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Groundwater Exploitation in Punjab: A Zone-wise Analysis

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Abstract

The present study was conducted to study the zone wise groundwater table behaviour in Punjab. The Central zone is the problematic zone, which encompasses roughly half of the state's area and continues to face negative water balance along with declining water levels due to intensive cultivation of paddy-wheat. The state has witnessed a fall in water table at the rate of 43 cm per year during the last 22 years; with a serious fall at the rate of 59 cm per year in Central region. The area of fall in water table has changed drastically. More than 20 m of the fall in water table, was recorded in 10 per cent of the state area from the Central zone. The groundwater balance has decreased in all the zones with negative water balance in Central and South West zone; with an increasing trend over time in Central zone. Increase in the rice area has badly affected the net monsoon recharge as well as the water table depth in all the zones, especially in Central region. The prominent districts of the Central Punjab with serious fall in water levels are Sangrur, Patiala, Jalandhar, Moga and Barnala. Effective harvesting of the monsoon rainfall through construction of artificial recharge structures, watershed management, intensive afforestation and awareness generation can resolve the water scarcity problem in Punjab to a greater extend.

Keywords: Groundwater, Critical Stage, Central Region, Over-exploitation

JEL Codes Q25, Q32, Q56

Introduction

Groundwater plays a major role in the supply of water, the functioning of the ecosystem and the well-being of people. Millions of farmers rely on groundwater irrigation to for producing 40 per cent of the world's agricultural output, which includes a large share of staple crops like rice and wheat (Dalin et al., 2017).

Punjab is one of the most endowed states of India, contributing 31 per cent to the central pool of rice and 46 per cent wheat (Punjab Economic Survey, 2023). Punjab is closely associated with the 'Green Revolution' which is well known to have singularly contributed to making India self-sufficient in food, by bringing a boom in food grain production and productivity. The Green Revolution, on the contrary, increased the need for irrigation water at two levels. Firstly, the millets, pulses and oilseeds were replaced by wheat and paddy cropping pattern increased the requirement for water all over the year and secondly, the new varieties improved the intensity of irrigation. The area under rice-wheat cultivation in the state has expanded 3.6 times since last four decades because of government support through stable prices, huge procurement programme and other institutional and infrastructural support, although rice has not been a staple crop of the state.

The higher yield of paddy and wheat, assured MSP and developed marketing channels have led to the dominance of the paddy-wheat cultivation leading to depletion of the water table in Punjab. As a result, the farmers are unable to benefit from other profitable crops that are ideal for Punjab soil in terms of market share and profit. Due to this paddy-wheat system, 84 per cent of the state area is under extreme stress and 16 per cent of the state area faces the issue of brackish water (which is unfit for irrigation) (NABARD 2019). The accessibility of groundwater in Punjab has aided the quick spread of High Yielding Varieties. Furthermore, the free power supply allowed the farmers to extract water from the ground and transplant rice before the monsoon arrival in mid-June, when temperatures were still high and the evapo-transpiration rate was highest. The number of tube wells in Punjab has grown from 0.19 million in 1970-71 to about 1.3 million in 2010, resulting in decline in the water table of 18 cm in 1982-87, 42 cm in 1997-2002 (Hira et al., 2004), and

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75 cm in 2002-2006 (Singh, 2006).

Punjab has lost a significant portion of its groundwater resources as a result of exploitation that exceeds recharging capacity. The present water demand exceeds the supply. Overexploitation of groundwater is being used to meet the excess demand, leading to decrease in water table. Various researches on groundwater utilization and availability reiterate that overexploitation of groundwater is a serious problem in Punjab and with time it is rapidly engulfing the majority of the state's blocks. Due to intensive mining of this valuable resource, its reserves are rapidly depleting, to the point that the water table is rapidly sinking.

The state of Punjab has the highest percentage of groundwater development as well as over-exploited blocks in comparison to the other states. There are many studies on Punjab's groundwater issues but there are very few studies on all the three zones together. This study includes a detailed analysis of all the three zones and 20 districts of Punjab at 22 different time periods. The goal of the research is to examine the long-term spatial behavior of groundwater levels in the study area during pre and post monsoon season, given the significant resource available to the state.

