WATER TABLE BEHAVIOUR IN PUNJAB: ISSUES AND POLICY OPTIONS

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Abstract

Punjab faces a sever problem of declining water tables by as much as 10 – 15m in most parts. The paper focuses on groundwater behavior in various parts (Blocks) of the Punjab in categories of low to high rainfall regions, saline to sweet groundwater zones, scanty to extensive canal water supply areas, the uplands to riverbeds and the cropping pattern in terms of low to high water intensive crops. Any changes in these parameters will affect the recharge and withdrawal of groundwater. In was found that as the area under rice cultivation increased, there was a corresponding decline in ground water recharge. It is often advocated that pricing policy for wheat and rice (Minimum Support Price (MSP) and its effectiveness) and free electricity supply are responsible for the critical ground water situation in Punjab. The paper tires to examine this and look at policy measures needed to address the situation.

1. INTRODUCTION

The groundwater situation in Punjab has been a serious issue for a long time now. The total water requirement for Punjab, with the present cropping pattern and practices and industrial uses, is estimated at 4.33 million ha metres. It varies from 4.30 to 4.40 million ha metres. The total availability of water is estimated at 3.13 million ha metres out of which 1.45 million ha meters is from canals and 1.68 ha meters is from rainfall and seepage. The deficit of almost 1.20 million ha metres is met by ground water withdrawal. The recharge rate is not able to match the rate of withdrawal. This has led to a decline in the water table in Punjab[1]

The annual rainfall in Punjab ranges from over 300 mm in 21 rainy days in the Western part to over 1100 mm in 48 rainy days in the North and North Eastern part. Mean annual rainfall during 1973 to 2005 was 600 mms in 32 rainy days. Almost 80 % of the rainfall comes in the monsoon period with about 57% falling in the months of July and August. Monsoon rain recharges groundwater for use during the remaining period. The heaviest rainfall of 1123 mm was recorded in 1988, when there were floods in the entire state. In 1997, the state received 709 mm rainfall, which was more than the state average.

There are three major perennial rivers - the Ravi, the Beas and the Satluj – in Punjab and their water is stored at Bhakra Dam, Ranjit Sagar Dam and Pong Dam respectively. This water is supplied through a vast canal network of about 14500 kms including distributaries and minor canals to irrigate about 1.6 million hectares (m ha) of land. The canal water supply is more extensive in the South western zone of the State, which receives less rainfall and high salinity in groundwater. This is the cotton-wheat dominant cropping belt and covers about 34 % of the cultivated area of the state.

Out of the total net sown area 96% is irrigated. The entire irrigated area is double cropped every year with a cropping intensity of 187 %. Rice and Wheat cover about 75 % of the total cropped area in the state. There are 11.44 lakh tubewells (8.56 lakh electricity operated) for groundwater abstraction for irrigation.

The paper focuses on groundwater behaviour in various parts (blocks) of the state in categories of low to high rainfall regions, saline to sweet groundwater zones, scanty to extensive canal water supply areas, the

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uplands to riverbeds and the nature of cropping pattern in terms of low to high water intensive (application, actual and tolerance vs requirements) crops. Any changes in these parameters will affect the recharge and withdrawal of groundwater, which is simulated. It is often advocated that pricing policy for wheat and rice (Minimum Support Price (MSP) and its effectiveness) and free electricity supply are responsible for the critical ground water situation in Punjab. The paper tires to examine this and look at policy measures needed to address the situation.

2. DATA AND METHODOLOGY

Hydrologically and agro-climatologically, Punjab is divided into three distinct zones - Foothill, Central and South-Western zones.[2] To study the movement of water table, which is significantly affected by the rivers flowing through the state, it is better demarcated into three regions, which are also culturally and historically called Majha (Between Ravi and Beas rivers – 29 Blocks), Doaba (Between Beas and Satluj rivers – 30 Blocks) and Malwa (South of Satluj river – 73 Blocks). The study is based on the data monitored and collected by the hydrological division of the department of agriculture, Government of Punjab since 1973. To begin with, the Department of Agriculture selected open (observation) wells and started recording the depth of water level in these wells during June (pre-monsoon period) and October (post-monsoon period) between the 10th to 25th of the month. When one observation well dried up, another well in the same village was selected. Later Piezometer wells (PZ meters) were installed. As many as 1842 observation points (wells and/or piezometer tubes) have been set up, though the maximum number of observations at any point of time were only 708. This was because some of the observation wells dried up in between. (This is a preliminary indicator of the enormity of the problem of depleting water table).

Each block carries a number of observation wells but the water table movement does not necessarily follow the block boundaries. Thus grouping of blocks into regions and sub-regions was difficult. Matching was done following the principle of continuity at the same time trying to include every block in every sub region using individual judgment[3].

The impact of rice area on groundwater table was scanned by observing the change in recharge during the monsoon season in those years which received almost similar rainfall. The area was scanned for each region along with the corresponding withdrawal during the rabi season. The recharge required to strike a balance was estimated using regression of recharge on rainfall and rice area.

To correct the water balance measures such as maximizing efficient surface water use, reducing water demand by restructuring incentives (competitive pricing of electricity for irrigation) and improving the water use efficiency are suggested.

3. WATER TABLE BEHAVIOUR IN PUNJAB AND ITS DETERMINANTS

An overview of the water table behaviour (Table 1) shows that although the water table in Punjab has been declining over a large area, there is a belt of 9 blocks in the south west of Malwa Region where the water table has been rising (Map).

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[2] These zones are:

1. Foothill Zone/ Kandi Area: 19 % area; Gurdaspur, Hoshiarpur and Ropar;
   Annual rainfall =950mm, groundwater is sweet but in areas difficult to explore
2. Central Zone: 47 % area, Amritsar, Kapurthala, Jalandhar, Ludhiana, Sangrur and Patiala
   Annual rainfall = 650 mm, groundwater sweet and extensively used; Water table declining
3. South Western Zone: 34 % area; Ferozepur, Faridkot and Bathinda.
   Annual rainfall = 400 mm, groundwater saline, canal water more extensive & precious

[3] The readers may feel that some other sub region or blocks should have been included and not the ones chosen for study.

The riverbed region has 35 blocks with each region (Majha, Doaba and Malwa) having 10 – 14 blocks. It is a rice growing area, though traditionally rice was grown more in the Majha and Doaba regions[4]. The water table in the riverbed blocks has been declining only gradually. The central block consists of 50 blocks out of

Table 1: Preliminary scan of water table situation, region wise, Punjab, 1973 to 2006

Particulars	Majha	Doaba	Malwa	Total
Number of observation point:				
Installed so far	430	464	948	1842
Actual: June 1973	145	141	288	574
Actual: June 2006	159	169	262*	590
Maximum 178	171	359	708	
		Number of Blocks		
Total	29	30	73	132
As river bed	11	14	10	35
Water Table behaviour (No of blocks)				
Rising	0	0	9	9
Static / fluctuating[@]	7	9	18	34
Declining	22	21	46	89
Rate of decline:				
Gradually	18	11	27	56
Severe: Around 10 metres or more	4	10	19	33
Severest: More than 15 metres	1	2	9	12
Water table level — Up to 5	12 → 1	6 → 1	29 → 11	47 → 13
1973 → 2006 — 5 to 10	14 → 12	20 → 7	32 → 17	66 → 36
(meters) — 10 to 15	2 → 11	4 → 7	3 → 21	9 → 39
15 to 20	1 → 1	0 → 10	4 → 17	5 → 31
Above 20	0 → 1	0 → 5	5 → 7	5 → 13
Water table behaviour zones:				
I. Rising	0	0	9	9
II. River bed (Gradual decline)	11	14	10	35
III. Central: Going deep	10	6	13	31
“ deeper	1	1	13	16
“ deepest	0	0	6	6
IV. Other: Fluctuating, generally static, declining lately	7	9	22[$]	36

[4] The river beds on both sides of the river taken together makes the Majha and Doaba Central regions look smaller. Rainfall and Rivers in Punjab is given in Annexure 2.

* Relates to 2005

[@] Some adjoining blocks with few observations are clubbed and considered as one block

[$] There is declining water table since 1999 or so in some of these blocks of which 6 are in the East, 9 in middle south and remaining in the west of Malwa region.

which 8 blocks are in Majha, 10 in Doaba and 32 in Malwa. Rice is intensively cultivated here. The water table here has been declining at varying degrees. The Foothill or Kandhi zone in the North / East side comprises 22 blocks and has a fluctuating water table and though the water is sweet, exploration is difficult. In the blocks in the South West of Malwa region the water table is generally shallow but fluctuating. In some blocks it has been declining since 1999.

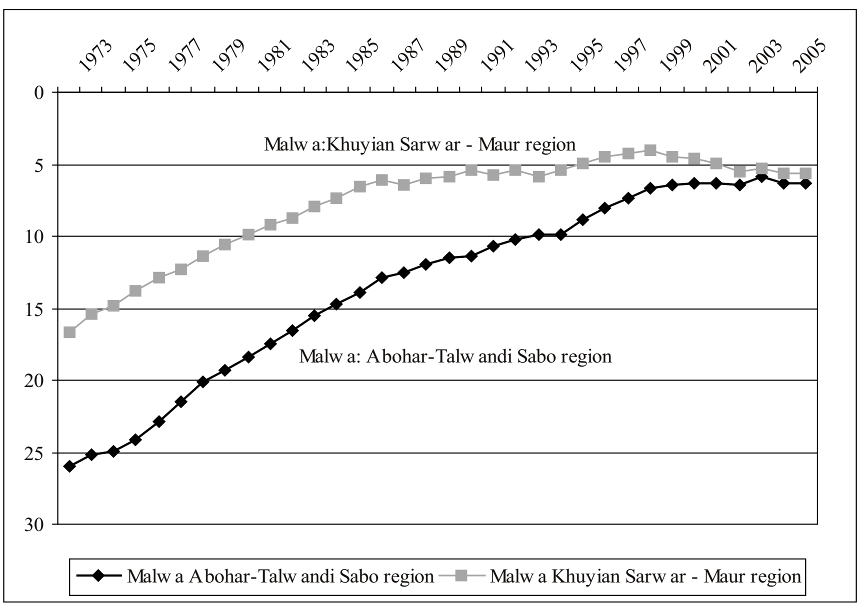
In 1973, there were as many as 113 blocks where water table was less than 10 metres, 9 blocks where water table was 10 to 15 metres and only 10 blocks with water table at more than 15 metres (most of which were in the south west with water unfit for irrigation and these had rising water table). In contrast, in 2005-2006 there were only 44 blocks with water table at more than 15 metres depth, 39 blocks where the water table was 10 to 15 metres and 13 blocks with water level of 5 meters. These 13 blocks like in the Malwa block where water table has been rising.

