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GROUNDWATER LEVEL ANALYSES OF PUNJAB, INDIA: A QUANTITATIVE APPROACH

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Abstract: Groundwater is considered to be the most vital for the livestock population. In Punjab, which is also the food basket of India, the groundwater level is declining at a rapid rate due to increase in the number of tube wells in the recent years and hence the groundwater abstraction has increased. In a recent study conducted for monitoring the groundwater level in Punjab, the water level data was monitored for the period 2006-2013 in Hoshiarpur, Jalandhar & Kapurthala districts of Bist-Doab; Faridkot, Firozepur, Ludhiana, Bhatinda & Patiala districts of Malwa region and Amritsar, Gurdaspur & Tarn Taran districts of Majha region of Punjab. The groundwater level data has shown that the maximum decline to the tune of 9.75 m was found in Patiala, followed by 8.57 m in Bhatinda and least decline of 3.13 m was found in Jalandhar during the period 2006-2013. The areas showing marked decline in water levels should practice artificial recharge. It is also essential to strengthen soil, water and groundwater institutions along with capacity building, training and education in specific areas like artificial recharge, groundwater modelling, watershed management, quality monitoring, and aquifer remediation on a continuous basis. Lastly, if immediate remedial measures are not taken to reverse the declining trend of water table, it would be difficult to sustain even the existing food grain production in the state, thereby, affecting the socio-economic condition of the farmers, specially the small and marginal farmers.

Keywords: Analysis; groundwater level; Punjab; quantitative approach

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INTRODUCTION

Punjab literally meaning the Land of Five Rivers ('punj' means five and 'ab' means rivers) that refers to the rivers: Jhelum, Chenab, Ravi, Satluj and Beas. All are tributaries of the Indus River. The Indian part of Punjab is divided into four natural regions: Malwa (region south of river Satluj), Bist Doab or simply Doaba (region between the rivers Satluj and Beas), Majha (region west of river Beas) and Powadh (region in Rupnagar and Ambala district) that falls between the rivers Satluj and Ghaggar (Figure 1). The people living in Malwa, Doaba, Majha and Powadh are known as Malwai, Doabi, Majhai and Pawadhi. Of these, the Doaba region is the largest producer of wheat in India. Majhi is the main dialect of Punjab. The rainfall deficiency in the state is made up by canals taken out from the perennial rivers Beas, Satluj and Ravi. It is this efficient canal system which has enabled this area to be called as the granary of the country and nucleus of the Green Revolution. Although there has been some decline in the importance of canal irrigation due to popularity of tube-wells and pumping sets but canals still irrigate over 39% in Punjab.

Agriculture is the largest industry in Punjab; it is the largest provider of wheat to India. Indian Punjab led the country's Green Revolution of the 1960s and earned for itself the distinction of

becoming 'Granary of India' or 'India's bread-basket'. The cropping pattern also got changed with the increasing facilities in agriculture field including irrigation (Table-1). Total cropped area and cropping intensity has increased during last 4 decades and as a result the rice cultivation has increased from 6.87 % in 1970-71 to 35.85 % in 2011-12 (Table 1).

The percent gross irrigated area to gross cropped area has also increased by 0.03% in last few years (Table 2). With the increase in number of water resources there is still annual water deficit of 1.28 M ha-m (Table 3). As evident from the table 4, it has been found during last few years that the land put to non-agricultural use has increased by 5% in the last few years. Table 5 shows that the irrigation from groundwater has increased while the irrigation from canals has decreased during last 5 years.

Table 1. Shift in cropping pattern in Punjab ('000ha.)

