

**AN ECONOMIC ANALYSIS OF GROUNDWATER DEPLETION IN SANGRUR
DISTRICT OF PUNJAB**

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In

Economics Studies

By

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April, 2014

CERTIFICATE

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ABSTRACT
**AN ECONOMIC ANALYSIS OF GROUNDWATER DEPLETION IN SANGRUR
DISTRICT OF PUNJAB**

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The adoption of high yielding variety seeds, increased in use of chemical fertilizers and irrigation has helped in raising the income level of the farmers and total foodgrain production. But it cannot be denied that the adoption of this modern technology is expensive and it takes place at the cost of unsustainable use of resources. Groundwater depletion is found to be one of the major problems in Central Punjab. Among all districts, stage of groundwater development is the highest in Sangrur district, i.e. 264 per cent. All the nine blocks of Sangrur district are over- exploited and groundwater usage is highest in Sunam block. Therefore, in the present study entitled “An Economic Analysis of Groundwater Depletion in Sangrur District of Punjab”, an attempt has been made to examine the economic analysis of ground water depletion. As many as 120 small, medium and large farmers formed the sample of the study. The sample is taken from the two villages, viz. Tolawal and Rattangarh of the Sunam block (former having pre-dominantly tubewell irrigated farms and the latter having canal+ tubewell irrigation facilities). The study reveals that with an increase in area under wheat- paddy crop has also increased the area under groundwater irrigation. In Punjab, area under wheat crop has increased from 274 thousand hectare to 287 thousand hectare and for paddy crop has increased from 11 thousand hectare to 274 thousand hectare, from 1970-71 to 2011-12. The study brought out that higher the farm size, higher is the ownership of motors and depth of motors and vice- versa. The technical efficiency on farms estimated through Data Envelopment Analysis (DEA), has indicated the mean technical efficiency of 90.3 per cent and 95 per cent in paddy production and 89.4 per cent and 94.9 per cent in wheat production, in tubewell irrigated and

canal+ tubewell irrigated farms, respectively. The multiple (step- up) regression analysis has revealed that land ownership, number of submersible motors and its depth had positive significant impact on farm income. The study suggests that the government should ensure minimum support prices for less water consuming crops. This will not only shift the existing cropping pattern but will also provide solution to over exploitation of groundwater. It also suggests that assured electricity may be provided to agriculture sector at subsidized rates to minimize this problem. Further, the government should take care for maintenance of canals on priority basis.

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Dr. Sandeep Kaur Bhatia

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LIST OF ABBREVIATIONS

S. No.	Full form	Abbreviation
1.	Gross Domestic Product	GDP
2.	Hectare	ha
3.	Hectare metre	ha.m
4.	Billion cubic metre	bcm
5.	Millimetre	mm
6.	Constant Returns to Scale	CRS
7.	Variable Returns to Scale	VRS
8.	Decision Making Unit	DMU
9.	Data Envelopment Analysis	DEA

Chapter 1

Introduction

The agriculture sector is the backbone of Indian economy. It accounts for almost 14.1 per cent of the total GDP in 2011-12 and about 58.2 per cent of the country's population depends on it (Economic Survey, 2012-13). Punjab, a small northern state contributes significantly to the agricultural economy of India. It is also known as 'food bowl' of the country (Jeevandas et al., 2008). Despite having a small geographical area of 50.36 lakh hectare, it leads all other states of the country to contribute maximum production of wheat and rice in the central pool. It has contributed 38.7 percent of wheat and 22.1 per cent of rice to central pool in 2011-12 (Statistical Abstract of Punjab, 2012). During the last four decades, the state of Punjab has set an example for contributing significantly towards agricultural development through green revolution technology. Growth of Punjab agriculture is closely related with "Green Revolution" i.e. package of new high yielding varieties of seeds, assured irrigation, use of chemical fertilizers, machinery and modern agricultural practices. Green revolution has helped in raising the income level of farmers as well as total foodgrains production. It transformed India from food deficit nation to a food surplus one (Chand, 1999). Its gross irrigated area to gross cropped area has increased from 85.4 per cent in 1980-81 to 98 per cent in 2011-12. The irrigation intensity was 190 in 2011 (Statistical Abstract of Punjab, 2012). But this increment takes place at the cost of unsustainable use of resources like land, water and chemical inputs.

Green revolution led to the extensive use of groundwater for irrigation and a shift to paddy- wheat water intensive cropping pattern. As Robert Repetto comments, "The green revolution has often been called a wheat revolution; it might also be called a tubewell revolution" (Mukherjee, 2007). The greed for maximizing economic returns has put water resources under huge pressure and exploitation which resulted in water depletion day by day, and it has created an alarming situation. The total water requirement for Punjab, with present cropping pattern and practices and industrial use is estimated at 4.33 million hectare meter. The total availability of water is estimated at 3.13 million hectare meter out of which 1.45 million hectare meter is from canals and 1.68 million hectare meter is from rainfall and seepage. The deficit of almost 1.20 million hectare meter is met by

groundwater withdrawal. This has led to a decline in the water table in Punjab (Singh, 2009). The state has three major rivers namely Ravi, Beas and Sutlej. The state receives about 660 mm normal rainfall out of that 80 per cent occurs during monsoon period i.e. July and August (Jha & Sinha, 2009). Groundwater irrigation has been a major component in agricultural development as it is most efficient, reliable and productive source and intensive use of groundwater rapidly expanded with the adoption of tubewell and diesel engine technology. Approximately 13.83 lakh tubewells are working in the state that irrigates about 73 per cent of the total irrigated area (Statistical Abstract of Punjab, 2012). Due to declining water table, the farmers are shifting towards the usage of submersible pumps in place of centrifugal pumps along with deepening of tubewells that resulted in additional expenditure and extra power consumption. This has adversely affected the socio-economic conditions of the small farmers.

The main reason for groundwater depletion in Central Punjab is linked with the existing (wheat- paddy) cropping pattern that has mainly replaced maize and pulses as a dominant crop of the kharif season. The area under wheat- paddy cultivation has increased 3.9 times during the past four decades due to their stable prices, massive procurement programme and other institutional and infrastructural back up. Rural electrification program and availability of credit at lower rates have further helped the farmers to increase area under groundwater irrigation. The increase in intensity of land use via reduction in seasonal fallowing and increased lining of canal network at the tertiary level has contributed a lot in groundwater depletion (Dhawan, 1993).

Groundwater is critical resource not only in the state of Punjab, but at the national level also. Groundwater has emerged as an essential resource for agricultural development in India, especially in areas where there is scarcity of surface water. In India, more than 80 per cent water is consumed in agriculture and out of this 50 per cent is used in cultivation of paddy alone. Water security is widely recognized as one of the major challenges to India's economic and social development as its per capita availability has declined from over 3000 m³/ year in 1951 to 1800 m³/ year in 2010 (Kumar & Raj, 2013). Approximately 200 billion cubic meter of groundwater is extracted annually in India that is the highest volume of annual groundwater extraction in world. The share of groundwater in the net irrigated area

is 61 per cent and share of surface water has declined to 30 per cent in 2010. Efficiency of groundwater use is higher than that of surface water due to the fact that groundwater is available on demand at the point of use and requires little conveyance.

Table 1.1 shows that the stage of groundwater development¹ in the country is 61 per cent. The status of groundwater development is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where the stage of groundwater development is more than 100 per cent, which implies that in these states the annual groundwater consumption is more than annual groundwater availability. It is found 170 per cent in Punjab. In the states like Gujarat, Tamil Nadu and Uttar Pradesh, it is 70 per cent and above. In the rest of states it is below 70 per cent.

¹Stage of groundwater development = $\frac{\text{Existing gross draft for all uses}}{\text{Net annual availability}} \times 100$

Table1.1: State-Wise Availability, Utilization and Development of Groundwater Resources, India

(Billion Cubic Meter)

Sr. No.	States	Annual Replenishable groundwater resources	Net annual groundwater availability	Annual groundwater draft			Groundwater availability for future irrigation	Stage of groundwater development (%)
				Irrigation	Domestic and industrial uses	Total		
1	Andhra Pradesh	33.83	30.76	12.61	1.54	14.15	15.89	46
2	Arunachal Pradesh	4.45	4.01	0.002	0.001	0.003	4.00	0.07
3	Assam	30.35	27.81	5.333	0.69	6.026	21.50	22
4	Bihar	28.63	26.21	9.79	1.56	11.36	13.85	43
5	Chattisgarh	12.22	11.58	3.08	0.52	3.60	7.85	31
6	Delhi	0.31	0.29	0.14	0.26	0.40	0.01	138
7	Goa	0.221	0.133	0.014	0.030	0.044	0.082	33
8	Gujrat	18.43	17.35	11.93	1.05	12.99	5.32	75
9	Haryana	10.48	9.80	11.71	0.72	12.43	-2.70	127
10	Himachal Pradesh	0.59	0.53	0.23	0.08	0.31	0.22	58
11	Jammu & Kashmir	3.70	3.33	0.15	0.58	0.73	2.35	22
12	Jharkhand	5.96	5.41	1.17	0.44	1.61	3.62	30
13	Karnataka	16.81	14.81	9.01	1.00	10.01	6.18	68
14	Kerala	6.62	6.03	1.30	1.50	2.81	3.02	47

Sr. No.	States	Annual Replenishable groundwater resources	Net annual groundwater availability	Annual groundwater draft			Groundwater availability for future irrigation	Stage of groundwater development (%)
				Irrigation	Domestic and industrial uses	Total		
15	Madhya Pradesh	33.95	32.25	16.66	1.33	17.99	13.76	56
16	Maharashtra	35.73	33.81	15.91	1.04	16.95	16.32	50
17	Manipur	0.44	0.40	0.0033	0.0007	0.004	0.35	1
18	Meghalaya	1.2343	1.1109	0.0015	0.0002	0.0017	1.0131	0.15
19	Mizoram	0.044	0.039	0.00	0.0004	0.0004	0.039	1
20	Nagaland	0.42	0.38	0.00	0.008	0.008	0.36	2.14
21	Orissa	17.78	16.69	3.47	0.89	4.36	11.94	26
22	Punjab	22.56	20.35	33.97	0.69	34.66	-14.57	170
23	Rajasthan	11.86	10.79	12.86	1.65	14.52	0.75	135
24	Sikkim	-	0.046	0.003	0.007	0.010	0.031	21
25	Tamil Nadu	22.94	20.65	14.71	1.85	16.56	4.70	80
26	Tripura	2.97	2.74	0.09	0.07	0.16	2.42	6
27	Uttar Pradesh	75.25	68.75	46.00	3.49	49.48	17.22	72
28	Uttaranchal	2.17	2.07	1.01	0.03	1.05	0.98	51
29	West Bengal	30.50	27.58	10.11	0.79	10.91	16.75	40
	Total States	430.45	395.52	221.29	21.83	243.14	153.26	61

Source: Ground Water Year Book- India, 2011-12

Table1.2: Block- wise Assessment of Groundwater in India, 2009

S.No.	States	Safe (%)	Semi-critical (%)	Critical (%)	Over-exploited (%)
1.	Andhra Pradesh	78	8	2	8
2.	Arunachal Pradesh	100	0	0	0
3.	Assam	100	0	0	0
4.	Bihar	99	1	0	0
5.	Chhattisgarh	90	10	0	0
6.	Delhi	7	19	0	74
7.	Goa	100	0	0	0
8.	Gujarat	70	9	3	12
9.	Haryana	16	8	18	59
10.	Himachal Pradesh	75	0	13	13
11.	Jammu & Kashmir	100	0	0	0
12.	Jharkhand	96	1	1	2
13.	Karnataka	57	13	4	26
14.	Kerala	83	14	2	1
15.	Madhya Pradesh	72	19	1	8
16.	Maharashtra	92	5	0	3
17.	Manipur	100	0	0	0
18.	Meghalaya	100	0	0	0
19.	Mizoram	100	0	0	0
20.	Nagaland	100	0	0	0
21.	Odisha	98	0	0	0
22.	Punjab	17	1	2	80
23.	Rajasthan	13	7	10	69
24.	Sikkim	100	0	0	0
25.	Tamil Nadu	35	17	9	36
26.	Tripura	100	0	0	0
27.	Uttar Pradesh	74	13	4	9
28.	Uttarakhand	65	29	6	0
29.	West Bengal	86	14	0	0
	Total States	73	9	3	14

Source: Ground Water Year Book- India, 2011-12

Table 1.2 shows the safe, semi- critical, critical and over- exploited blocks of India. Over- exploited blocks are 14 per cent, 3 per cent are critical, 9 per cent are semi-critical and 73 per cent are in safe category. Percentage of over- exploited and critical blocks are significantly higher in Delhi, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan and Tamil Nadu. Among states Punjab is having highest percentage of over- exploited blocks i.e. 80 per cent, followed by Delhi

with 74 per cent. Out of 138 blocks in Punjab, 110 blocks (80 per cent) are over-exploited, 3 blocks (2 per cent) are critical, 2 blocks (1 per cent) are semi-critical and 23 blocks (17 per cent) are in safe category in 2009.

Thus, Punjab state has the highest percentage of groundwater development and even over-exploited blocks are also more than other states. The situation of central Punjab is worst in groundwater depletion. The water table in the Central Punjab has gone down by more than 20 meter in the past one decade and the trend is continuing. The central region is also known as the 'sweet water' region and comprises about 47 per cent of the area of the state. The problem of groundwater depletion has emerged mainly in the central region districts which include Amritsar, Barnala, Kapurthala, Fatehgarh Sahib, Jalandhar, Ludhiana, Patiala, Sangrur, Tarn Taran, where the stage of development is more than 150 per cent shown in Table 1.3. Among all these districts Sangrur has highest gross groundwater draft i.e. 367244 hectare meter and minimum in Mohali district as 28005 hectare meter in 2008-09. The stage of groundwater development in Sangrur is 264 per cent. The net annual groundwater availability of Punjab is 20.35 billion cubic meter (bcm) and total gross groundwater draft is 34.66 bcm, out of that 33.97 bcm is for irrigation only.

Table1.3: District- wise Assessment of Groundwater Resources in Punjab, 2008-09

(Hectare Meter)

S.no.	District	Net Annual Groundwater Availability	Existing Gross Groundwater Draft for Irrigation	Existing Gross Groundwater Draft for all uses	Stage of Groundwater Development (%)
1.	Amritsar	123026	215724	220547	179
2.	Barnala	60641	118371	119594	197
3.	Bathinda	97638	117778	120702	124
4.	Faridkot	61226	95253	97195	159
5.	Fatehgarh	53505	110450	112483	210
6.	Ferozepur	196553	273766	277032	141
7.	Gurdaspur	177929	218298	224753	126
8.	Hoshiarpur	88158	86475	91297	104
9.	Jalandhar	118137	265594	270181	229
10.	Kapurthala	65376	150083	153954	235
11.	Ludhaina	203448	334616	345504	170
12.	Mansa	67246	143790	143804	214
13.	Moga	119411	240557	242319	203
14.	Muktsar	76810	51286	53746	70
15.	Nawanshahr	64014	70277	71765	112
16.	Patiala	149083	286960	291165	195
17.	Ropar	41518	43487	45818	110
18.	Mohali	27514	23438	28005	102
19.	Sangrur	139322	364296	367244	264
20.	Tarn Taran	104368	186441	189011	181
	Total	2034922	3396941	3466117	170

Source: Dynamic Groundwater Resources of Punjab State, 2012

Table1.4: Year- wise Groundwater Assessment of Blocks in Punjab

Year	Over- exploited	Critical	Semi- critical	Safe
1984	53	7	22	36
1986	55	9	18	36
1989	62	7	20	29
1992	63	7	15	33
1999	73	11	16	38
2004	103	5	4	25
2009	110	3	2	23

Source: Dynamic Groundwater Resources of Punjab State, 2012

Table 1.4 shows that over the period of time number of dark/ over-exploited blocks has increased from 53 in 1984 to 110 in 2009. The number of white/ safe blocks has decreased from 36 in 1984 to 23 in 2009. The categorization of blocks has shown tremendous change from semi- critical to over- exploited due to extensive use of tubewells and rise in area under paddy crop, along with increase in domestic/ industrial water use due to urbanization. The districts Sangrur, Barnala and Moga, which are known as the granary of Punjab, have shown alarming dips in their water table. In the last three decades, district Sangrur has great achievements in the field of wheat and paddy production. In Sangrur, area under wheat crop has increased from 274 thousand hectare to 287 thousand hectare and under paddy crop increased from 11 thousand hectare to 274 thousand hectare during 1970-71 to 2011-12. District stands on the top in the productivity of wheat and paddy (Statistical Abstract of Punjab, 2012).