In Punjab, the water table situation is becoming critical, especially in the Malwa region, which was traditionally not a rice growing area. The situation is less critical but still serious in Doaba and Majha region, where the proportion of the rice cultivation was traditionally higher.

3.1 Rising Water Table Zone

In two sub regions in the Malwa region, the water table has been increasing, which is creating problems of waterlogging. In the 4 blocks of Abohar to Talwandi Sabo sub-region, the water table has gone up from more than 25 meters in 1970s to 5–6 meters in 2003 (Figure 1). Just above these blocks, in the 5 blocks from Khuyian Sarwar to Maur, water table rose from 17 meters in 1970s to 5 metres in 2003 (Figure 1). In both cases, the water table was 5 meters before monsoon. The water is saline and unfit for irrigation. The only solution is draining out the water but it requires huge investment.

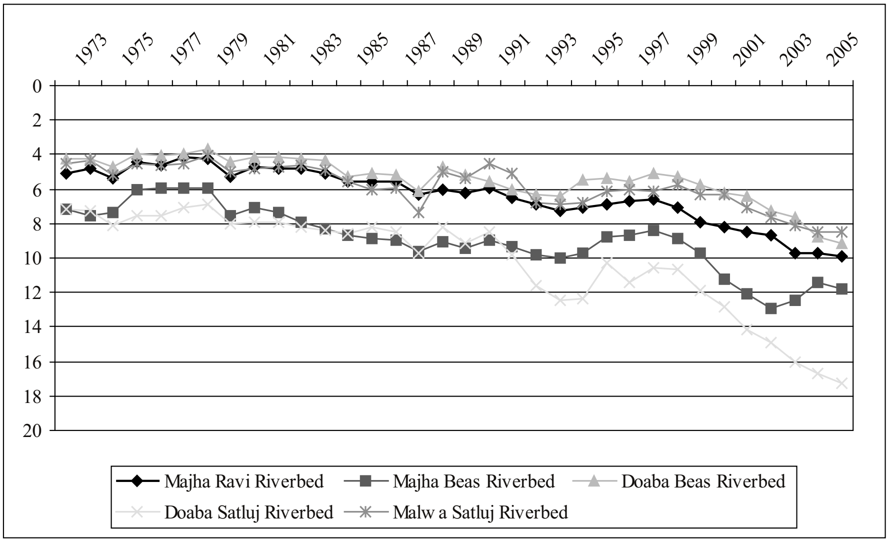
Figure 1. Trend in water table in south-west Malwa sub-region



3.2 River Bed Area

The blocks in the riverbed on the South side of the river (Malwa-Satluj, Doaba –Beas and Majha – Rawi) show a slight decline from 4–5 metres in 1983 to 6-8 metres in 2000 and further to 8–10 metres in 2006. The North side riverbed blocks (Doaba Satluj and Majha – Beas) showed a decline in water table from 8 metres in 1973–75 to 13–15 metres in 2003 though from 1975 to 1979 the water table rose (Figure 2). In Shahkot, Nakodar and Sultanspur blocks in the Western clip of Doaba, the water table declined by more than 10 metres. There were 8 Blocks in all in the Doaba region where water table dropped by more than 10 metres.

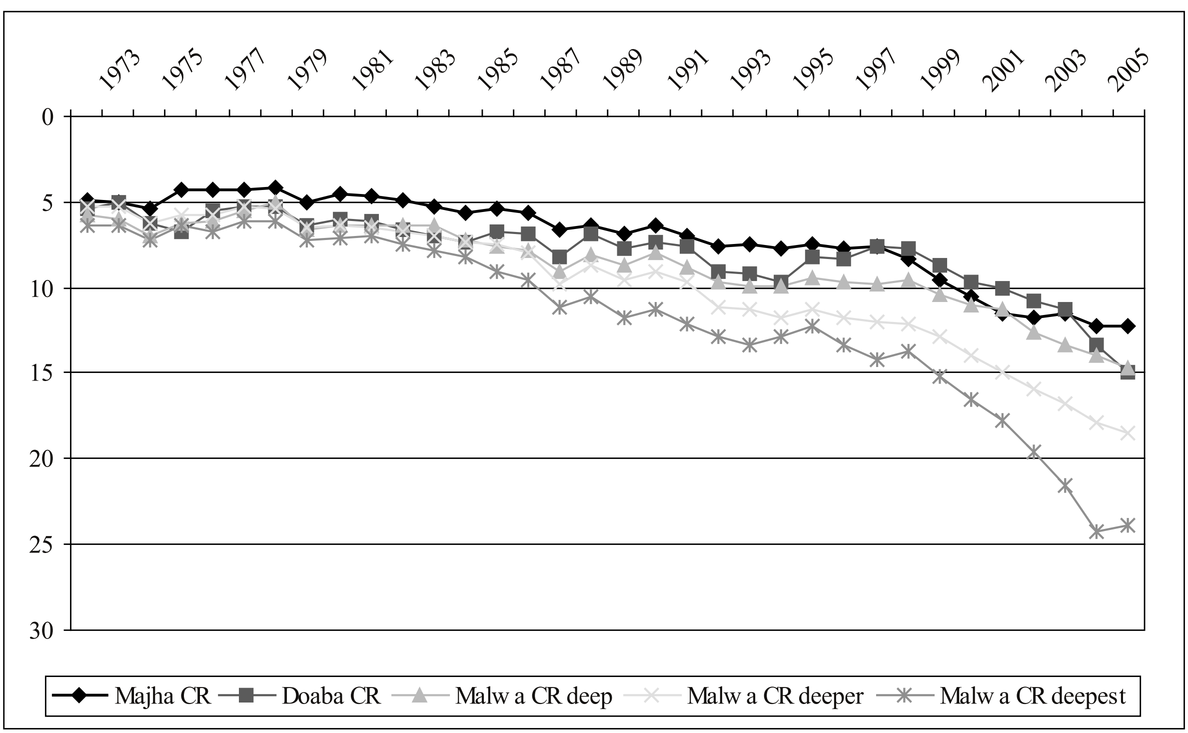
Figure 2. Trend in water table in the riverbed blocks



3.3 Central sub-regions

In all the zones, the central sub-regions are the worst hit. In 1970, the water table in all the central sub-regions was found at 4 to 7 metres. In the Majha Central region (11 Blocks), it has gone down to more than 12 metres and in the Doaba central region (7 Blocks) it has gone down to more than 14 metres. The Malwa Central region is the worst hit where in 13 blocks the water table has gone down to 15 metres, 13 blocks where it has gone down to 20 metres and 6 blocks where it has gone down by more than 24 metres (Figure 3). In 18 blocks of Malwa, the water table has gone down by more than 10 metres, in 9 of these blocks the water table has even gone down by more than 15 metres.

Figure 3. Trend in water table in the Central blocks



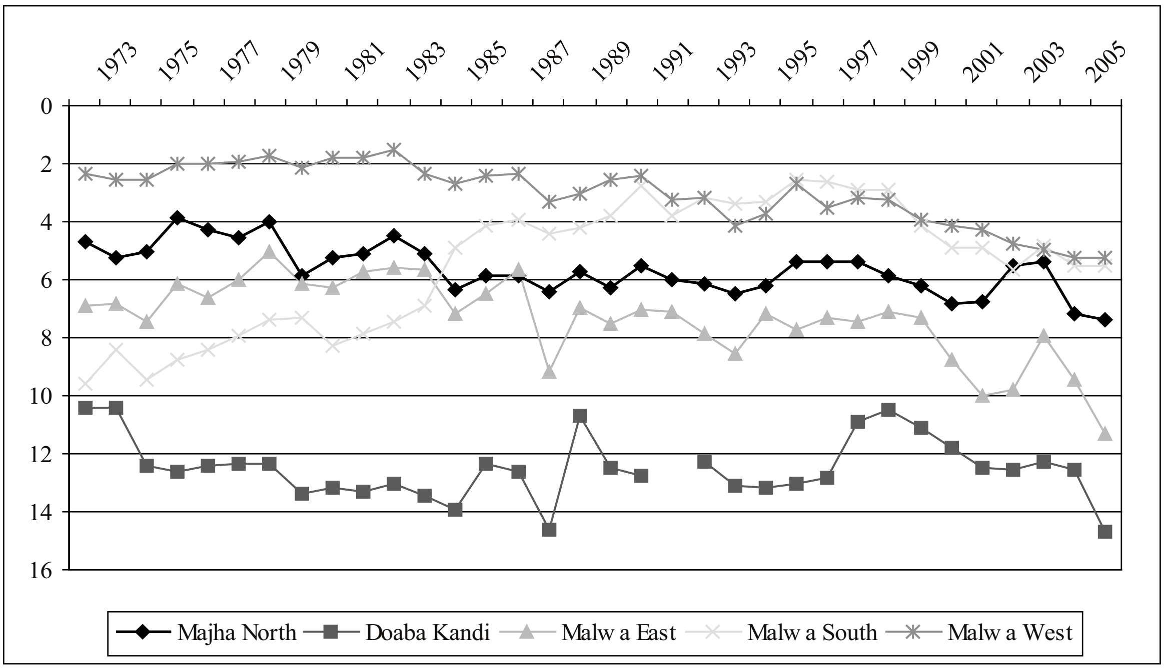
3.4 Static, fluctuating and lately declining water table area

The key observations on water table situations in the other regions are shown in Figure 4.

Majha North	(6 Blocks):	Fluctuating a little but more or less static
Doaba Kandi	(9 Blocks):	Fluctuating but more or less static
Malwa East	(6 Blocks)	Fluctuating widely but more or less static
Middle South	(9 Blocks)	Fluctuating widely with lately declining trend
Western	(7 Blocks)	Shallow, fluctuating and static / some decline

The water table scenario in Punjab is getting worse, more so in the Central Region[5] where there is concentrated rice cultivation. The Malwa central region where rice was not an important crop in early 1970s, is now a dominant rice growing area and worst affected. Malwa region has witnessed major groundwater fluctuations from mild to gradual to serious decline in some places and rising water tables in other places. Some sub regions in Malwa have seen wild fluctuations, more or less static or mildly declining water table.

Figure 4. Trend in water table in the other regions[§]



Grouping the Blocks according to different water level depths in 1975 and 2005, in the categories of up to 5, 5-10, 10-15, 15-20 and above 20 metres shows the up and down of water table more literally (Table 2)[6].

- In 1975, there were almost 90 per cent blocks (27, 25 and 63 out of 29, 30 and 73 blocks in Majha, Doaba and Malwa respectively) where water table was up to 10 metres in June. But in June 2005, there were as many as 16, 20, and 45 blocks in these regions respectively, i.e. more than ½ to 2/3rd where water level was more than 10 metres deep.

