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Act to Save Groundwater in Punjab: Its Impact on Water Table, Electricity Subsidy and Environment**

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Abstract

The fall in water table in Punjab has been a serious issue. One of the main reasons for it has been the early transplanting of rice (before mid-June), which means severe withdrawal of groundwater, as the monsoon is still far away, temperatures are very high and evapo-transpiration rate (ETR) is maximum. On the initiative of the Punjab State Farmers Commission, "The Punjab Preservation of Sub Soil Water Act" (not to sow paddy nursery before May 10 and not to transplant paddy before June 10) was promulgated as an Ordinance in 2008 and encouraged by the response, it has been changed into an Act in March 2009. The time series and experimental data on transplanting pattern, water requirements rice, rainfall, monsoon recharge, groundwater behaviour and rice area have been used and it is estimated that the fall in water table can be checked by about 30 cm, which is about 65 per cent of the long-term falling rate, by delaying the transplanting with the effective implementation of the Act. The water table during 2008, which also had better monsoon rainfall of 51 cm, has risen as per estimated by about 80-100 cm, which is close to the provisional releases. To maintain the water balance in the long-run, about 47-50 cm of water (as equivalence of monsoon rain) is required, of which 40 cm is the long-run average rain and about 5 cm gets compensated by the Act in its present form. 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 are recommended.

The savings in electricity due to the Act have been estimated at 276 million units, which means the savings to the State exchequer of about Rs 122 crore per year, split as savings of the government including its extra tax earnings as Rs 77 crore and the additional net earnings of the State Electricity Board as Rs 45 crore. The other long-term benefits include reprieve from the relative humidity by about 15-16 per cent point, which might help reducing the harmful pests and bacteria vulnerable to high and dry temperatures, saving the farmers from frequent deepening and ultimately installing the submersible tubewells, saving and even restoring the rural drinking water supply sources of hand-pumps, acting as a catalyst to fine tune the paddy-transplanters, mandating the breeders to evolve the rice varieties that yield better when transplanted after mid-June, giving more crucial time to the farmers for reinvigourating the research-extension-farmer linkage and, delayed harvesting and marketing causing less pollution due to the increase in dew-factor and encouraging the adoption of happy seeder type innovations for timely wheat sowing without burning the rice straw.

The Problem

The fall in water table in Punjab, even more so in central Punjab, which comprises the rice belt of the state was becoming more serious day by day. The rate of fall in water table per year was 18 cm during 1982-87; it increased to 42 cm during 1997-2002 (Hira *et al*., 2004) and further to 75 cm during 2002-06 (Singh, 2006). The extensive rice cultivation and its early

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transplantation, before mid-June, have been considered the main reasons for the steep fall in water table.

The area under rice in Punjab increased from 1182 thousand hectares in 1980-81 to 2016 thousand hectares in 1990-91 and further to 2612 thousand hectares in 2000-01. It continues to be around that level since then. Various fora have recommended reduction in rice area in Punjab (GOP, 1986; GOP, 2002; Kalkat *et al*., 2006), but it has not been happening as rice remains the more profitable, more stable and less risky crop with assured market and minimum support price.

The proportion of transplanted rice area up to mid-June becomes too high in Punjab. During 1996-2005, it had reached, on an average, about 25 per cent up to May-end and about 60 per cent by mid-June. The maximum area transplanted up to May- end touched 36 per cent in 1997-98. The maximum area up to mid-June also touched a peak of 66 per cent in 1998-99 and almost remained at this level up to 2004-05. It happened in spite of the concerted appeals by the eminent scholars, scientists and development administrators. These concerted efforts did yield positive results but only to a limited extent. About, 48 per cent of rice area was transplanted before 15 June even in 2007-08 (Table 1).

The water requirement, in terms of applied water is the highest for the rice transplanted in early-May based on 5-inch irrigation at puddling, followed by about 3-inch irrigation after every three days, assuming no rainfall up to 15 June (and there is hardly any rainfall or its expectation at this time of the year). During this period in Punjab, the relative humidity is lowest, wind speed is highest and temperature is maximum, due to which water evaporates very fast. Thus, besides over-exploitation of underground water, the early transplantation of rice, which requires pouring (underground) of water like on a hot oven, leads to a rise in relative humidity at a faster rate, prior to the onset of the monsoon season.

An effective check on early transplantation of rice is expected to help in controlling the fall in water table; decline in irrigation water to be applied, which will result

Table 1. Area transplanted (paddy) on different dates in Punjab: 1990-2008

(in per cent)

Year	Up to 15 May	16 – 31 May	Up to 31 May	1 – 15 June	Up to 15 June
1990-91	0	12	12	34	56
1991-92	6	12	18	31	49
1992-93	5	13	18	31	49
1993-94	8	12	20	31	51
1994-95	7	14	21	32	53
1995-96	6	12	18	40	58
1996-97	5	11	16	41	57
1997-98	8	28	36	26	62
1998-99	8	20	28	38	66
1999-2k	4	15	19	45	64
2000-01	6	12	18	46	64
2001-02	5	12	17	48	65
2002-03	4	9	13	46	59
2003-04	4	10	14	48	62
2004-05	7	15	22	43	65
2005-06	5	9	14	45	59
2006-07	0.3	8	8	43	51
2007-08	0.3	6	7	42	48
2008-09	0	0.6	0.6	22	22.6

Source: Department of Agriculture, *Agricultural Statistics* (various issues), Govt. of Punjab, Chandigarh
Data for 2008-09 is from the surveys by the Dept. of Economics & Sociology, PAU, Ludhiana

in the saving of electricity; and control of humidity at early stages, which will reduce the harmful pests and bacteria that are vulnerable to high and dry temperatures. The other changes expected in the environment and technology development and adoption scenarios have also been highlighted.

Act for Preservation of Sub-soil Water

The Punjab State Farmers Commission (PSFC, 2007) took the initiative of drafting a legistation entitled, 'Act to provide for preservation of sub-soil water in the state of Punjab'. Its main provisions are "the prohibition on sowing nursery of paddy and transplanting of paddy before the notified dates, and for the matters connected therewith or incidental thereto" ….. and "No farmer shall sow nursery of paddy before the 10th day of May……. and "No farmer shall transplant paddy before such date, as may be notified in this regard by the State Government through notification in the Official Gazette"[1] (Annexure I)[2]. Its main purpose was to ensure the delay in the transplanting of rice till mid-June for saving the groundwater resources. The draft of the Act was submitted to the Government of Punjab in 2006, which was promulgated as an Ordinance in May 2008, and implemented effectively. Encouraged by the response, the Government of Punjab changed it to an Act in March 2009[3]. The State Government Cabinet accorded approval to convert the Ordinance into an Act in its meeting of 20 February 2009 and the Bill for the same was brought up and passed in the Legislative Assembly in March 2009. It received the assent of the Governor of Punjab on 2nd April, 2009. The Act is called, "The Punjab Preservation of Sub Soil Water Act, 2009"[4]

Methodology

Although one year is too short a span to measure the precise impact of a legislative measure[5], that too with too many and too complexly interlinked parameters in the long-term. This exercise was mostly based on the experimental data, generally the time-series from 1990 onwards and was supplemented wherever possible with the field data from other projects, and corroborated with the field observations during 2008. Accordingly, the developed variables / parameters of the study bear the scientific stamp[6].

The field surveys by the Department of Economics and Sociology, Punjab Agricultural University (PAU), Ludhiana, and the crop cut experiments conducted by the Department of Agriculture, Government of Punjab have reported the changes in rice transplantation pattern during 1990 to 2008. The change in 2008 shows the impact of the Act.

The field experiments conducted by the Department of Soils, PAU, Ludhiana, during 1974 to 1977 on irrigation needs of rice (Sandhu *et al*., 1980) and again during 1988 to 1991 on the effect of transplanting date and irrigation regime for rice (Singh *et al*., 1996) showed a remarkable consistency. These data were used for developing an index of water application needs of rice. It may also be noted that most of the rice varieties in Punjab have been of the medium duration of around 145 days, which is the main determinant of the water requirements of rice, other things being the same.

In Punjab, the data on water level is monitored by the Hydrological wing of the State Department of Agriculture, from around 600 selected locations (observation wells) in the state since 1973. To begin

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[1] The Notification issued on the 21st May 2008 stated that, "No farmer shall transplant paddy before the 10th day of June 2008".

[2] The research institutes and waterlogged areas, specifically defined, have been exempted.

[3] The State Government Cabinet accorded approval to convert the Ordinance into an Act in its meeting of 20 February 2009 and the Bill for the same was brought up and passed in the Legislative Assembly in March 2009. It received the assent of the Governor of Punjab on 2 April, 2009.