Crop	1970-71	1980-81	1990-91	1999-00	2000-01	2011-12
Rice	390 (6.9)	1183 (17.5)	2015 (26.9)	2604 (33.2)	2612 (32.9)	2826 (35.9)
Maize	555 (9.8)	304 (4.5)	183 (2.4)	163 (2.1)	164 (2.1)	133 (1.7)
Bajra & Jowar	212 (3.7)	70 (1.0)	12 (0.2)	5 (0.1)	6 (0.1)	2.5 (0.03)
Ground nut	174 (3.1	83 (7.2)	11 (0.2)	5 (0.1)	4 (0.1)	2.0
Cotton (Amer.)	212 (3.7)	502 (7.4)	637 (8.5)	381 (4.9)	358 (4.5)	482.8 (6.3)
Sesame	15 (0.3)	17 (0.3)	18 (0.2)	145 (1.9)	19 (0.2)	5
Sugar cane	128 (2.3)	71 (1.1)	101 (1.4)	108 (1.4)	121 (1.5)	70 (0.9)
Kharif Pulses	33 (0.6)	58 (0.9)	73 (1.0)	51 (0.7)	42 (0.5)	-
Wheat	2299 (40.5)	2812 (41.6)	3273 (43.6)	3388 (43.2)	3408 (43.0)	3510 (44.5)
Barley	57 (1)	65 (1.0)	37 (0.5)	51 (0.7)	32 (0.4)	11.7 (0.2)
Gram	358 (6.3)	258 (3.8)	60 (0.8)	6 (0.1)	8 (0.1)	2.2 (0.03)
Rapeseed & Mustard	103 (1.2)	136 (2.0)	69 (1.0)	56 (0.7)	55 (0.7)	-
Potato	17 (0.3)	40 (0.6)	23 (0.3)	76.0 (1)	64 (0.8)	64 (0.8)
Other Vegetable	23 (0.4)	24 (0.4)	31 (0.4)	47 (0.6)	46 (0.6)	-
Fruits	50 (0.9)	29 (0.4)	69 (0.9)	30 (0.4)	34 (0.4)	71.5
Net Sown Area	4053	4191	4218	4243	4264	4158
Total Cropped Area	5678	6763	7502	7847	7935	7882
Cropping Intensity	140	161	178	185	186	190

Source: Statistical Abstract of Punjab, 1971, 1981, 2000, 2001, 2010; Figures in parentheses indicate area under crops as percentage share to total cropped area.

With the continuous rotation of wheat & paddy cropping pattern, the soil and water of Punjab have been degraded and depleted. Intensive use of groundwater has resulted 93 out of 138 blocks to dark category. The present study is undertaken in Punjab keeping in mind a sharp decline in water level due to high rate of population growth and increasing pressure for agriculture and drinking water demand. The extensive water use in Punjab is resulting in falling groundwater levels.

Table 2. Gross cropped and irrigated area in Punjab ('000 ha.)

Year	Gross cropped area	Irrigated area	% of gross irrigated area to gross cropped area
2007-08	7870	7689.3	97.7
2008-09	7912	7723.6	97.6
2009-10	7876	7714.2	97.9
2010-11	7882	7723.8	98.0

Source: Statistical Abstract, Punjab

Table 3. Status of Water Resources of Punjab

Annual canal water available at H/w	1.79 M ha-m
Annual canal water available at outlets	1.45 M ha-m
Annual canal water available	2.03 ha-m
Total annual available water resource	3.48 M ha-m
Annual water demand	4.76 M ha-m
Annual water deficit	1.28 M ha-m

Source: Jain A K, Department of Soil & water Engineering, PAU, Ludhiana

Table 4. Land use pattern in Punjab ('000 ha.)

Area/Period	2007-08	2008-09	2009-10	2010-11
Geographical area	5036	5036	5036	5036
Forests	287	296	295	294
Barren and un cultivable land	24	23	25	24
Land put to non – agriculture use	483	494	503	508
Cultivable waste	3	2	2	4
Permanent pastures & other grazing land	3	4	4	4
Land under misc.& groves not included in net area sown	4	4	5	4
Current fallow	41	38	37	33
Fallow land other than current fallow	1	1	4	4
Net area sown	4187	4171	4158	4158

Net area sown as percentage to total area	83	83	83	83
Area sown more than once	3683	3741	3718	3724
Gross cropped area	7870	7912	7876	7882

Source: Statistical Abstract, Punjab

Table 5. Source wise net irrigated area in Punjab ('000 ha.)