- 27, 37 and 21 per cent blocks in Majha, Doaba and Malwa had the same water level in 1975 as well as in 2005

[5] The Central Region of Majha, Doaba and Malwa is different from the Central Punjab

[6] The rise or fall from Table 2 is shifting from one group to another one and is thus an approximation and could give some difference from the actual numbers explained elsewhere

Table 2. No of blocks according to water table depth in 1975 and 2005

1975 (metres	Water table level in 2005 (metres)					
	Upto 5	5-10	10-15	15-20	> 20	Total
MAJHA						
Upto 5	1	5	1		↓↓↓↓	7
5-10		6	10	3	1	20
10-15			1			1
15-20		1				1
> 20	↑↑↑↑					
Total	1	12	12	3	1	29
DOABA						
Upto 5	1	1				2
5-10		8	6	8	1	23
10-15			1		2	3
15-20					1	1
> 20					1	1
Total	1	9	7	8	5	30
MALWA						
Upto 5	6	3	6	3	1	19
5-10	2	8	14	14	6	44
10-15	1	1	1			3
15-20	1	2				3
> 20	1	3				4
Total	11	17	21	17	7	73
TOTAL						
Upto 5	8	9	7	3	1	28
5-10	2	22	30	25	8	87
10-15	1	1	3		2	7
15-20	1	3			1	5
> 20	1	3			1	5
Total	13	38	40	28	13	132

↓↓↓↓ Water table declined from 1975 to 2005

↑↑↑↑ Water level rose from 1975 to 2005

Note: 1. The severity of change is maximum in the bottom left cell and top right cell and declines towards the center

2. The white boxes show no change

- A significant rise in water table was observed in Malwa only in 11 Blocks of which in 3 it came up by more than 20 metres, in 7 it came up by more than 15 metres and in 10 it came up by more than 10 metres
- The decline in water table is observed every where but more prominent in Malwa where in 10 blocks it went down by more than 15 metres, in 30 blocks it went down by more than 10 metres and in other 17 blocks it declined by more than 5 metres
- In Majha and Doaba, the water table declined by more than 10 metres in 5 and 11 blocks respectively

3.4.1 The fluctuations and determinants

The water table was analyzed for each year during 1973 to 2006 in June (pre-monsoon level) and October (post monsoon level). Monsoon is a major determinant of the water table recharge. During this season, the river flow is also high. Area of rice cultivated is the determinant of ground water withdrawal during this season, since rice is a high water consuming crop, especially when transplanted early.

Post monsoon rains are scanty and the normal withdrawal continues during the rabi season too. In 1994 and 2005, there was similar rainfall (around 600 mm) with significant area under rice cultivation. In all three regions, with an increase in the area under cultivation, ground water recharge declined (Table 3).

Table 3: Impact of rice area on withdrawal gauged through change in recharge of water table in years with similar rainfall

Region	Rice area (000 ha)			Recharge during monsoon (m)		
	1994	2005	% increase	1994	2005	% decrease
Majha	488	524	7.4	1.11	0.69	38
Doaba	364	396	8.8	1.41	0.79	24
Malwa	1424	1723	21.0	0.80	0.16	80

The impact was severe in Malwa where a increase in rice cultivation by 21%, caused a decrease in ground water recharge by 80%[7]. Concentration of rice cultivation over time has significantly increased the usage of water during the monsoon season resulting in insufficient recharge in the post monsoon season. Subsequently, there is a decline in water table every year.

The rainfall (positively), the rice area (negatively), and withdrawals in the rabi season affect recharge during the monsoon season and determine the change in water table from year-to-year. The average recharge during 1974 to 2005 was around 1 metre in the rice-zones of Majha and Doaba and little less than 0.5 metres in Malwa. In Majha and Malwa, the average recharge remained almost the same during 1990-2005. It doubled in Doaba from the periods between 1974 - 1987 to 1990- 2005. It could be due to intensive project investments in integrated watershed development in the Kandi area, which started in 1980, which significantly reduced the run-off and flash flow in ten years, i.e., from 1990 onwards. The floods of 1988 had a significant impact on recharge, which were 2.25, 3.58 and 1.86 metres in the rice-zones of Majha, Doaba and Malwa respectively (Table 4).

The average rabi withdrawal has also changed significantly over time. The average rabi withdrawal in Majha zone was 1.03 m during 1974 – 1987 which was more intensively irrigated (and cultivated) even earlier. It increased to 1.18 m during 1990 – 2005, an increase by about 15%. The increase was almost 100% in Malwa (from 0.44 m to 0.85 m and 140% in Doaba (from 0.67 m to 1.60 m). The Doaba region not only has the lowest canal irrigation (2.4 % as compared to 39.3% in Majha and 29.7% in Malwa) but grows highly water intensive crops in the rabi season like sugarcane, potato, sunflower and lately winter maize. The first three crops covered 16.1% of irrigated area in Doaba region compared with 4.5% in Majha and only 1.9% in Malwa (Appendix A)

[7] Although the rainfall zones in Malwa range from 300 to 1100+ mm, the rice zone in Malwa also lies in the rainfall range of 550 – 1000 mm, almost the same as Majha and Doaba

Table 4: Rainfall, recharge, rabi withdrawal and change in water table in the Rice-zones of Majha, Doaba and Malwa, select years and periods, 1974 to 2005

Year /Period	Rainfall (mms)	Average Rechargein monsoon (metres)			Average change in Water table (metres)			Rabi withdrawal (metres)		
		Majha	Doaba	Malwa	Majha	Doaba	Malwa	Majha	Doaba	Malwa
1988	1123	2.25	3.58	1.86	0.40	1.40	0.92	1.86	2.17	0.94
1990	755	1.71	1.99	1.37	0.40	0.24	0.46	1.31	1.74	0.91
1995	794	1.77	2.96	1.38	0.46	1.22	0.55	1.31	1.74	0.84
1997	709	1.35	2.46	0.73	0.14	0.66	-0.14	1.21	1.80	0.87
1999-2005	430	0.53	0.67	-0.10	-0.61	-0.83	-0.87	1.14	1.50	0.77
Av 1974-87	645	0.96	0.58	0.38	-0.07	-0.09	-0.05	1.03	0.67	0.44
Av 1990-05	539	0.89	1.21	0.42	-0.29	-0.39	-0.43	1.18	1.60	0.85
Av 1974-05	603	0.95	0.99	0.44	-0.19	-0.23	-0.26	1.14	1.22	0.70

Note: The years selected here from 1988 to 1997 were high rainfall (700 mm) years. The rainfall during 1999 to 2004 was less than 400 mm in 4 years and less than 500 mm in other two years. In 2005, the rainfall was only 595 mm

Regression analysis was used to determine the effect of rainfall and rice area on recharge during the monsoon period and the final impact on water table and the reduction in rice area required to maintain water balance under different scenarios[8]. Regression was run for each region on recharge and area under rice irrigation. All the regression coefficients were statistically significant and logical (Table 5).

The rainfall coefficient showed a positive impact on water table recharge from 2.8 cms for Malwa, 3.0 cms for Majha and the highest at 4.3 cms for Doaba for each centimeter of rainfall. This is interpreted along with the coefficient of rice area[9], which showed negative impact in each region.

Doaba region received low rainfall but gained because it recharged better. The coefficient of rice area was also the highest (negative) for Doaba. When rice coefficient and coefficient of rainfall were interpreted simultaneously, the ratio was 7 for Doaba, 5 for Majha and 2.5 for Malwa. This means that a relatively smaller cut in rice area and improvement in water use efficiency can restore the equivalent water balance in Doaba and Majha. To achieve the same balance in Malwa, a greater cut in rice area will be required along with water use efficiency.

These coefficients were used to estimate the reduction in rice area that would restore the water balance in each region, which declined at the rate of 38, 58 and 59 cms per year during the last ten years in Majha, Doaba and Malwa respectively. The average rainfall during this period was below normal at 600 mm. In fact, the rainfall during 1990 to 1997 was 640 mm. The rainfall was 760 mm in 1990, 790 mm in 1995 and 710 mm in 1997. Between 1998 to 2005, it was only 440 mm with less than 400mm in 4 years, less than 500 mm in 3 years and 600 mm in 2005. However, area under rice kept on increasing.

At the normal rainfall level of 600 mm, the rice area reduction to restore the water balance in the long run[10] was estimated at 1.2, 1.0 and 6.0 lakh ha in Majha, Doaba and Malwa regions while the current rice area is 5.3, 4.0 and 17.3 lakh ha, respectively. It means about 25% area under rice in Majha and Doaba and about

[8] Regressions were tried for different periods and with different logical variables. As cropping intensity, which is also an important determinant of water use was also increasing along with the rice area, the regressions for the whole period, though mostly had significant coefficients but with lower t-values and low goodness of fit (R^2). The cropping intensity almost reached the saturation by 1990 but the rice area was still increasing through substitution. Thus the regressions, reported here for 1990-2005 were the best of all.

[9] Although the coefficient of rice area was too different for different regions varying from 7.1 to 30.6, but when adjusted with the rice area in each region as per cent of net area sown, the coefficient ranged only from 2.5 to 4.4 only

Table 5: Water table recharge during monsoon (cms) regressed[a] on rainfall (cms) and rice area (lac ha)

Region	Coefficient of[b]			Decline in water table (last ten years) cms/year	Maximum rice area (lac ha) during the period	The rice area to be cut to restore water table balance[d]		
	Rain-fall	R^2	Rice area			With average rainfall (54 cm)	Rainfall at 60 cm	With improved water use efficiency[c]
Majha	2.973 (9.91)	-14.426 (4.26)	0.86	35	525	2.4 (46)	1.2 (23)	0.16 (3)
Doaba	4.337 (5.19)	-30.565 (2.43)	0.63	58	396	1.9 (48)	1.0 (25)	0.34 (9)
Malwa	2.759 (6.24)	-7.059 (4.36)	0.71	59	1726	8.4 (49)	6.0 (35)	4.06 (23)

Note: a. Regressions had intercept at zero as the water recharge is mainly with the rainfall, and even negative in case the rainfall was lower than the withdrawal during the monsoon season.
b. All the coefficients are significant as shown by t-values given in the brackets below
c. Improved water use efficiency was approximated as equivalent to another 5 cm rainfall
d. Figures in brackets are the % of the maximum rice area, i.e. current area in each region

35% area under rice in Malwa needs to be reduced. The improvement in water use efficiency, equivalent to an additional 50 mm of rainfall[11] will almost achieve the same balance in Majha and Doaba. However, in the Malwa region, even with improved water use efficiency, a rice area cut of about 20% would be required to restore the water balance in the long run. The importance of water use efficiency in improving the water balance in the sate is also significant and demands intensive research on the subject.

4. SUMMARY

The water table in the central regions of Majha, Doaba and Malwa has declined alarmingly since 1980. Although in the riverbed-blocks of the three regions, the decline in water table started since 1990s, the situation is alarming in these areas too. Both these sub-regions are the predominant rice growing zones in each region. The Malwa region, where rice cultivation gained prominence only after late 1970s, is the worst hit by decline in water table.