[4] Although going by the spirit of required actions envisaged under the Act — not to sow paddy nursery before 10 May and not to transplant paddy before 10 June — one may call it as 'Rice Nursery Act' but the main objective was 'reversing the over-exploitation of underground water' 'to preserve the scarce sub-soil water'. I have often said, 'rice is not the problem, water (scarcity, overexploitation, whatever be called) is the problem'.

[5] But then after a few years, it would be only a usual post-mortem exercise.

[6] Encouraged by the response / likely impacts of the Act in Punjab during 2008, the neighbouring Haryana State has also passed a similar Act in 2009. It took its first punitive action as early as 18 March, 2009 in Kirmich village, Kurukshetra district, where its Agriculture Department uprooted the planted nursery of *Saathi* paddy (*Khetri*, 2009).

with, it had selected the open (observation) wells and started recording the depth of water level at two points of time during the year, viz. June (pre-monsoon) and October (post-monsoon), on any day during 10th to 25th of a month. When a particular well dried up, another well in the same village was selected, and it also carried on for some years, when finally, it came to installing the Piezometer tubes (PZ meters). These data from 1990 to 2005 were used to estimate the net recharge during the monsoon period, when rice is grown, i.e. October over June[7]. The relationship between the rice water application needs based on the transplanting pattern, rainfall during the monsoon period, fall in water table and rice area, etc. was studied. The expected impact of the Act on water table was sifted out from that of the likely impact of the monsoon rainfall and other related variables using the estimated parameters and relationships.

The above information was further used to estimate the effect on electricity consumption. It was cross-checked with the data on 'cost of cultivation' being regularly collected by the cost accounting method from 300 farmers by the Department of Economics and Sociology, PAU, Ludhiana. Some other impacts were supported with the data from the Department of Soil and Water Engineering.

The meteorological data for 15 years, from 1990 to 2005, on rainfall, temperature (minimum and maximum) and relative humidity (morning and evening) available from the Department of Agro-meteorology, PAU, Ludhiana, was used to study the impact on relative humidity. Finally, there were some field observations made during the year on some other related aspects of the likely impact of the Act, which were also supplemented wherever possible, from the other studies in vogue in the PAU, Ludhiana.

Impact of the Act

(i) Change in Rice Transplantation Pattern

The effective implementation of the Act resulted in reducing the area transplanted before mid-June. The area transplanted up to May-end was only 0.6 per cent (PAU surveys) and picked up only after June 10. The total area transplanted up to mid-June was only 22.6 per cent, mostly after the notified date of 10 June (Table 1).

[7]For detailed analysis of these data, see, Singh (2006; 2007; 2008).

The early transplantation of rice was started in early-1990s. The area transplanted during 16-31 May was first observed in 1988-89 when it was 9 per cent. The transplanting earlier than May 15 (1-15 May) was first observed in 1991-92, which was 6 per cent and another 12 per cent in that year was transplanted during 16-31 May (Singh and Kalra, 2002).

Area transplanted during hot days of May (up to 31st) reached the peak of 36 per cent in 1997-98. The concerted appeals made by eminent scholars, scientists and development administrators and professionals like the former and in-position vice-chancellors of PAU, were intensified and did make some impact to bring it down to 13 per cent in 2002-03, but it again picked up and reached 22 per cent in 2004-05. Some other ad-hoc initiatives like announcing the delayed date of procurement or restricting of electricity supply during the early transplanting period, etc. did not achieve much impact either and almost about 65-66 per cent of the rice area was being transplanted early up to 2004-05. And, some 48 per cent of rice area was transplanted before 15 June in 2007-08.

(ii) Impact on Water Table

Early transplantation of rice has a higher evapo-transpiration rate (ETR) and consequently, there would be more fall in water table. The fall in water table, early transplantation of rice, monsoon recharge, net withdrawal during the *rabi* season along with exogenous variables of rainfall are all inter-related. Total area under rice is also an important variable in this correlation matrix.

The experimental data on the application of water to rice, which formed the base for recommendations about irrigation to rice, is abridged in Table 2. The irrigation needs (water applied) for rice transplanted from July onwards, which coincide with the monsoon having been really in swing, and that was the practice in 1970s, depend straight on the seasonal rainfall. The sum of water applied plus the rainfall during the growing period for the rice sown from July onwards was only 177-180 cm, whereas the seasonal rainfall varied from 18.8 cm to 63.2 cm and the irrigation water applied varied from 117 cm to 151 cm during different years.

The total water application needs of rice transplanted on 16 May, 31 May and 16 June based on the 4-year experiments more than a decade later were

Table 2. Water needs of rice according to rice transplanting dates, Punjab

(in cm)

Date of rice plantation	Irrigation water applied[a]	Seasonal rainfall	Total water application	Year of experiment
16 May	179	69	248	Average of 1988
31 May	160	70	230	to 1991[c]
16 June	137	67	204	
2 July	117	63.2	180	1975
12 July	121	56.6	178	1976
19 July[b]	(151)[b]	18.8[b]	170[b]	1974[b]
2 August	136	41.1	177	1977

Sources: Sandhu, *et al*. (1980), Singh *et al*. (1996)

Notes: [a]These are for the recommended practice (which emerged from these and other experiments) of one week continuous submergence, followed by 2-day drainage system.

[b]The experiment of 19 July in 1974 is not strictly comparable as in this case the particular treatment was not included, but still the results are very close with the closely similar practice of 1-day drainage. The total water application of 170 cm was still very close to 180 cm inspite of too little rainfall during this year, which was supplemented with much higher irrigation water applied of 151 cm.

[c]The experimental data for individual years were not available from the published sources referred to here.

179 cm, 160 cm and 137 cm, when the rainfall during the respective growing periods was 69 cm, 70 cm and 67 cm, thereby giving the total water application needs at 248 cm, 230 cm and 204 cm, respectively. Thus, for estimating the indexed[8] water application needs for rice transplanted from 2 July backwards, on 16 June, 31 May and 16 May, could be approximated as 180 cm, 204 cm, 230 cm and 248 cm, respectively. The 'indexed water application need of rice based on the transplantation pattern' was estimated for each year from 1990 to 2008. It varied from 194 cm to 206 cm during 1990 to 2007, but declined significantly to 185 cm in 2008 when the rice transplanting pattern has changed significantly in response to the Act (Annexure II).

During the period 1990-2005, the net monsoon recharge varied from 0.037 m to 1.834 m, the monsoon rainfall from 250 mm to 581 mm and the total rice area from 2015 thousand ha to 2642 thousand ha. The relationships between these variables are revealing. The irrigation water need index (per unit of rice area) is negatively correlated with the monsoon rain (-0.32); the total rice area negatively impacts the net monsoon recharge (- 0.47) as well as the change in water table (-0.56); and the net monsoon recharge significantly determines the water table in a positive way (0.91).

The impact of rice water need index, which is function of the rice transplanting pattern, on water level is derived through various relationships by stratifying the data from 1990-2005 according to different variables (Table 3). The net monsoon recharge with monsoon rainfall at less than 400 mm and more than 400 mm was 0.688 m and 1.054 m (scenario B and C in Table 3), respectively, i.e. the higher the monsoon rainfall, the higher is the net monsoon recharge. However, in this stratification, the average rice area as well as the water need index were lower when the rainfall was higher. The relationships emerged more clearly when the stratification was done into 3 levels of net monsoon recharge, i.e. <0.5 m, 0.5-1.0 and >1.0 m. When the rice area and water application needs were about the same, the higher monsoon rainfall from 375 mm to 437 mm increased the net monsoon recharge from 0.286 m

[8] It is called as 'indexed' for the reason that once the rice transplanting starts, it goes on every day, whereas we have the data of area transplanted for the specific periods and the data for water application for specific dates only. Also, the rainfall is for the whole period of monsoon, whereas it really matters on the distribution and intensity of 'a' given rain that affects the water actually applied. Thus, if a farmer has already applied the water, it does not matter even if there is too much rain afterwards on that day or likewise if 'a' given rain is too much more on a day, it substitutes only for one irrigation. Such cases are not uncommon during the rainy season.