Table 1.5 shows the area under wheat and paddy crop in Punjab. The area under wheat and paddy crop shows the mixed trend. The problem of groundwater depletion is positively correlated with their area coverage as these are water intensive crops. The area under wheat crop has increased from 1400 thousand hectares to 3528 thousand hectares and for paddy crop 227 thousand hectares to 2818 thousand hectares, during 1960-61 to 2011-12.

Table 1.5: Area under Wheat and Rice in Punjab
(Thousand Hectare)

Year	Wheat	Rice	Total Cropped Area
1960-61	1400	227	4732
1970-71	2299	390	5678
1980-81	2812	1183	6763
1990-91	3273	2015	7502
2000-01	3408	2612	7941
2001-02	3420	2487	7941
2002-03	3375	2530	7773
2003-04	3444	2614	7907
2004-05	3481	2646	7931
2005-06	3464	2647	7868
2006-07	3467	2621	7861
2007-08	3487	2609	7870
2008-09	3526	2735	7912
2009-10	3522	2802	7876
2010-11	3510	2826	7882
2011-12	3528	2818	NA*

Source: Statistical Abstract of Punjab, Various Issues

* Not Available

Scope of the Present Study

With the adoption of green revolution technology, the area under wheat- paddy crop has increased and farmers' income level has risen. But all this takes place at the cost of unsustainable use of resources like land, water etc. Groundwater depletion is one of the most serious problems of Punjab agriculture. The degradation of groundwater resource is a threat to economic and social development. Many studies have exposed the problem of groundwater depletion among the different parts of the country. While all these studies mainly associated with falling water tables and looked at ecological sustainability. Although a very few micro level studies have highlighted the equity implications of groundwater exploitation with falling water levels, but mostly represent Amritsar region of

Punjab and South Indian states. However, these crucial aspects have somewhat neglected in Sangrur district, in spite of the fact that all the nine blocks of Sangrur district is in the overexploited category. The present study's concern is with the groundwater depletions impact on agriculture in Sangrur district, which has a significant role in the Punjab agricultural economy.

Objectives of the Present Study

- To study the changing pattern of irrigation in Punjab since Green Revolution.
- To measure the technical efficiency of farms irrigated either through tubewells or canal +tubewells.
- To study the impact of groundwater over draft on farm income.

Plan of the Study

In order to achieve the envisaged objectives of the study, it has been divided into six chapters including the present chapter. Second chapter reviews the studies related to the socio- economic impact of groundwater depletion on agriculture in India. Third chapter explains the data base and methodology adopted for analyzing the data. Fourth chapter analyses the changing pattern of irrigation and socio-economic profile of sampled farmers of Sunam block while fifth chapter examines the farm efficiency and impact of groundwater over- draft on farm income. Lastly, sixth chapter summarizes the study with suggestions.

Chapter 2

Review of Literature

The present chapter is an attempt to discuss the literature review related to the theme of the study. The major concern of these discussions is with the increase in levels of groundwater mining due to groundwater irrigation that threatened the sustainability of agriculture in Punjab. A brief review of these studies has been divided into two sections. Section- I deals with the review of studies related to groundwater depletion at India level. Section- II explains briefly the readings at Punjab level.

Section- I

Externalities of new groundwater technology on small farmers have been evaluated by **Dhawan (1975)**. The study revealed that the small and marginal farmers have not been as fortunate as the large farmers backed with bureaucratic-political influence and even those who opted new groundwater technology are in bad situation due to the decline in water table, especially when they failed to raise additional finance. Even the small and marginal farmers operating the traditional waterlifts in an area having tubewells are facing short term diseconomies. At the peak time of agricultural season when tubewells have a high probability of working simultaneously, would have harmful impact on crops under the command of traditional waterlifts due to depletion in water table.

Singh (1991) highlighted some important issues regarding groundwater irrigation in Punjab as the watertable depth has increased in most of the regions since early 1970s. Introduction of hybrid paddy and extension of its cultivation to non- paddy growing areas boosted the demand for assured irrigation that was met by over exploitation of groundwater. The study revealed that the increase in gross cropped area, rise in cropping intensity, expansion in area sown to paddy and emergence of wheat- paddy rotation appear to have impinged upon the groundwater resources of the state. The study also dealt with the sources of recharge and draft of groundwater. The 1988 floods provided only temporary relief regarding the groundwater balance. Therefore, rapid exploitation of groundwater is bound to deplete the resource at a faster rate. A policy that aims at correcting the imbalance

must scrutinize various aspects of recharge and draft components. An alternative technology being tried selectively by farmers in Punjab is submersible technology. While high technology is the choice of the relatively rich farmers, the poor and small ones, for want of funds continue to operate with low technology. Thus, greater emphasis is laid either on increasing the recharge by artificial means or on reducing the draft by suggesting a shift in cropping pattern.

Impact of green revolution on long term sustainability of land and water resources in Haryana has been examined by **Chaudhary and Aneja (1991)**. The green revolution successes have led to a breakthrough in foodgrains production in the north-western region of the nation including the states of Punjab, Haryana and western Uttar Pradesh. But continuously unscientific use of modern technology has resulted in a number of problems. Over-exploitation of land and water resources has led to deterioration of soil texture and structure, created nutritional imbalance and disturbed the natural hydrology, particularly in intensively irrigated areas. Large tracts of land go out of cultivation due to the problem of waterlogging and salinity. Therefore, the new development strategy should be aimed at maintaining growth in productivity while reducing its harmful side-effects. This can only be achieved through scientific management of land and water resources and better crop planning.

Shah (1991) discussed about the water markets and irrigation development in India. With the increase in demand of water for irrigation, the owners of tubewells enjoying unchallenged de facto ownership right on the community's groundwater resource. The three types of water based tenancy contracts predominates in southern states of India- labour contract, crop- sharing contract and crop- and input sharing contract. To make the water markets more competitive, the study suggested that the investments in underground pipelines would increase the efficiency in water as well as power- use.

Impact of land use change on groundwater in the Punjab- Haryana plains is highlighted by **Singh (2001)**. The green revolution brought prosperity in Punjab and Haryana but problems of soil and water degradation have emerged. The groundwater table decline has forced farmers to lower the pumps, increasing the cost of pumping and energy use and thus decreasing the profitability and

efficiency of agriculture. The study recommended that the cropping pattern should include not only low water consuming crops between April and June but also groundwater recharge projects be initiated for augmenting the available supply.

Banerji et al. (2006) discussed about the groundwater irrigation in North India. The study analysed the institutions and markets that govern groundwater allocation in the sugarcane belt of Uttar Pradesh, India, using primary plot level data from a village that shares the typical features of this region. A simple model showed that a combination of such rationing and the village level mechanism of water sales can lead to great misallocation of water across plots and result in the large crop losses for plots that irrigate using purchased water. The narrow focus on a single village brings out elements and institutions common to the sugarcane belt as a whole, these insights can be used in a larger study.

Bhalla (2007) examined the impact of declining groundwater level on the farmers crop response function in Haryana. The decline in water table is not confined only to those regions where cultivation of water- intensive crops is more predominant. Two water intensive crops and two less water demanding crops are estimated by using Nerlovian supply response function. The Arellano Bond dynamic panel estimator is used in the study. The study found that the declining water table depth discourages farmers to cultivate water intensive crops.

Dubash (2007) attempted to analyse the political interpretation of the electricity-groundwater conundrum. The unmetered electricity supply for agriculture has contributed to an erosion of electricity distribution systems and also encouraged wasteful groundwater use. For the viability of both the water and electricity sectors, the study suggested a three stage path i.e. building a common base of knowledge through improved understanding of farmers' perspectives, negotiated compromise between various parties involved and a multifaceted implementation strategy that includes economic, administrative, technical and institutional solutions.

Manjunatha et al. (2009) attempted to analyse the impact of groundwater markets in Peninsular India on water use efficiency. The overdraft of groundwater has led to negative externalities and increases the cost of groundwater irrigation. A sample of 90 respondents containing water sellers, water buyers and control farmers was collected to test the hypothesis of more efficient water use by using data

envelopment analysis. The study found that water buyers' use water most efficiently. Even water sellers were more efficient in their water use than the control group. This paper concludes that groundwater markets can add to improving efficiency of water use and offers access to groundwater to resource poor farmers.

Mahdhi et al. (2011) highlighted the water use and technical efficiencies in private irrigated perimeters in South- Eastern of Tunisia. This paper assessed the technical efficiency (TE) and proposed to measure for irrigation efficiency (IE) based on the concept of input- specific technical efficiency for a sample of 100 irrigators by using data envelopment analysis. The study found that the irrigation systems were clearly inefficient. The same level of output level can be produced by saving 36 per cent of farm inputs. The similar was the case of IE that the same level of output can be produced using the same level of other inputs but, on an average 52.2 per cent less water irrigation.

Sharif and Ashok (2011) conducted a study to analyse the impact of groundwater depletion on farm income in Chamarajanagar district of Karnataka. It covered 180 farmers from over-exploited, semi-critical and safe villages. There is huge difference between large and small farms in their access to groundwater resource in terms of cost. The technical efficiency range of 81-90 per cent was highest among farmers of over exploited villages, while it was 48.3 per cent in semi-critical villages and 35 per cent in safe villages. The total cost of groundwater over-draft has been found more in over-exploited villages and it increases with the increase in the size of holdings. The over-exploited villages reflected better water use efficiency mainly due to scarcity of groundwater that motivated the farmers to use it more efficiently. The study brought out that for efficient use of groundwater there should be adoption of irrigation technologies like drip, sprinkler etc.

Palanisami et al. (2011) examined the groundwater over- exploitation and efficiency in crop production by using Data Envelopment Analysis in Coimbatore district of Tamil Nadu. Block level data for the period 1991-92 to 2002-03 were used for analyzing the magnitude of groundwater over- draft. The results indicate that the technical efficiency has increased as the water scarcity has increased viz., when moving from the safe regions to over- exploited regions. The study

recommended that the adoption of a crop pattern with minimum crop failure and introduction of regular farm educational programs as well as participatory crop management programs for better use of the resources.

Watto (2013) measured the groundwater irrigation efficiency in Pakistan. The study surveyed 189 cotton producers comprising 98 tubewell owners and 91 water buyers to get the differential impact of tubewell ownership on groundwater use efficiency. The data envelopment analysis sub vector and slack based models were used. The results indicated that majority of cotton growers were operating at increasing returns to scale, suggested that efficiency can be improved by expanding the scale of operation. The study also suggested that the knowledge of crop water requirements and the use of improved crop varieties can play role in improving the efficiency of groundwater use.

Section- II

Joshi and Tyagi (1991) examined the sustainability of existing farming system in Punjab and Haryana. The study explained that the issue of sustainability during the green revolution period, the post green revolution period and the prospects in the long run. The production of important crops viz. rice, wheat, cotton and sugarcane has slowed down in Punjab and Haryana. In good water quality regions the existing production levels are maintained by over- exploitation of groundwater. On the other hand, the poor quality water regions are under- utilising groundwater and deteriorating the soil health by salinity and water-logging. Both these phenomena are undesirable as it will affect the small farmers and threaten the production and ecological sustainability. Appropriate technological, institutional and price policies should be initiated to save land and water resources for the next generation.

Sustainability of water resources in Punjab has been examined by **Singh and Sankhayan (1991)**.The study found that cropping pattern has been shifted towards more water consuming crops like paddy, sugarcane etc. The annual net draft of water is increasing in the area where the groundwater is the major source of irrigation. The requirements for irrigation water are increasing but its supply is same. The study concluded that there is need to develop the research for the

techniques to use the marginally fit water for various purposes and the agricultural price policy should ensure the sustainability of water resources.

Dhawan (1993) had attempted to highlight the problem of groundwater depletion in Punjab. The continuously receding watertable in the state is phenomenon of the 80s. It is mainly linked with changes in the agriculture system of state, particularly to the rise of paddy-wheat crop sequence, increase in intensity of land use via reduction in seasonal fallowing and increased lining of canal network. The study also explains the perception that the cultivation of paddy in Punjab (& Haryana) does need some curbing, the extreme forebodings of either total groundwater exhaustion in Punjab or of the state turning into a desert if paddy growing is not curbed forthwith are unwarranted. Research work has suggested a very simple water management practice for paddy, letting the field remain dry for a day or two after the ponded water has subsidized. The state should start subsidy programme for installing sprinkler and drip irrigation.

Crisis in agrarian economy of Punjab has been highlighted by **Sidhu (2002)**. Agrarian economy is showing bad signs as the agricultural production and crop yields have nearly stagnated. The state with requisite irrigation facilities and infrastructure was major beneficiary of 'new agricultural strategy', but over the period of time wheat –paddy rotation is becoming economically as well as ecologically non-sustainable. The two important resources, land and water have sharply deteriorated over time. The future of Punjab agriculture will depend upon their conservation, sustainable use and efficient management. The study suggested that there is an urgent need to diversify not only in narrow sense within the crop husbandry sector but in a broader sense to allied activities and in a still broader sense means moving apart from agriculture to other rural non-farm activities and agro processing.

Singh and Kalra (2002) discussed about various issues related to the huge expansion of rice cultivation in Punjab and its environment and ecological implications, such as falling yields and water tables and stagnant production. A sample of 300 farmers comprising five farm size groups has taken during 2000. The entropy index is used to measure the varietal diversity. The study found that 44 per cent of the farmers have been adversely affected by the water table going down and 37 per cent farmers reported insect pests as the major problem in rice.

A majority of farmers did not envisage any alternative to rice at a significant level in the near future.

Impact of environmental degradation in Punjab agriculture has been examined by **Singh and Sidhu (2006)**. The study found that to sustain the existing level of Punjab agriculture, the costs are increasing and natural resources are being depleted at a fast rate. In the central belt, water table is declining at an average rate of 24-25 cm and in the cotton belt, it is rising 16-18 cm per year. As the area under rice and wheat is increasing the cost of pumping out water with electricity has been going up, shortage of electric and diesel tubewells further increase the cost of production. Due to depletion in macro and micro nutrients of soil health and increased pesticide use have also been observed as to increase the cost. Thus, the cost on account of these factors together has gone up by Rs 63/t in wheat and Rs 189/t in rice. The study suggested to minimize excessive use of natural resources requires suitable input pricing and to encourage diversification of state agriculture from rice to alternative less water consuming crops.

Jeevandas et al. (2008) conducted a study in two districts, viz. Amritsar (pre-dominantly tubewell irrigated area) and Faridkot (canal + tubewell irrigation) to estimate the extent of water depletion and to measure irrigation efficiency at farm level. The study revealed that due to availability of water at shallow depths during 1970s, paddy and wheat two high water consuming crops replaced the less water consuming crops like maize, groundnut and pulses in the entire state. A sample of 150 households comprising 75 farms irrigated by tubewells and the rest 75 farms both from canal +tubewell from six villages each was taken during 2005-06. By applying Data Envelopment Analysis for this analysis they have concluded that there is potential to improve irrigation efficiency by 39 per cent and 32 per cent, in tubewell irrigated and canal +tubewell irrigated farms, respectively. For sustainable crop production in state, there is an urgent need to do away with the rice-wheat cropping system in the regions where groundwater depletion is very severe and strict regulation for exploiting groundwater and conjunctive use of surface water need to be introduced.

