriculture, Government of West Bengal

Mohanty, N. and S. Gupta (2002): Breaking the Gridlock in Water Reforms through Water Markets: International Experience and Implementation Issues for India. Working Paper Series, Julian L. Simon Centre for Policy Research.

Porter, R. H. (1983): A Study of Cartel Stability: The Joint Executive Committee, 1880-1886, *Bell Journal of Economics* (Autumn), 14 (2), 301-14.

Saleth, R. M. (1991): Factors Affecting Farmers' Decision to Buy Groundwater: Empirical Evidence from the Indo-Gangetic Region, *Indian Journal of Agricultural Economics*, 46(3), 354-94.

Shah, T. (1991): Water Markets and Irrigation Development in India, *Indian Journal of Agricultural Economics*, 46(3), 335-48.

________ (1994): Groundwater Markets: An Overview and New Questions. In *Selling Water: Conceptual and Policy Debates Over Groundwater Markets in India*, ed. M. Moench. Gujarat, India: VIKSAT, Pacific Institute, Natural Heritage Institute.

Shah,T. and K. V. Raju (1988): Ground Water Markets and Small Farmer Development, *Economic and Political Weekly*, March 26, A-23-A28.

Tirole, J. (1996): The Theory of Industrial Organization. New Delhi: Prentice-Hall of India Pvt. Ltd.

Todd, D.K. (2001): Groundwater Hydrology, Second Edition. New York: John Wiley & Sons.

Webster, N. (1999): Institutions, Actors and Strategies in West Bengal's Rural Development – A Study on Irrigation. In *Sonar Bangla? Agricultural Growth and Agrarian Change in West Bengal and Bangladesh,* ed. B. Rogaly et al. Sage Publications, New Delhi.

Wood. G. D. (1995): Private Provision After Public Neglect: Opting Out with Pumpsets in North Bihar, Centre for Development Studies, University of Bath, Bath.

Wolfram, C. (1999): Measuring Duopoly Power in the British Electricity Spot Market, *American Economic Review* (Sept.), 805-26.