Table 3. Impact of different variables on monsoon recharge and water level in Punjab: 1990-2005

Scenario	Variable	Rice water need index (cm)	Total rice area (000 ha)	Monsoon rainfall (mm)	Net monsoon recharge (m)	Annual rainfall (mm)	Change in water level (m)	
							June over June	Oct over Oct
A	1990-2005	199.9	2374	399	0.802	522	-0.440	-0.435
				Monsoon rainfall (mm)				
B	< 400	200.4	2489	313	0.688	434	-0.452	-0.398
C	> 400	199.2	2226	510	1.054	636	-0.424	-0.482
				Net monsoon recharge (cm)				
D	< 0.5	199.6	2450	375	0.286	478	-0.944	-0.921
E	< 0.5-1.0	198.8	2410	437	0.747	548	-0.524	-0.462
F	> 1.0	200.4	2287	412	1.334	558	0.087	0.059
				Rice water needs indexed based on transplanting pattern (cm)				
G	194-198	196.3	2052	443	0.784	587	-0.309	-0.205
H	198.1-200	199.0	2368	437	0.856	560	-0.440	-0.324
I	> 200	203.6	2541	333	0.749	444	-0.505	-0.678
				Rice area (thousand ha)				
J	< 2500	198.9	2153	470	1.080	613	-0.159	-0.111
K	> 2500	200.8	2594	328	0.524	431	-0.721	-0.758

Note: For details of variables, refer to Annexure II

to 0.747 m (scenario D & E)[9]. But, when the monsoon rainfall was even marginally lower at 412 mm, the lower rice area by more than 150 thousand hectare still resulted in the net monsoon recharge further increasing to 1.334 m (scenario F).

The rice transplantation pattern changed after implementation of the Act and accordingly, the rice water needs index decreased significantly to 185 cm in 2008. It was the highest at 206 cm in 1997 and the average for 1990 to 2005 was 200 cm. Thus, the decline in the rice water need index could be 15-21 cm. However, the actual decline in water need would be more than this, as the data are for specific points, viz. 16 May, 31 May, 16 June and 2 July (it is the same as of 2 July onwards as already discussed), which was superimposed on the area transplanted by the end points of the respective periods. To estimate the same, the data on ETRs of rice transplanted as of various dates, available from the experiments of PAU, Ludhiana, were used (Table 4)[10] The dates which could better reflect the water needs for the rice transplanted during the given period fall closer to the middle of the period such as 10 May for the period 1-15 May. The extra water needs for 10 May (over 16 May as used for indexing the water need) were estimated as the proportionate change in ETR changing the need for water in the same proportion. Thus, the average extra water need of rice was estimated at about 10 cm over the indexed water need estimates. However, there will be extra water need for all the years and the change in transplanting pattern with the Act may account for about half of this, i.e. about 5 cm. It also needs to be noted that as the delayed transplanting reduces not only the water application need but also the groundwater withdrawal

[9] The additional rainfall of 62 mm increasing the water recharge by 461 mm, with all other factors remaining the same, means the soil porosity (% of soil void of material or the air space between the soil particles which can be filled with water) of 0.134. The net fall in water table during the 1990-2005 *rabi* seasons (June over October) was 124 cm per year, the ETR of wheat was 35 cm and the rainfall was 12 cm; these parameters gave the soil porosity as 0.185. The porosity of sandy loam soils is 0.2 (Hira and Khera, 2000) and it is higher as the sandy proportion increases, and decreases when the clay component increases.

[10] Ludhiana is in the centre of the central Punjab (rice belt), and thus, the experiments at Ludhiana involving the agro-meterology factors, would very likely approximate the average situation of the central Punjab.

Table 4. Impact of date of transplanting of rice on its ETR and water application needs in Punjab

Date of rice transplantation	ETR of rice (cm)	Rice water need from experiments (cm)	Estimated rice water needs (ETR basis)* (cm)	Extra water needs over 'indexed' (cm)
1-May	84			
10-May	80		255	+7
15-May / 16 May	(78)	248		
20-May	76		242	+12
30-May / 31 May		230		
10-June	60		211	+7
15-June / 16 June	(58)	204		
20-June	56		194	+14
30-June / July	52	180		

Source: Hira and Khera (2000), p. 57 for ETR; Kalkat *et al*. (2006).

Notes: The figures within brackets are averages of two surrounding dates.

*For example, for 10 May the ETR is 80 cm and the estimated ETR for 15/16 May is 78 cm; the water need for 15/16 May from experimental data is 248 cm. Thus, the change in ETR from 78 cm to 80 cm increases the estimated water need to 255 cm (=248/78*80).

(read gain in water table) by more than the difference because the rainfall is higher and evaporation is lower in the later part of the growing season[11]. Thus, considering the late transplanting substituting the monthly rainfall of May by that during September, the net rainfall increase to supplement the water application to rice is 55 mm. It means another saving of 5 cm in water from the changed transplanting pattern and thus, the total savings would be, on an average, of about 30 cm[12].

The parameters developed as above were used to estimate the fall in water table due to early transplantation of rice and accordingly the impact of the Act was simulated. It must be mentioned that the food-security demands of the nation will remain on the forefront, maintaining the effective price support and the relative profitability of rice would perforce the rice to continue covering as much area as possible. Little wonder that the rice area increased gradually up to 1997 to 2278 thousand ha, from 2015 thousand ha in 1990. But, it jumped up to more than 2500 thousand ha in 1998 and had been more than this level since then with maximum at 2647 thousand ha in 2004 and in fact, the highest at more than 2660 thousand ha in 2008, the first year of the Act.

Over time, there would be other improvements bringing increase in water-use efficiency, *albeit* may be slowly and some assumptions about the rainfall have to be factored in for developing the estimated impact of the Act (Table 5). From 1990 to 2005, the average monsoon rainfall at 40 cm (scenario A) yielded the average monsoon recharge of 80 cm and the average

[11]The month-wise average rainfall, evaporation, maximum temperature and wind speed in Punjab, (1990 to 2006):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall, mm	20	28	18	11	15	50	154	138	70	9	7	12
Evaporation, mm	43	61	114	190	303	248	154	146	123	109	69	46
Max temp, °C	17.7	21.7	27.2	35.9	39.0	37.5	34.0	34.1	33.2	32.5	26.9	20.7
Wind speed, km/hour	3.6	4.1	4.4	4.8	6.8	6.5	5.2	3.6	3.4	2.4	2.4	2.6

Note: The maximum temp. and wind speed are averages of 2000-2007 for Ludhiana.

[12] In fact, the 5 cm gain as rainfall water would mean, considering the soil porosity as 0.2, the recharge of 25 cm (Hira and Khera, 2000, p 34). But, since the rainfall would have been there even otherwise, we consider the difference in net withdrawal as the contribution of changed transplanting pattern.

Table 5. Estimation of the impact of Act on the water table in Punjab

Parameter	Average of 1990-2005	Average with rice area > 2.5 million ha	Projected	
			Basis	Actual
Average rice area, '000 ha	2374	2594	Food security	2500
Monsoon recharge, cm	80	75	Corresponds to monsoon rain of > 40 cm	105
Rabi withdrawal*, cm	124	125		124
Monsoon rainfall, cm	42	33		51
Total rainfall, cm	54	43		64
Water need indexed based on transplanting pattern, cm	199.9 (max=205.7)	200.8	1st year of the Act	184.9
Fall in water table**, cm	44	74		Rise***
Check on water table fall due to the Act				
(i) Reduction in water applied (including rainfall) = 21 - 26 cm				
(ii) Substitution of more rainfall for water withdrawal = 5 cm****			About 30 cm	
As per cent of average water fall			About 65%	

* The average r*abi* withdrawal is generally about the same in all the years (Annexure II and Table 4)

** For fall in water table, refer to the averages of June-over-June and October-over-October (Table 3)

*** The normalized rainfall gives 20 cm extra recharge *plus* about 30 cm as savings of rice nursery Act, which *add* up to 50 cm, which is more than the long-term fall in water table. However, the savings with improvements in water-use efficiency over time are still needed to cope with the higher rice area and lower rainfall situations.

**** The average rainfall during May and September is 15 mm and 70 mm, respectively

fall in water table of 44 cm (Annexure II). Thus, the change in rice transplanting pattern effected due to the Act demanding less water by about 30 cm means that 60-65 per cent fall in water table would be controlled. Conversely, it would be the gain in water table due to the Act. The improvements in water-use efficiency over time can be gauged by comparing situations A and H (Table 3); with rice area at more than 2.5 million ha, which was 9 per cent more than the average of 1990-2005 even with a lower monsoon rain by 9 cm (42 vs 33 cm - K) resulted in a decline in the monsoon recharge of 5 cm only (80 cm vs 75 cm). It means another 4 cm control on decline in water table due to gradual improvements in overall water-use efficiency. And the concerted measures to improve the water-use efficiency like the laser levellers, etc. have been taken up on a large scale only since 2005[13]. These may be taken as safely another equivalent control on fall in water table, i.e. about 8-10 cm until now and it would increase further as the area coverage and other measures of improvement in water-use efficiency gather momentum.