Vashisht (2008) has examined the status of water resources in Punjab. The study found that even after fully exploring the surface and groundwater resources, these

are able to meet less than 75 per cent of total water requirements. In the central Punjab, the situation is more critical. The excessive decline in water table is affecting the socio- economic condition of small farmers. In order to correct the imbalance in water budget and to restore sustainability in farming system, there is immediate need to diversify the cropping system.

Singh (2009) has attempted to highlight the problem of falling water table in the heart of rice belt in Punjab. The main reason for it has been the early transplanting of rice that means severe withdrawal of groundwater, as the monsoon is still far away, temperature is very high and evapo-transpiration rate is the maximum. The time series and experimental data on transplanting pattern, water requirements of rice, rainfall, monsoon recharge, groundwater behaviour and rice area have been used and it is estimated that the fall in water can be checked by about 30 cm, that is about 65 per cent of the long term falling rate, by delaying the transplanting with the effective implementation of 'The Punjab Preservation of Sub Soil Water Act'. The delay in transplanting to 15 June would maintain the balance but it cuts down the transplanting period further, thus intensifying the efforts to improving the water use efficiency and some substitution by low water requiring crops is recommended. The savings in electricity due to the act have been estimated at 276 million units. The act has many other long term benefits like saving the farmers from frequent deepening and even installing submersible tubewells.

Kaur et al. (2010) has suggested the optimal cropping pattern for maximizing the net return and ensuring significant saving of groundwater at different levels of groundwater availability for sustainable use of groundwater resources in Punjab. The study has revealed that a shift in transplanting dates of paddy from early June to last week of June could save water without any adverse impact on profitability. The study has also found that the area under paddy has reduced from 70.65 per cent of cultivated area at 100 per cent water availability level to 57.34 per cent at 64 per cent water availability level. The area has shifted towards less water consuming crops. A single strategy will not work to ensure sustainable use of groundwater resources in Punjab, but a multi-pronged strategy encompassing improvement in productivity of alternative crops, strengthening of market infrastructure and increase in their prices is required.

Sarkar (2011) made an attempt to examine the externality of groundwater irrigation from both private and social angles in Amritsar district. It analysed the external diseconomies in groundwater utilization in terms of its accessibility to groundwater irrigation to different farm size groups at different levels of groundwater depletion. This study brings to light the fact that profitability in agriculture declines with falling water tables and the cost of depletion is disproportionately carried by the resource poor farmers as they fail to invest capital in changing technology and deepening and also get excluded from the state financed free electricity in agriculture. In mixed irrigation systems, marginalized farmers can avail of canal irrigation, but in completely groundwater dependant irrigation systems the farmers are forced to buy water to sustain agriculture or lease out land and sell their land. This situation is perpetuated with further scarcity leading to unequal economic returns and finally takes the most exploitative form where the “large landlords” also emerge as “water lords” through surplus accumulation, forcing the small and marginal landholders to become landless agricultural labourers. There is an urgent need to divert procurement of rice considerably towards eastern India which is traditional area of rice cultivation and is also not threatened by low water tables and other possible option could be to direct the minimum support price (MSP) towards less water intensive crops like oilseeds and pulses.

Sustaining livelihoods in face of groundwater depletion has been examined by **Sarkar (2012)**. The study focuses on comparative analysis of livelihood status of different classes of farmers facing different levels of groundwater depletion. The government subsidy of electricity is also disproportionately favour the wealthy minority of the farming community because they own larger number of the modern water extraction machines and can gain enormously from growing water intensive rice crop. To cope with this resource depletion, the large farmers dig more tubewells or deep their existing tubewells and the small and marginal farmers who are unable to invest in costly water extraction machines, buy water, change cropping pattern to maize and fodder less profitable crop, lease out or sell their land and shift to other occupation. The farmers do not consider sustainability of groundwater to be their concern, but that of the state.

Above studies mainly associated with falling water tables and looked at ecological sustainability; but failed to figure out the rise in economic impact of scarce groundwater resource. Some micro level studies had highlighted the equity implications of groundwater misuse with falling water levels, but these studies represented Amritsar region of Punjab and South Indian states. However, these important aspects have somewhat neglected in Sangrur district, in spite of the fact that all blocks of Sangrur district is in the overexploited category. So the present study's concern is with the economic impact of groundwater depletion in Sangrur district.

Chapter 3

Study Area and Methodology

This chapter deals with the methods of data collection, selection of the sample and analytical techniques used for the analysis of the data. This study was carried out in Sunam block of Sangrur district of Punjab, located at a distance of 18 km from Sangrur and 48 km from Mansa. Two villages namely Tolawal and Rattangarh alias Pattianwali were selected. Tolawal village is located at a distance of 5 km from Sunam town and Rattangarh village at a distance of 3 km from Tolawal and 8 km from Sunam town.

Sampling Design

The sampling design was a multi- stage sample viz. selection of district, block, villages and ultimate selection of respondent farmers.

1. Selection of District: The whole state on the basis of levels of agro- climatic conditions have been divided into three regions, viz. north eastern shivalik foothill (kandi), central and south western region. On the basis of this criterion, the districts of Gurdaspur, Hoshiarpur, Mohali, Nawashahar, Pathankot and Ropar comprise the kandi region (Region I); districts of Amritsar, Barnala, Fatehgarh Sahib, Jalandhar, Kapurthala, Ludhaina, Patiala, Sangrur and Tarn Taran form the central region (Region II) and the remaining seven districts, namely Bathinda, Faridkot, Fazilka, Ferozpur, Mansa, Moga and Muktsar form the south western region (Region III). Water table falls alarmingly in the central Punjab because gross draft of water is more than net annual availability. Stage of groundwater development is highest in Sangrur district. Keeping in view the stage of groundwater development, Sangrur district was selected.

2. Selection of Block: The Central Ground Water Authority (CGWA) has declared seven blocks out of nine blocks of Sangrur district as notified area by banning any new tubewells for drawing groundwater. Out of the total number of 9 blocks of the Sangrur district, one block is selected on the basis of highest stage of groundwater development. The net annual availability, gross groundwater draft and stage of groundwater development are given in Table 3.1. The Sunam block has the

highest stage of groundwater development and gross groundwater draft. Accordingly, the Sunam block had been selected for the present study.

Table 3.1: Block- wise Assessment of Groundwater Resources in Sangrur District, 2008-09

(Hectare Meter)

S.no.	Block	Net annual groundwater availability	Existing gross groundwater draft for irrigation	Existing gross groundwater draft for all uses	Stage of groundwater development (%)
1.	Ahmedgarh	14523	40396	40646	260
2.	Andana	11633	25095	25245	217
3.	Bhawanigarh	16004	34754	35014	217
4.	Dhuri	11755	31763	32030	272
5.	Lehraghaga	14296	29201	29467	206
6.	Malerkotla	18958	49147	49599	262
7.	Sangrur	19964	46683	47129	236
8.	Sherpur	9966	31261	31460	315
9.	Sunam	20183	72008	72645	360

Source: Dynamic Groundwater Resources of Punjab State, 2012

3. Selection of Villages: Two villages namely Tolawal having tubewell irrigation and Rattangarh alias Pattianwali having canal+ tubewell irrigation were selected purposely for primary survey.

4. Selection of Farmers: Samples of 120 farmers comprising 60 farmers from each village were randomly selected. These selected farmers were categorized into three categories (Small, Medium and Large) on the basis of size of land holdings. A cultivator who owns land up to 5 acres, more than 5 and up to 10 acres and more than 10 acres and his main source of income is farm income belong to small, medium and large farmer group, respectively (Jeevandas et al., 2008).

Data Collection

In order to examine the access to groundwater irrigation, technical efficiency on farms, impact of groundwater over- draft on farm income and cost and returns to agriculture of the small, medium and large farmers structured schedule had been prepared (given in Appendix-B). The schedule focuses mainly on the following:

- I. Demographic Information of the Farmers;
- II. Particulars of Landholdings;
- III. Income from Agriculture and Non- agriculture Sector;
- IV. Operating Costs;
- V. Crop- wise Inputs used;
- VI. Particulars of Water Sources; and
- VII. Availability of Electricity facility

Data Analysis

Technical Efficiency

The most common concept of efficiency is “Technical Efficiency” that means transferring physical inputs into outputs at the best level of performance i.e. TE requires there is no waste in using inputs to produce specific quantity of output (Charnes et al., 1978). The data envelopment analysis (computer) program version 2.1 was used for the analysis of technical efficiency of farm.

Data Envelopment Analysis

Data envelopment analysis is a linear programming problem that provides a means of calculating apparent efficiency levels within a group of organizations. The efficiency of an organization is calculated relative to the group’s observed best practice (Bhagavath, 1998).

Coelli (1996) explained ‘A Data Envelopment Analysis (Computer) Program version 2.1’. “Suppose data are available on K inputs and M outputs on each of N farms or DMU’s. For the i^{th} farm in t^{th} time period, input and output data are represented by the column vectors x_i and y_i , respectively. The data for all N farms may be denoted by $K \times NT$ input matrix, X and $M \times NT$ output matrix, Y. The purpose

of DEA is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. The best way to introduce DEA is via the ratio form. For each DMU, a measure of the ratio of all outputs is obtained over all inputs, such as $u'y_i/v'x_i$, where u is an $M \times 1$ vector of output weights and v is a $K \times 1$ vector of input weights. The mathematical programming problem is specified, to select the optimal weights:

$$\begin{aligned} & \text{Max}_{u,v} (\mu'y_i), \\ & \text{st} \quad u'y_j/v'x_j \leq 1, \quad j= 1, 2, \dots, N \\ & u, v \geq 0 \end{aligned} \quad (1)$$

This involves finding of values for u and v , such that the efficiency measure of the i^{th} DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has infinite number of solutions. To avoid this one can impose the constraint $v'x_i= 1$, which provides:

$$\begin{aligned} & \text{max}_{\mu,v} (\mu'y_i), \\ & \text{st} \quad v'x_i= 1 \\ & \quad \mu'y_j- v'y_j \leq 0, \quad j= 1, 2, \dots, N \\ & \mu, v \geq 0, \end{aligned} \quad (2)$$

where the notation change from u and v to μ and v reflects the transformation. This form is known as the multiplier form of the linear programming problem. Using the duality in linear programming, one can derive an equivalent envelopment form of this problem:

$$\begin{aligned} & \text{min}_{\theta,\lambda} \theta, \\ & \text{st} \quad -y_i + Y\lambda \geq 0, \\ & \quad \theta x_i - X\lambda \geq 0, \\ & \quad \lambda \geq 0, \end{aligned} \quad (3)$$

Where θ is a scalar and λ is a $N \times 1$ vector of constants. This envelopment form involves fewer constraints than the multiplier form ($K + M < N + 1$), and hence is generally preferred". The value of θ obtained is the efficiency score for the i^{th} DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the Farrell (1957) definition.

The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint: $N1'\lambda = 1$ to (3) to provide:

$$\begin{aligned} \min_{\theta, \lambda} \quad & \theta, \\ \text{st} \quad & -y_i + Y\lambda \geq 0, \\ & \theta x_i - X\lambda \geq 0, \\ & N1'\lambda = 1 \\ & \lambda \geq 0, \end{aligned}$$

Where $N1$ is a $N \times 1$ vector of ones. This specification is often used for agricultural production because in general farmers may not operate at the optimal scale. In the case of agriculture, increased amounts of inputs do not proportionally increase the amounts of output (Manjunatha et al., 2009).

The per acre yield (qt.) data of two crops i.e. wheat and paddy were included as the output level. The inputs were taken on per acre basis and included human labour (days), seed quantity (kg.), fertilizers (kg.), pesticides and weedicides (litre), number of irrigation and use of tractor in hours.

Correlation Analysis

In order to study inter- correlations amongst different variables, correlation matrix was constructed.

Regression Analysis

To examine the impact of groundwater overdraft on farm income, simple regression analysis has been used with the help of following equation:

$$\text{Log}(Y) = \alpha + \beta(X)_i + e_i$$

Where, Y is dependent variable (farm income in Rs.) while X_i varies from X_1 to X_7

X_1 = Area under irrigation (Acres)

X_2 = Land ownership (Acres)

X_3 = No. of submersible motors

X_4 = Size of household (nos.)

X_5 = Depth of motors (ft.)

X_6 = Education (Years)

X_7 = Dummy 1 for access to canal water, 0 otherwise

e = Error term

Multiple (Step-up) Regression Analysis

The major problem that occurs in the multiple regression analysis is that of multicollinearity. In order to overcome the problem of multicollinearity stepwise forward regression analysis is used:

$$\text{Log}(Y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e_t$$

It is hypothesized that β_i 's > 0

To compare the explanatory power of different sets of multiple regression equation adjusted coefficients of determination (R^2) has also been calculated for each regression equation:

$$\bar{R}^2 = 1 - (1 - R^2) \frac{n-1}{n-k}$$

n is sample size; $n-k$ is the degree of freedom

Explanatory variables are entered in the stepwise forward regression model in accordance with the correlation of dependent variable and also taking into account the collinearity as well as explanatory power in view. To results obtained through the regression analysis are interpreted accordingly.

Chapter 4

Changing Pattern of Irrigation: Its Socio- Economic Dynamics

Punjab agriculture scenario has witnessed fast transformation since the middle of 1960's. Due to this transformation, the irrigation pattern has drastically changed. This chapter gives an overview of changing irrigation pattern in Punjab and socio-economic features of the sampled farmers. The social background of the farmers has been taken into consideration for the reason that it helps in understanding their level of living.

Irrigation Pattern in Punjab

According to Natural Resources Management and Environment Department, *"Irrigation is an act of artificially applying water to soil to allow plant growth. The term usually refers to providing large amounts of water in arid and dry regions to grow crops. In some places, snowfall and rainfall are the main suppliers of irrigation water, but in other locales, groundwater is essential. Surface water used for irrigation is stored naturally in lakes and ponds and is conveyed by rivers and streams"*.

In 2011-12, out of total irrigated area, 27 per cent is irrigated by canals and remaining 73 per cent by tubewells in Punjab. There are six major canal systems viz. Upper Bari Doab, Sirhind, King Bikaner, Rajasthan, Bist Doab and Bhakra. Only Upper Bari Doab canal is taking off from river Ravi and the other five canals from river Satluj. The total cropped area has increased from 4732 thousand hectare in 1960-61 to 7882 thousand hectare in 2010-11, due to this change the irrigation water requirements have increased tremendously. After the adoption of green revolution technology, the number of tubewells has increased. Thus, the irrigation pattern has been shifted from canal irrigation to tubewell irrigation as it is more reliable and flexible source of irrigation (Kaul & Sekhon, 1991). Table 4.1 and Table 4.2 show this scenario.

Table 4.1: Source wise Net Irrigated Area in Punjab
(Thousand Hectare)

Year	Canal	Tubewells & Wells	Other Sources	Total	% of net area irrigated to net area sown
1970-71	1292	1591	5	2888	71.0
1980-81	1430	1939	13	3382	81.0
1990-91	1669	2233	7	3909	93.0
2000-01	962	3074	2	4038	95.0
2001-02	969	3084	3	4056	95.0
2002-03	1260	2745	7	4012	95.0
2003-04	1041	3047	9	4097	97.0
2004-05	1100	2918	10	4028	96.0
2005-06	981	2912	126	4019	95.9
2006-07	1148	2878	46	4072	97.3
2007-08	1142	2922	4	4068	97.2
2008-09	1113	2950	1	4064	97.4
2009-10	1114	2955	2	4071	97.9
2010-11	1116	2954	NA*	4070	97.9

Source: Statistical Abstract of Punjab, Various Issues

* Not Available

Table 4.1 shows the source wise net irrigated area in Punjab. The area under tubewell irrigation has increased from 1591 thousand hectares in 1970-71 to 2954 thousand hectares in 2010-11. On the other side, area under canal irrigation has declined from 1292 thousand hectares to 1116 thousand hectares during the same time period. The total irrigated area has also increased from 2888 thousand hectares to 4070 thousand hectares during 1970-71 to 2010-11. The perusal of Table 4.2 shows the number of tubewells in Punjab. Due to increase in area under tubewell irrigation, demand for electric motors and diesel engines has increased. In 1970-71, the number of tubewells used was 1.92 lakh and its number increased to 13.83 lakh in 2011-12. The electric operated tubewells has increased at faster rate than the diesel operated tubewells because electricity facility is available almost at zero cost as the Punjab government has subsidized agricultural

electricity, on the other side price of diesel is rising. So the farmers prefer more electric operated tubewells than the diesel operated.