Data Sources and Methodology

Punjab is situated in the North West part of the country with 1.54 per cent of the total geographical area. The State is divided into three agro climatic zones viz., Sub-mountainous Zone or Kandi region, Central Alluvial Zone or Central Plains and Southern Dry zone. Kandi zone is characterized by sub-mountainous undulating plains. In the Kharif season, paddy/ maize is cultivated while in Rabi season, wheat cultivation is dominant. In this region, irrigation facilities are comparatively less developed. Central region is characterized by fertile plain lands. The dominant crops in this region are wheat and paddy. Irrigation facilities are very well developed. South Western region is also known as the cotton belt of the state. However, due to decreased productivity of cotton owing to water logging problems and threat of pests, cotton is being steadily replaced with long grain varieties of paddy.

Data on groundwater levels and rainfall were obtained from Central Ground Water Board and Indian Meteorological Department respectively. The data on water table was used to work out the following parameters:

(i) June-over-June and October-over-October - The change in water level from June-over-June and October-over-October captures the effect of annual rainfall and other variables. A fall shows that the withdrawal has been more than the recharge during the year.

(ii) June-October - The change through June-October shows the net monsoon recharge through the paddy season. It captures the impact of monsoon rainfall, the paddy area (the main crop that needs water) and other factors such as water management and water-use-efficiency. Negative monsoon recharge indicates poor monsoon years i.e. deficit rainfall.

(iii) October-June - The change through October-June depicts the effect of withdrawals in the rabi season. The withdrawals during the rabi season affect the monsoon recharge. There is always a fall, as there is very low rainfall throughout October-May.

Results and Discussion

Groundwater Level in Punjab

There are many problems associated with groundwater in the state of Punjab. A large part of the state is facing decreasing groundwater levels due to over-exploitation of the water resources while, there are increasing cases of groundwater pollution due to various human activities.

During the pre-monsoon period, i.e. the month of June, the water table in 1996 was at a shallow depth of 8.34 and 8.84 metres in the Kandi and Central zones respectively, while in the South West zone, it was at a depth of 5.23 metres (Fig. 1). By June 2018, the water table in these zones reached at 14.72, 21.89 and 10.36 metres depth respectively. A similar trend was seen for the month of October, which is the post-monsoon, wherein the water table declined for all the three zones from 6.83 to 14.36 metres, 8.96 to 24.86 metres and 5.10 to 11.09 metres for Kandi, Central and South West zones respectively. The water level for Punjab as a whole, decreased from 7.57 metres to 15.66 metres (pre-monsoon) and 6.96 metres to 16.77 metres (post-monsoon) during the same period.

The data reveals a declining water table trend for the zones as well as for Punjab (Vashisht, 2008; Singh and Sharma 2020, Sharma et al., 2021). The water table levels are in the range of 10 to 20 metres below ground level in major parts of the state. The trends of groundwater depletion in the last few decades of the Punjab state has doubled (Singh and Singh, 2023). This scenario of groundwater declination is due to increased demand for irrigation water as the surface water resources are limited and have deteriorated over time.

The rate of fall in water table from 1996 to 2018 showed a serious fall 59 cm per year in the Central zone, whereas the fall in Kandi zone was 28 cm per year (Table 2). For the South West zone, the fall in water table was least 23 cm per year. Punjab state as a whole, has witnessed pre-monsoon fall of 43 cm per year during the last 22 years.

The rate of fall in water table in the central zone was relatively more as compared to other zones, one of the reasons being high increase in paddy area. The area under rice was less than 2.3 m ha in 1998 which increased to 2.5 m ha in 1999, since then it is increasing and has reached 3.1 m ha in 2018 (Statistical Abstract of Punjab, various issues). Other reasons being access to free power for irrigation leading to increased tube wells, assured market for paddy and wheat, deficit rainfall etc.