The monsoon rainfall and the rice area are the major determinants (positive and negative respectively) of the extent to which the water table gets recharged during the monsoon season, when about 80% of the yearly rainfall is received. The water is used in the rabi season when there is little rain. The average recharge during 1974 to 2005 was around one metre in the rice-zones of Majha and Doaba but little less than 0.5 m in Malwa. The average recharge in Majha and Malwa remained about the same during 1990-2005 as it was during 1974 - 1987 but it has improved significantly in Doaba where it doubled during 1990- 2005. It could be due to the intensive project investments in integrated watershed development in the Kandi area starting 1980 onwards.

The average rabi withdrawal has increased by 15, 100 and 140% in Majha, Malwa and Doaba regions respectively. The Doaba region not only has the lowest canal irrigation (2.4 % as compared to 39.3 % in Majha and 29.7 % in Malwa) but is also now known for highly water intensive crops in the rabi season like sugarcane,

[10] Perhaps this is the first time that the reduction in rice area to restore water balance is based on detailed simulated analytical exercise. The earlier figures given by various experts, based on expert judgment, had been generally around 10 lakh ha. These estimates did not take any cognizance of the impact of better rainfall or better water use efficiency either.

[11] Various agronomic practices of water use efficiency, as given in the next section, show that the savings in water use vary from 10% to 35%. The farmers are already using some of these measures for some water-intensive crops like sugarcane, etc. Neither all the crops nor all the area would be covered, in practical parlance. A 50 mm rainfall amounts to meeting 10% of the water requirements of about 5000 cubic metres per hectare of most of the normal water-using crops like maize and wheat.

potato, sunflower and lately winter maize. The first 3 crops covered 16.1% of irrigated area in Doaba region compared with 4.5% in Majha and only 1.9% in Malwa.

At the normal rainfall level of 600 mm, the rice area reduction to restore the water balance in the long run was estimated to be about 25% in Majha and Doaba and about 35% in Malwa. The improvement in water use efficiency, approximated, as equivalent to another 50 mm of rainfall will almost achieve the balance in Majha and Doaba. However, in the Malwa region there is no reprieve from cut in rice area. Even with this improved water use efficiency, a cut in rice area to about 20% would be required in the long run. The importance of water use efficiency in improving the water balance in the sate is significant and demands intensive research on the subject.

5. CORRECTING THE WATER BALANCE

The groundwater balance (recharge minus withdrawal) in Punjab has been negative for a long time now, particularly since 1990 as shown by the decline in water table in the previous section. As of April 1, 2002, the net groundwater resources of Punjab state were estimated by the Central Ground Water Board at 16394 MCM, whereas the net draft was estimated at 17189 MCM, a groundwater overdraft of 795 MCM[12]. In-storage fresh groundwater resources of the State are estimated as 907 BCM. The stage of groundwater development for the State is 114% and the State as a whole falls under dark category.

The negative balance between the annual available water supply and the actual use of water needs to be urgently corrected through multi-pronged strategies[13] such as:

- Maximising use of surface water and increasing recharge of groundwater
- Reducing the water demand:
  - orienting incentives to encourage substitution of high-water consuming crops with low-water consuming crops
  - improving water use efficiency
  - redirecting the research on water use efficiency in all-dimensions

Head work	River	Canals
Nangal Head Work	Satluj	1. Bhakhra Main Line 2. Anandpur Hydel Channel
Ropar Head Work	Satluj	1. Sirhind Canal 2. Bist Doab Canal
Shah Nehar Canal System	Beas	1. Mukerian Hydel Channel 2. Kandi Canal
Madhopur Head Work	Ravi	1. UBDC Canal 2. Kashmir Canal
Harike Head Work	Satluj and Beas	1. Rajasthan Feeder 2. Sirhind Feeder
Hussainiwala Head Work	Satluj and Beas	1. Bikaner Canal 2. Eastern Canal

[12] Source: Central Ground Water Board (2004). Water Security through Ground Water Management: Punjab. Central Ground Water Board, North Western region, Chandigarh, July 2004. pp10.

[13] It is also important to aim at "water-democracy", which means, "ensuring that every drop of water is conserved, harvested and shared by the people". It demands massive funding for water projects alongwith the government policies which ensure that the benefits are more equitably shared.

6. MAKING MAXIMUM USE OF SURFACE WATER

Punjab has a fully developed, fully exploited, river water system (Annexure 2) through the canal network of about 14500 kms including distributaries and minors for assured irrigation to about 16 lakh ha as follows.

There is full exploitation of surface water through the above canals and no new canal is under construction. The canal water irrigation policy needs modification as per the prevailing groundwater conditions. It must encourage crop substitutions for low water requiring crops. At present the water allowance is 5.5 cusec per thousand acres in Eastern Canal system and 3.5 cusec per thousand acres in Sirhind Feeder system. Both the systems are water logged at present. While the Bist Doab Canal system has an allowance of 1.95 cusec per thousand acres, and the area is facing depletion in ground water. The canal water allowances in areas, which are waterlogged must be diverted to areas facing severe ground water depletion. However, this is not a substitution for improving water use efficiency. In areas with potential for growing basmati rice, which requires less water but matures late, the canal water supply should be extended towards the maturity season of basmati (October).

7. INCREASING RECHARGE

Harnessing surface run-off for human use and maximizing the recharge should receive priority. Existing dug wells, dug-cum-bore wells, cavity wells, recharge wells in trenches, shaft-cum-recharge wells and excavated ponds effectively recharge the groundwater. Unpolluted stored water in depressions and ponds, used water of swimming pools and accumulated water in low-lying areas should be recycled and used to recharge groundwater[14]. Surplus canal water during monsoon period particularly in good rainfall years should not be wasted.

Major part of Punjab is plain area, which is a natural recharge system it deserves attention. However, the semi-hilly sloping region of the state in the entire eastern belt has tremendous scope for investment in watershed management[15]. The construction of small water harvesting tanks and other integrated water management technologies in the Kandi belt helped in increasing water supplies, reducing run-off and siltation

Table 6: Water requirements of rice and other crops, Punjab.

Crop	Water requirements[a] Cub m per ha	Electric motor hrs[b] Per ha
Paddy	24181	290
Maize	5474	50
G.nut	1123	35
Kh pulses	2355	35
Wheat	5504	60
Barley	4486	35
Gram	2243	30
Rabi puls.	2187	30

[a.] Source: Department of Soils, Punjab Agricultural University, Ludhiana

[b.] Source: Cost of cultivation data for 300 farmers. See, Karam Singh and K. K. Jain (2002), Dynamics of Structural Shifts on Costs and Returns in the Farm Economy in Punjab. Report for the Commission for Agricultural Costs and Prices. Agro Economics Research Centre, PAU Ludhiana. March 27, 2002.

[14] Note that using 1 ha metre of rain-water harvested in a village pond for one irrigation to 33 ha (or any combination such as 3 irrigations to 11 ha) means equivalent full recharge because the same quantum of groundwater would have been withdrawn. However, in the simple recharge system, quite a significant proportion of water would be lost through evaporation.

[15] The impact in Doaba region is already discussed in previous section with Table 3.

[16] See: 1. Karam singh, Nirmal singh and Rachhpal Singh (1998). Impact evaluation of Integrated Watershed Development Project (Hills), Punjab. World Bank Project. PAU Ludhiana.

2. Nirmal singh and K K Jain (2004). Long-term Impact Evaluation of Watershed Development Projects in Punjab. *Indian Journal of Agricultural Economics 59 (3) July-Sept. pp. 321 -330*

loads, recharging ground water and decreasing flash floods on a sustainable basis[16]. There is need for more investments on similar initiatives. In many areas, the choes still get flooded and the water flow is still as muddy as it used to be.

The potential of rainfed horticulture is still unexploited though it presents a unique and promising opportunity. Animal grazing though reduced is still not uncommon and the few patches, untreated or inadequately treated, do more harm than good.

8. REDUCING THE DEMAND FOR WATER:

The scope to address the supply side of water, though important, remains limited. Major scope lies in managing demand of water.

The rice crop, though bears greater returns than other kharif crops, is also the most water intensive, using about 24000 cu. metres of water per ha. This is about 6 times more water than maize, almost 20 times more than groundnut and 10 times more than kharif pulses (Table 6).

Rice has benefited the most from its effective Minimum Support Price (MSP), electric power supply (there are 8.56 lakh electric tubewells out of 11.44 lakh) and free electricity supply during 1997-2002. Subsidized (and sometimes even totally free) electricity to the farm sector in Punjab has done more harm than good. Recharging groundwater can be addressed through the following:

- Electricity tariff policy, and
- Minimum Support Price (MSP) of rice (and wheat
- Supporting and encouraging crops other than rice

9. ELECTRICITY TARIFF POLICY

The key question is whether the withdrawal of electricity subsidy would reduce the area under rice or at least reduce the over-irrigation of rice. Rice is the only crop that does not have a negative stage of marginal productivity of water. Nothing is done to restructure subsidies and incentives to improve water use efficiency, especially in case of rice.

It is thus pertinent to work out how much increase in pricing of water will make the other crops compete with rice in terms of area cultivated. Some straight simulations are attempted, which show that with water (electricity) priced at 150 % of the cost of supply, it will make some crops compete with rice. For most of the other crops to compete with rice, the electricity (water) must be priced at 200% of the cost of supply. This is already five times the current cost with subsidy (Table 7).

Table 7: Economic / competitive pricing of water /electricity.

Crop	Yield (Kgs / ha)	Price Factor	With subsidy	No subsidy	Increase in rate	
					150 %	200 %
			Index of profitability relative to rice			
Paddy	6500	1	100 (20000)	100 (75)	100 (60)	100 (47)
Basmati	3000	2.00	100 (100)	125 (94)	145 (87)	178 (84)
Maize	5000	1.00	77 (100)	90 (90)	109 (85)	141 (86)
Groundnut	2250	2.00	48 (100)	61 (95)	74 (93)	97 (95)
Cost / irrigation with electric tubewell Rs/ha			50	250	375	500

Note: 1. The figure in parentheses under paddy with subsidy is the gross margin (Rs / ha) All other figures in brackets are relative to those with subsidy and thus show the decline in profitability of each crop as the electricity supply price is increased

2. The index of profitability is measured with gross margins.

The rate at which Basmati rice can compete when price is relatively favourable. But the area increase reduces the relative margin of price advantage and thus offers limited scope. This simulation of charging water at prices to make crop alternatives compete with rice means reduced income for the farmers. The gross margins from rice with water (electricity) priced at two times the actual cost of supply by the Electricity Board will be only 47% of the current prices with subsidy. If electricity is charged at one and a half times the cost of supply, the farmers' gross margins will decline by 40% of that with subsidy. Charging water for its scarcity value to reduce its use is highly impractical. Hence, the need for some alternative measures where farmers' incomes are not affected.