Table 4.2: Number of Tubewells in Punjab

(Lakh)

Year	Diesel Operated	Electric operated	Total
1970-71	1.01	0.91	1.92
1980-81	3.20	2.80	6.00
1990-91	2.00	6.00	8.00
2000-01	2.85	7.88	10.73
2002-03	2.88	8.45	11.33
2003-04	2.88	8.56	11.44
2004-05	2.88	8.80	11.68
2005-06	2.88	9.05	11.93
2006-07	2.80	9.52	12.32
2007-08	2.75	9.71	12.46
2008-09	2.71	10.05	12.76
2009-10	2.70	11.06	13.76
2010-11	2.40	11.42	13.82
2011-12	2.26	11.57	13.83

Source: Statistical Abstract of Punjab, Various Issues

It is clear that area under tubewell irrigation has been increasing in Punjab. The Sangrur district of Punjab is no exception of this. To analyse the scenario, the farmers had been selected from two villages i.e. Tolawal and Rattangarh of Sangrur district were distributed across different farm size groups shown in Table 4.3. The farmers having land holdings of five acres and less than five acres were grouped as small farmers, while, the farmers having land holdings more than five acres, but not more than ten acres were grouped as medium farmers and the farmers having land holdings of more than ten acres were grouped as large farmers¹.

¹Jeevandas et al. (2008).Concerns of Groundwater Depletion and Irrigation Efficiency in Punjab Agriculture: A Micro-Level Study. *Agriculture Economic Research Review*,191-197.

Table 4.3: Distribution of Farmers

Size of Farm	Tolawal (Tubewell)	Rattangarh (Canal+ Tubewell)
Small (up to 5 acres)	20 (33.3)	20 (33.3)
Medium (5- 10 acres)	20 (33.3)	20 (33.3)
Large (above 10 acres)	20 (33.3)	20 (33.3)
Total	60 (100)	60 (100)

Source: Survey Data

Note: Figures within the parentheses are percentages.

The total number of 120 farmers had been randomly selected for present study from two villages i.e. Tolawal dependent on tubewells and Rattangarh using both canal and tubewell water for irrigation. Sample of 60 farmers from Tolawal village include 20 small farmers, 20 medium and 20 large farmers while 60 farmers from Rattangarh village, out of that 20, 20 and 20 were small, medium and large farmers respectively. There was 100 per cent irrigation in both sampled farms and all were using submersible tubewells.

General Characteristics of the Farmers

Demographic information of the respondents play very important role in surveys. Table 4.4 shows the age of sampled farmers belonged to both villages. The average age of the sample respondents of Tolawal village was 45.27 years and it was 45.7 years, 48.4 years and 41.7 years for small, medium and large farmers respectively. On the other side, the average age of the sample respondents of Rattangarh village was 37.57 years and it was 36.38 years, 38.64 years and 37.24 years for small, medium and large farmers respectively. In Tolawal village, 13.33 per cent of sample farmers were in the age group of 20-30 years and 33.33 per cent of Rattangarh village farmers. Age of most of the sampled farmers of Tolawal lie between 40-50 years i.e. 35 per cent while in Rattangarh village, the mostly lie in age group of 30-40 years i.e. 35 per cent. Further, 1.67 per cent of sample farmers of both villages belonged to the age group of 70-80 years.

Table 4.4: Age of Farmers

Age group	Tolawal Farmers				Rattangarh farmers			
	Small (n=20)	Medium (n=20)	Large (n=20)	Total (n=60)	Small (n=20)	Medium (n=20)	Large (n=20)	Total (n=60)
20-30	3 (15)	3 (15)	2 (10)	8 (13.33)	6 (30)	5 (25)	9 (45)	20 (33.33)
30-40	5 (25)	4 (20)	7 (35)	16 (26.67)	10 (50)	6 (30)	5 (25)	21 (35)
40-50	7 (35)	4 (20)	10 (50)	21 (35)	4 (20)	5 (25)	2 (10)	11 (18.33)
50-60	3 (15)	7 (35)	1 (5)	11 (18.33)	0 (0)	4 (20)	3 (15)	7 (11.67)
60-70	2 (10)	1 (5)	0 (0)	3 (5)	0 (0)	0 (0)	0 (0)	0 (0)
70-80	0 (0)	1 (5)	0 (0)	1 (1.67)	0 (0)	0 (0)	1 (5)	1 (1.67)
Average age (yrs.)	45.7	48.4	41.7	45.27	36.38	38.64	37.24	37.57

Source: Survey Data

Note: Figures in parentheses are percentages.

The family composition of sample farmers has been discussed in Table 4.5. The average family size was around seven members that composed of three males, two females and two children in Tolawal village while in Rattangarh village it was around six members that composed of two males, two females and two children. It indicates that the family composition was almost same in both villages.

Table 4.5: Family Composition of Farmers

Particulars	Tolawal				Rattangarh			
	Small (n= 20)	Medium (n= 20)	Large (n=20)	All (n=60)	Small (n=20)	Medium (n=20)	Large (n=20)	All (n=60)
Male	2.45 (47.45)	2.9 (41.43)	2.5 (39.37)	2.62 (42.46)	1.92 (39.68)	1.81 (37.74)	2.44 (40.67)	2.1 (39.5)
Female	1.85 (35.93)	2.5 (35.71)	2.4 (37.80)	2.25 (36.47)	1.69 (34.92)	1.77 (36.79)	2.36 (39.33)	2 (37.62)
Children	0.85 (16.50)	1.6 (22.86)	1.45 (22.83)	1.3 (21.07)	1.23 (25.40)	1.23 (25.47)	1.2 (20)	1.22 (22.88)
Average family size	5.15 (100)	7 (100)	6.35 (100)	6.17 (100)	4.85 (100)	4.82 (100)	6 (100)	5.32 (100)

Source: Survey Data

Note: Figures in parentheses are percentages.

The educational status of the farmers is presented in Table 4.6. Among literates in Tolawal, 18.32 per cent of farmers had education up to primary level, 21.76 per cent of them studied up to matric and 8.32 per cent studied up to secondary school. The farmers who had college education worked out to be 6.60 per cent. The remaining 45 per cent of the farmers were illiterate. It was noticed that 70 per cent of the large farmers were literate. Mainly small farmers were illiterate i.e. 55 per cent. On the other side, in Rattangarh 28.33 per cent of farmers had education up to primary level, 46.67 per cent of them studied up to matric, 15 per cent studied up to secondary school and 10 per cent had education up to college level. Thus on an average 65 per cent were literate in Tolawal village while in Rattangarh, it was found that the 100 per cent sample farmers were literate. This is a surprising result when the literacy rate in Sangrur district is just 68.9 per cent (Census Data, 2013).

Table 4.6: Educational Status of Farmers

Size of farmers	Illiterate	Primary	Matric	Secondary	College & above	Total
Tolawal (Tubewell)						
Small (up to 5 acres)	11 (55)	3 (15)	3 (15)	3 (15)	0 (0)	20 (100)
Medium (5 to 10 acres)	10 (50)	2 (10)	4 (20)	2 (10)	2 (10)	20 (100)
Large (above 10 acres)	6 (30)	6 (30)	6 (30)	0 (0)	2 (10)	20 (100)
All	27 (45)	11 (18.32)	13 (21.76)	5 (8.32)	4 (6.60)	60 (100)
Rattangarh (Canal+ Tubewell)						
Small (up to 5 acres)	0 (0)	8 (40)	9 (45)	2 (10)	1 (5)	20 (100)
Medium (5 to 10 acres)	0 (0)	7 (35)	10 (50)	2 (10)	1 (5)	20 (100)
Large (above 10 acres)	0 (0)	2 (10)	9 (45)	5 (25)	4 (20)	20 (100)
All	0 (0)	17 (28.33)	28 (46.67)	9 (15)	6 (10)	60 (100)

Source: Survey Data

Note: Figures in parentheses are percentages

In Rattangarh village, maximum farmers were under the age group of working population i.e. 20- 40 years. This may be one of the reasons for 100 per cent

literate sample farmers in this village. The average age of Rattangarh farmers was less than the Tolawal farmers.

Table 4.7 shows the landholdings of farmers. The average landholding ranged from 3.14 acres for small farmers to 7.79 acres for medium and 23.6 acres for large farmers in the Tolawal village and 3.50 acres for small farmers, 7.55 acres for medium and 19.8 acres for large farmers in the Rattangarh village. Out of 100 per cent irrigation in the sample farms, in Tolawal village 90 per cent farmers land irrigated totally through tubewells but 10 per cent farmers those were having landholdings in area of nearby villages also had facility of canal water and in Rattangarh village 48 per cent area was irrigated through canal water and the remaining 52 per cent were irrigated through tubewells.

Table 4.7: Landholdings of Farmers

Size of Farm	Area of Tolawal (Acres)	Area of Rattangarh (Acres)
Small farms (up to 5 acres)	62.75 (3.14)	70 (3.50)
Medium farms (5- 10 acres)	155.75 (7.79)	166 (7.55)
Large farms (above 10 acres)	472.00 (23.6)	495 (19.8)
Total farms	690.50 (11.51)	731 (12.18)

Source: Survey Data

Note: Figures within the parentheses indicate average land ownership (in acres) among the related farm size group.

In tubewell irrigated village, the depleting groundwater was positively correlated with the trend of land 'leased out' and 'leased in'. For small farmers, leasing out their land to the large farmers was more profitable than cultivating their own land through buying water from nearby farms. It is a serious issue of the emerging rural economy of the farms depending only on groundwater. Moreover, many farmers are losing their land and in this process they are turning into landless labourers or workers as they have started to do work on others farms. Table 4.8 shows the incidence of tenancy by landownership. The small farmers preferred to give land

on rent more on the other side medium group of farmers mainly did self cultivation in Tolawal. But in the Rattangarh village the scenario was opposite to Tolawal, as in this village all categories of farmers mainly do self cultivation and also involved in 'lease in' land. The trend on 'leased out' in this village was negligible and the farmers mainly indulged in agriculture, few number of farmers were involved in other activities like dairy, drivers etc.

Table 4.8: Incidence of Tenancy by Landownership

Land Owned (Acres)	No. of farmers	Leasing In		Leasing Out	
		No. of farmers	Area (Acres)	No. of farmers	Area (Acres)
Tolawal (Tubewell)					
Small farmers (up to 5 acres)	20 (33.33)	5 (25)	26 (34.55)	5 (25)	13.5 (17.94)
Medium farmers (5 to 10 acres)	20 (33.33)	0 (0)	0 (0)	2 (10)	5.25 (3.49)
Large farmers (above 10 acres)	20 (33.33)	3 (15)	24 (5.28)	4 (20)	41.5 (9.13)
Total	60 (100)	8 (13.33)	50 (7.35)	11 (18.33)	60.25 (8.86)
Rattangarh (Canal+ Tubewell)					
Small farmers (up to 5 acres)	20 (33.33)	5 (25)	19 (28.04)	0 (0)	0 (0)
Medium farmers (5 to 10 acres)	20 (33.33)	4 (20)	22 (11.7)	0 (0)	0 (0)
Large farmers (above 10 acres)	20 (33.33)	4 (20)	62 (11.23)	1 (5)	5 (0.91)
Total	60 (100)	13 (21.67)	103 (12.75)	1 (1.7)	5 (0.62)

Source: Survey Data

Note: Figures in parentheses are percentages

In Tolawal village 13.33 per cent and 18.33 per cent farmers were involved in 'leased in' and 'leased out' respectively. Out of operated area 7.35 per cent area was leased in and 8.86 per cent area was leased out. On the other side, in Rattangarh village 21.67 per cent farmers were involved in leased in land, but the trend of leased out land was less, as only 1 per cent farmers had leased out their

land. Out of operated area, 12.75 per cent area was leased in and 0.62 per cent area was leased out.

Accessibility to Irrigation Water

The farms in Tolawal village were irrigated mainly through owned tubewells or the hired ones. However, almost all the farmers face the shortage of irrigation water mainly during the kharif crop season. Sharing of water among farmers was also very common. These trends had been found in sampled villages also. Due to erratic power supply farmers could not irrigate their farms timely and therefore they had to depend on generators by using costly diesel. Earlier farmers had access to canal water for irrigation but since last 5-6 years, 90 per cent farmers are unable to get canal water due to poor maintenance of canals. Due to persistent decline in watertable, deepening of tubewells was a common and for these farmers required huge amount of investment annually. Therefore, many of farmers were of the opinion that canal water irrigation facility must be there. Contrary to it, the farms of Rattangarh village were irrigated through tubewells as well as canal water. The Ghaggar branch of Sirhind canal and Bhakhra Main canal has been serving the Sunam block for irrigation and hence this village also (Punjabrevenue.nic.in). The respondents of this village had access to canal irrigation once in a week at the rate of 18 minutes per acre that was, however insufficient to irrigate water-intensive crop like paddy, so they had to depend on tubewells too.

The access to good quality reliable irrigation is important as it not only reduces risks; but also reduces the cost and simultaneously, increases the production of crop. Groundwater being a common pool resource, the right to access this resource should be equal to all. But there is an inherent inequality in groundwater accessibility as the groundwater rights are attached to land rights and land distribution is skewed in favour of large farmers (Dhawan, 1988). Table 4.9 shows the ownership of submersible tubewells across farm size classes. There was positive correlation between the ownership of motors and the depth of motors to the landholding sizes in both studied villages. In Tolawal village, the average number of motors ownership was 0.8, 1.2 and 2.7 for small, medium and large farmers respectively and 0.87, 1 and 2.65 motors for small, medium and large farmers respectively in Rattangarh village. The average depth of motors was 153.25 ft. in Tolawal and 158.37 ft. in Rattangarh. It was really surprising that in

mixed irrigation village the average depth of motors was higher because farmers installed tubewells at deeper lever initially but in Tolawal, the depth has been increasing slowly, but still the depth limit is not more than Rattangarh.

Table 4.9: Ownership of Submersible Tubewells across Farm Size Classes

Particulars	Small farmers	Medium farmers	Large farmers	Total
Tolawal (Tubewell)				
No. of farmers	20	20	20	60
Total no. of motors	16.08	24	53.5	93.58
Average no. of motors	0.8	1.2	2.7	1.55
Average horse-power of motors	18	22	24	21.33
Average depth of motors (ft.)	149.17	153.33	154.58	153.25
Rattangarh (Canal+ Tubewell)				
No. of farmers	20	20	20	60
Total no. of motors	17.50	20	53	90.5
Average no. of motors	0.87	1	2.65	1.51
Average horse- power of motors	20	23	25	22.67
Average depth of motors (ft.)	158.46	156.82	158.95	158.37

Source: Survey Data

This is a natural phenomenon as the large farmers with more capital savings invest in new water extracting machines and are able to adopt the best suitable technology as the water level declines. So the rich farmers continuously exploit groundwater and as a result the water table goes down.

Table 4.10: Access to Irrigation Water for different Farm Sizes

(per cent respondents)

Size of farmers	Very poor	Poor	Average	Good
Tolawal (Tubewell)				
Small	20	30	30	20
Medium	5	40	50	5
Large	10	20	55	15
Overall	15	27	45	13
Rattangarh (Canal+ Tubewell)				
Small	0	61.54	38.46	0
Medium	13.64	27.27	50	9.09
Large	4	56	32	8
Overall	6.67	46.67	40	6.66

Source: Survey Data

On the basis of farmers perception, the access to irrigation water for different farm sizes is given in Table 4.10, reveals that the farmers had varying degree of accessibility to irrigation water. Though, they had access to irrigation water in their cultivated land, it varies across farms in the case of different crops in a year. The mainly small farmers had very poor accessibility to irrigation water i.e. 20 per cent in Tolawal, but in Rattangarh no one responded for very poor accessibility because they had facility of canal water. Most of the farmers responded for average accessibility i.e. 45 per cent and 40 per cent in Tolawal and Rattangarh village, respectively.