Year	Govt. canal	Pvt. canal	Tube well & wells	Other sources	Total	% of net irrigated area to net area sown
2007-08	1142	-	2922	4	4068	97.2
2008-09	1110	3	2950	1	4064	97.4
2009-10	1111	3	2955	2	4071	97.9
2010-11	1113	3	2954	-	4070	97.9

Source: Statistical Abstract, Punjab

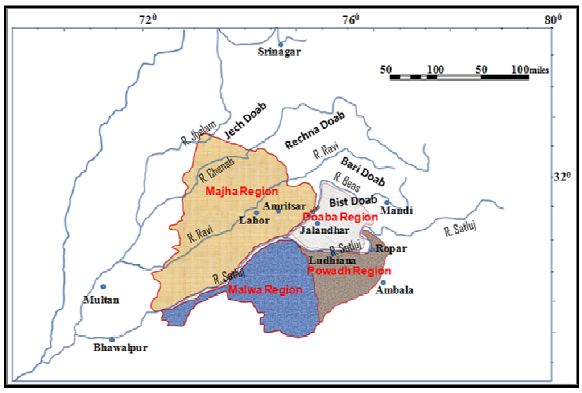

Figure 1. Rivers and Doabs (Majha, Doaba, Malwa and Powadh) of Punjab

The Punjab plains in the past 3-4 decades witnessed a boom in groundwater use and numerous important works exist on the problem of depleting water quality and fall in water tables (Dhawan 1995; Sondhi *et al*. 2001; Ambast *et al*. 2006; Krishan *et al*. 2013a, b; Krishan *et al*. 2014a, b, c; Rao et al., 2014; Sharma *et al*., 2014). Many districts of Punjab show 100% or even greater levels of exploitation and the same is exhibited by a secular decline in pre-monsoon water tables except for extremely wet years. Irrigation has been a major cause for high water level depletion (Rodell *et al*. 2009).

EXPERIMENTAL

The monthly water level data was measured in Hoshiarpur, Jalandhar & Kapurthala districts of Bist-Doab; Faridkot, Firozepur, Ludhiana, Bhatinda & Patiala districts of Malwa region and Amritsar, Gurdaspur and Tarn Taran districts of Majha region as shown in Table 6 and Figure 2. Across these districts, detailed water level data sets has been generated sequentially on monthly basis over the last 8 years between January 2006 to December 2013 for assessing the patterns of groundwater level trends. The data processing was done to remove the erroneous data before statistical analysis. The erroneous values were rectified. The box part of a box and whisker plot represents the central 50% of the data or the Inter-quartile Range (IQR). The lower edge of the box plot is the first quartile or 25th percentile. The upper edge of the box plot is the third quartile or 75th percentile.

Table 6. Observation sites

District	Block	Longitude (E)	Latitude (N)
Hoshiarpur	Bhunga	75.77083	31.65556
	Mukerian	75.61000	31.95000
	Talwara	75.89000	31.94000
Jalandhar	Adampur	75.71000	31.42000
	Bhogpur	75.64000	31.56000
Kapurthala	Dhilwan	75.24722	31.40833
	Kapurthala	75.42222	31.30000
	Nadala	75.43889	31.54556
	Phagwara	75.77000	31.21750
	Sultanpur Lodhi	75.26806	31.24722
Faridkot	Faridkot	74.70278	30.62222
	Kotkapura	74.97500	30.54167
Firozepur	Firozepur	74.60000	30.91660
	Guruharsahai	74.41638	30.71705
	Mamdot	74.51667	30.79583
Ludhiana	Machivara	76.16250	30.96389
	Mangat	76.11250	30.88750
	Pakhoval	75.81302	30.87133
Patiala	BhunerHeri	76.52167	30.27222
	Nabha	76.17500	30.41250
	Patiala	76.30000	30.36667
	Rajpura	76.59583	30.47500
	Samana	76.14583	30.22778
Bhatinda	Bathinda	74.81667	30.20000
	Maur	75.23167	30.06444
	Nathana	75.10833	30.30000
	Phul	75.24306	30.28194
	Sangat	75.16972	30.08333
	Talwandi	75.11667	29.91667
Amritsar	Ajnala	74.89583	31.85833
	Majitha	75.05000	31.72917
	Rayya	75.23333	31.54167
	Tarsika	75.17917	31.58333
Gurdaspur	Batala	75.22167	31.76528
	Dera Baba Nanak	75.01250	31.96528
	Dina Nagar	74.95972	31.92222
	Gurdaspur	75.32167	32.06306
	Fatehgarh Churian	74.98333	31.93333
	Kahnuwan	75.45833	31.90833
	Kalanaur	75.24167	32.01250