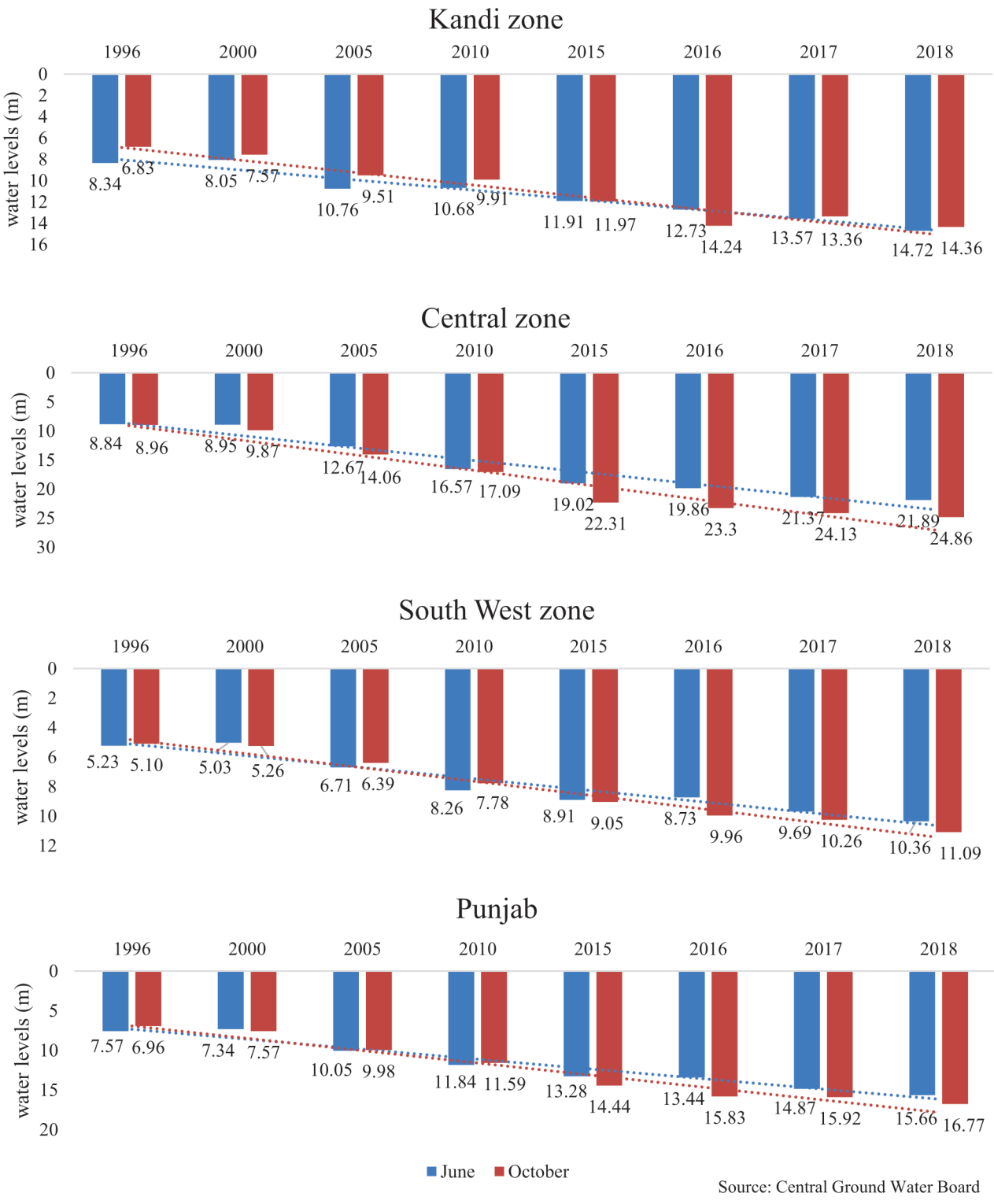

Figure 1: Water table depth (in metres) in Punjab, zone-wise, 1996-2018

Table 2. Rate of fall in water table (m/year) in Punjab, zone-wise, 1996-2018

Years	Kandi zone		Central zone		South West zone		Punjab	
	June	October	June	October	June	October	June	October
1996-2007	0.18	0.29	0.48	0.67	0.11	0.17	0.25	0.41
2007-2018	0.39	0.40	0.71	0.76`	0.35	0.36	0.40	0.51
1996-2018	0.28	0.34	0.59	0.72	0.23	0.27	0.43	0.50

Over the years, the decreasing rainfall over the years has adversely affected the flow of water in major rivers and natural recharge to the ground water resources (Vatta *et al.*, 2018) and it has reduced the availability of water in the state (Kaur *et al.* 2010). Approximately 14.76 lakh tube wells in both cropping seasons draw ground water for irrigation of crops. The concern is that Punjab's average annual rainfall is approximately 438 mm, of which 51 percent fall in July and August. Therefore, ground water replenishment is not adequate (State Focus Paper 2019).

Year- to -Year Fall in Water Level

The perusal of Table 3 depicts the June-over-June and October-over-October fall of water table for the different zones of Punjab. The cumulative fall of groundwater in Central Punjab during 1996-2018 has been the highest among all zones, with a fall of 13.05 metres while the October-over-October cumulative fall was 15.9 metres. The cumulative fall for South West zone was lowest at 5.13 metre. The cumulative June-over-June fall for Kandi zone was 6.38 metre. The October-over-October cumulative fall for Kandi and South West zone was nearly equal. The cumulative fall in water table during October-over-October is more as compared to June-over-June period. The reason being, high water withdrawals for paddy irrigation causing a decline in the water table. For Kandi zone and South West zone, the cumulative fall was 7.5 and 5.9 metres respectively.