When the annual rainfall is 64 cm correspondingly pouring about 51 cm during the monsoon period, the rice area on average gives monsoon recharge of 105 cm (scenario C). Thus, the situation of good rainfall and the rice area as envisaged to being above 2.5 million ha, would lower the monsoon recharge by 5 cm only (from 105 cm to 100 cm). This gives another 20 cm check on the fall in the water table due to the higher monsoon recharge (from 80 cm to 100 cm). These combined factors give a rise in water table, which will be compared later with the situation of 2008. There have been gradual improvements in water-use efficiency over time for which some allowance must also be incorporated. It may also be noted that the contribution of the Act in controlling the fall in water

[13] The laser levellers along with high-powered tractors till date have been given on subsidy to 130 Village Cooperative Societies and 315 Agricultural Service Centres managed by agriculture graduates / private entrepreneurs for custom-hiring since then through the Punjab State Farmers Commission. Another 228 individual farmers' applications have also been approved.

table by about 30 cm or in supplementing the rise in water table, as the situation may be, would be about the same[14].

It may be noted that about 70 per cent of the water applied to rice percolates down / recharges groundwater again: seepage = water applied *less* ETR (Table 4) and the applied water to rice (around 16 June) is about 58 per cent of its total water needs (Table 2). Thus, an average of 28 cm of water in application means reduction in the net withdrawal of about 4.87 cm only, which means, with the average soil porosity of 0.16, a saving of 30.5 cm of groundwater level.

The relative contribution of rainfall to the water needs of rice also determines the impact of the Act on the water table (check on the fall or contribution to the rise on year-to-year basis). Water need index with the given transplanting pattern remaining the same, 1 cm less of monsoon rain means another 0.3 cm of water withdrawal from the sub-soil, which will lead to about 2 cm net fall in water table. The delay in transplanting from June 10 to June 15 reduces the water need index by 5 cm. Thus, in the years of low rainfall, when the groundwater withdrawal is more severe, the impact of the Act on the fall in water table would be even more than 65 per cent. The remaining fall is manageable in the long-run with the rainfall becoming normalized and continuous improvements in the water-use efficiency[15]. And finally, although there are too many exogenous variables in each system[16], the estimates as derived above from the historical data, are the most likely ones.

The Case Study of Year 2008

The rainfall was better during 2008; it was 51 cm from April to September 2008. Using the coefficients developed in this paper, the approximation of the rise in water table in the central Punjab would be as follows:

Rice area = More than 2.5 million ha

Monsoon rainfall = 51 cm

Average monsoon rainfall when rice area was more than 2.5 million ha = 33 cm

Excess monsoon rainfall = 18 cm

Therefore, rise in water table = 18 / soil porosity[17] = About 113-134 cm

Fall in water table when rice area was more than 2.5 million ha = 74 cm

Net raise in water table due to better rainfall = About 40 - 60 cm

Check in fall in water table due to the Act = About 30 cm

Improvements in water-use efficiency, etc. = About 8-10 cm

Total estimated rise in water table during 2008 = About 80-100 cm

This estimated rise in water table in central Punjab is close to what has been recently reported in the press, which is the provisional one and is attributed to the sources of Department of Agriculture. One paper has reported it as one to two metres (Kaur, 2009) and the other one has reported as from 50 cm in some districts to two to three metres in other districts (Singh, 2009). However, these statements refer to the general situation including the areas outside the central zone where, at some places, the water table has already been rising. Nonetheless, this estimated rise in water table in central Punjab is most likely to be close to the actual one.

[14] Our estimate of about 30 cm, as the contribution of change in transplanting pattern of rice for the central Punjab due to the Act, accounts for the change in ETR and the substitution of more rainfall for water withdrawal. Based on ETR only, the saving in water due to delayed transplanting in Ludhiana was estimated at 16 cm in 1994-96 when the water table in Ludhiana showed the average increase of 24 cm per year over the average decline of 38 cm per year during 1990-94. However, the change in transplanting pattern during 1995-96 and 1996-97 seasons was marginal only (see Table 1). The rainfall was higher during 1994-96 over 1990-94 by 9.2 cm per year and accounted for 46 cm change in water level (Hira and Khera, 2000, p. 34).

[15] The improvement in water-use efficiency, assumed at equivalent of 50 mm rainfall, decreased the required reduction in rice area for maintaining water table balance from about 10 lakh ha to less than 5 lakh ha, see, Karam Singh (2007; 2008).

[16] For instance, see the following relationships, which, however, are not exhaustive:
ETR = f (Temperature, humidity, transplanting, rainfall, wind, etc.)
Fall in water table = f (Rainfall, rice area, transplanting, withdrawal, other uses, canal water, etc.)
Fall due to early transplanting = f (Rainfall, total area, temperature, humidity, etc.)

[17] As shown earlier, the estimated average porosity ranged from 0.134 (based on the behaviour during the monsoon) to 0.185 (based on the behaviour during the *rabi* season) for the central Punjab. The mid value is 0.16.

It may also be noted that during 1994, the year of maximum monsoon rainfall of 58 cm and the rice area even less than 2.5 million ha (2265 thousand ha, which was also the highest till then and as record for the next two years), the water level had improved, but less. Following the same logic, when the average monsoon rainfall was 47 cm and the rice area was less than 2.5 million ha, the excess rainfall of 11 cm would give a raise in water table of about 69-82 cm, which is close to the one recorded for the next June-over-the previous June at 71 cm.

Alternatively, to maintain the water balance in the long-run, considering the water requirements of the *rabi* season as well, the total monsoon requirement is estimated at about 47 cm[18], say 50 cm, to be on the safe side. The long-term average monsoon rainfall being 40 cm, additional arrangement of 7-10 cm is required, of which about 5 cm would be compensated by the Act. Thus, it is still very pertinent to improve the water-use efficiency and/or to delay the transplanting still further. At June 15, the water need index goes down by about another 5 cm, which after allowing for the combination of percolation of the water applied from the withdrawn source, and the substitution by the rainfall, would maintain the water balance in the long-run. In fact, on year-to-year basis it depends on when the monsoon starts. An early monsoon can cope with an early date of transplantation and vice versa, which again reflects the earlier connotation that the impact of the Act would be more pronounced in the years of low rainfall.

It is also important to note that before the Act, the transplanting used to start much earlier, say as by mid-May when the expectation of the rainfall was low and it was not a significant factor in consideration for the transplanting pattern. But after the Act, the behaviour of the pre-monsoon showers is expected to determine significantly the daily coverage of the transplanted area. In the years when it rains or has already rained by June 10 (2008), the transplanting is expected to pick up quickly but in the years of low or no rainfall by this cut-off date (2009), the transplanting would pick up rather at a slower rate and it may also lead to higher impact of the Act in such years. Thus, rather emphasizing on the delaying of the transplanting to June 15, which may further limit the transplanting period, it is better to emphasize on improving the water-use efficiency and substitution of other low water-requiring crops to the extent possible in the years of poor rainfall[19].

(iii) Impact on Electricity Consumption and State Subsidy

The early transplanting of rice, which needs more irrigation water application, means use of more electricity / power. The extra irrigation requirement for 15-June transplanted paddy is 1 irrigation more over the one transplanted later. The additional irrigation water applied for rice transplanted on 16-May is 42 cm, which is equivalent to 6 irrigations. Likewise for rice transplanted on 31-May, the additional irrigation water applied is 23 cm, which is equivalent to 3 irrigations[20]. It takes about 10-12 hours for one ha irrigation. An electric motor consumes about 6 units (kWh) per hour. Considering the rice area, which was transplanted earlier at 6 per cent up to 15 May, another 12 per cent between 16-31 May and another 46 per cent from 1 to 15 June (Total up to 15-June = 64 per cent, which is the average of 1998 – 2005, when the rice area was more than 2500 thousand ha), the savings in electricity were worked out as shown in Table 6[21]. These estimates show that some 46 million electric motor

[18] The average fall in water table during October-over-October when the rice area is more than 2.5 million ha has been 76 cm, which itself requires some 46 cm monsoon rainfall for correction, and only a marginal allowance of additional net *rabi* withdrawal (i.e. excess over the monsoon recharge) of 4 -5 cm makes it 47 cm of monsoon rainfall.

[19] During the field visits in 2009 transplanting season, the farmers have been even more appreciative of the Act for saving them from the otherwise high irrigation expenses (with diesel engine) because the electricity crisis / shortage also increases in the years of low rainfall. Also for similar reasons, the possibility and probability of substitution for low-water requiring crops is also higher with the Act in the low rainfall years.