The farmers face difficulty in getting enough irrigation water in certain months, especially during June, July and August. During the rabi crop season too, they had difficulty in getting enough water to their crops due to non availability of canal water for some time and insufficient time of electricity facility. Poor maintenance of canals, erratic power supply and depletion of groundwater were the main reasons for the poor accessibility of irrigation water in Tolawal village, whereas erratic power supply and depletion of groundwater were the major concerns in Rattangarh, as given in Table 4.11.

Table 4.11: Farmers perceptions on Poor Accessibility of Irrigation Water

Particulars	Tolawal				Rattangarh			
	Small	Medium	Large	Total	Small	Medium	Large	Total
Smaller landholdings	14 (70)	3 (15)	0 (0)	17 (28.33)	7 (53.85)	4 (18.18)	0 (0)	11 (18.33)
Erratic power supply	14 (70)	19 (95)	18 (90)	51 (85)	20 (100)	20 (100)	20 (100)	60 (100)
Depletion of groundwater	20 (100)	19 (95)	20 (100)	59 (98.33)	20 (100)	20 (100)	19 (95)	59 (98.33)
Shortage of water due to poor maintenance of canal	17 (85)	17 (85)	17 (85)	51 (85)	7 (53.85)	8 (36.36)	13 (52)	28 (46.67)

Source: Survey Data

Note: Figures in parentheses are percentages

There were variations on perceptions of farmers for causes behind poor accessibility of irrigation water in Tolawal. The most important reason considered by farmers were depletion of groundwater as 98.3 per cent farmers complained about this, followed by the reason shortage of water due to poor maintenance of canal and erratic power supply and 28.33 per cent of farmers consider smaller landholdings. On the other side, 18.33 per cent farmers considered smaller landholdings as reason, 100 per cent complained about erratic power supply, 98.33 per cent gives the reason of groundwater depletion and 46.67 per cent farmers of Rattangarh consider shortage of water due to poor maintenance of canals. Even the present cropping pattern is also reason behind poor accessibility as most of the farmers involved in wheat- paddy crop rotation and these are more water consuming crops.

Cropping Pattern under different Irrigation Systems

The crops grown by farmers during both the crop seasons in both the villages are given in Table 4.12. In the Sangrur district, paddy is the dominant crop across all farm- size groups. The choice of crops among different farm sizes did not differ in general and most of the farmers relied heavily on the wheat- paddy cropping system. With greater accessibility to groundwater resources, the large farmers devote a larger proportion of area to rice cultivation as compared to small and

medium farmers. As compared to small farmers, the large farmers gain more with the government support in the form of the high minimum prices.

Table 4.12: Cropping Pattern among Farmers

(per cent of gross cropped area)

Crop	Small farmers	Medium farmers	Large farmers	Total farmers
Tolawal (Tubewell)				
Paddy	46.70	46.63	48.73	48.06
Wheat	46.35	46.72	48.73	48.04
Veg. & Fodders	6.95	6.65	2.54	3.90
Gross cropped area	100 (7.01)	100 (14.1)	100 (44.33)	100 (21.81)
Rattangarh (Canal+ Tubewell)				
Paddy	46.55	46.48	48.23	47.69
Wheat	46.55	46.48	48.41	47.81
Veg. & Fodders	6.90	7.04	3.36	4.5
Gross cropped area	100 (9.75)	100 (16.48)	100 (42.88)	100 (26.02)

Source: Survey Data

Note: Figures in parentheses indicate gross cropped area in acres

The area under paddy and wheat crop was almost same in both villages. Out of total gross cropped area 48.06 per cent area was under paddy, 48.04 per cent area was under wheat and the remaining 3.9 per cent area was under vegetables and fodder in Tolawal village. In Rattangarh village, 47.69 per cent area was under paddy, 47.81 per cent area was under wheat and 4.5 per cent area was under vegetables and fodder out of gross cropped area. In case of small and medium farmers in both villages more per cent of gross cropped area was under vegetables and fodder as compared to large farmers. The small farmers, 6.95 per cent and 6.90 per cent of gross cropped area was under vegetables and fodder in Tolawal and Rattangarh, respectively. But in case of large farmers, only 2.54 per cent and 3.36 per cent of gross cropped area was under vegetables and fodder in Tolawal and Rattangarh, respectively. Hence, there was no significant influence of

irrigation systems on the cropping pattern in the two villages, because minimum support price and assured market for these crops forced the farmers to grow water intensive crops like paddy and wheat.

Costs and Returns to Agriculture

The decline in water table gives rise to technological externalities in terms of rising costs of installing new tubewells, deepening of existing tubewells and pumping and other maintenance activities (Shah, 1991). The declining water table may not only raise the marginal operational cost, but also give rise to a situation of diminished water availability, resulting in loss of farm output and lowering net returns (Dhawan, 1975). So, the net returns per unit of cost were used as a measure of profit margins to compare the profitability of cultivation of the two major crops- paddy and wheat in Sangrur across landholding size classes at different levels of groundwater depletion.

Table 4.13: Cost and Returns in Wheat and Paddy Cultivation

Particulars	Small farmers	Medium farmers	Large farmers
Tolawal (Tubewell)			
Paddy			
Net Sown Area (acres)	65.5	131.5	432
Total Return (Rs.)	2090695	4412690	14170980
Total Cost (Rs.)	841990	1699876	5641035
Return per unit of cost	2.48	2.6	2.51
Wheat			
Net Sown Area (acres)	65	131.75	432
Total Return (Rs.)	1642950	3543000	11904600
Total Cost (Rs.)	458850	931950	3286840
Return per unit of cost	3.58	3.8	3.62
Rattangarh (Canal+ Tubewell)			
Paddy			
Net Sown Area (acres)	59	168.5	517
Total Return (Rs.)	2233330	6398015	20441795
Total Cost (Rs.)	1115920	2175160	6979022
Return per unit of cost	2	2.94	2.93
Wheat			
Net Sown Area (acres)	59	168.5	519
Total Return (Rs.)	1564650	4517950	14334050
Total Cost (Rs.)	581855	1701245	5324970
Return per unit of cost	2.68	2.66	2.70

Source: Survey Data

Note- Total cost includes cost on seeds, fertilizers and pesticides, human labour, repairing and deepening cost of motor, fuel and interest on working capital

Table 4.13 shows the costs and returns in wheat- paddy cultivation. In tubewell irrigated village i.e. Tolawal, ratio of return per unit of cost for paddy was 2.48, 2.6 and 2.51 and for wheat crop was 3.58, 3.8 and 3.62 among small, medium and large farmers respectively. In canal+ tubewell irrigated village i.e. Rattangarh, ratio of return per unit of cost for paddy was 2, 2.94 and 2.93 and for wheat crop was 2.68, 2.66 and 2.70 among small, medium and large farmers respectively. The return per unit of cost for paddy crop was almost same in both tubewell and canal+ tubewell irrigated villages, but for wheat crop it was more in Tolawal village as compared to Rattangarh village. The higher cost spent by Rattangarh village farmers on motors and other inputs were not effective for wheat crop.

The analysis indicates that the returns to cost ratio were maximum for medium landholdings. This shows that the small farmers were the most sufferers as they were unable to invest in technology. On the other side, the returns of large farmers were less than medium farmers because their cost on technology i.e. motors and generators were higher for their large fields. As some of the small farmers had only one motor and others had shared basis ownership of motor and also limited electricity timings, so the sufficient water was not available for irrigation for them. The large farmers had large number of motors, so they get easily water for irrigation as the running cost of motors is marginally zero on account of the supply of free electricity to agriculture.

Cost of Water Extraction

The 'deepening and digging investment' on submersible tubewells is rising due to continuously lowering of water table in the study area. In the process of competitive race for groundwater development, farmers access to water and average productive age of motors was declining with time.

Farmers put the 10 meter piece of pipe every year in submersible motors for the continuous accessibility of water. This has led to a situation that costs on motors have been turned into short- term investments. The farmers of all categories were facing similar electricity problems, but the small farmers face an additional problem of lower motor yield because their motors were on shared basis. Electricity charges are subsidized in the agricultural sector for pumping groundwater. Therefore, the electricity cost of groundwater irrigation was nearly nil. Table 4.14 shows the cost of submersible tubewells in Tolawal village. The annual cost of

irrigation for large farmers was the highest (Rs. 32017.5), as against medium (Rs. 15900.5) and small (Rs. 9800) farmers. The average number of generator ownership was zero for small farmers, 0.35 for medium and 0.45 for large farmers. Due to these, fuel cost was almost nil for small farmers. Rs. 1018 and Rs. 2290 was average fuel cost incurred by medium and large farmers, respectively. The gross irrigated area per motor was 7.18, 12.98 and 17.64 acres for small, medium and large farmers, respectively.

Table 4.14: Cost and Area Irrigated through Submersible Tubewells in Tolawal Village

Particulars	Farmers		
	Small	Medium	Large
Total no. of motors	16.08	24	53.5
Total generator ownership (nos.)	0	7	9
Average amortized cost of motor (Rs.)	37691.25	51616.50	52626.00
Average amortized cost on total motors (Rs.)	40706.25	61840.50	140794.50
Average generator cost (Rs.)	Nil	23250	42250
Average deepening cost (Rs.)	9420	14362.5	28675
Total fuel cost (Rs.)	Nil	20360	45800
Annual average fuel cost (Rs.)	Nil	1018	2290
Annual average repair cost (Rs.)	380.00	520.00	1052.50
Gross irrigated area (Acres)	115.5	311.5	944
Gross irrigated area per motor ¹ (Acres)	7.18	12.98	17.64
Annual average cost of irrigation ² (Rs.)	9800.00	15900.50	32017.50
Annual average cost of irrigation per motor ³ (Rs.)	609.45	1044.27	598.46

Source: Survey Data

Note: ¹Gross irrigated area per motor= Gross irrigated area/ Total no. of motors, ²Annual average cost of irrigation= Average deepening cost+ average fuel cost+ average repair cost, ³Annual average cost of irrigation per motor= Annual average cost of irrigation/ total no. of motors.

Table 4.15 shows the average cost of groundwater irrigation in Rattangarh village. The initial cost on total motors was Rs. 193461.54; Rs. 204545.45 and Rs. 477900 incurred by small, medium and large farmers respectively. The average fuel cost was nil for small farmers, Rs. 1000 for medium and Rs. 14550 for large farmers. The cost of irrigation was the highest for large farmers (Rs. 50762.00) than medium farmers (Rs. 16718.18) and lowest for small farmers (Rs. 7165.39) in Rattangarh village.

Table 4.15: Cost and Area Irrigated through Submersible Tubewells and Canal in Rattangarh Village

Particulars	Farmers		
	Small	Medium	Large
Total no. of motors	17.50	20	53
Total generator ownership (nos.)	0	1	8.5
Average amortized cost of motor (Rs.)	193461.54	204545.45	210800
Average amortized cost on total motors (Rs.)	193461.54	204545.45	477900
Average generator cost (Rs.)	Nil	2727.27	29200
Average deepening cost (Rs.)	6730.77	13377.27	35076
Total fuel cost (Rs.)	Nil	20000	291000
Annual average fuel cost (Rs.)	Nil	1000	14550
Annual average repair cost (Rs.)	434.62	513.64	1136
Gross irrigated area (Acres)	140	332	985
Gross irrigated area through canals (Acres)	75	172	495
Gross irrigated area through motors (Acres)	65	160	490
Gross irrigated area per motor (Acres)	3.71	8	9.24
Annual cost of irrigation (Rs.)	7165.39	16718.18	50762
Annual average cost of irrigation per motor (Rs.)	409.45	835.91	957.77

Source: Survey Data

The data shows that the cost of motors was more in Rattangarh village than Tolawal village. The reason behind this was that in Rattangarh village canal water facility was available but in Tolawal, farmers had not such facility due to poor maintenance of canals. To irrigate their farms, farmers had adopted tubewell irrigation since 1980's. At that time Government of Punjab had given the motor connections at low price to encourage paddy production. At that period of time connection fees was just in hundreds. On the other side, in Rattangarh motor connections were taken by farmers after 2000. So the connection fees had been increased to Rs. 80000 and recently the connection fees has raised to Rs. 125000. Due to this reason motors cost in Rattangarh was almost 3 times greater than the Tolawal village.

The changing irrigation pattern has changed the agricultural scenario in Punjab. The small farmers prefer to give land on rent more in tubewell irrigated village. Almost farmers consider groundwater depletion and erratic power supply were main reasons for the poor accessibility of irrigation water. There was no significant influence of irrigation systems on the cropping pattern as mainly farmers grow wheat and paddy. The results show that the depth and cost of motors were more in mixed irrigated village. The situation of small farmers in tubewell irrigated village was worst as most of them had motor ownership on share basis. Even the farmers are turning from self- cultivators to landless labourers or workers.

Chapter 5

An Economic Analysis of Groundwater Depletion

The changing irrigation pattern of Punjab agriculture has large impact on farm efficiency and farm income. Therefore, an attempt has been made to discuss the farm efficiency and impact of groundwater depletion in this chapter. More specifically, effort is made to estimate the technical efficiency of two types of farms producing mainly two crops but depending upon either tubewell irrigation or canal+ tubewell irrigation system and also to analyse the impact of groundwater overdraft on income of both farms.

Technical Efficiency

The data from two villages' farms namely Tolawal farms depending only on tubewell irrigation while other Rattangarh farms depending on irrigation through canal as well as tubewell were taken. The input- output data on paddy and wheat production for the year 2012-13 collected from the sample farms were used to estimate the technical efficiency of the farms. The per acre yield (quintal) data of two crops i.e. wheat and paddy were included as the output level. The inputs were taken on per acre basis and included human labour (days), seed quantity (kg.), fertilizers (kg.), pesticides and weedicides (litre), number of irrigation and use of tractor in hours. Summary statistics of these variables for paddy crop for both villages i.e. Tolawal and Rattangarh are given in Table 5.1.

Table 5.1: Descriptive Statistics of Paddy Crop Variables used in the DEA Analysis

(Per Acre)

Variable	Output	Inputs					
	Yield (qtl.)	Human labour (days)	Seed quantity (kg.)	Fertilizers (kg.)	Pesticides & weedicide (l.)	No. of irrigation	Tractor use (hrs.)
Tubewell (Tolawal)							
Average	25.2	1.97	8.07	118.75	8.17	61.15	2.82
Standard Deviation	1.99	0.61	0.85	20.99	0.86	3.82	0.39
Minimum	16	0	4	80	5	35	2
Maximum	32	3	9.5	225	9	65	3.3
Canal+ Tubewell (Rattangarh)							
Average	29.43	11.63	8.18	187.5	8.34	63	2.88
Standard Deviation	2.04	2.13	0.77	35.09	1.02	2.41	0.32
Minimum	25	5	3.5	100	4	56	2
Maximum	36	18	9	285	10	69	3.3

Source: Survey Data

The technical efficiency was estimated using the Data Envelopment Analysis Program (DEAP). In case of agriculture, increased amounts of inputs do not proportionally increase the amount of outputs. Under constant returns to scale (CRS), the efficiency score derived is either less or equal to the efficiency score derived from the variable returns to scale (VRS) requirement for every farms. This reflects the fact that, under VRS, inefficient farms are only compared to efficient farms of a similar size. For this reason, more farms are efficient under the VRS formulation (Mahdhi et al., 2011).