Assuming 25 cloudy weather days when evapo-transpiration losses are reduced, the required water depth is 1600 mm for paddy grown in an area of one hectare, of which 500 mm may be available from rainfall and almost 1100 mm comes from groundwater. Paddy crop uses 18 mm water/day for a minimum of 100 days whereas; the total water needed for wheat is about 500 mm (Tiwana *et al*., 2005).

The insufficient recharge due to inconsistent rainfall over the years, an increase in the number of tube wells and subsidized power has resulted in declining groundwater resources. The relation between the increase in paddy area and the corresponding decrease in water level is shown in Table 4. With an increase in the area under rice cultivation, groundwater recharge in all three zones declined.

For the state as a whole, with an increase in area under rice cultivation from 52.06 per cent in 1996 to 74.43 per cent of area sown in 2018; the water table depth decreased from 8.06 m to 19.11 m indicating a fall of 11.05 m from 1996 through 2018.

In the Kandi Zone, the rice area increased from 48.63 per cent to 57.42 per cent of area sown from 1996 to 2018 respectively, which led to decrease in water table depth from 6.83 m in 1996 to 14.36 m in 2018. The highest decline in water table was observed for SAS Nagar followed by SBS Nagar whereas, the increase in area sown was lowest for SAS Nagar and highest for SBS Nagar and Hoshiarpur. In Central Zone, the area under rice increased from 68.47 per cent to 85.84 per cent of area sown from 1996 to 2018 respectively. The water table fall from 8.96 metres to 24.86 metres for the given period, exhibiting a fall of 15.90 metres. The increase in area sown was highest in Moga, Jalandhar and Sangrur while, the decline was highest for Barnala, Sangrur and Patiala districts. In South West Zone, the water table decreased from 5.10 metres to 11.09 metres during the period 1996 to 2018. The increase in rice area was highest in South-West Zone from 366 thousand ha in 1996 to 849 thousand ha in 2018. The highest decline in water table was observed for Mansa and Bathinda districts. In the South West zone, a large proportion of the cultivated area was traditionally under cotton cultivation, but decreasing yield and price fluctuations, insect-pest attack, climatic variations, on the one hand, and assured MSP, stable yield, well-established market infrastructure for the rice crop, on the other hand, has recently caused a large shift in the area from cotton to paddy. This resulted in fall of water level in South West zone.

Increase in the rice area over time has substantially increased the groundwater use during the monsoon season causing inadequate recharge in the post-monsoon season. Thus, the change in cropping pattern towards rice is primarily responsible for fall in the water table depth in Punjab (Sharma and Sidana, 2021; Singh and Sharma, 2020) and the problem in Central Punjab is more severe (Vashisht, 2008; Singh, 2011; Singla et al. 2024). As a result, every year, the water table in Punjab has been deteriorating over time.

Decreasing Groundwater Balance

The use of groundwater in excess of recharge has led to fall in water table and has put a huge pressure on groundwater resources. The groundwater balance has decreased from 0.027 m ha m in 1997 to -1.063 m ha m in 2017 (CGWB, 2017). In Kandi zone, the net annual recharge for all the years is more than the net annual draft (Table 5). The net

Table 3. Zone-wise Year-to-Year fall of water table (m) in Punjab, June-over-June and October-over-October (1996-2018)