[20] The total extra water application needs of rice over the rice transplanted during the succeeding fortnight (see, Table 2), based on the experiments were 18 cm, 26 cm and 24 cm for May 15, May 31 and June 15, respectively. An irrigation requires about 7-10 cm, which means 2, 5 and 8 additional irrigations (water including rainfall) for the rice transplanted on 15 June, 31 May and 15 May, respectively over that transplanted in July; and, out of these one (additional) irrigation can be attributed to be from the rainfall in each case.

[21] These estimates are a bit conservative as the adjustment was not made for corresponding the dated coefficients with the period coefficients, like in the previous section.

Table 6. Estimation of the savings in electricity requirements and subsidy due to the Act in Punjab

Date of transplanting rice	Total irrigation water applied (cm)*	No. of extra irrigations**	Percentage of area transplanted	Additional electric motor hours (emhr)
16-May	179	7	6	420
23-May		6	4	240
31-May	160	4	8	320
7-June		3	20	600
15-June	137	1	26	260
July onwards		0	36	0
Total electric motor hours for every 100 ha of rice area		=	1840	
Total electric motor hours for 2.5 million ha of rice area		=	46 million	
Total electricity saved***		=	46 m × 6 units / emhr =276 million kwh	
Value / subsidy @ Rs 3.92 per unit****		=	Rs 1082 million (Rs 108 crores)	

Notes: * See, Singh *et al*. (1996); and Table 2.

** An irrigation applied to rice was assumed to be equivalent of 7-10 cm

*** The total electricity supply to the agriculture sector was 8229 million kwh during 2006-07

**** The average revenue per unit sold to small industry was Rs 3.95 and that to agriculture was Rs 0.03; the difference of Rs 3.92 per unit is considered as the subsidy to agriculture

hours were saved because of the strict adherence of the ordinance, i.e. not transplanting rice before June 10. This amounted to a saving of 276 million kWh of electricity and the consequent decline in electricity subsidy to agriculture (direct savings of the Government of Punjab), which worked out to be Rs 108 crore. These are only conservative estimates[22], as shown by the actual broadly comparable field data from the cost of cultivation scheme, which showed that the total irrigation motor hours (of which 97 per cent were electric motor hours) were less by 26 per cent in case the paddy was transplanted after June 10 over that for planted before 10th June[23] (Table 7). These savings in electric subsidy are indeed significant for the economy of Punjab state.

The first[24] indicator of confirmation of the parameters used and the estimates arrived at are given by a brief comparison with the data from the Punjab State Electricity Board (PSEB). During 2008; there was an increase in rice area by 4.8 per cent, there were additional tubewell connections by about 3.7 per cent and there has been a continuous increase in electricity consumption per tubewell at the rate of 5.2 per cent per year during 2000-2007. These parameters would have increased the electricity consumption in agriculture during 2008-09 over 2007-08 by about 8 per cent, the rate which was also estimated by the PSEB, though the Punjab State Electricity Regulatory Commission approved the growth rate of 5 per cent in the Tariff Order for 2008-09 and accordingly, PSEB gave the projected estimate of 6595 million units for April-September 2008. But, it is striking to note that it is one of the few exceptional years when the PSEB has reported a decline in electricity consumption (actual) in agriculture during April to September (rice season) 2008 by 562 million units, from 6288 million units in 2007 to 5726 million units in 2008 (Table 8).

The decline in electricity consumption has included the savings due to the Act and the better rainfall during 2008-09. In its 2009-10 report, while giving the actual Agricultural Power (AP) consumption figure, the PSEB has acknowledged the role of the Act and better rainfall

[22] It would increase further as the water table improves over time. It takes 2-times more power to lift the same quantity of water from 10 metre depth and 3-times more power from 15 metre depth as compared to power required to lift water from a water table at 5 metre depth. See, Government of Punjab (2002), pp14.

[23] This could be done for a limited sample from 10 villages only in the central Punjab districts.

[24] The first draft of the paper was completed in October 2008 since when this section above is unchanged; the data from the Punjab State Electricity Board became available to the author in May 2009.

Table 7. Date of transplanting and irrigation machine use for paddy in Punjab: 2007-08

Date of transplanting		No. of plots	Total area (ha)	Electric motor (hours/ha)	Diesel engine, etc. (hours/ ha)	Total irrigation motor (hours/ ha)
Up to June 10		45	99	298.90	6.01	304.91
After June 10		97	136	231.66	9.47	241.13
Increase in irrigation for early transplanting	Absolute			67.24	(-) 3.46	63.78
	%			29.03	(-)	26.45

Source: Derived from the cost of cultivation data

Table 8. The Act and electricity subsidy as per Punjab State Electricity Board

Increase in rice area during 2008 over 2007	= 2.61-2.65 million ha (1.53 %)		
Av. additional tubewell connections / year[a]	1990s = 21435 (3.8%)		
	2000s = 29277 (3.7%)		
Growth rate of electricity used in agricultureduring 2000-01 to 2007-08	Per tubewell	= 5.2 %	
	Per year	= 8.6 %	
Electricity consumption during April-Sep (actual) million units	2007-08	= 6288	
	2008-09	= 5726[b]	
Growth rate over the previous year		-8.94	
Decline in electricity consumption during *kharif* 2008-09 (million units)	Due to the Act[c]	= 276	
	Due to better rainfall	= 286	
	Total	**= 562**	
Decline in electricity subsidy during *kharif* 2008-09 (in crore Rs)	Rate per unit	Rs 3.92 [d]	Rs 2.277 [e]
	Due to the Act	108	63
	Due to better rainfall	112	65
	Total	220	128

Source: PSEB (2008) and Government of Punjab, *Statistical Abstracts of Punjab*, various issues.

Notes: [a] Total number of tubewells in Punjab as of March 31, 2008 were 968007 [submersible: 456680 (47.2%) and monoblock: 511327 (52.8%)]; (PSEB, 2008). There were 53858 sample meters (21128 on submersible and 32730 on monoblock tubewells) installed for assessment of agricultural power (AP) consumption and PSEB is continuously increasing the sample meters for improving the accuracy of AP consumption.

[b] In its 2008-09 report, the PSEB has given the projected estimate of AP consumption for April to September @ 5 per cent growth as allowed by the Punjab State Electricity Regulatory Commission, at 6595 million units.

[c] As estimated in the previous section (Table 6).

[d] See foot note to Table 6. Also note that the average earning (tariff) of PSEB from supply to manufacturing unit in 2008-09 is Rs.3.92 per unit.

[e] The PSEB receives subsidy @ approved by the PSREC. During 2007-08, PSEB received the subsidy of Rs 2084 crore for the supply of 10030 million units to the agriculture sector, which gives the per unit rate of subsidy at Rs 2.277.

by saying, "Taking into account heavy rain in first half of FY08-09 and late start of paddy season ….., it is observed that the actual AP consumption for first half of the FY08-09 has been very low as compared with that observed in similar period of previous year …..". It has already been estimated in the previous section that about 276 million units of electricity were the savings due to the Act in 2008-09 rice season. Thus, the remaining 286 million units of electricity had been due to the better rainfall during 2008-09. In terms of subsidy, the savings to the PSEB for supplying the saved electricity during April to September 2008 to the manufacturing sector comes to Rs 220 crore out of which Rs 108 crore is due to the Act and Rs 112 crore due to the better rainfall (including the improvements in water-use efficiency, if any) during 2008-09. It may

also be noted that there are additional 10 per cent electricity taxes on the electricity sold and another Rs 1 lakh for 1 million units of electricity sold to consumers in the municipality areas as octroi charges. This adds to another about Rs 28 crore flowing to the State Exchequer[25]. Thus, considering the Act alone, the savings to the State exchequer are about Rs 122 crore per year, split as savings of the government including its extra tax earnings as Rs 77 crore and the additional net earnings of the State Electricity Board as Rs 45 crore. And if buying the electricity on peak consumption days beyond the allocated ones is considered, it almost touches a double-digit buying rate per unit, the impact of the Act on the Punjab economy would be even more enormous indeed.

(iv) Impact on Relative Humidity

In Punjab during May, the relative humidity (RH) is lowest, wind speed is highest and temperature is maximum; all of which are positively and highly conducive to increase the rate of evaporation. The early transplanting of rice, which requires submergence of transplanted seedlings at least for two weeks as recommended, is like pouring of water on a hot oven fuelled by high wind speed. Both, minimum and maximum values of RH, have been simulated as a function of 'Rainfall', 'Temperature' and ' percentage of Rice Area Transplanted' (which approximates the additional quantum of water made available through irrigation on soil surface). During 2008, there was a quite reasonable and well-spread rainfall during May to mid-June (onwards too) at almost regular intervals, and the RH was nowhere close to pinching. The rainfall from early-May to mid-June though makes the water available on surface (and even in the atmosphere) to raise the RH, but it also cools down the temperatures[26]. In contrast, the standing water in early-transplanted rice applied as irrigation through pumping out underground water, though also makes it available for excessive evaporation (and builds RH), it does not cool down the temperatures.