Table 5.2: Technical Efficiency of Farms in Paddy Production under different Sources of Irrigation

Efficiency (%)	Tubewell (Tolawal)		Canal+ Tubewell (Rattangarh)	
	CRS Number of farms	VRS Number of farms	CRS Number of farms	VRS Number of farms
Up to 60	0	0	0	0
60-E-69	0	0	1	0
70-E-79	3	0	10	0
80-E-89	32	33	36	5
90-E-99	18	17	8	44
100	7	10	5	11
N	60		60	
Mean efficiency	89	90.3	85	95
Min. efficiency	78.9	81.8	68.7	85.3
Max. efficiency	100	100	100	100

Source: Survey Data

CRS= Constant returns to scale

VRS= Variable returns to scale

Results for estimates of technical efficiency of paddy crop for both villages are presented in Table 5.2. In the case of tubewell irrigated farms of Tolawal village, the minimum technical efficiency in paddy production was 78.9 per cent and the mean technical efficiency was 89 per cent, indicating that on an average, the farms operated 11 per cent below the frontier output levels. The efficiency was lower in the case of the farms of Rattangarh village irrigated through canals as well as tubewells with the mean technical efficiency of 85 per cent, implying that there was injudicious use of inputs, and the outputs of paddy could be increased by 15 per cent in the area.

Under the VRS specification the estimated input- oriented technical efficiency ranged from a minimum of 81.8 per cent to 100 per cent with a mean estimate of 90.3 per cent in tubewell irrigated village. This results means that a 9.7 per cent

decrease in all inputs is possible with present state of technology and unchanged outputs, or the same level of output can be reached by only using 90.3 per cent of the used inputs, if technical inefficiency is completely removed. On the other hand, in the mixed irrigated village the technical efficiency ranges from 85.3 per cent to 100 per cent with a mean efficiency of 95 per cent. This means that 5 per cent decrease in all inputs is possible with present state of technology and unchanged outputs by removing technical inefficiency completely.

The descriptive statistics of the variable used in wheat crop for both (tubewell and canal+ tubewell irrigated) villages are given in Table 5.3. The inputs taken were human labour, seeds, fertilizers, pesticides and weedicides, number of irrigation and tractors use in hours.

Table 5.3: Descriptive Statistics of Wheat Crop Variables used in the DEA Analysis

(Per Acre)

Variable	Output	Inputs					
	Yield (qtls.)	Human labour (days)	Seed quantity (kg.)	Fertilizer (kg.)	Pesticide & weedicide (l.)	No. of irrigation	Tractor use (hrs.)
Tubewell (Tolawal)							
Average	19.63	9.17	39.33	162.95	2.13	4.06	2.71
Standard Deviation	1.47	2.04	2.75	31.04	0.64	0.28	0.44
Minimum	17	0	29	120	0.5	3	1.3
Maximum	24	14	45	275	3.8	5	3.3
Canal+ Tubewell (Ratangarh)							
Average	19.87	11.53	40.53	227.37	2.25	4.12	2.98
Standard Deviation	1.16	1.38	2.33	39.47	0.46	0.31	0.33
Minimum	17	6	36	100	1	3.5	2
Maximum	23	16	45	350	3.7	5	4

Source: Survey Data

Table 5.4 shows the technical efficiency of farms producing wheat under different sources of irrigation. The technical efficiency was slightly higher in case of mixed irrigated farms. Under CRS, the mean technical efficiency was found 84.1 per cent

and 88.4 per cent in tubewell and canal+ tubewell irrigated farms, respectively. A majority of farms fell under 80-89 per cent in the case of both irrigation systems.

Table 5.4: Technical Efficiency of Farms in Wheat Production under different Sources of Irrigation

Efficiency (%)	Tubewell (Tolawal)		Canal+ Tubewell (Rattangarh)	
	CRS Number of farms	VRS Number of farms	CRS Number of farms	VRS Number of farms
Up to 60	0	0	0	0
60-E-69	0	0	0	0
70-E-79	21	1	9	0
80-E-89	24	39	28	8
90-E-99	8	10	17	41
100	7	10	6	11
N	60		60	
Mean efficiency	84.1	89.4	88.4	94.9
Min. efficiency	70.6	78.1	76.2	85.1
Max. efficiency	100	100	100	100

Source: Survey Data

Under the VRS the estimated technical efficiency ranged from 78.1 per cent to 100 per cent with mean efficiency of 89.4 per cent in tubewell irrigated farms of Tolawal village. This means that the same level of output can be reached by only using 89.4 per cent of the used inputs, if technical inefficiency is completely removed. On the other hand, in the canal+ tubewell irrigated village, the technical efficiency ranged from 85.1 per cent to 100 per cent with a mean efficiency of 94.9 per cent. This means that a 5.1 per cent decrease in all inputs is possible with present state of technology and unchanged outputs by removing technical inefficiency completely. The majority of the farms fall under 80-89 per cent efficiency category in the case of tubewell irrigated farms and above 90 per cent in

canal+ tubewell irrigated farms. Similar results had been given by Jeevandas et al. (2008)¹ and Mahdhi et al. (2011)².

Thus from above analysis it is clear that the mean technical efficiency for both crops i.e. paddy and wheat was more in canal+ tubewell irrigated farms as compared to tubewell irrigated farms. It shows that inputs were used inefficiently in both villages, but comparatively in Tolawal village inputs use was more inefficient.

Impact of Groundwater Overdraft on Farm Income

Groundwater depletion results in higher cost of extraction and reduced availability of irrigation water for crops that affects the farm income. The impact of groundwater over- draft on farm income was analyzed by using simple regression analysis and multiple (step- up) regression analysis. The dependent variable used was farm income (Rs.) and independent variables taken were area under irrigation (acres), land ownership (acres), number of submersible motors, depth of motors (ft.), education (years), size of household (nos.) and dummy 1 for availability of canal water, 0 otherwise.

Table 5.5 shows the inter correlation of the different indicators i.e. farm income, area under irrigation, land ownership, number of submersible motors, depth of motors, education and size of household. The result shows that the farm income of farmers was significantly and positively correlated with most of the variables. Only education level of famers was non- significantly but positively related to farm income. Area under irrigation was positive and significant related to all the variables (except depth of motors and education of farmer). Land owned by farmers was significantly and positively associated with income level, area under irrigation, number of submersible motors and size of household. Number of submersible motors was significantly and positively related with all the variables. Size of household was significantly and positively related with all variables (except depth of motors). Depth of motor was significantly and positively related only with

¹The mean technical efficiency was 76 per cent and 80 per cent in tubewell (Amritsar) and canal+ tubewell (Faridkot) irrigated farms respectively, in paddy crop. In the wheat crop, the mean efficiency was 80 per cent and 82 per cent in tubewell and canal+ tubewell irrigated farms, respectively.

²The average technical efficiency of the sample was 64 per cent means that by saving 36 per cent of all inputs the same output level could be produced in South Eastern Tunisia.

income level and number of submersible motors. Education was significantly and positively related with number of submersible motors and size of household.

Table 5.5: Correlation Matrix (Tolawal Village)

Variable	Income (Rs.)	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of household in nos.	Depth of motors (ft.)	Education (Years)
Income (Rs.)	1.00	0.740**	0.737**	0.741**	0.371**	0.393**	0.175
Area under irrigation (Acres)	0.740**	1.00	0.999**	0.818**	0.443**	0.204	0.156
Land ownership (Acres)	0.737**	0.999**	1.00	0.814**	0.440**	0.178	0.153
No. of submersible motors	0.741**	0.818**	0.814**	1.00	0.428**	0.287*	0.311*
Size of household in nos.	0.371**	0.443**	0.440**	0.428**	1.00	0.072	0.275*
Depth of motors (ft.)	0.393**	0.204	0.178	0.287*	0.072	1.00	0.177
Education (Years)	0.175	0.156	0.153	0.311*	0.275*	0.177	1.00

Source: Survey Data

* denote significant at five per cent level

** denote significant at one per cent level

Table 5.6 represents the results of simple regression analysis to find out the impact of groundwater over- draft on farm income. The results revealed that out of six variables, five variables namely area under irrigation, land ownership, number of submersible motors, size of household and depth of motors significantly and positively affected the farm income level in tubewell irrigated village. Only education was non-significantly, but positively related with farm income.

Table 5.6: Results of Regression Analysis (Tolawal Village)

Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of household in nos.	Depth of motors (ft.)	Education (Years)	R ²	R ² (F)
5.209* (89.684)	0.027* (8.436)	-	-	-	-	-	0.551	0.543 (71.173)
5.207* (88.76)	-	0.027* (8.359)	-	-	-	-	0.546	0.538 (69.89)
5.001* (64.656)	-	-	0.337* (8.318)	-	-	-	0.544	0.536 (69.198)
5.082* (31.107)	-	-	-	0.072* (2.944)	-	-	0.130	0.115 (8.669)
4.491* (13.845)	-	-	-	-	0.007* (3.252)	-	0.154	0.139 (10.575)
5.448* (60.756)	-	-	-	-	-	0.014 (1.274)	0.027	0.010 (1.623)

Source: Survey Data

* denote significant at five per cent level

Note: Figures in parentheses are t-values

Table 5.7: Results of Multiple (Step-up) Regression Analysis (Tolawal Village)

Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of household in nos.	Depth of motors (ft.)	Educa-tion (Years)	R ²	R ² (F)
5.209* (89.685)	0.028* (8.436)	-	-	-	-	-	0.551	0.543 (71.172)
5.217* (87.621)	0.088 (1.043)	-0.061 (-0.715)	-	-	-	-	0.555	0.539 (35.542)
5.073* (63.848)	0.042 (0.513)	-0.026 (-0.322)	0.177* (2.608)	-	-	-	0.603	0.582 (28.375)
5.068* (40.834)	0.042 (0.502)	-0.026 (-0.315)	0.176* (2.562)	0.001 (0.053)	-	-	0.603	0.574 (20.903)
4.165* (13.302)	-0.164 (-1.603)	0.179 (1.765)	0.144* (2.221)	0.008 (0.446)	0.006* (3.102)	-	0.663	0.632 (21.270)
4.133* (13.039)	-0.172 (-1.670)	0.187 (1.824)	0.158* (2.339)	0.011 (0.603)	0.006* (3.167)	-0.006 (-0.767)	0.673	0.629 (15.286)

Source: Survey Data

* denote significant at five percent level

Note: Figures in parentheses are t-values

To find out the most significant input among all inputs, the multiple regression analysis had been used. Table 5.7 represents the results of Multiple (Step-up) regression analysis for the impact of groundwater overdraft on farm income. The results show that in the first step of regression equation, area under irrigation was positively and significantly affected the farm income. It explained the 55.1 per cent variations in farm income. The addition of land ownership by farmers in the second step resulted in improvement in the value of R² (55.5 per cent). It affected the farm income negatively but non- significantly. The addition of submersible motors in the third step resulted in an increase in the value of R² (60.3 per cent) and adjusted R² (increased to 58.2 per cent). It significantly and positively affected the farm income. The addition of size of household non-significantly and positively affected the farm income but the value R² remained same. The addition of depth of motors positively and significantly affected the farm income and further increased the

value of R^2 to 66.3 per cent and adjusted R^2 (increased to 63.2 per cent). Finally, the education level of farmer was added in equation. It non- significantly and negatively affected the farm income. The value of R^2 (increased to 67.3 per cent) and adjusted R^2 (increased to 62.9 per cent). So in the final equation number of submersible motors and depth of motors significantly and positively affected the farm income. It depicts that in tubewell irrigated village the farmers who owned more submersible motors and their motors were installed at more depth had more farm income.

Table 5.8: Correlation Matrix (Rattangarh Village)

Variable	Income (Rs.)	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of households in nos.	Depth of motors (ft.)	Educa- tion (Years)
Income (Rs.)	1.00	0.866**	0.866**	0.799**	0.317*	0.282*	0.043
Area under irrigation (Acres)	0.866**	1.00	1.00**	0.925**	0.207	0.340**	0.131
Land ownership (Acres)	0.866**	1.00**	1.00	0.925**	0.207	0.340**	0.131
No.of submersible motors	0.799**	0.925**	0.925**	1.00	0.227	0.395**	0.104
Size of households in nos.	0.317*	0.207	0.207	0.227	1.00	-0.108	-0.003
Depth of motors (ft.)	0.282*	0.340**	0.340**	0.395**	-0.108	1.00	0.074
Education (Years)	0.043	0.131	0.131	0.104	-0.003	0.074	1.00

Source: Survey Data

* denote significant at five per cent level

** denote significant at one per cent level

Table 5.8 shows the inter correlation of the farm income and between independent variables i.e. land ownership, number of motors, depth of motors and education of farmer for canal+ tubewell irrigated village. The result shows that the farm income was significantly correlated with all the variables except education level. However, it was positively related with all the variables. Area under irrigation was positively

and significantly related with all the variables except size of household and education of farmer. Land ownership was significantly and positively related with income level, area under irrigation, depth of motors and number of submersible motors. Number of submersible motors was significantly and positively related with all variables except size of household and education level of farmer. Size of household was significantly and positively related only with farm income. Depth of motor was significantly and positively related only with farm income, area under irrigation, land ownership and number of submersible motors. Education was non-significantly related with all the variables.

Table 5.9 represents the results of simple regression analysis for the impact of groundwater utilization on farm income. The results revealed that out of six variables, five variables namely area under irrigation, land ownership, number of submersible motors, size of household and education significantly and positively affected the farm income level in canal+ tubewell irrigated village. Depth of motors was non-significantly affected the income, the reason behind this may be the farmers had alternative of canal water irrigation.

Table 5.9: Results of Regression Analysis (Rattangarh Village)

Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of household in nos.	Educa-tion (Years)	Depth of motors (ft.)	R ²	\bar{R}^2 (F)
5.326* (144.88)	0.033* (13.176)	-	-	-	-	-	0.749	0.745 (173.623)
5.326* (144.88)	-	0.033* (13.176)	-	-	-	-	0.749	0.745 (173.623)
5.297* (108.001)	-	-	0.281* (10.120)	-	-	-	0.638	0.632 (102.414)
5.425* (44.434)	-	-	-	0.055* (2.547)	-	-	0.101	0.085 (6.487)
5.433* (40.493)	-	-	-	-	0.029* (2.238)	-	0.079	0.063 (5.008)
5.279* (3.947)	-	-	-	-	-	0.003 (0.328)	0.002	-0.015 (0.108)

Source: Survey Data

* denote significant at five per cent level

Note: Figures in parentheses are t-values

Table 5.10: Results of Multiple (Step-up) Regression Analysis (Rattangarh Village)

Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Size of household in nos.	Educa- tion (Years)	Depth of motors (ft.)	R ²	R̄ ² (F)
5.326* (144.876)	0.331* (13.176)	-	-	-	-	-	0.749	0.745 (173.623)
5.344* (483.661)	1.540 (1.337)	-1.540 (-1.337)	-	-	-	-	0.757	0.749 (88.885)
5.342 -	1.542 (1.322)	-1.542 (-1.322)	0.001 (0.019)	-	-	-	0.757	0.744 (58.218)
5.232 -	1.342 (1.182)	-1.342 (-1.182)	-0.012 (-0.197)	0.024* (2.125)	-	-	0.776	0.759 (47.533)
5.128* (2.488)	1.35* (2.155)	-1.325 (-1.155)	-0.015 (-0.247)	0.025* (2.103)	0.002 (0.228)	-	0.776	0.755 (37.381)
5.893* -	1.38* (2.112)	-1.3 (-1.112)	-0.019 (-0.303)	0.025* (2.089)	0.002 (0.269)	-0.004 (-1.01)	0.78	0.755 (31.336)

Source: Survey Data

* denote significant at five percent level

Note: Figures in parentheses are t-values

Table 5.10 represents the results of Multiple (Step-up) regression analysis for the impact of groundwater overdraft on farm income in canal+ tubewell irrigated village. This results show that in the first step of regression equation, area under irrigation significantly and positively affected the farm income. The addition of land ownership by farmers in the second step resulted in improvement in the value of R² (increased to 0.757) and adjusted R² (increased to 0.749). It non-significantly and negatively affected the farm income. The addition of submersible motors in the third step resulted in the same value of R². It non- significantly and positively affected the farm income. The addition of size of household significantly and positively affected the farm income. The value of R² (increased to 0.776) and adjusted R² (increased to 0.759). With the addition of education, the value of R² remained same. It non- significantly and positively affected the farm income. Finally, the depth of motors was added in equation. It non- significantly and negatively affected the farm income. In the final equation area under irrigation and

size of household came significant. In this canal+ tubewell irrigated village, the scenario was different number of submersible motors and depth of motors had not significantly affected. The size of household had significantly and positively affected the farm income.