	SriHargovindpur	75.41528	31.63194
Tarn Taran	Bikhiwind	74.67361	31.16556
	Gandiwind	74.86346	31.53333
	Khadur Sahib	75.13333	31.38750
	Naushera Pannua	74.83472	31.35417
	Taran Taran	74.93333	31.49722

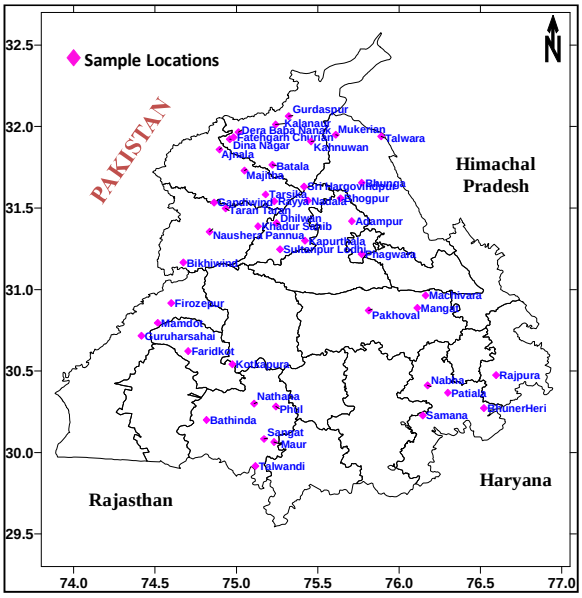

Figure 2. Observation sites

RESULTS AND DISCUSSION

The groundwater level data has shown that the maximum decline due to tune of 9.75 m was found in Patiala, followed by 8.57 m in Bhatinda and least decline of 3.13 m was found in Jalandhar during the period 2006-2013 (Table 7, Figure 3). The difference in change in phreatic water levels may be due to local aquifers or variation in the aquifer structures and availability of groundwater. Since the water level is variable and all the locations, therefore, the spatial variation of water level is shown in Figure 4.

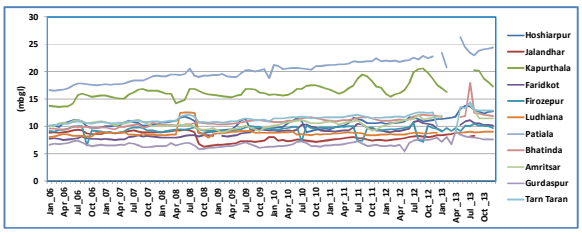

Figure 3. Groundwater level variation in Punjab (2006-13)

As evident from the Figure 5 that the data is almost symmetrical with maximum inter quartile (2.87) is observed in Patiala, which is followed by 1.50 in Faridkot and the least (0.61) was found in Gurdaspur and Firozepur. In Gurdaspur the data is found negatively skewed and in Tarn Taran it is positively skewed.