10. MINIMUM SUPPORT PRICE OF RICE AND WHEAT

The second issue is the procurement policy followed effectively for paddy and wheat. The MSP has been effective in the move towards food security of the country. Wheat is not the a contributor to the groundwater situation in Punjab. Rice is a more stable crop than alternative crops and has remained relatively more profitable even when MSP was almost frozen for 5 years during 2000-2005. Freezing MSP leads to the decline in profitability and farmers' income, and consequent increase in their indebtedness. It also leads to the problem of food security. Freezing MSP caused more problems. Little wonder that for improving food security and farmers' income, increasing the MSP of rice and wheat are on the cards again. However, little care is exercised to price out alternatives (like maize) that give good margins and use less water.

11. SUPPORTING ALTERNATE CROPS TO RICE

The reduction of area under paddy and introduction of alternative crops, particularly in the Malwa region, is required to restore the water balance in the long run. Alternative crops like groundnut, maize, pulses (arhar, moong) and soyabean must be made competitive with paddy. Besides saving water, there are other long-term benefits to the society in terms of improvement in soil fertility and improvement in sanitation and health, improvement of the environment and saving of power. Currently the Punjab government is purchasing high-cost power to irrigate paddy during the critical period. In addition, the government diverts power from the high-return industrial sector to mature paddy crop. If the current acreage and system of paddy cultivation continues, the depleted groundwater will necessitate putting submersible pumps, which will need even more power to irrigate the same acreage.

An average electric motor of 6+ HP (Punjab average), on the average, is used for about 300 hrs / ha for rice and about 40 to 50 hrs / ha for groundnut, soyabean and most other kharif crops[17]. The saving of 250 hrs of such an electric motor, which would consume about 1250 units (KWH), which @ Rs.3.80 per unit works out to a savings of Rs.4,750 / ha of replaced paddy. The income from the use of saved high-cost electric power for high-return industry sector should be invested in the agriculture sector.

Restructuring the electricity subsidy incentives is a bold decision. For example declaring basmati blocks in potential and worst affected areas may be tried by providing yield, price and income insurance for basmati and cutting down farmers' costs (through public nurseries), all equivalent to the cost of the saved electricity is worth the merit. Same strategy should work for maize elsewhere.

Paddy is one crop in Punjab that shone from almost a zero (except some basmati) to hero. It requires more water, occupies a large area and leads to excessive mining of groundwater - leading Punjab towards a stage of hydrological suicide and rice is called the villain. The villain is strong in profitability and stability and neither the farmer nor the rice is willing to leave each other like the proverbial blanket and the wolf story. Strategies are required to achieve a balancing of natural water resources with the maximum possible area of rice. India (read Government of India) wants maximum possible area under rice in Punjab for its food security and it gives a high price and high coverage to rice.

[17] The cost of cultivation data collected on cost accounting basis for 300 farmers in 30 village clusters by the Department of Economics, PAU Ludhiana. Karam Singh and K. K. Jain (2002), *Dynamics of Structural Shifts on Costs and Returns in the Farm Economy in Punjab.* Report for the Commission for Agricultural Costs and Prices. Agro Economics Research Centre, PAU Ludhiana. March 27, 2002.

Some possibilities do exist for improving water use efficiency in case of rice; the major one is transplanting it towards the end of June so that the groundwater withdrawal in hot summer months is minimized (discussed below in detail). However, there is no incentive for late transplanting; there is no variety that gives better yields when transplanted late except for some premium varieties closer to basmati or of basmati but then the area under these varieties is limited by market demand. Though these varieties have higher price, they give lower yield. The profitability advantage works only at the margin, positive in some years, negative in others, and fluctuating yields add to their uncertainty. The geographical indicators of basmati under WTO and the resultant lower use of electricity (read for drawing out less water) need to be placed in proper incentive perspective

12. IMPROVING THE WATER USE EFFICIENCY

There are so many alternatives such as planting time, irrigation scheduling, mulching, tillage, weed control and land leveling, which improve water use efficiency. Some of these are discussed below:

12.1Time of Planting

The rate of evapo-transpiration of rice, which is the most crucial crop to use or save water decreases with the delay in the date of transplanting. The rice transplanted after June 15th is the most important agronomic practice for saving water, as shown by the data in Table 8

Table 8. Impact of date of rice transplanting on ETR and water table

Date of transplanting	May 1	May 10	May 20	May 30	June 10	June 20	June 30
ETR of rice (cms)	84	80	76	67	60	56	52
Fall/rise in water table	70	60	50	28	10	0	(-) 10

Source: G S Hira, S K Jalota and V K Arora (2004). Efficient Management of Water Resources for Sustainable Cropping in Punjab. Department of Soils, PAU Ludhiana

Rice transplanting after June 15th needs to be promoted even by taking the hard decision like enacting the necessary act for regulating the planting of rice nurseries not before May 10th (The Punjab preservation of Sub Soil Water Act as proposed by the Punjab State Farmers Commission in 2006)

12.2 Water Economizing Irrigation Schedules

Proper scheduling (amount and timing) of irrigation to crops is an important component of water saving technologies. The meteorological approach to schedule irrigation based on the ratio between fixed depth (75 mm) of irrigation water (IW) and net cumulative pan evaporation since previous irrigation (PAN-E minus rainfall) saved 2 irrigations for wheat (IW/PAN-E = 0.9) as compared to 5-6 irrigations at fixed growth satges without any yield loss[18]. Similarly in case of rice, it has been demonstrated that higher yields can be maintained by irrigating crop at 2 d drainage interval after soaking in of previous irrigation (after 2 weeks of continuous ponding following transplanting) This helps in saving as many as 8 irrigations to rice[19]. There should be more research on irrigation scheduling with the objective to save water yet achieve the same (higher) yield levels.

12.3 Irrigation methods:

Water use efficiency in field crops can be increased by using improved irrigation methods. For example, furrow irrigation in wide-row crops like cotton, sunflower and maize. In case of cotton, 33.3% saving of

[18] S S Prihar, et al (1974). Scheduling irrigation to wheat using pan evaporation. Indian Journal of Agricultural Research, New Delhi. Pp. 142.

[19] G S Sandhu et al (1980)Irrigation needs and yield of rice on a sandy loam soil as affected by continuous and intermittent submergence. Indian Journal of Agricultural Science 50 pp 492-496.

irrigation water has been reported by sowing cotton on ridges and application of water in furrows over flat sown crop without any reduction in seed cotton yield[20]. This method is helpful in increasing application efficiency as applied water has less contact area with land surface. The proper orientation of ridges and furrows with respect to solar trajectory will help reduce the net solar radiation reaching the surface of the earth and hence, reducing the net energy available for ET. The north facing side of the East-West oriented ridge had on an average 6.1°C lower temperature and the East face of the North-South oriented ridge 2.6°C higher temperature than flat surface. Therefore, the North face of the east-west oriented ridges would receive less evaporating radiation and hence less water would be lost in evaporation.

Recent innovations of sprinkler and drip irrigation methods apply water without much loss, and can irrigate 1.5 to 3.0 times areas having excessively coarse textured as well as slowly permeable soils, undulating lands having high cost of leveling, and in area of high water table more so with poor quality water. There is need for capital investment subsidy in such irrigation technologies.

12.4 Tillage

Tillage affects water use efficiency by modifying the edaphic environment, which in turn influences root growth and canopy development of crops. Depending upon the changes it causes in soil environment, tillage may enhance or retard the development of root and above ground shoot growth. The rate of canopy development determines the pattern of total water use by the crop, and the proportion of T and E. As the canopy cover increases, the direct soil water evaporation from the cropped field decreases and the ratio of T/ET increases. This affects the WUE favourably. On the other hand, sparse cover resulting from reduced emergence, sub optimal soil temperatures, and high soil bulk density lowers the T/ET ratio by increasing direct water evaporation from soil.

13. CHANGING FROM FLAT TO BED LAYOUTS

Changing from flat to bed layouts alters the hydrology of the system and transport and transformation of nutrients. The water moves horizontally from the furrow into the bed then upwards the bed surface driven by evaporation and capillarity action while downwards driven largely by gravity. The application of irrigation based on IW/CPE (1.0) proves more effective in increasing yield and WUE of wheat sown on beds compared with applying irrigations on fixed crop growth stages[21]. 16.7%, 25% and 33.3% net saving of irrigation water were reported from bed planted for maize, soybean and maize over flat treatment, respectively[22]. Likewise, 25% to 45% higher WUE and about 30% saving of irrigation water were found under planting of one row of maize per bed/trench (furrow) 67.5 cm apart or trench 60 cm apart than flat sowing at 60 cm spacing[23]. The direct seeded rice helps in saving water upto 13% over conventional planted crop[24]. Further direct seeded basmati matures two weeks earlier than transplanted crop, therefore reduction in duration also helps to save water[25]. However, for widespread field application and acceptance by farmers, such water saving technologies need to be researched and established on economics basis.

The ridge transplanting of paddy also saves water by about 30 – 35%, as shown by recent experiments at PAU and the field experiments by the Department of Agriculture. There are more problems of weeds reported

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[20] Butter, G S and Aujla, M S (2005) Save water by sowing cotton on ridges. *Progressive Farming*. April 2005 pp 21.

[21] Kaur, M (2003) Studies on seed rate, irrigation, weed control and their interactive effects in bed planted soybean (*Glycine max* L.). Ph.D. Dissertation, PAU Ludhiana.

[21] G S Kalkat, K S Pannu, Karam Singh and P S Rangi (2006). *Agricultural and Rural development of Punjab: Transforming from Crisis to Growth.* The Punjab State Farmers Commission, GOP

[22] Hari, Ram (2006) Micro-environment and productivity of maize-wheat and soybean –wheat sequences in relation to tillage and planting systems. Ph.D. Dissertation, PAU Ludhiana.

[23] Tarundeep, Kaur (2002) Studies on irrigation requirement in relation to methods of planting of maize (*Zea mays* L.). M.Sc. Thesis, PAU Ludhiana.

[24] Mann,R A, Munir, M and Haqqani, A M (2004) Effect of resource conserving techniques on crop productivity in rice-wheat cropping system. *Pakistan Journal of Agricultural Research* 18 (1) : 58.

[25] Gill, M S and Dhingra, K K (2002) Growing of basmati rice by direct seeding method in Punjab. *Indian Farmer's Digest* 13 : 141.

in this sytem, which are being addressed to in further experiments. Nonetheless, as rice is the most water consuming crop, such experiments and recommendations will be very crucial for saving the groundwater.

13.1 Leveling of land

The leveling of land has great significance in irrigation efficiency. A well-leveled field required less time to irrigate same piece of land than unleveled field. In case of cotton, it was reported that only 156 minutes were required to irrigate one hectare under leveled conditions against 187 minutes required under unleveled conditions. Furthermore, lint yield was also higher under leveled conditions due to equal distribution of irrigation water (Table 9).