Table 5.11 shows the inter correlation in the different indicators of both (tubewell and canal+ tubewell irrigated) villages. The result shows that the farm income was significantly correlated with all the variables. However, it was positively related with all the variables. Area under irrigation was positively and significantly related with all the variables. Land ownership was significantly and positively related with income level, area under irrigation, number of submersible motors, education level and size of household. Number of submersible motors was significantly as well as positively related with all variables. Depth of motor was significantly and positively related with income level, area under irrigation, number of submersible motors and education level. Size of household was significantly and positively related with income, area under irrigation, land ownership and number of submersible motors. Education was significantly related to all variables except size of household. The dummy variable for availability of canal water was significantly related with farm income, depth of motors, size of household and education.

Table 5.11: Correlation Matrix (Rattangarh and Tolawal Village)

Variable	Income (Rs.)	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Depth of motors (ft.)	Size of household in nos.	Education (Years)	Dummy 1 canal water, 0 otherwise
Income (Rs.)	1.00	0.760**	0.758**	0.728**	0.367**	0.294**	0.280**	0.223*
Area under irrigation (Acres)	0.760**	1.00	0.999**	0.847**	0.180*	0.355**	0.192*	0.014
Land ownership (Acres)	0.758**	0.999**	1.00	0.845**	0.159	0.353**	0.189*	0.010
No. of submersible motors	0.728**	0.847**	0.845**	1.00	0.212*	0.348**	0.284**	-0.008
Depth of motors (ft.)	0.367**	0.180*	0.159	0.212*	1.00	0.006	0.248**	0.250**
Size of household in nos.	0.294**	0.355**	0.353**	0.348**	0.006	1.00	0.055	-0.203*
Education (Years)	0.280**	0.192*	0.189*	0.284**	0.248**	0.055	1.00	0.416**
Dummy 1 for canal water, 0 otherwise	0.223*	0.014	0.010	-0.008	0.250**	-0.203*	0.416**	1.00

Source: Survey Data

* denote significant at five per cent level

** denote significant at one per cent level

Table 5.12 represents the results of simple regression analysis for the impact of groundwater over- draft on farm income combined on tubewell and canal+ tubewell irrigated village. The results revealed that all the seven variables were significantly and positively affected the farm income. The significant positive

coefficient of dummy variable for canal water indicates higher income for farms in canal+ tubewell irrigated village.

Table 5.12: Results of Regression Analysis (Rattangarh and Tolawal Village)
Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land ownership (Acres)	No. of submersible motors	Depth of motors (ft.)	Size of household in nos.	Education (Yrs.)	Dummy 1 for canal water, 0 otherwise	R ²	R ² (F)
5.279* (142.01)	0.029* (12.85)	-	-	-	-	-	-	0.583	0.579 (165.18)
5.278* (140.78)	-	0.029* (12.74)	-	-	-	-	-	0.579	0.575 (162.38)
5.148* (104.12)	-	-	0.311* (11.54)	-	-	-	-	0.53	0.526 (133.25)
4.462* (16.17)	-	-	-	0.007* (4.25)	-	-	-	0.132	0.125 (18.03)
5.303* (50.69)	-	-	-	-	0.056* (3.29)	-	-	0.084	0.076 (10.82)
5.448* (78.74)	-	-	-	-	-	0.023* (3.04)	-	0.072	0.065 (9.22)
5.52* (96.59)	-	-	-	-	-	-	0.193* (2.46)	0.049	0.041 (6.07)

Source: Survey Data

Note: Figures in parentheses are t-values

The results of Multiple (Step-up) regression analysis for the impact of groundwater overdraft on farm income for both (tubewell and canal+ tubewell irrigated) villages are shown in Table 5.13. This results show that in the first step of regression equation, area under irrigation was positively and significantly affected the farm income. The addition of land ownership by farmers in the second step resulted in improvement in the value of R² (increased to 0.588) and adjusted R² (increased to 0.581). It non-significantly and negatively affected the farm income. The addition of submersible motors in the third step resulted in an increase in the value of R² (increased to 0.609) and adjusted R² (increased to 0.599). It significantly and positively affected the farm income. The addition of depth of motors positively and

significantly affected the farm income. The value of R^2 (increased to 0.665) and adjusted R^2 (increased to 0.653). With the addition of size of household R^2 (increased to 0.666) and adjusted R^2 (decreased to 0.651). It non-significantly and positively affected the farm income. The addition of education level positively and non-significantly affecting the farm income. Finally, the dummy variable for availability of canal water was added in equation. It significantly and positively affected the farm income. The value of R^2 (increased to 0.696) and adjusted R^2 (increased to 0.677). So in the final equation land ownership, number of submersible motor, depth of motors and dummy for availability of canal water was positively and significantly affected the farm income. The significant positive coefficient of dummy variable for canal irrigated village indicates higher income in mixed irrigated village compared to tubewell irrigated village. The significant and positive coefficient of land ownership implies that the large farmers had more income as compared to small farmers. On the same time, the number of submersible motors and depth of motors had significant and positive impact on farm income indicating that large farmers had more motors. So due to over draft of groundwater small farmers were most sufferers. The situation of small farmers in tubewell irrigated village was the worst.

Table 5.13: Results of Multiple (Step-up) Regression Analysis (Rattangarh and Tolawal Village)

Dependent variable: Farm Income (Rs.)

Constant	Area under irrigation (Acres)	Land Ownership (Acres)	No. of submersible motors	Depth of motors (ft.)	Size of household nos.	Education (Years)	Dummy 1 for canal water, 0 otherwise	R ²	R ² (F)
5.279* (142.003)	0.029* (12.852)	-	-	-	-	-	-	0.583	0.579 (165.17)
5.286* (140.687)	0.110 (1.597)	-0.081 (-1.17)	-	-	-	-	-	0.588	0.581 (83.53)
5.209* (109.403)	0.084 (1.231)	-0.064 (-0.94)	0.118* (2.531)	-	-	-	-	0.609	0.599 (60.39)
4.218* (18.16)	-0.151 (-1.803)	0.170* (2.05)	0.106* (2.427)	0.006* (4.349)	-	-	-	0.665	0.653 (57.02)
4.164* (16.826)	-0.157 (-1.864)	0.177* (2.103)	0.103* (2.344)	0.007* (4.385)	0.007 (0.641)	-	-	0.666	0.651 (45.47)
4.180* (16.801)	-0.152 (-1.789)	0.171* (2.031)	0.095* (2.117)	0.006* (4.131)	0.007 (0.651)	0.004 (0.765)	-	0.667	0.650 (37.85)
4.187* (17.532)	-0.152 (-1.872)	0.170* (2.105)	0.116* (2.663)	0.006* (3.804)	0.015 (1.367)	-0.003 (-0.628)	0.172* (3.258)	0.696	0.677 (36.72)

Source: Survey Data

* denote significant at five percent level

Note: Figures in parentheses are t-values

Sharif and Ashok (2011) had also analysed the impact of groundwater over-draft on income in the Chamarajanagar district of the Karnataka. The education and irrigation had a positive significant influence on income; the small households were most efficient in managing the groundwater resources than the large households and in the over-exploited and semi-critical villages the farm income level is lower than the safe villages.

Thus from above economic analysis, it is clear that mean technical efficiency for both crops i.e. paddy and wheat was more in canal+ tubewell irrigated farms as compared to tubewell irrigated farms showing that inputs were used inefficiently in both villages, but comparatively in Tolawal village use of inputs was more inefficient. The results of multiple regression revealed that the variables like land ownership of farmers, number of submersible motors, depth of motors and dummy for canal water availability came significant and positive. The significant and

positive sign of the coefficient for land ownership implies that large farmers had more farm income. Number of submersible motors and depth of motors had a positive significant influence on farm income. It means the farmers who owned more number of motors and installed their motors at more depth had positive impact on farm income. In short, the small farmers of Tolawal village were the most sufferers.

Chapter 6

Summary and Conclusions

Punjab state contributes significantly in the agricultural economy of India. Despite a small geographical area of 1.5 per cent, it has contributed to the central pool significantly towards strengthening India's self-sufficiency. During 2011-12, it contributed 38.7 per cent wheat and 22.1 per cent rice to the central pool. Growth in Punjab agriculture has been closely associated with the well-known "Green Revolution". The adoption of high yielding varieties of seeds, increased use of chemical fertilizers and irrigation has helped in raising the income level of the farmers and total food grain production. But it cannot be denied that the adoption of modern technology is expensive and it takes place at the cost of unsustainable use of resources. Inefficient application of fertilizers and pesticides, heavy mechanization, water-logging and groundwater depletion has made cultivation increasingly unviable. Now a days, groundwater depletion is found to be one of the major problems in Central Punjab.

Water table in the Central Punjab has gone down by more than 20 meters in the past one decade. The stage of groundwater development is more than 200 per cent in Fatehgarh Sahib, Jalandhar, Kapurthala, Mansa, Moga and Sangrur indicating that these districts are using groundwater more than its availability. Among all districts, this indicator is the highest in Sangrur district, i.e. 264 per cent. All the nine blocks of Sangrur district are over- exploited. But the stage of groundwater development is the highest in Sunam block. Therefore, the present study is an attempt to analyse the economic concerns of groundwater depletion in Sunam block of Sangrur district. For this purpose, an attempt has been made to analyse the efficiency of farms irrigated either through tubewells or canal+ tubewells and also to examine the impact of groundwater over draft on farm income. In order to achieve these envisaged objectives of the study, the data was collected from primary as well as secondary sources. From Sunam block, two villages namely Tolawal with tubewell irrigation and Rattangarh alias Pattianwali with canal+ tubewell irrigation were selected purposely for primary survey. The primary data was collected from 120 farmers of these two villages with the help of a structured schedule. The secondary data was also collected from the Statistical Abstract of Punjab and Central Ground Water Board.

In Punjab, the total cropped area increased from 4732 thousand hectares in 1960-61 to 7882 thousand hectares in 2011-12. The area under wheat crop increased from 1400 thousand hectares in 1960-61 to 3528 thousand hectares in 2011-2012 and for paddy crop 227 thousand hectares to 2818 thousand hectares during the same period. Both these crops are water- intensive, so this sharp change in cropping pattern has increased water requirements for irrigation tremendously. Therefore, the irrigation pattern has shifted from canal irrigation to tubewell irrigation as groundwater is considered more reliable and flexible source of irrigation. Out of the total irrigated area in Punjab, 27 per cent area is irrigated by canals and remaining 73 per cent by tubewells. In Punjab, area under canal irrigation declined from 1292 thousand hectares to 1116 thousand hectares from 1970-71 to 2010-11. On the other hand, area under tubewell irrigation increased from 1591 thousand hectares in 1970-71 to 2954 thousand hectares in 2010-11. Due to increase in area under tubewell irrigation, the demand for diesel and electric operated tubewells has also been increased i.e. 1.92 lakh in 1970-71 to 13.83 lakh in 2011-12. To fulfill their requirements; farmers are extracting more groundwater with the help of tubewells.

Main Findings

The total number of 120 farmers was randomly selected for present study from two villages i.e. Tolawal and Rattangarh. A sample of 60 farmers from each village was taken, including small farmers, medium and large farmers in equal numbers. There was 100 per cent irrigation in both sampled farms and all were using submersible tubewells. The respondents from Tolawal and Rattangarh belong to an average age of 45.27 years and 37.57 years respectively and their average family size was 7 and 6 respectively. It had been found that on an average 65 per cent and 100 per cent of farmers were literate in Tolawal and Rattangarh respectively. In Rattangarh village, maximum farmers were in age group of working population i.e. 20- 40 years. This may be one of the reasons for 100 per cent literate sample farmers in this village. The average size of the landholdings was found as 3.14 acres for small farmers, 7.79 acres for medium and 23.6 acres for large farmers in Tolawal village and 3.50 acres for small farmers, 7.55 acres for medium and 19.8 acres for large farmers in Rattangarh. Among the group of large farmers, the size of their landholdings of Rattangarh was comparatively less than Tolawal farmers' landholdings. Out of 100 per cent irrigation in the sample farms,

in Tolawal village 90 per cent farmers irrigate totally through tubewells remaining 10 per cent farmers also had facility of canal water. These 10 per cent farmers had landholdings in area of nearby villages so they had facility of canal water. In Rattangarh village, all farmers had access to both (tubewell and canal) water, as 48 per cent area was irrigated through canal water and the remaining 52 per cent was irrigated through tubewells.

In Tolawal, the depleting groundwater was positively correlated with the trend of 'leasing out' and 'leasing in' land. For small farmers, leasing out their land to the large farmers was more profitable than cultivating their own land through buying water from nearby farms. Large farmers cultivate their owned land as well as leased in land. On the other side medium farmers preferred to self cultivate their land. But in the Rattangarh village, the scenario was opposite to Tolawal, as in this village all farmers favoured self-cultivation and 'leasing in' rather than 'leasing out' because all had at least one option of irrigation. The study also revealed a positive correlation of land ownership with the ownership of motors and the depth of motors in both villages under the study. In Tolawal village, the average numbers of submersible motors ownership were 0.8, 1.2 and 2.7 for small, medium and large farmers respectively and 0.87, 1 and 2.65 motors for small, medium and large farmers respectively in Rattangarh village. The average depth of motors was 153.25 ft. in Tolawal and 158.37 ft. in Rattangarh. It was really surprising that in mixed irrigation village the average depth of motors was higher, though they had facility of canal irrigation. In this village, first installation of tubewells was at deeper level while in Tolawal though tubewells usage started in 1980's; still the depth limit was not more than Rattangarh.

In Tolawal, some small farmers was not satisfied with accessibility to irrigation water but in Rattangarh scene was different because they had an alternative facility of canal water. Most of the farmers responded for average accessibility i.e. 45 per cent and 40 per cent in Tolawal and Rattangarh village respectively, as the farmers face difficulty in getting enough irrigation water in certain months, especially during June, July and August. Poor maintenance of canals, erratic power supply and depletion of groundwater were the main reasons for the poor accessibility of irrigation water in Tolawal village, whereas erratic power supply and depletion of groundwater were the major concerns in Rattangarh.

The main crops grown in sampled area were paddy, wheat, vegetables and fodder. Out of total gross cropped area in Tolawal village, 48.06 per cent area was under paddy, 48.04 per cent area was under wheat and the remaining 3.9 per cent area was under vegetables and fodder. In Rattangarh village, out of gross cropped area, 47.69 per cent area was under paddy, 47.81 per cent area was under wheat and only 4.5 per cent area was under vegetables and fodder. The cost of motors was more in Rattangarh village than Tolawal village. The reason behind this was that in Rattangarh village canal water facility is available but in Tolawal, farmers had not such facility due to poor maintenance of canals. To irrigate their farms, farmers had adopted tubewell irrigation since 1980's. At that time Government of Punjab had given the motor connections at low price to encourage paddy production. On the other side, in Rattangarh motor connections were taken by farmers after 2000, at that time connection fees have been raised. In Tolawal, ratio of return per unit of cost for paddy was 2.48, 2.6 and 2.51 and for wheat crop was 3.58, 3.8 and 3.62 for small, medium and large farmers respectively. In Rattangarh, ratio of return per unit of cost for paddy was 2.00, 2.94 and 2.93 and for wheat crop was 2.68, 2.66 and 2.70 for small, medium and large farmers respectively. The return per unit of cost for paddy crop was almost the same in both villages, but for wheat crop it was more in Tolawal village as compared to Rattangarh village. The higher cost spent by Rattangarh farmers on motors and other inputs was not effective for wheat crop.