Years	Kandi zone		Central zone		South West zone	
	June-over-June	October-over-October	June-over-June	October-over-October	June-over-June	October-over-October
1996	…	…	…	…	…	…
1997	1.02	0.42	-0.01	0.10	-0.39	0.45
	(1.02)	(0.42)	(-0.01)	(0.10)	(-0.39)	(0.45)
1998	0.21	0.06	0.66	0.26	0.87	-0.13
	(1.23)	(0.48)	(0.65)	(0.37)	(0.48)	(0.32)
1999	-0.05	-0.70	0.20	-1.02	0.14	-0.14
	(1.18)	(-0.22)	(0.85)	(-0.65)	(0.62)	(0.17)
2000	-0.89	-0.53	-0.95	-0.26	-0.42	-0.33
	(0.28)	(-0.75)	(-0.10)	(-0.91)	(0.20)	(-0.15)
2001	-0.06	-0.13	-0.19	-1.08	-0.55	-0.36
	(0.22)	(-0.88)	(-0.30)	(-1.99)	(-0.34)	(-0.52)
2002	-0.88	-0.95	-1.60	-1.62	-0.33	-0.99
	(-0.66)	(-1.84)	(-1.90)	(-3.62)	(-0.67)	(-1.50)
2003	0.17	-0.14	-1.22	-0.59	-0.56	0.35
	(-0.49)	(-1.97)	(-3.13)	(-4.22)	(-1.24)	(-1.16)
2004	-2.08	-0.93	-0.41	-1.59	0.13	-0.66
	(-2.57)	(-2.90)	(-3.54)	(-5.81)	(-1.11)	(-1.82)
2005	0.14	0.22	-0.28	0.72	-0.36	0.53
	(-2.43)	(-2.68)	(-3.83)	(-5.09)	(-1.47)	(-1.28)
2006	0.18	0.78	-0.84	-0.94	0.20	-0.08
	(-2.24)	(-1.89)	(-4.67)	(-6.04)	(-1.27)	(-1.37)
2007	0.21	-1.27	-0.59	-0.46	0.05	-0.55
	(-2.03)	(-3.17)	(-5.26)	(-6.50)	(-1.22)	(-1.93)
2008	-0.31	1.04	-1.31	-1.52	-1.08	-0.39
	(-2.35)	(-2.13)	(-6.57)	(-8.02)	(-2.30)	(-2.32)
2009	-0.40	-1.21	-0.27	-0.66	0.001	-0.21
	(-2.75)	(-3.33)	(-6.85)	(-8.68)	(-2.29)	(-2.53)
2010	0.41	0.25	-0.87	0.55	-0.73	-0.15
	(-2.35)	(-3.08)	(-7.73)	(-8.13)	(-3.02)	(-2.68)
2011	-0.65	0.79	0.09	-1.43	0.23	-0.05
	(-3.01)	(-2.28)	(-7.63)	(-9.55)	(-2.79)	(-2.74)
2012	-0.52	-0.93	-1.12	-0.67	0.73	-0.98
	(-3.52)	(-3.22)	(-8.75)	(-10.23)	(-2.06)	(-3.72)
2013	-0.86	-1.75	-1.19	-1.41	-1.18	0.27
	(-4.38)	(-4.97)	(-9.94)	(-11.64)	(-3.24)	(-3.44)
2014	0.52	-0.25	0.54	-0.81	-0.09	-0.57
	(-3.86)	(-5.22)	(-9.40)	(-12.45)	(-3.34)	(-4.01)
2015	0.29	0.08	-0.77	-0.89	-0.34	0.07
	(-3.57)	(-5.14)	(-10.17)	(-13.34)	(-3.67)	(-3.94)
2016	-0.82	-2.26	-0.84	-0.99	0.17	-0.91
	(-4.39)	(-7.41)	(-11.02)	(-14.34)	(-3.49)	(-4.85)
2017	-0.84	0.87	-1.51	-0.83	-0.95	-0.30
	(-5.24)	(-6.53)	(-12.53)	(-15.16)	(-4.45)	(-5.16)
2018	-1.15	-0.99	-0.52	-0.73	-0.67	-0.83
	(-6.38)	(-7.53)	(-13.05)	(-15.90)	(-5.13)	(-5.99)

*****Figure in parantheses indicates cumulative fall for respective zones*

annual recharge has increased to 76 per cent over the year; whereas, the draft has increased to 65 per cent. As Kandi zone is sub-mountainous, situated at a higher altitude and receives a good amount of average rainfall is the reason for more recharge. The groundwater balance estimates was positive in the year 1997 but it declined to a great amount to 0.026 m ha m. The reason was increase in the rice area from 287 thousand hectares in 1995 to 311 thousand hectares in 2004. After 2011, it again becomes positive from 2013. Though the water balance was positive but, it has decreased by 295 per cent from 1997 to 2017.

The net annual recharge increased to 0.626 m ha m during 2017 from 0.393 m ha m in 2013. There was an increase in the annual draft as well from 0.368 m ha m to 0.372 m ha m in 2017 through 2013. The result of which was decrease in the groundwater balance from 0.025 m ha m during 2013 to 0.254 m ha m in 2017.