Table: 9. Effect of land leveling on mean irrigation time

Condition of the land	Irrigation time (min/ha)	Lint yield (kg/ha)
Unleveled	187	2050
Leveled	156	2320

Laser leveling of fields for more uniform and thin/light irrigation is very important. It needs capital investment subsidy. As the investment is very heavy and for use only once in many years it needs to be promoted with the cooperative societies. The agronomic practices for saving water need to be put in to commercial experimentation for testing the economic feasibility.

14. INTENSIFY RESEARCH ON WATER USE EFFICIENCY:

Although the scarcity of water had come to be recognized as the most serious problem of the State in 1985, yet the research, development and investment in water use efficiency did not get the requisite priority in the last 20 years. The research and development programmes on water use efficiency needs to be given the top priority in all-dimensions.

Punjab needs to develop a long-term policy for ground water use and ground water recharge so that water balance is maintained. The government should put in place the necessary investment and policy. Research on water use efficiency needs to be stepped up on the following:

- Evolving varieties of rice, which yield maximum returns when transplanted later than 20th June.
- Experiments on methods of irrigation that save water without reduction in yield
- Experiments on sowing of rice, sugarcane, maize, pulses and soyabean etc. on bunds and beds
- Field experimentation of crop systems, which are more profitable when rice is replaced with incentives to adopt it.

15. TO SUM UP

The water table movement in Punjab is a bad dance with bad rhythms. The beats (table) are rising in the South West for no use, from too deep in 1970s to waterlogged, seriously or nearly, now as groundwater is not fit for use. Still worse, it is falling in major parts of the state, which at many a places is at too alarming a rate. Worse still even the river beds are not immune from this malaise, though it is gradual in major belt. And the fluctuations in some pockets are erratic, which also remain a reason for worry.

The water table has been declining for long time now in 89 blocks of which in 45 blocks it has gone deeper by more than 10 mand in 12 blocks by more than 15 m. The increase in rice area, particularly in the Malwa region has affected adversely the recharge during the monsoon season through more withdrawal of underground water. A 2% increase in Malwa region between 1994 and 2005, which were the similar (normal of 60 cms) rainfall years decreased the recharge level by as much as 80%; in Majha and Doaba, where rice area increased by about 10% the monsoon recharge declined by about 30%.

At the normal rainfall level of 60 cms, the rice area reduction to restore the water balance in the long run was estimated at 1.2, 1.0 and 6.0 lac ha in Majha, Doaba and Malwa regions where it has reached the maximum level of 5.3, 4.0 and 17.3 lac ha, respectively. It means about 25 per cent area under rice in Majha and Doaba and about 35% area under rice in Malwa needs to be reduced. The improvement in water use efficiency, approximated, as equivalent to another 50 mm of rainfall will almost achieve the balance in Majha and Doaba. However, in the Malwa region there is no reprieve from cut in rice area, which even with this improved water use efficiency would be demanding a cut in the long run to about 20% of the rice area.

The freeze in MSP of rice and wheat would lead to reduction in farmers' incomes and thus is not a solution. The electricity tariff at cost of supply will also reduce the farmers' incomes and would still not achieve any significant cut in rice area.

The negative balance between the annual available water supply and the actual use of water needs to be urgently corrected through multi-pronged strategies:

- Making maximum use of the surface water and increasing the recharge
- Addressing the urban sector
- Reducing the water demand:
  - orienting incentives to encourage substitution of low-water consuming crops for high-water consuming crops
  - enacting the nursery act to discipline rice transplanting only after June 10 onwards will reduce significantly the water withdrawal (read losses) from early transplanting of rice
  - improving the water use efficiency through public and private investments in laser leveling, ridge planting, etc
  - redirecting the research on water use efficiency in all-dimensions

Annexure 1

SYL CANAL: POLITICS AND LITIGATION

1960: Indus Water Treaty, signed by India and Pakistan. It reserved waters of the Ravi, Beas and Sutlej exclusively for India
1966: Novemeber 1, 1966. Punjab reorganized. New Haryana state claims share of waters
1976: GOI announced that both the States would receive 3.5 MAF (million acre-feet) of water from the available annual flow of 15 MAF through the construction of the SYL Currently Haryana gets 1.62 MAF of the allotted 3.5 MAF, the balance to be made available through SYL
SYL: Starts from the tailend of Anandpur Hydel canal of Bhakra dam near Nangal and goes up to the Western Yamuna Canal in Haryana
Why the conflict:

- Punjab considers the formation of Haryana under the Punjab Reorganization Act 1966 illegal
- The Punjab Reorganization Act does not mention sharing of the Ravi waters while the 1976 decision of the GoI does
- Dispute over the amount of surplus water actually available based for allocations.
- Distribution based on the utilization in 1960, not on actual use in 1976.
- The political compulsions of the GoI and GoS

The Constitution: It gives full and exclusive powers to the states over water and hydel power. However, when Punjab was bifurcated into Punjab and Haryana, the Punjab Reorganization Act, 1966, gave all powers to the centre ultra vires to the Constitution.
1976: Ministry of Water Resources, GoI unilateral notification:

Estimated surplus river water = 15.85 MAF
Punjab = 3.5 (MAF), Haryana = 3.5, Rajasthan = 8, J & K = 0.65 and Delhi = 0.2

Ground reality: The surplus water available in Punjab was a mere 1.2 MAF
GOP (Giani Zail Singh, CM) asked for a review of the notification
1978: GOP (P S Badal) moved a petition in the Supreme Court challenging the constitutional validity of the notification; GOH also went to SC for implementation of the GOI notification
1981: GOP (Darbara Singh) withdraws the case, signed an agreement with Haryana and Rajasthan for revised allocation of surplus flow of the Ravi and Beas based on 1921-60 flow data estimated at 17.17 MAF as Haryana = 3.5 MAF, Rajasthan = 8.60 MAF and Punjab = 5.07 MAF
The agreement, widely believed to have been signed under pressure, created a furore in Punjab. The Akalis protested and started agitation.
(Haryana completes the first phase of SYL canal by 1982,which it had started in 1976, a 75.5 km long stretch from Ismailpur to Karnal, at a cost of Rs.40 crores)
1985: Punjab Accord: (PM Rajiv Gandhi and Akali leader Harchand Singh Longowal:

- The resentment of the people of Punjab was noted
- A tribunal under the retired Supreme Court Judge (Justice Eradi) was set up
- The Tribunal will conclude on how much water Punjab and Haryana actually used, so that the surplus could be apportioned accordingly
- The SYL canal would be completed by August 15, 1986, allowing Haryana and other downstream states to utilize whatever share of water the Tribunal would eventually allot
- The farmers in Punjab would not have to compromise with lesser water

(There were other clauses of The Punjab Accord to be complied with by 26.1.1986 by GOI, which were backed out)
1987: Justice Eradi concluded that the three states of Punjab, Haryana and Rajasthan use 3.106, 1.620 and 4.985 MAF. Total use = 9.711 MAF, estimated surplus = 6.6 MAF. It awarded 5.00 MAF to Punjab and 3.83 to

Haryana; The arithmetics was wrong – allocating 8.83 against the available 6.6 MAF. The water below the rim stations of the Ravi and Beas, the lowest points at which the data were recorded, was assumed to make up the difference for Punjab. Punjab contested the claim as no dam or barrage could be built along the Pakistan border.

1987: Punjab contested the Eradi Tribunal award – i. It overestimated the available water, and ii. Underestimated the use of water by Punjab farmers

July 1988: Justice Eradi adjourned the tribunal because of violence in the state. It began functioning again in November 1997, after being ordered by the SC to do so. It did not take any clear decision and GoH again approached the SC.

July 1990: Chief engineer, SYL and some labourers killed and all work on SYL canal in Punjab was stopped. Nearly 60 per cent of the 112 km long canal had been constructed till then.

January 15, 2002: SC ordered the Punjab to complete the construction of SYL within 12 months, failing which the GOI would appoint a central agency to complete the work

July 2002: GoH approached the SC to ensure that the GOP kept to the deadline

January 15, 2003: Deadline expires 7th time (December 1983, August 1986, December 1987, March 1988, June 1988, November 1989, January 1991 and January 2003)

January 2003: GoP (Amrinder Singh) files the plea in SC to refer the matter to a larger bench. It also argued that there is no surplus water. The river flow data between 1981 and 2002 show only 14.37 MAF against the 17.17 MAF believed to be available. The transfer would affect 9 lakh acres of irrigated land in Ferozepur, Faridkot, Moga and Mukatsar. The recharge of groundwater in Punjab will be seriously affected.

January 2004: SC rejects the GoP plea to refer the matter to a larger bench

January 15, 2004: GoH petitions the SC about the GoP failure to act on the SC order of January 15, 2002

June 4, 2004: SC directs the GoI to appoint a central agency by June end, which will take up the work of constructing the unfinished part of the SYL by July 15, 2004. GoI directs the central PWD as the agency to take up the work

July 3, 2004: GoP moves the SC to review its June 4 judgement. GoP contended that SC did not have jurisdiction on water dispute under Article 262 of the Constitution, which falls within the exclusive jurisdiction of the Interstate River Waters Dispute Tribunal

August 24, 2004: SC dismissed the GoP petition

GoP threatens to stop releasing water to the neighbouring states

GoR assembly passes a resolution authorizing the GoR to initiate legal and administrative steps to ensure that the state got its full share of water from the Ravi-Beas system as per the 1981 agreement. (In December 2004, Rajasthan CM, Vasundhara Raje met PM to demand water; The Bhakra-Beas Management Board immediately released water as per requisition for the month)

GoP decides to bring a bill to counter the obligation of handing over the SYL project to central agency. The bill was drafted with the help of former solicitor general, Soli Sorabjee with the aim of nullifying the agreement with retrospective effect. It dug up the Northern India Canal and Drainage Act, 1873 for amendment proposing to make it mandatory for any work on a canal – maintenance, repair or construction – that ferried water beyond the borders of Punjab to be sanctioned by the assembly

July 12, 2004: A special session of the Punjab Assembly passes unanimously the Punjab Termination of Agreements Bill, 2004 terminating all agreements relating to sharing of waters of Ravi and Beas with Haryana and Rajasthan. It also abrogated the Yamuna Agreement of May 12, 1994 between Punjab, Haryana, Rajasthan, Delhi and Himachal Pradesh (which allotted 4.6 MAF of Yamuna water to Haryana to be further augmented by SYL) and all other accords for sharing water

The Bill declared the Indus system that existed before Partition had become irrelevant after the event since only three east flowing rivers – Ravi, Beas and Sutlej – out of the six that constitute the Indus River System remained in India. All these rivers flow through Punjab: neither Haryana nor Rajasthan are part of these river basins. The diversion of these waters was contrary to the National Water Policy.