The technical efficiency of farms producing paddy and wheat was calculated under constant returns to scale (CRS) and variable returns to scale (VRS) by Data Envelopment Analysis Program. Under CRS the minimum technical efficiency was 78.9 per cent in tubewell irrigated farms and the mean technical efficiency was 89 per cent, which indicated that on an average, the farms operated 11 per cent below the frontier output levels. In the case of the canal+ tubewell irrigated farms, the mean technical efficiency was 85 per cent, which implied that there was injudicious use of inputs, and the outputs of paddy could be increased by 15 per cent in the area. Under the VRS specification the estimated input- oriented mean technical efficiency was 90.3 per cent in tubewell irrigated village. This means that the same level of output can be reached by only using 90.3 per cent of the used inputs, if technical inefficiency is completely removed. On the other hand, in the

canal+ tubewell irrigated village the mean technical efficiency was 95 per cent. It is clear that mean technical efficiency for paddy was more in Rattangarh village.

In wheat production, the mean technical efficiency was 84.1 per cent and 88.4 per cent in tubewell and canal+ tubewell irrigated farms, respectively under CRS. Under the VRS the estimated technical efficiency range from 78.1 per cent to 100 per cent with mean efficiency of 89.4 per cent in tubewell irrigated farms. This means that the same level of output can be reached by using only 89.4 per cent of the used inputs, if technical inefficiency is completely removed. On the other hand, in the canal+ tubewell irrigated village the technical efficiency ranged from 85.1 per cent to 100 per cent with a mean efficiency of 94.9 per cent. At the farmers' level, the adoption of efficient input use technologies (especially the scarce resources like water) can save a lot of water in the state without adversely affecting the crop production and productivity.

The impact of groundwater over-draft on farm income was estimated through simple regression analysis and multiple (step- up) regression analysis for both villages separately as well as together. The results of simple regression revealed that out of six variables, five variables namely area under irrigation, land ownership, number of submersible motors, size of household and depth of motors significantly and positively affected the farm income level in tubewell irrigated village. Only education was non-significantly, but positively related with farm income. According to multiple regression results, the number of submersible motors and depth of motors significantly and positively affected the farm income. It depicts that in tubewell irrigated village the farmers who owned more submersible motors and their motors were installed at more depth had more farm income. On the other side, five variables namely area under irrigation, land ownership, number of submersible motors, size of household and education significantly and positively affected the farm income level in canal+ tubewell irrigated village. Depth of motors non- significantly affected the income, the reason behind this may be that the farmers had alternative of canal water for irrigation. As per multiple regression analysis, area under irrigation and size of household had significant and positive impact on farm income.

In combined analysis of both villages, the results of simple regression analysis revealed that all the seven variables significantly and positively affected the farm

income. The results of multiple regression revealed that the variables like land ownership of farmers, number of submersible motors, depth of motors and dummy for canal water availability came significant and positive. The significant and positive sign of the coefficient for land ownership implies that large farmers had more farm income. Number of submersible motors and depth of motors had a positive and significant influence on farm income. It means that the farmers who owned more number of motors and installed their motors at more depth had positive impact on farm income. The significant positive coefficient of dummy variable for availability of canal water indicates higher farm income in this category of farms as compared to farms without availability of canal water. In short, the small farmers of Tolawal village were the sufferers.

The present study concludes that the problems of groundwater depletion in Punjab are due to present wheat- paddy crop rotation. The inefficiency in production of wheat and paddy crop is more in tubewell irrigated farms as compared to canal+ tubewell irrigated farms, impacting the farm income and the situation is worst on those farms where the facility of canal water is not available.

Suggestions

The following suggestions would be useful to minimize the problems related to the theme of the study:

In view of the excessive use of scarce resources like water and ever- increasing doses of other inputs, there is an urgent need to develop the alternative cropping system that could save Punjab from turning into dark zone (Romana, 2011). But there is no alternative crop combination that could replace wheat- paddy cropping system in the Central Punjab, because other crops are not economically viable for farmers. Dr. Shergill also claims that there is no suitable alternative because water consumption requirement of only maize is lower than of paddy, but this shift would come at a heavy price because it would result in a substantial fall in the net return per acre¹. The alternative cropping system must give at least equal to the return from the existing (wheat- paddy) rotation, if not more than that. In the absence of this, the farmers of Punjab can not shift to any other cropping system. That would

¹ Singh, J. (2013, July 28). Area under Paddy may Rise: Study. *The Tribune*, Chandigarh.

require strengthening of Research and Development for some less water consuming crops.

As the farmers dig deeper to draw groundwater, the process is going to be costly due to the installation of expensive machinery. The small farmers cannot afford to install tubewells at a depth of hundreds of meter to irrigate their crops. Therefore, some alternative should be given for shifting towards less water consuming crops.

Though the Central Ground Water Board (CGWB) has banned new tubewells installation in 18 blocks of Punjab for drawing underground water, still farmers, particularly the wealthy ones, can often tap private sources of capital for tubewell construction. Where electricity connections are concerned, large farmers can afford them. It was learnt from the survey of farmers in the villages of Sangrur that for small farmers, getting new electricity connection is virtually impossible as there is a huge amount of fees. But this ban cannot stop the large farmers in limiting the growth of groundwater extraction.

The government should take efforts for the maintenance of canals, so that the farmers can rely upon canal water for irrigation instead of groundwater, as situation is worst in those farms where there is no availability of canal water. It has been observed in the present survey that farms without canal water facility yielded less income and efficiency of farm was less as compared to farms with facility of canal water.

In order to encourage use of energy efficient equipment, assured electricity may be provided to agriculture sector at subsidized rates and incentives can be given in the form of support price. The present survey observed that the farmers are ready to pay electricity charges, if the government availed them assured electricity during kharif season.

The findings of the present study conclude that a single strategy to ensure sustainable use of groundwater resources in Punjab may not work efficiently, therefore a multi-approach strategy to enlarge the productivity of different crops, increase in their prices and strengthening of market infrastructure is obligatory. Such steps taken on priority basis can help to lessen the economic and other problems of groundwater depletion.

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APPENDIX-A**Table A.1: Summary of Literature Review (India)**

S. No.	Author	Year	Objectives	Conclusion and Suggestion
1	Dhawan	1975	Evaluated externalities of new groundwater technology on small farmers.	Deleterious impact on crops under the command of traditional water lifts.
2	Singh	1991	Highlighted issues regarding groundwater irrigation in Punjab.	Greater emphasis is laid either on increasing the recharge by artificial means or on reducing draft by shifting cropping pattern.
3	Chaudhary and Aneja	1991	Analyzed the impact of green revolution on sustainability of land and water resources in Haryana.	New development strategy should be aimed at maintaining growth in productivity through scientific management of land and water resources.
4	Shah	1991	Discussed about the water markets and irrigation development in India.	To make water markets more competitive required the investment in underground pipelines would increase the efficiency in water and power- use.
5	Singh	2001	Pointed out the impact of land use change on groundwater in Punjab- Haryana plains.	It recommended the cropping pattern should include only low water consuming crops and to initiate groundwater recharge projects.

S. No.	Author	Year	Objective	Conclusion and Suggestion
6	Banerji et al.	2006	Analyzed the institutions and markets that govern groundwater allocation in the sugarcane belt of Uttar Pradesh.	Water sales lead to great misallocation of water and result in large crop losses for plots that irrigate using purchased water.
7	Bhalla	2007	Examined the impact of declining groundwater level on farmers crop in Haryana.	Declining water table depth discourages farmers to cultivate water intensive crops.
8	Dubash	2007	Analyzed the political interpretation of the electricity-groundwater conundrum.	For the viability of water and electricity, some multifaceted implementation strategy that includes economic, administrative, technical and institutional solutions.
9	Manjunatha et al.	2009	Examined the impact of groundwater markets in Peninsular India on water use efficiency.	Groundwater markets can add to improving efficiency of water use and offers access to groundwater to resource poor farmers.
10	Mahdhi et al.	2011	Highlighted the water use and technical efficiencies in private irrigated perimeters in Tunisia.	The irrigation systems were clearly inefficient as the same level of output can be produced by using less farm inputs.
11	Sharif and	2011	Discussed the impact	Over- exploited villages

S. No.	Author	Year	Objective	Conclusion and Suggestion
	Ashok		of groundwater depletion on farm income in Chamarajanagar district of Karnataka.	reflected better water use efficiency thus there should be adoption of irrigation technologies like drip, sprinkler etc.
12	Palanisami et al.	2011	Examined the groundwater over-exploitation and efficiency in crop production in Coimbatore district of Tamil Nadu.	There is need for the adoption of crop pattern with minimum crop failure and regular farm educational programs as well as participatory crop management programs for better use of resources.
13	Watto	2013	Measured the groundwater irrigation efficiency in Pakistan.	There is need to provide knowledge of crop water requirements and the use of improved crop varieties.

Table A.2: Summary of Literature Review (Punjab)

S. No.	Author	Year	Objective	Conclusion and Suggestion
1	Joshi and Tyagi	1991	Examined the sustainability of existing farming system in Punjab and Haryana.	Some appropriate technological, institutional and price policies should be initiated to save land and water resources for next generation.
2	Singh and Sankhayan	1991	Identified the sustainability of water resources in Punjab.	There is need to develop the research for the techniques to use marginally fit water and the agricultural price policy.
3	Dhawan	1993	Highlighted the problem of groundwater depletion in Punjab.	Recommended that to let the paddy field remain dry for a day or two after ponded water and to start subsidy programme for installing sprinkler and drip irrigation.
4	Sidhu	2002	Examined the Punjab's agrarian economy crisis.	There is an urgent need to diversify not only in narrow sense within the crop husbandry sector; but in a broader sense to allied activities means moving away from agriculture to other rural non- farm activities and agro processing.

S. No.	Author	Year	Objective	Conclusion and Suggestion
5	Singh and Kalra	2002	Briefly discussed about various issues related to huge expansion of rice cultivation Punjab.	Majority of farmers did not envisage any alternative to rice at a significant level in the near future.
6	Singh and Sidhu	2006	Examined the impact of environmental degradation in Punjab agriculture.	Suggested to minimize excessive use of natural resources and to encourage diversification of state agriculture from rice to alternative less water consuming crops.
7	Jeevandas et al.	2008	Investigated the extent of water depletion and measured irrigation efficiency at farm level in Amritsar and Faridkot district	There is need to do away with rice- wheat cropping system in the regions where groundwater depletion is very severe and conjunctive use of surface water need to be introduced.
8	Vashisht	2008	Examined the status of water resources in Punjab.	The excessive decline in water table is affecting the socio- economic condition of small farmers and for sustainability there is need to diversify the cropping pattern.
9	Singh	2009	Highlighted the problem of falling	The delay in paddy transplantation to 15

S. No.	Author	Year	Objective	Conclusion and Suggestion
			water table in the heart of rice belt in Punjab.	June would improve water use efficiency and some substitution to less water consuming crop.
10	Kaur et al.	2010	Presented some suggestions for optimal crop plan with sustainable water use.	A multi- pronged strategy encompassing improvement in productivity of alternative crops, strengthening of market infrastructure and increase in their prices is required.
11	Sarkar	2011	Examined the extent of groundwater irrigation from private and social angles in Amritsar.	There is need to divert procurement of rice towards eastern India and other could be direct the MSP towards less water intensive crops.
12	Sarkar	2012	Discussed the comparative analysis of different classes of farmers facing different levels of groundwater depletion.	The farmers do not consider sustainability of groundwater to be their concern, but that of the state.

APPENDIX-B
CENTRAL UNIVERSITY OF PUNJAB (BATHINDA)
An Economic Analysis of Groundwater Depletion in Sangrur District of
Punjab
Schedule for Farmers

Date.....

1. Farmer's Particulars

1.1 Respondent profile

Name of the respondent	
Age	
Village	
Post office	
Block	
Tehsil	
Contact no.	

1.2. Education:

Illiterate	Primary	Matric	Secondary	College & above
0	1	2	3	4

1.3. Family composition

Name	Sex (M/F)	Age	Education al Status (years)	Nature of family #	Occupation \$		

Nuclear family-1, Joint family-2.

\$ Self Cultivation-1, Causal Labour in Agriculture-2, Casual Labour in non Agriculture-3, Long term attached labour-4, Salaried/govt.job-5, Individual Service (Caste Occupation)-6, Self business based on agriculture and allied activities-7 (Animal Husbandry, Poultry etc.), Small Business/trade/construction-8, Big Business/trade/construction-9, Unemployed-10, Student-11, Only domestic work-12, Retired/ Very old-13, Disable/Handicapped/ sick-14, Others (Specify)-15.

2. Farm Particulars (in acres)

2.1

Land	Acres
Ownership	
Taken on lease	
Given on lease	

2.2

Land	Acres
Irrigated	
Un-irrigated	

2.3

Land	Acres
Tubewell	
Canal	

3. Details of allied activities

3.1

Dairying	2012-13
Buffaloes (Nos.)	
Cows (Nos.)	
Sale of milk (Lt./ day)	
Annual sale (Rs.)	

3.2

Others (specify.....)	2012-13
Numbers	
Annual Production	
Annual income (Rs.)	

4. Income from agriculture

Products	Acre	Yield(qt./ acre)	Price (Per qt.)	Production (qts.)	Gross return
Wheat					
Paddy					
Sugarcane					
Maize					
Vegetables					
Coarse cereals					
Fodder					
Others					
Grand total					

5. Cost

5.1 Cost of paddy crop

Items	Quantity per acre	Price	Total cost
Human labour			
Nursery raising			
Preparatory tillage			
Weeding			
Harvesting			
Tractor expenditure			
Seeds/ planting material			
Manure			
Plant protection chemical			
Fertilizer type (Kgs) 1.DAP 2.Potash 3.Urea 4.Others			
Transport			
Other cost including irrigation			

Quantity of water use			
Working capital			
Total/ acre			
Grand total			

5.2 Cost of wheat crop

Items	Quantity per acre	Price	Total cost
Human labour			
Preparatory tillage			
Weeding			
Harvesting			
Tractor expenditure			
Seeds/ planting material			
Manure			
Plant protection chemical			
Fertilizer type (Kgs) 1.DAP 2.Potash 3.Urea 4.Others			
Transport			
Other cost including irrigation			
Quantity of water use			
Working capital			
Total/ acre			
Grand total			

6. Return

6.1 Return for paddy

Indicators for return	Quantity (qtl.)	Price/unit	Total
Main product			
By product			

6.2 Return for wheat

Indicators for return	Quantity (qtl.)	Price/unit	Total
Main product			
By product			

7. Particulars of water source

7.1 Public water resources

7.1.a	Is canal water available?	Yes	1
		No	2
7.1.b	If yes, then specify the no. of hours per month/acre?		
7.1.c	If no, then specify the reason for not availability?		
7.1.d	Have any facility of public tubewell?	Yes	1
		No	2
7.1.e	If yes, how much is the rent cost for per hour?		

7.2 Private water resources

No. of submersible motors	
Depth	
Cost of digging in Rs.	
Cost of motor	
Horse power of motor	
Type of motor	
Connection fees	
Tractor cost (HP)	
Generator cost (HP)	
Cost on fuel (Rs)	
Duration of pumping out water in hours	

7.3 Details of submersible motors

7.3.1	Year of digging		
7.3.2	How many times, you have done deepening?		
7.3.3	Cost of deepening in one time		
7.3.4	Had there been any loss, while deepening the well?	Yes	1
		No	2
7.3.5	If yes, then specify		
7.3.6	Had someone shifted from agriculture to other business/ job/ agricultural labour?	Yes	1
		No	2

8. Electricity facility

	Rabi season	Kharif season
No. of hours		

9. Access to irrigation

9.1	What do you feel regarding the access to irrigation water?	Very poor	1
		Poor	2
		Average	3
		Good	4
		Very good	5
9.2	If there is poor accessibility of irrigation water, then reason behind is:		
9.2.a	Erratic power supply	Yes	1
		No	2
9.2.b	Shortage of water in canal during crop season	Yes	1
		No	2
9.2.c	Depletion of groundwater	Yes	1
		No	2
9.2.d	Poor maintenance of canals	Yes	1
		No	2
9.2.e	Smaller and fragmentation of landholdings	Yes	1
		No	2

10. Please give a brief description about your 10yrs agriculture experience (water focused):.....

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