In Central Zone, the groundwater balance estimates were not only negative but have increased over time. The net annual recharge increased by 85 per cent while the draft has increased by 114 per cent, thus, resulting in a negative groundwater balance with a decrease of 171.5 per cent (Table 6). In the Central zone, net annual recharge was 0.734 m ha m, whereas the net annual draft was 1.106 m ha m during 1997 resulting in a groundwater balance of -0.372 m ha m. The condition got worsened by 2017, when net annual recharge was 1.359 m ha m and the net annual draft was 2.365 m ha m with a groundwater balance of -1.01 m ha m.

In South West zone, the groundwater balance was positive till 2004 but afterwards, it decreased and became negative. Though the net annual recharge has increased by 19.5 per cent, the increase in annual draft was by 154.8 per cent thus, resulting in 120.8 per cent decrease in the groundwater balance (Table 7).

A severe imbalance in the usage and availability of ground resources has resulted from intensive agriculture based on paddy-wheat rotation. Of the total water demand of 4.40 m ham, the water supply falls by 1.27 m ham of the

Table 4. Zone wise water-level depth (Oct-over-Oct) and paddy area in Punjab, 1996 to 2018

Districts	1996			2018		
	Water level (m)	Paddy area		Water level (m)	Paddy area	
		Area in 000 ha	As a per cent to Net Sown Area		Area in 000 hectares	As a per cent to Net Sown Area
Gurdaspur	4.43	191	65.41	7.13	204	79.68
Hoshiarpur	8.85	57	26.51	17.33	75	36.76
SAS Nagar	6.35	29	61.70	22.80	31	40.26
Rupnagar	5.51	37	48.05	13.99	40	49.38
SBS Nagar	10.05	42	41.58	19.93	60	62.50
Kandi Zone	6.83	356	48.63	14.36	410	57.42
Ludhiana	10.08	230	76.67	21.06	258	86.28
Sangrur	7.75	228	70.59	34.03	284	90.15
Jalandhar	9.92	112	49.12	25.54	171	70.37
Patiala	10.24	209	73.34	30.28	233	90.66
Fatehgarh Sahib	9.46	80	77.67	23.24	86	84.31
Amritsar	5.57	154	67.84	14.74	180	82.19
Tarn Taran	8.06	150	68.49	18.95	182	83.48
Moga	9.60	108	55.67	25.80	181	93.29
Kapurthala	9.03	102	75.55	18.76	118	88.72
Barnala	10.87	93	73.23	34.19	113	91.12
Central Zone	8.96	1466	68.47	24.86	1806	85.84
Bathinda	7.82	39	13.08	16.73	160	54.6
Mansa	3.72	50	24.51	14.85	107	57.83
Faridkot	4.32	38	28.78	9.14	115	90.55
Ferozepur	4.72	233	50.43	10.15	294	62.42
Sri Muktsar Sahib	3.96	06	2.56	3.71	173	77.23
South West Zone	5.10	366	27.52	11.09	849	65.31
Punjab	8.06	2188	52.06	19.11	3065	74.43

Table 5. District wise groundwater balance estimates, Kandi Zone, Punjab

Net annual recharge (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Gurdaspur	0.154	0.185	0.196	0.196	0.216	0.204	32.47
Hoshiarpur	0.097	0.092	0.097	0.098	0.100	0.094	-3.09
SAS Nagar	0.022	0.026	0.03	0.03	0.032	0.283	1186.36
Rupnagar	0.042	0.044	0.045	0.045	0.045	0.045	7.14
SBS Nagar	0.039	0.066	0.07	0.069	0.074	0.070	79.48
Total	0.355	0.412	0.368	0.369	0.393	0.626	76.34
Net annual draft (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Gurdaspur	0.109	0.193	0.218	0.219	0.217	0.221	102.75
Hoshiarpur	0.043	0.074	0.086	0.087	0.085	0.084	95.35
SAS Nagar	0.015	0.020	0.023	0.023	0.023	0.023	53.33
Rupnagar	0.018	0.037	0.043	0.043	0.043	0.044	144.44
SBS Nagar	0.038	0.114	0.07	0.07	0.069	0.071	86.84
Total	0.225	0.440	0.370	0.372	0.368	0.372	65.33
Ground water balance (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Gurdaspur	0.045	-0.008	-0.022	-0.023	-0.001	-0.017	-137.78
Hoshiarpur	0.054	0.017	0.011	0.011	0.015	0.010	-81.48
SAS Nagar	0.006	0.006	0.007	0.007	0.009	0.260	4233.33
Rupnagar	0.023	0.007	0.002	0.002	0.002	0.001	-95.65
SBS Nagar	0.001	-0.048	0.00	-0.001	0.005	-0.001	-200.00
Total	0.130	-0.026	-0.002	-0.003	0.025	0.254	-295.38

Source : Dynamic ground water resources of India , various issues
**Pathankot is included in Gurdaspur district*

total supply of 3.13 m ha m. The scarcity is met by overuse of groundwater reserves by wells and tube-wells (Singh and Bhangoo, 2013).