Haryana termed the Act unconstitutional and lawless. Its implementation would lead to the destruction of cooperative federalism and disintegration of the country.
July 15, 2004: GoI filed petition in the SC for fresh directions as a result of the GoP controversial act.
July 20, 2004: GoHP also decides to move the SC against the Punjab Termination of Agreements Act to safeguard its interests
July 22, 2004: President refers the controversial law passed by Punjab Assembly to the SC
August 2, 2004: SC agrees to examine the validity of the Punjab Act and issued notices to the Centre, Punjab, Haryana, Rajasthan, Himachal Pradesh, Jammu and Kashmir and the National Capital Territory of Delhi to file written submissions on facts and the questions of law formulated under the presidential reference under the Article 143 (1) of the Constitution, seeking opinion on:

a. Whether the Punjab Termination of Agreement Act, 2004 and its provisions are constitutionally valid;
b. Whether the Act and the provisions are in accordance with the provisions of the Interstates Water Disputes Act, 1956, Section 78 of the Punjab Reorganization Act, 1966 and the notification dated March 24, 1976 issued thereof; and
c. Whether in view of the provisions of the act, the state of Punjab is discharged from its obligation flowing from the judgement and order dated June 4, 2004 of the Supreme Court.

April 13, 2006: SC admits contempt petition against GoP and GoI for not implementing its January 15, 2002 and June 4, 2004 orders respectively. It is listed for hearing along with the Presidential reference of July 22, 2004.
March 3, 2007: New Punjab CM (P S Badal) announces to scrap the section 5 of PTA Act, 2004, which says that existing use of water to Haryana and Rajasthan will be protected.

March 9, 2007: Haryana moves SC for early hearing of Presidential reference of July 22, 2004. The SC fixes July 29, 2007 for the hearing
March 28, 2007: Punjab states in SC to honour the water pacts. Next hearing is fixed in July 2007
March 30, 2007: CM (Badal) says to challenge the section 78 of the Punjab Reorganization Act, 1966, which says: "….all rights and liabilities of the existing state of Punjab with respect to the Bhakra and Beas projects may be fixed through an agreement by the states after consultation with the central government. If no such agreement is entered into within two years of the appointed day, the central government may, by order, determine the purpose of the projects….." In other words, the central government kept powers with itself to decide the sharing of waters of Punjab and make allocation of the same to other states.This section was "lifted" from the act that was drafted at the time of the organization of the southern states in 1956.

The GoP later filed the civil suit in the SC challenging the legality of Sections 78 and 79 of the Act. GoP also manages to get the SC to stay construction of Hansi-Butana canal by the Haryana Government
October 22, 2007: Delhi High Court admits the GoP petition for furthr hearing a petition challenging the constitutional validity of the reconstitution of the Ravi Beas Water Disputes Tribunal by the union Government, which was reconstituted through a notification dated June 10, 2003 as per the provisions of the Inter-State River Waters Disputes Act, 1956.

Source : Mainly adapted from Indira Khurana (2006). Transboundary Disputes: Politics and Litigation Play
Havoc : Sutlej Yamuna Link Canal. Economic & Political Weekly, February 18. Pp. 608-11. The update is from various newspapers.

Annexure 2

Rainfall and Rivers in Punjab

The annual rainfall in Punjab ranges from 390 mm in 21 rainy days in the Western part to 1100 mm in 48 rainy days in the north and north eastern part. Mean annual rainfall during 1973 to 2005 has been 600 mms in 32 rainy days. July and August are the rainiest months (57 % of annual rainfall). Almost 80 % of the rainfall comes in the monsoon period. The heaviest rainfall was in 1988 (1123 mms), when there were floods all over the state. The last heavy rainfall (more than the normal) was 1997 when it was 709 mms.
There are three major rivers - the Ravi, the Beas and the Satluj.

The Ravi river rises from the Northern face of Rohtang Pass in the Kuku hills in H.P. at an elevation of 4116 m. and enters Punjab at Madhopur where the head works of Upper Bari Doab Canal are constructed. The river flows through Gurdaspur and Amritsar districts forming the international boundary between India and Pakistan and finally enters Pakistan near Kakar Manj, 30 kms from Lahore. The length of the river from its source to the Pakistan border is 725 kms. The catchment area is 5957 sq km. The minimum discharge is 34 cumecs, while the highest flood discharge is 15400 cucecs. The annual mean flow is 7894 million cubic metres. A flood protection embankment on the left side for 150 kms length from Madhopur to Kakar Manj was constructed in 1955. The river is in the share of India and is being extensively utilized through Kashmir canal and Upper Bari Doab Canal.

The Beas river rises close to the source of river Ravi on the southern face of the Rohtang pass ar 4060 m and enters Punjab at the trijunction of Gurdaspur, Hoshiarpur districts of Punjab and the State of Himachal Pradesh and traversing through the Doaba and Majha regions, it finally joins the Satluj river at Harike Pattan. The total length of the river from the source to the confluence with Satluj is 470 kms. The maximum discharge of 17600 cumecs was experienced in 1961. At Pandoh, above Mandi in H. P., a dam has been constructed to divert 257 cumecs of water in to Satluj above the Gobind Sagar lake. At Pong near Talwara a large earthen dam has been constructed to impound water for gradual release into the Rajasthan Canal and Sirhind Feeder taking off from Harike.

The Satluj river rises close to the course of mighty Indus and Brahmaputra rivers near the south-west of the Tibetan lakes of Rakasthal and Mansarovar. The Bhakhra dam, the second highest dam in the world, has been built on this river. This is followed by the Nangal dam 14 kms down to Bhakhra. The river enters the plains of Punjab at Ropar where the headworks of the Sirhind Canal is constructed. About 160 kms below Ropar, the river Beas joins the Satluj at Harike. The river leaves Punjab near Ferozepur and enters Pakistan forming international boundary and finally enters Pakistan at Suleimanki near Fazilka. After the construction of the Bhakhra Dam, the Satluj river has been canalized between Ropar and Harike for a length of 160 km in a width of about 1 km instead of 9-10 kms existing earlier.

There is Ghaggar river, which is defunct Saraswati, emerging from the hills midway between Yamuna and Satluj, flows along the boundary of Punjab and Haryana, and finally disappears itself into the sands of the Rajputana desert. It is more or less a flashy stream, swells with rainfall in the higher catchment and subsides immediately after the rains. Sometimes flash floods in this river cause extensive losses in the Patiala and Sangrur districts.

Note: This section is mainly based on Central ground Water Board, North western Region, Chandigarh. Report on “Water Security through Ground Water Management”. July 2004; and H S Mavi and D S Tiwana (1993). Geography of Punjab. National Book Trust, New Delhi, India

Appendix A: Water-table related characteristics, region-wise, Punjab, 2004-05

Characterestics		Unit	Majha	Doaba	Malwa	Punjab
Blocks		No.	29	30	73	132
Geographical area		000 ha	864	988	3184	5036
Net area sown	1975	000 ha	666	697	2795	4158
	1990	000 ha	736	681	2800	4217
	2004	000 ha	743	668	2789	4200
	2004	% of GA	86	68	88	83
Rainfall		Range (mm)	550 –	600 –	< 300 –	< 300 –
			1100+	1100+	1100+	1100+
Net irrigated area		000 ha	680	616	2739	4035
		% of NAS	92	92	98	96
Canal irrigated area		000 ha	267	21	813	1101
		% of NIA	39.3	3.4	29.7	27.3
Rice area	1975	000 ha	207	97	263	567
	1990	000 ha	450	310	1255	2015
	2004	000 ha	536	358	1753	2647
	1975	% of NAS	31.1	13.9	9.4	13.6
	1990	% of NAS	61.1	45.5	44.8	47.8
	2004	% of NAS	72.1	53.6	62.9	63.0
Area under:	Sugarcane	000 ha	27.0	41.0	18.0	86.0
	Potato	000 ha	3.1	36.4	28.3	67.8
	Sunflower	000 ha	0.7	11.5	5.1	17.3
	Sub-total	000 ha	30.8	98.9	51.4	171.1
		% of NAI	4.5	16.1	1.9	6.5
		% of Rice A	5.7	27.6	2.9	4.2

APPENDIX B.1: MAJHA - Water table level in 1975 and 2005 and monsoon recharging in 1994 and 2005

Region	District	B name	Jun-75	5-Jun	Oct-75	5-Oct	Rechg-94	Rechg-05
A	GDP	NAROT JAIMAL SINGH	3.41	3.61	2.74	3.05	0.98	0.56
A	GDP	GURDAS PUR	5.03	7.21	3.74	6.19	1.86	1.02
A	GDP	DINA NAGAR	5.45	5.64	4.04	4.70	1.84	0.94
A	GDP	KALANAUR	5.92	7.10	3.24	6.10	2.42	0.99
A	GDP	PATHANKOT	6.70	6.07	5.78	5.14	1.84	0.93
A	GDP	KAHNUWAN	12.04	11.77	9.58	10.99	1.05	0.78
B	ASR	AJNALA	4.60	8.93	2.82	8.59	1.67	0.34
B	GDP	DERA BABA NANAK	4.62	7.39	2.49	6.86	2.02	0.54
B	ASR	BHIKHIWIND	5.27	10.39	3.07	9.27	0.61	1.12
B	ASR	CHOGWAN	5.30	11.46	3.12	10.91	2.00	0.55
B	ASR	VALTHOA	6.29	8.95	4.54	8.31	0.31	0.64
B	ASR	GANDIWIND	6.39	11.04	3.42	10.96	0.67	0.09
C	GDP	BATALA	4.00	7.10	1.37	6.31	1.25	0.79
C	GDP	FATEHGARH CHURIAN	4.01	6.83	1.57	5.96	1.82	0.88
C	ASR	MAJITHA	4.12	8.47	1.74	7.60	1.27	0.87
C	ASR	TARSIKKA	4.61	11.52	2.15	10.69	0.60	0.83
C	ASR	VERKA	5.08	22.15	3.13	20.64	0.44	1.51
C	ASR	JANDIALA	5.47	14.17	3.81	13.97	0.27	0.20
C	ASR	HARSA CHHINA	5.77	10.92	3.44	9.54	1.22	1.38
C	ASR	TARN TARAN	6.24	15.39	3.96	15.28	0.55	0.11
C	ASR	NAUSHERA PUNNUAN	6.28	14.93	3.47	14.69	0.39	0.24
C	ASR	PATTI	6.85	14.25	5.22	13.50	0.40	0.75
C	GDP	DHARIWAL	7.26	10.63	4.65	9.50	0.51	1.13
D	ASR	RAYYA	5.55	10.86	2.69	10.57	1.69	0.30
D	GDP	QADIAN	5.78	9.11	3.33	8.25	1.30	0.86
D	ASR	CHOHLA SAHIB	7.14	12.83	5.74	13.02	0.34	-0.19
D	ASR	KHADUR SAHIB	8.73	19.00	6.80	19.00	0.98	0.00
D	GDP	SHRI HAR GOBINDPUR	9.73	12.81	7.68	11.82	2.30	0.99
E	GDP	DHARKALAN	16.80	8.54	10.20	6.32	6.81	2.22