The average values of different variables for 7 weeks (April 30 to June 17) for different years (1996 to 2005) are given in Table 9. The maximum relative humidity[27] during these weeks ranged from 62 per cent to 80 per cent, while the minimum one ranged from 12 per cent to 26 per cent. The cumulative rainfall ranged from 9 mm with on rainy day (2005) to 141 mm (1997), though the number of rainy days were maximum in 2002 (8) when the rain fall was 86 mm. The maximum temperature ranged from 38.8 °C (1997) to 42.9 °C (2003).

Various regressions[28] tried with different combinations of 3 years and 5 years had the R square, varying from 0.53 to 0.82 in the case of minimum RH and from 0.34 to 0.67, in the case of maximum RH. It may be noted that with the summer season approaching the monsoon, the maximum RH builds up, which minimizes its variation. The coefficients of early transplanted rice area (up to June 15 – week-wise), which was the main focus of this study and temperature were mostly significant at 90-99 per cent level of confidence, but that of the rainfall was not generally statistically significant. The rainfall during this period (May 1 to June 15), which is the pre-monsoon period in Punjab, is scanty and sparse and hence cannot be expected to be a significant variable in determining the RH during this period. In any case, the normal

[25] The financial transactions between the Government of Punjab (GOP) and the PSEB would be : The GOP gets all the taxes, i.e. Rs 22 crore and its Municipal Corporations get the octroi of Rs 5.62 crore. The GOP would pay fewer subsidies to PSEB by Rs 128 crore and thus its total savings would be of Rs 156 crore. The PSEB's additional earnings would be Rs 220 crore *minus* the lower subsidy receipts by Rs 128 crore, i.e. Rs 92 crore. The impact of the Act in 2008 was about 50 per cent of these transactions; and, in absolute terms, it will be about the same every year. The balance would be the impact of the rainfall, which would vary from year to year.

[26] During 2008, the period under reference started with maximum temperatures of above 40 ^{0}C (from May 1 to May 4); the rainfall on May 4 and May 5 lowered the temperature. The temperature again reached above 40°C on May 16 and May 17 and the rainfall during 19-21 May brought it down again.

[27] The RH of 40-70 per cent is considered normal. Going by this criterion, during the period 1996-2005, RH crossed more than 70 per cent at least in one or the other week every year. In fact out of the 70 weeks under reference, the RH reached more than 70 per cent in 37 weeks. It was so in 3 out of 10 years in the 1st week (18th SMW) which built up to be so in 4 years (not necessarily the same) during the next 2 weeks, in 5 years during the following 2 weeks and in 8 years during the last 2 weeks (SMW 23 & 24).

[28] The regressions are omitted for the sake of brevity. The interested readers may request these from the author.

[29] The rainfall was recorded even when it was less than 3 mm, but the rainfall on a rainy day is to be at least 3 mm.

Table 9. Average values of different variables, May 1 to June 15

(based on 7 meteorology weeks)

Variables	Normal	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Maximum RH, %	51	66	80	73	71	78	77	73	62	75	65
Minimum RH, %	26	21	24	18	21	26	26	20	12	20	20
Rainfall, mm (per week)	8.0	14.5	20.2	6.9	5.2	16.6	10.6	12.2	3.1	15.4	1.3
Rainfall (cummulative)	56	101	141	48	36	116	75	86	22	108	9
Rainy days	4.0	5	3	1	4	5	6	8	3	4	1
Of which during the last two weeks	2.7	5	3	1	1	3	4	4	1	2	1
Temp, °C (max)	39.1	39.9	38.8	42.2	42.0	41.7	40.5	42.3	42.9	42.7	40.5

Source: Department of Agrometeorology, P A U, Ludhiana

cumulative rainfall for this period was only 56 mm on 4 rainy days only, of which 2.7 rainy days[29] were during the last two weeks of June (June: 4-17)

The significant regression coefficients of per cent rice area ranged from 0.20 to 0.33 for impacting minimum RH and from 0.18 to 0.28 for impacting maximum RH. It means as the transplanted rice area increases by 10 per cent, the relative humidity will rise by about 2.5 per cent points. When the rice area comes to about 50 per cent or higher up to mid-June, which had been the case earlier in the past (up to 2007), there is about 12-13 per cent points raise in the relative humidity (Table 10).

The rice area by May-end reaches on an average to 18.8 per cent which adds to about 4 per cent points in relative humidity. It was maximum at 28 per cent in 1997-98, which added to the relative humidity by about 7 per cent points. By mid-June, the average rice area has been about 58 per cent with addition to relative humidity by about 14 per cent points. The maximum rice area transplanted up to June 15 reached 66 per cent in 1998-99 in Punjab and has been covering close to it up to 2004-05, with consequent increase in RH by about 16 per cent points[30].

During 2008, there were well-spread rains from May to June 15 (an unusual case), but the rice area transplanted was almost nil (0.6%) up to May-end and was only 22 per cent up to mid-June, and that too mostly after June 10. Thus, the role of decline in rice area transplanted up to mid-June, an obvious impact of the Act, in containing the relative humidity, is significant.

(v) Other Long-term Developments and Environmental Impacts of the Act

The legality of regulating the sowing of the nursery of paddy in order to delay the rice transplanting to mid-June was not a hard decision for which two different governments dilly-dallied for two years[31]. However, it did require some bold actions[32]. And the government exemplified in ploughing the fields transplanted earlier than the mandate and even in initiating actions including the suspensions of some of the officials who did not take action / showed laxity against the violating farmers. There were no resentments from the farmers / farmers' organizations. In fact, the farmers now opine that this legislative control should have been brought much earlier rather than the campaigns like "delay rice transplanting - save water – save Punjab".

[30] The RH builds up with time too towards monsoon. Thus, time also enters as a variable, which obviously is highly correlated with the rice transplanted area whether considered as additional every week or the cumulative during the successive weeks. Even using the coefficient of rice area from these regressions, the build up to the maximum RH by rice area was found to be 11.5 per cent points.

[31] The draft of the Act was first put to the Government in early-2006, but it was finally accepted in 2008.

[32] "Hard decisions, bold actions ….. put the agricultural economy of the state (Punjab) on a high growth pattern …… the state again needs to take some hard decisions and initiate bold actions" *See*, Kalkat *et al*. (2006).

[33] In 2002, a rough estimate of replacement cost of existing centrifugal pumps in 28 % area of the state, where the water table has fallen by more than 10 metre depth, with submersible pumps in the next 5 to 6 years was placed at about Rs 3000 crore (Government of Punjab, 2002).

Table 10. Impact of rice area on relative humidity (RH)

(% points)

SMW	Per cent rice area		Increase in RH (% points) with rice area as	
	Assumed	Average	Assumed	Average
April 30 – May 6	10	1.0	2	0
May 7 - May 13	20	4.8	5	1
May 14 – May 20	30	9.5	7	2
May 21 – May 27	40	15.5	9	4
May 28 – June 3	50	25.8	12	6
June 4 - June 10	60	43.3	14	10
June 11- June 17	70	64.0	17	15
15-May	Maximum		Maximum	
	8	6.3	2	1
31-May	28 (33.5)	18.8	7 (8)	4
15-Jun	66 (82)	58.0	16 (20)	14

Source: Estimated from the fitted regressions, using the average of the significant coefficients

Note: Figures within the brackets refer to the Ludhiana district.

And the farmers are right; they are always right. They had been deepening the tubewells every few years and ultimately even going for the submersible tubewells, which had been too costly[33]. The high cost involved was particularly one of the strong root-cause of the agrarian crisis for the small and marginal farmers (Singh, 2009). There were reports that the hand pumps (for drinking water supply) in many a villages in Punjab were also drying up, and it was being apprehended that it might lead to some social tensions. During 2008, some of these have started yielding water again; and even if we assume the revival of one such pump in each village over time, it means some 10,000 drinking water sources having been saved; a marvelous bonus indeed!

It was generally apprehended that it would be difficult to manage the transplanting within a short span and there could be labour shortage, leading to rise in wage rates. The transplanting has been well managed and in fact, the total area under rice has increased to 2735 thousand ha in 2008-09, surpassing the previous peak of 2647 thousand ha in 2004-05. But, the wage rates did rise, though these had increased due to other factors like the implementation of the National Rural Employment Guarantee Scheme (NREGA) reducing the inflow of migrant labour to some extent, inflation rate and rise in minimum support prices, which also trickle down partly in increasing the wage rates.