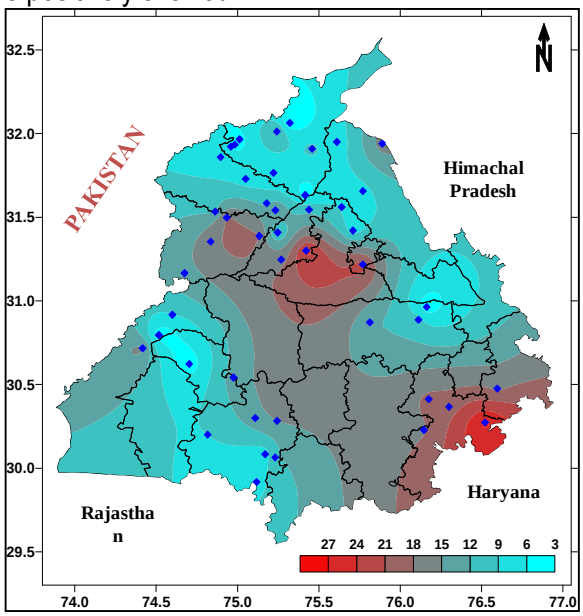

Figure 4. Spatial variation in groundwater level in Punjab (2006-13)

The maximum no. of upper outliers to the tune of 9 are found in Kapurthala, 5 in Gurdaspur, 4 in Ludhiana and 3 each in Amritsar and Tarn Taran. The maximum no. of lower outliers to the tune of 6 are found in Firozepur and followed by 2 in Kapurthala, 1 each in Gurdaspur and Tarn Taran.

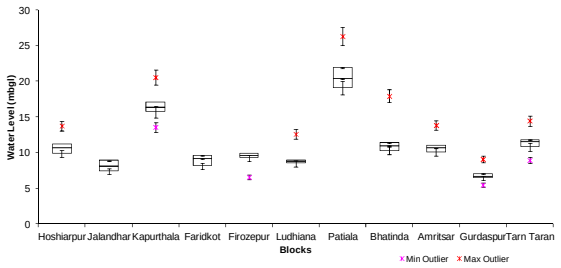

Figure 5. Box plot- groundwater level variation in Punjab (2006-13)

The continuous rotation of wheat & paddy cropping pattern, the soil and water of Punjab have been degraded and depleted. The extensive water use in Punjab is resulting in falling groundwater levels. Similar results are also obtained in the detailed study carried out in Bist Doab region by Krishan et al (2014b, 2013a). In the study, the automatic water level recorders were installed in the 6 piezometers and a high resolution data was obtained. It was observed that the water level depth increased due to the more use of groundwater during Kharif season

and the water level depth decreased during the pre-monsoon period.

Table 6. Statistics of Groundwater level variation in Punjab (2006-13)

District	(mbgl)			
	Min	Max	Average	S D
Hoshiarpur	8.76	13.75	10.62	1.06
Jalandhar	6.25	9.38	8.07	0.83
Kapurthala	13.57	20.54	16.53	1.54
Faridkot	7.52	11.18	8.95	1.00
Firozepur	6.56	10.63	9.43	0.68
Ludhiana	7.94	12.58	8.83	0.82
Patiala	16.55	26.30	20.31	2.08
Bhatinda	9.35	17.92	10.89	1.06
Amritsar	8.78	13.83	10.57	0.84
Gurdaspur	5.46	9.07	6.80	0.61

CONCLUSION

In this millennium, the fully developed groundwater resources in Punjab will continue to be utilized for precious water, to enhance the agriculture production, to meet stipulated food demand and ensure food security. In order to correct the imbalance in water budget and to restore sustainability to farming system, there is immediate need to revert, at least partially, to the cropping systems. No doubt, the challenge before the farming community, development workers and agricultural scientists is really difficult but the challenge must be met if we are really interested to sustain agriculture in the granary state. The areas showing marked decline in water levels should practice artificial recharge. It is also essential to strengthen soil, water and groundwater institutions along with capacity building, training and education in specific areas like artificial recharge, groundwater modeling, watershed management, quality monitoring, and aquifer remediation on a continuous basis. Lastly, if immediate remedial measures are not taken to reverse the declining trend of water table, it would be difficult to sustain even the existing food grain production in the state, thereby, affecting the socio-economic condition of the farmers, specially the small and marginal farmers. The management measures are for reducing water withdrawal by increasing groundwater recharge–construction of check dams, recharging in Kandi area, recharge through village ponds, tubewells, dug wells, paddy fields, rivers (Beas, Sutlej, Ravi), rain water harvesting, managing saline water etc.

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