During the period 1996-2018, the area of fall in water table has changed drastically. Table 8 depicts the area of fall in water table for different zones of Punjab. In Central zone, 44 per cent of the area has recorded fall within the range of 10-20 m; accounting for 21.6 per cent of the state area. In Kandi zone, 56 per cent of the area showed fall of the water table in the range of 5-10 m, which constitutes 12 per cent area of the state. Similarly, in South West zone 5-10 m fall in water table has been recorded in 88 per cent of the area, constituting 21.6 per cent of state area. More than 20 m of the fall in water table, was recorded in 10 per cent of the state area from the Central zone. Only 10 per cent area of state showed fall in the range of 0-5 m depth.

Moreover, the water table depth is expected to recede to 50 metres in nearly 66 percent of the core districts by 2030 (Hira *et al*., 2006). It can be seen that the current uninviting groundwater situation in many regions of the state is mostly the result of poor production methods that lead to excessive and unsound water usage (predominantly for paddy crop). Other causes include lack of surface water availability, support pricing and procurement facilities for only a few crops, free power to the agriculture sector and tube wells installation by farmers in disproportionate numbers (Kalkat *et al.,* 2006).

Conclusion and Policy Implications

The optimal development of its water resources is one of the prime requirements for any state's self-reliance and development. The study revealed that the water table in all three zones of Punjab has been declining. The decline of water table in Central zone was found severe; it declined from 9.8 m in 1996 to 24.2 m in 2018. In South West zone, the fall was comparatively less and a 2.1 per cent rise was observed in Muktsar district. The rate of fall in the water table from

Table 6. District wise groundwater balance estimates, Central Zone of Punjab

Net annual recharge (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Ludhiana	0.149	0.260	0.226	0.231	0.236	0.215	44.29
Sangrur	0.091	0.153	0.154	0.145	0.192	0.160	75.82
Jalandhar	0.065	0.155	0.131	0.13	0.144	0.130	100.00
Patiala	0.107	0.151	0.165	0.166	0.17	0.152	42.06
F. Sahib	0.038	0.058	0.059	0.059	0.065	0.061	60.53
Amritsar	0.081	0.129	0.136	0.137	0.194	0.171	111.11
Taran Tarn	0.079	0.106	0.115	0.116	0.156	0.140	77.21
Moga	0.043	0.135	0.132	0.133	0.129	0.119	176.74
Kapurthala	0.032	0.069	0.726	0.073	0.082	0.077	140.62
Barnala	0.046	0.070	0.066	0.065	0.068	0.064	39.13
Total	0.734	1.286	1.98	1.324	1.51	1.359	85.15
Net annual draft (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Ludhiana	0.204	0.323	0.334	0.336	0.333	0.338	65.69
Sangrur	0.155	0.303	0.364	0.336	0.362	0.368	137.42
Jalandhar	0.128	0.257	0.265	0.267	0.264	0.268	109.37
Patiala	0.138	0.264	0.286	0.288	0.285	0.290	110.14
F. Sahib	0.054	0.083	0.11	0.111	0.109	0.112	107.41
Amritsar	0.089	0.187	0.215	0.217	0.214	0.217	143.82
Taran Tarn	0.089	0.179	0.186	0.187	0.185	0.188	111.24
Moga	0.107	0.214	0.24	0.242	0.239	0.243	127.10
Kapurthala	0.081	0.124	0.150	0.150	0.148	0.151	86.42
Barnala	0.057	0.111	0.118	0.118	0.117	0.119	108.77
Total	1.106	2.045	2.338	2.322	2.325	2.365	113.83
Ground water balance (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Ludhiana	-0.054	-0.063	-0.108	-0.105	-0.097	-0.123	-127.78
Sangrur	-0.063	-0.150	-0.21	-0.191	-0.17	-0.208	-230.16
Jalandhar	-0.063	-0.102	-0.134	-0.137	-0.12	-0.138	-119.05
Patiala	-0.031	-0.113	-0.121	-0.122	-0.115	-0.138	-345.16
F. Sahib	-0.016	-0.025	-0.051	-0.052	-0.044	-0.051	-218.75
Amritsar	-0.008	-0.058	-0.079	-0.08	-0.02	-0.046	-475.00
Taran Tarn	-0.009	-0.073	-0.071	-0.071	-0.029	-0.048	-433.33
Moga	-0.065	-0.079	-0.108	-0.109	-0.11	-0.124	-90.77
Kapurthala	-0.048	-0.055	0.576	-0.077	-0.066	-0.074	-54.17
Barnala	-0.012	-0.041	-0.052	-0.053	-0.049	-0.055	-358.33
Total	-0.372	-0.759	-0.358	-0.998	-0.815	-1.01	-171.50