The Act in place will also mandate the breeders to include the time of transplanting as a variable in their programmes so that the emphasis is on 'evolving varieties of rice that yield maximum when transplanted from 10 June onwards'[34].

The delayed transplanting delays the build-up of relative humidity. As a result, the harmful bacteria and pests vulnerable to lower humidity and high temperatures would be exposed for a longer duration and effect a natural control[35]. Second, the continuous availability of the host material will be adversely affected and reduce the population of some pests.

The delayed transplanting also changes the managerial requirements for agriculture. Many farmers told during the September *Kisan Mela* at PAU, Ludhiana, that they could visit *Mela* this year because the rice crop was still not mature. Thus, it might be another push factor in reinvigourating the research-extension-farmer linkage.

As the crop matures late, the problem of excess moisture, which used to be common in September at the time of marketing, will be less severe. It used to create problems for the farmers while marketing as the government was unwilling to enter the market early for procurement (and price support)[36]. However, the marketing gluts might increase but the Punjab's marketing system is well known with its good infrastructure to handle the situation.

Another most important effect of delayed transplanting of rice is on the environment. The harvesting, particularly the marketing of rice creates huge amount of fine dust but the delay in these

[34] This was recommended earlier but hardly got any action so far [*see*, Kalkat (2006), p 28].

[35] An example is that of the surface grasshopper, which emerges in hot months only after the building up of relative humidity.

[36] It used to be a problem more for the small and marginal farmers who often ended with unreasonable price cuts in case of early marketing. The large farmers having large quantity to sell could prevail upon the commission agents to lift the produce early by offering to receive the payment only after the government entered the market.

operations due to delayed transplanting brings it to the higher dew-factor times, which helps in its settling down every night. In some years, the pollution had been so aggravated that it became difficult to breathe even for a healthy person and the dust could be settled with rain only. Secondly, the farmers being aware of the timely sowing of wheat, preferably up to 3rd week of November, due to shorter time–span left after delayed rice harvesting, would be under pressure to go in for new machinery like happy seeders, which help direct sowing with simultaneous cutting and burying the rice stubbles. This will control the burning of rice straw[37], thereby saving the soil micro-organisms and environment as well as effecting cost-saving[38].

Conclusions

The falling water table in the heart of rice belt in Punjab has been a matter of serious concern. Among other factors, the early transplanting of rice when the temperatures are very high, humidity is low and the evapo-transpiration rate is maximum, has been aggravating the crisis through higher demands on irrigation water to be applied, which has been as high as 68 cm, 50 cm and 24 cm for rice transplanted on 16-May, 31-May and 16-June over that transplanted from July onwards, respectively. Moreover, the delayed transplanting substitutes more rainfall for irrigation water to be applied. It also has other repercussions on the electricity requirements for irrigating rice and hence the electricity subsidy. The impact of the Act has been estimated using the time series (1990 to 2005) data on the transplanting pattern (and accordingly estimating the water need index for rice based on the experimental data on evapo-transpiration rates and actual water applied), rainfall, monsoon recharge and rice area. The overall general impact incidence matrix of the Act, and specifically for 2008 has been encapsulated in Table 11.

It has been estimated that (i) The fall in water table can be checked by about 30 cm, which is about 65 per cent of the long-term rate of fall, by delaying the transplanting beyond 10th June, as envisaged in the Act (The Punjab Preservation of Sub-soil Water Act, 2009: *to provide for the prohibition of sowing nursery of paddy and transplanting of paddy before the notified dates*), enacted on the initiative of Punjab State Farmers Commission. The government had issued an Ordinance in 2008, and changed into an Act in March 2009. The remaining 40 per cent is manageable with other measures by improving the water-use efficiency and better recharge in better rainfall years; (ii) The total savings in electricity due to the Act come to 276 million kWh and the saving in electricity subsidy is of Rs 108 crore. The increase in rice area (1.53 per cent), additional tubewell connections (3.7 per cent) and the growth rate of electricity used per tubewell (5.2 per cent) per year would have increased the electricity consumption in agriculture during 2008-09 over 2007-08 by about 8 per cent, but strikingly it is one of the few exceptional years when the PSEB has reported a decline in electricity consumption in agriculture during April to September (Rice season) 2008 by 562 million units (and also acknowledged it being due to better rainfall and the Act). Thus, the savings of 286 million units during 2008-09 have been due to better rainfall (including improvement in water-use efficiency, if any). There are additional 10 per cent electricity taxes on the electricity sold and another Rs 1 lakh for 1 million units of electricity sold to consumers in the municipality areas as octroi charges. This adds to another about Rs 28 crores flowing to the State Exchequer. Thus, considering the Act alone, the savings to the State exchequer are of about Rs 122 crore per year, split as savings of the government including its extra tax earnings as Rs 77 crore and the additional net earnings of the State Electricity Board as Rs 45 crore; and (iii) As early transplanting of rice builds up relative humidity by about 15-16 per cent points, a check would control the harmful pests and bacteria, which are sensitive to high and dry temperatures.

The Act has many other long-term benefits like saving the farmers from frequent deepening and even

[37] Field surveys show that the Punjab farmers were burning about 82 % of rice straw (Beri *et al*., 2003). This meant the saving of the Nitrogen fertilizer that would be available after decomposition worth Rs 250 crores (The Punjab State Farmers Commission, 2008).

[38] With rice-straw burning, the crucial moisture is also lost, which means generally the pre-sowing irrigation has to be applied. It takes time to reach the proper moisture level for sowing, and the delay can be avoided by not burning the rice straw even if zero tillage method was not to be adopted. The cost-saving through direct sowing is about Rs 3000 to Rs 3750 per ha.

Table 11. Impact Incidence Matrix of the Punjab Preservation of the Sub-Soil Water Act

Parameter	Impact (in general and for 2008 in particular)		
1. Change in rice transplanting pattern	Up to 2007:	Up to June 15	More than 42 %
		Up to June 10	More than 30 %
	During 2008:	Up to June 15	22 % only
		Up to June 10	Negligible
2. Water table	Fall during 1990 to 2005		44 cm/ year
	Fall during 1998-2005		74 cm/year
	(when rice area was more than 2.5 million ha)		
	During 2008		**Rise in water table**
3. Electricity consumption	During April- September 2007		6288 million units
	During April- September 2008		5726 million units
	Decline in electricity consumption		562 million units
	Decline due to rice nursery act		276 million units
	Decline due to better rainfall in 2008		286 million units
	Thus, during 2008, the impact of the Act was about 50 %.		
	The absolute impact of the Act will be about the same every year.		
	The impact of the rainfall would vary from year to year.		

4. Financial earnings of the Punjab State Electricity Board and the Punjab Government	Beneficiary	Total including the impact of better rainfall (in crore Rs)	Due to Nursery Act (in crores Rs)
	Punjab State Electricity Board	**220**	**108**
	Earnings from selling the electricity saved from agriculture to the manufacturing sector		
	Government	22	11
	Earnings as taxes on electricity tariff @ 10 %		
	Municipal Corporations	**5.62**	**2.8**
	Earnings as octroi @ Rs 0.10 / unit		
	Total	**248**	**122**
5. Electricity subsidy	**Government of Punjab**		
	Saving on electricity subsidy @ Rs 2.277/unit	128	63
	Tax earnings	28	14
	Total savings	**156**	**77**
	Increase in the net earnings of PSEB	92	45

6. Other impacts	
• Relative humidity	Lower by about 10-15 % points up to mid-June
• Plant breeders	Will look for genes that yield better after mid-June transplanting
• Paddy transplanters	Will be profitable to adopt; also improves yield
• Hydrological	Hand pumps will not go dry; check on more use of submersible pumps
• Marketing	Less problematic as little rain during October to November
• Pollution	Decreases as higher dew factor helps in settling of dust quickly
Scenario for restoring water table balance in the long-run	The estimated rise in water table was about 80-100 cm in 2008. 47-50 cm of monsoon rainfall would restore the long-term balance. The long-term average monsoon rainfall is 40 cm. The Act gives about 5 cm in its present form. The delay in transplanting to June 15, though would maintain the balance but continuing improvements in water-use efficiency and possible substitution for low water requiring crops are recommended.

installing submersible tubewells, saving and even restoring the rural drinking water supply sources of hand-pumps in homes, acting as a catalyst to fine tune the paddy-transplanters, mandating the breeders to evolve the rice varieties that yield better when transplanted after mid-June, giving more crucial time to the farmers for reinvigourating the research-extension-farmer linkage and delayed harvesting and marketing causing less pollution due to the increase in dew-factor, and less burning of rice straw (saving nitrogen wastage and environment pollution) through adoption of happy seeders, etc. for timely sowing of wheat.