APPENDIX B.2: DOABA - Water table level in 1975 and 2005 and monsoon recharging in 1994 and 2005

Region	District	B name	Jun-75	5-Jun	Oct-75	5-Oct	Rechg-94	Rechg-05
A	HPR	HAZIPUR	8.73	9.80	4.52	8.80	2.20	1.01
A	HPR	TALWARA	9.39	12.03	8.94	10.75	1.40	1.28
B	HPR	HOSHIAR PUR-I	7.09	7.05	5.31	5.83	2.73	1.22
B	HPR	HOSHIAR PUR-II	7.63	15.35	5.66	14.40	2.47	0.95
B	HPR	BHUNGA	7.99	8.12	6.61	7.51	1.93	0.61
C	HPR	MAHIL PUR	11.81	24.98	11.10	24.49	3.05	0.50
C	NWS	BALACHAUR	12.43	12.57	12.29	12.25	0.96	0.32
C	HPR	GARHSHANKAR	15.38	22.35	13.14	21.76	1.01	0.59
C	NWS	SAROYA	28.54	27.13	16.80	26.28	1.76	0.84
D	NWS	AUR	5.92	12.08	4.92	11.99	3.87	0.10
D	JAL	NAKODAR	7.04	23.83	6.06	23.36	0.82	0.47
D	JAL	LOHIAN	7.28	15.27	7.54	12.88	0.00	2.39
D	NWS	NAWAN SHAHAR	7.63	11.11	6.15	11.05	0.63	0.06
D	JAL	RURKA KALAN	8.01	16.00	5.61	17.50	1.18	-1.50
D	JAL	PHILLAUR	9.19	14.72	7.67	14.16	3.04	0.56
D	JAL	NURMAHAL	9.46	16.24	8.45	13.88	0.67	2.36
D	JAL	SHAHKOT	10.32	24.65	9.41	25.39	-0.06	-0.74
E	HPR	MUKERIAN	1.94	3.63	1.47	2.38	1.50	1.25
E	KPT	DHILWAN	3.87	6.67	2.76	5.93	1.32	0.74
E	KPT	NADALA	5.19	8.75	3.04	8.14	1.53	0.60
E	KPT	SULTANPUR	5.20	17.33	3.87	15.31	2.05	2.02
E	HPR	DASUYA	5.99	8.58	5.07	9.31	2.30	-0.73
E	HPR	TANDA	6.13	7.43	4.26	6.91	2.14	0.52
F	JAL	ADAMPUR	5.32	9.42	4.52	8.67	0.78	0.75
F	JAL	BHOGPUR	5.85	7.76	4.26	9.10	0.50	-1.34
F	NWS	BANGA	5.99	11.73	2.10	11.54	2.39	0.19
F	KPT	PHAGWARA	6.15	13.69	3.59	12.82	1.15	0.87
F	KPT	KAPURTHALA	6.15	16.27	4.70	15.36	0.42	0.91
F	JAL	JALANDHAR WEST	7.12	15.97	5.66	13.46	0.89	2.51
F	JAL	JALANDHAR EAST	7.18	18.19	5.89	13.81	0.70	4.37

APPENDIX B.3: MALWA - Water table level in 1975 and 2005 and monsoon recharging in 1994 and 2005

Region	District	B name	Jun-75	5-Jun	Oct-75	5-Oct	Rechg-94	Rechg-05
A	Ropar	Chamkaur Sahib	3.11	7.15	2.01	7.25	1.67	-0.09
A	Ludhiana	Sidhwan Bet	4.72	10.92	3.70	9.84	1.80	1.08
A	Ropar	Nurpur	4.94	10.16	3.81	9.56	2.03	0.60
A	Ropar	Ropar	5.11	9.74	3.83	8.23	2.01	1.51
A	Ludhiana	Mangat	6.35	8.99	5.65	8.58	1.19	0.41
A	Ludhiana	Machhiwara	7.10	4.25	6.74	3.68	1.10	0.57
AB	Ferozepur	Zira	2.78	14.70	1.57	15.37	-0.23	-0.67
AB	Ferozepur	Dharam Kot	3.52	18.90	1.73	19.63	0.37	-0.73
ABC	Ferozepur	Makhu	1.45	10.50	0.39	11.10	-1.11	-0.60
ABC	Ferozepur	Ferozepur	2.77	8.70	1.75	8.55	1.11	0.15
B	Ferozepur	Jalalabad	2.29	1.40	1.15	1.15	0.86	0.25
B	Faridkot	Faridkot	2.55	5.23	1.51	5.08	0.66	0.15
B	Ferozepur	Ghall Khurd	2.68	3.20	1.55	2.00	1.31	1.20
B	Ferozepur	Mamdot	2.81	4.80	1.54	6.00	1.77	-1.20
B	Ferozepur	Guru Harsahai	2.95	4.80	2.05	6.00	0.97	-1.20
B	Muktsar	Muktsar	3.87	2.34	3.55	2.50	0.45	-0.16
B	Ferozepur	Fazilka	4.03	3.30	3.07	3.73	0.15	-0.43
BA	Faridkot	KotKapura	7.06	8.38	6.18	7.75	0.19	0.63
BB	Ferozepur	Khuyian Sarwar	9.26	4.22	8.78	4.60	0.61	-0.38
BC	Bathinda	Talwandi Sabo	23.36	7.16	23.06	6.98	0.23	0.19
BC	Ferozepur	Abohar	24.04	6.18	23.65	6.12	-0.37	0.06
BC	Bathinda	Sangat	25.31	8.07	25.06	8.22	0.07	-0.15
BC	Muktsar	Lambi	27.08	3.86	26.36	3.85	0.27	0.00
C	Muktsar	Malot	14.94	3.20	14.40	2.84	0.39	0.36
C	Bathinda	Bathinda	15.15	7.60	14.92	7.60	0.47	-0.01
C	Muktsar	Kot Bhai	16.46	3.89	16.11	3.40	0.40	0.49
C	Bathinda	Maur	18.08	9.22	18.00	9.19	0.33	0.03
CA	Bathinda	Nathana	9.27	12.19	8.62	12.30	0.77	-0.10
CA	Mansa	Mansa	9.48	5.53	8.88	5.12	0.52	0.42
CA	Mansa	Sardoolgarh	9.61	7.78	8.91	7.52	1.80	0.26
CA	Mansa	jhunir	13.44	5.08	12.65	4.92	0.45	0.17
CD	Mansa	Budhlada	4.02	10.78	3.00	10.96	0.76	-0.18
CD	Mansa	Bhikhi	4.40	11.09	3.07	11.23	0.37	-0.14
CD	Bathinda	Phul	5.22	12.93	4.39	13.51	0.19	-0.58
CD	Bathinda	Rampura	8.30	11.78	8.18	12.33	-0.58	-0.55

APPENDIX B.3: MALWA - Water table level in 1975 and 2005 and monsoon recharging in 1994 and 2005

Region	District	B name	Jun-75	5-Jun	Oct-75	5-Oct	Rechg-94	Rechg-05
D	Patiala	Nabha	4.46	18.55	3.77	18.07	0.93	0.48
D	Sangrur	Sehna	4.47	15.39	3.88	14.78	0.50	0.61
D	Patiala	Samana	4.78	20.75	2.56	21.30	0.93	-0.55
D	Fatehgarh S	Sirhind	5.06	12.03	2.88	12.30	0.67	-0.27
D	Patiala	Patiala	5.27	18.26	3.38	18.21	0.27	0.05
D	Sangrur	Lehragaga-Andana	5.29	12.91	3.97	14.54	2.59	-1.63
D	Sangrur	Mehal Kalan	5.31	15.38	4.45	16.00	-0.08	-0.62
D	Ludhiana	Doraha	5.33	14.90	4.59	14.48	1.35	0.42
D	Sangrur	Bhawanigarh	5.49	19.65	4.28	18.50	0.18	1.15
D	Fatehgarh S	Amloh	5.82	18.50	4.91	17.90	0.44	0.60
D	Sangrur	Barnala	5.83	18.87	5.23	19.55	0.92	-0.68
D	Sangrur	Dhuri-Sherpur	5.83	22.76	5.47	22.93	4.15	-0.17
D	Moga	Moga	5.90	24.08	5.07	24.45	0.70	-0.38
D	Patiala	Sanaur	5.93	15.10	3.74	14.80	0.07	0.30
D	Sangrur	Sangrur	5.97	18.64	5.05	14.87	-2.00	3.77
D	Sangrur	Sunam	6.11	17.43	5.41	18.87	1.52	-1.43
D	Moga	Nihal S Wala	6.32	17.05	5.57	17.90	0.44	-0.85
D	Patiala	Bhunarheri	6.49	22.44	3.91	21.45	1.55	0.99
D	Ludhiana	Dehlon	6.51	12.76	5.54	12.39	1.27	0.37
D	Fatehgarh S	Khamanon	6.62	13.26	6.09	13.00	0.66	0.25
D	Sangrur	Maler Kotla-Amargarh	6.93	16.90	5.83	16.65	0.22	0.25
D	Patiala	Patran	6.98	28.20	5.45	23.90	1.94	4.30
D	Ludhiana	Jagraon	7.46	16.00	6.53	15.97	0.39	0.02
D	Patiala	Rajpura	7.79	13.22	5.33	13.36	2.14	-0.14
D	Ludhiana	Pakhowal	8.39	15.60	7.54	16.55	0.21	-0.95
D	Ludhiana	Khanna	8.57	16.24	7.91	16.22	1.16	0.02
D	Sangrur	Ahmedgarh	8.80	23.85	8.14	23.65	0.60	0.20
D	Ludhiana	Sudhar	8.90	15.01	7.93	14.92	0.76	0.09
D	Fatehgarh S	BassiPathana	9.09	14.60	7.15	15.15	0.53	-0.55
D	Ludhiana	Samrala	9.21	12.53	8.95	11.91	0.92	0.62
D	Ludhiana	Ludhiana	9.45	24.31	8.88	24.44	0.30	-0.13
D	Fatehgarh S	Khera	10.95	14.03	8.55	12.82	1.78	1.21
E	Patiala	Ghanaur	5.89	10.68	3.26	9.63	2.27	1.05
E	Ropar	Kharar	6.17	7.88	3.61	5.99	2.85	1.89
E	Patiala	DeraBassi	7.43	9.44	5.82	8.12	2.68	1.31
E	Ropar	Anandpur	8.12	9.32	6.86	8.65	1.80	0.67
E	Ropar	Morinda	9.68	11.72	9.28	11.14	1.86	0.57
E	Ropar	Majri	9.93	10.84	9.21	9.98	2.18	0.86