Source : Dynamic Groundwater Resources of India, various issues

Table 7. District wise groundwater balance estimates, South West Zone, Punjab

Net Annual Recharge (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Bathinda	0.050	0.093	0.107	0.111	0.157	0.153	206.00
Mansa	0.073	0.089	0.074	0.077	0.114	0.114	56.16
Faridkot	0.053	0.056	0.068	0.067	0.068	0.067	26.41
Ferozepur	0.272	0.243	0.218	0.21	0.255	0.240	-11.76
Muktsar	0.099	0.092	0.085	0.086	0.084	0.081	-18.18
Total	**0.548**	**0.573**	**0.552**	**0.551**	**0.678**	**0.655**	**19.53**
Net annual draft (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase** 1997 to 2017
Bathinda	0.036	0.078	0.117	0.118	0.130	0.132	266.67
Mansa	0.028	0.140	0.143	0.144	0.143	0.145	417.86
Faridkot	0.026	0.054	0.095	0.095	0.094	0.096	269.23
Ferozepur	0.175	0.228	0.273	0.275	0.282	0.287	64.00
Muktsar	0.014	0.051	0.051	0.051	0.051	0.051	264.28
Total	**0.279**	**0.551**	**0.679**	**0.683**	**0.70**	**0.711**	**154.84**
Ground water balance (m ha m)							
Districts	**1997**	**2004**	**2009**	**2011**	**2013**	**2017**	**% increase 1997 to 2017**
Bathinda	0.014	0.015	-0.01	-0.007	0.027	0.021	50.00
Mansa	0.045	-0.051	-0.069	-0.067	-0.029	-0.031	-168.89
Faridkot	0.026	0.002	-0.027	-0.028	-0.026	-0.029	-211.54
Ferozepur	0.097	0.015	-0.055	-0.065	-0.027	-0.047	-148.45
Muktsar	0.085	0.041	0.034	0.035	0.033	0.030	-64.71
Total	0.269	0.022	-0.127	-0.132	-0.022	-0.056	-120.82

Source : Dynamic Groundwater Resources of India, various issues
**Fazilka is included in Ferozepur district*

Table 8. Zone wise area of fall in water table in Punjab, 1996-2018

Fall	**Area (km²)**			**Per cent to state area**			
	Kandi Zone	**Central Zone**	**South West Zone**	**Kandi Zone**	**Central Zone**	**South West Zone**	**Total**
0-5 m	3564 (33.44)	--	1469 (11.92)	7.07	--	2.92	**9.99**
5-10 m	6001 (56.31)	8863 (35.79)	10859 (88.08)	11.92	17.59	21.56	**51.07**
10-20 m	1093 (10.25)	10878 (43.93)	--	2.17	21.59	--	**23.76**
>20 m	--	5020 (20.27)	--	--	9.97	--	**9.97**
Total	100	100	100	21.16	49.15	24.48	94.79

**Figure in parantheses indicates percentage to total fall area of the respective zones*
**Area indicates state's geographical area*
NOTE: 5.19 per cent of the state area showed increase in water table

1996 to 2018 showed a serious fall of 0.59 metres per year for the Central zone, whereas the fall in Kandi zone and South West zone was 0.28 and 0.23 metres per year respectively. The area of fall in water table also changed drastically. 10-20 m of fall was recorded in 44 per cent of the area in Central zone, which was 21.6 per cent of state area. The net annual draft has increased drastically as compared to the net annual recharge in all the three zones, thus, creating a negative groundwater balance in the state. The decrease of water table can be halted by either limiting the groundwater draft or increasing the recharge of groundwater. The government should take the initiative of implementing policy regarding effective on-farm water conserving techniques viz. cultivation of less water-intensive crops, direct seeded rice, practicing the short duration varieties of paddy, in the over-exploited zone especially the Central Punjab. Conjunctive use of surface water and groundwater, rainwater harvesting, construction of ponds/tanks and awareness generation needs to be tailored to make Punjab a sustainable state.

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