During 2008, the water table in Punjab, which also had better monsoon rainfall of 51 cm, rose by the estimated 80-100 cm, which is close to the provisional data of the Department of Agriculture. The rise in water table has been even more than that during 1994 when the rice area was less than 2.5 million ha and the monsoon rainfall was 58 cm, a record since 1990. To maintain the water balance in the long-run, about 47-50 cm of water (measured in terms of monsoon rainfall) is required, of which 40 cm is the long-run average and about 5 cm get compensated by the Rice Nursery Act in its present form. Although the delay in transplanting to 15 June, which reduces the water need index further by 5 points and thus would almost maintain the balance, but as it further cuts down the transplanting period, continuing the improvements in water-use efficiency and some substitution by low water requiring crops have been recommended.

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Annexure I

The Punjab Preservation of Sub Soil Water Act

Department of Legal and Legislative Affairs, Punjab

Notification The 28th April, 2009

No. 7-Leg./2009.b—The following Act of the Legislative of the State of Punjab received the assent of the Governor of Punjab on the 2nd April, 2009, and is hereby published for general information:-

THE PUNJAB PRESERVATION OF SUB SOIL WATER ACT, 2009

(Punjab Act No. 6 of 2009)

An

ACT

to provide for the prohibition of sowing nursery of paddy and transplanting paddy before the notified dates, and for the matters connected therewith or incidental thereto.

Be it enacted by Legislature of the State of Punjab in the Sixtieth Year of the Republic of India as follows:-

(Short title and commencement)

1. *(1)* This Act may be called the Punjab Preservation of Sub Soil Water Act, 2009

(2) It shall come into force at once

(Definitions)

2. In this Act unless the contests otherwise requires:-

(a) "authorised officer" means an officer authorised by the State Government by notification in the Official Gazette;

(b) Collector" shall have the same meaning, as has been assigned to it in the Punjab Land Revenue Act, 1887 and includes any other officer, as may be appointed under this Act by the State Government by notification in the Official Gazette to exercise the powers of a Collector;

(c) "farmer" means any person cultivating land either as an owner or as tenant or as a tenant or as a share cropper for the purpose of agriculture, horticulture, agro forestry and the like;

(d) "notified date" means the date, as notified under sub-section *(1)* and *(2)* of section 3; *and*

(e) "State Government" means the Government of the State of Punjab

(No farmer to sow or transplant paddy before the notified date)

3. *(1)* No farmer shall sow nursery of paddy before the 10th day of May of the agricultural year or such other date, as may be notified by the State Government in the Official Gazette for any local area.

Explanation — For the purpose of this Section shall, "agricultural year" means the year commencing on the 16th day of June or on such other date, as may be appointed by the State Government in the Official Gazette for any local area.

(2) No farmer shall transplant paddy before such date, as may be notified in this regard by the State Government by notification in the Official Gazette.

(3) Not withstanding anything contained in this sub-section *(1)* and *(2)*, the provisions of this section, shall not be applicable to –

(a) any research project of the Punjab Agricultural University, Ludhiana;

(b) any other Research Institute, as may be declared by the notified by the State Government by notification in the Official Gazette;

(c) any water logged area, as may be declared by the State Government by notification in the Official Gazette.

Explanation — For the purpose of this clause, the term 'water logged area' means an area, having depth to water table less than one metre below the ground level; and

(d) any other method of paddy crop, as may be declared by the State Government by notification in the Official Gazette.

(Power to enter into estate)

4. The authorized officer or his subordinate, servant or workman shall have the right to enter into the estate of any farmer for the purpose of surveying the area to assess the violation of the provisions of this Act.

Explanation — The term 'estate' shall have the same meaning, as have been assigned to it under the Punjab Land Revenue Act, 1887.

(Power to issue directions)

5. The authorized officer, either *suo moto* or on the information brought to his notice regarding the violation of any provision of this Act, shall be competent to issue directions to the farmer, who has violated any provision of this Act to destroy the nursery of paddy or sown or transplanted paddy before the notified date.

(Power to destroy the nursery of paddy or transplanted paddy and recover expenses)

6. In case, the concerned farmer does not act as per the directions of the authorized officer given under section 5, the authorized officer shall cause such nursery of paddy or sown or transplanted paddy, as the case may be, to be destroyed at the expenses of such farmer.

(Penalty)

7. (1) Any farmer, who contravenes the provisions of this Act shall be liable for penalty of rupees ten thousand for every month or part thereof, per hectare of land till the period, such contravention continues.

(2) The penalty referred to in sub-section *(1)*, shall be in addition to the recovery of expenses, incurred for destroying the nursery of paddy or sown or transplanted paddy before the notified date.

(3) Before passing any order for imposing penalty under sub-section *(1*, the authorized officer shall make such enquiry, as he may deem necessary and shall give an opportunity of being heard to the concerned farmer.

(Appeal)

8. Any farmer, aggrieved by an order of the authorized officer, passed under sub-section *(3)* of section 7, may prefer an appeal to the Collector within a period of thirty days from the date of passing the order.

(Recovery)

9. The penalty and the expenses referred to in Section 7, shall be recoverable as arrears of land revenue.

(Protection for action taken in good faith)

10. No suit, prosecution or legal proceeding shal lie against the State Government or its officer or employee for anything, which is done or intended to be done in good faith under this Act.

(Bar of jurisdiction)

11. No civil court shall have jurisdiction to entertain any suit or proceeding in respect of any matter arising under or connected with this Act.

(Overriding effect)

12. Notwithstanding anything to the contrary contained in any other law, enacted by the Punjab State Legislature for the time being in force, the provision of this Act shall have effect.

Source: PUNJAB GOVT GAZ. (EXTRA.) APRIL 28, 2009 (VYSK 8, 1931 SAKA) pp 93-95

For the original draft submitted in 2006, see, The Punjab State Farmers Commission, "*Initiatives: 2005-06*", Government of Punjab, January, 2007, pp 24-25.

Annexure II

Rainfall, rice area, indexed water needs, recharge, withdrawal, and change in water level in central Punjab: 1990 to 2005

Year	Net monsoon recharge (m)	Net *rabi* withdrawal (m)	Monsoon rainfall (mm)	Other rainfall (mm)	Total rice area ('000 ha)	Rice water needs index (cm)	Change in water level	
							June-o-June (m)	Oct-o-Oct (m)
1990	1.702	1.127	353.0	150.1	2015	194.16	0.575	0.778
1991	0.333	0.914	416.4	155.8	2069	197.52	-0.582	-0.795
1992	0.316	1.236	559.2	125.5	2072	197.34	-0.920	-0.599
1993	0.966	1.533	550.2	83.9	2179	198.88	-0.567	-0.270
1994	1.090	1.244	580.9	113.3	2265	199.44	-0.154	-0.444
1995	1.834	1.125	452.0	162.9	2188	199.68	0.709	0.590
1996	1.062	1.428	568.5	155.5	2160	198.74	-0.366	-0.063
1997	1.340	1.308	276.8	198.8	2278	205.68	0.032	-0.088
1998	1.269	1.405	327.2	144.5	2518	204.56	-0.135	-0.039
1999	0.392	1.170	293.4	77.1	2604	201.02	-0.778	-1.013
2000	0.354	1.364	335.2	78.2	2612	201.12	-1.011	-0.816
2001	1.042	1.091	325.1	95.9	2585	200.92	-0.049	-0.322
2002	0.037	0.853	332.0	48.7	2530	198.26	-0.816	-1.054
2003	0.477	1.886	250.3	147.5	2614	199.24	-1.409	-0.376
2004	0.094	1.184	440.0	86.2	2647	202.58	-1.090	-1.791
2005	0.529	1.008	324.5	149.8	2642	198.70	-0.480	-0.655
2006			336.4	81.9	2621	195.06		
2007					2610	193.82		
2008					2735*	184.86		
Average 1990-05	0.802	1.242	399.0	123.4	2374	199.86	-0.440	-0.435

Notes:

1. The water level recharge and withdrawal are based on all the observation wells during different years for which the data were available; these were about 250 to 400.
2. The net monsoon recharge is the difference in water level during October over June and the net *rabi* withdrawal is the difference in water level during October to the following June.
3. Monsoon rain is from June to September; the other (*rabi*) rain is from October to May.
4. The water need index is based on the transplanting pattern (Table 1) and the coefficients as in Table 4.

**Source:* Government of Punjab (2009). Economic Survey of Punjab: 2008-09. Economic Advisor to GOP