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Statistical model to analyze the impact of land use activity for district Ludhiana

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Abstract - *Understanding the effects of intensive agricultural land use activities on water resources is essential for natural resource management and environmental improvement In Punjab the surface water has almost been fully exploited and additional demand is being met by tubewells. During the period 1983-84 to 2002-03 the average rate of fall of water table was 18 cm per year. For efficient utilization and management, there is a need to predict the water table behaviour. The statistical model is developed to predict the behaviour of water table based on area under paddy, wheat, total cropped area, rainfall and number of tubewells. The close agreement was achieved between observed and predicted water levels. Shifting of paddy by 20 per cent with maize, groundnut, pulses, vegetables and oilseeds crops help arresting the declining trend of water table.*

Key Words: Statistical Modelling, water table behaviour, land use activity, land use impact, water balance

1.INTRODUCTION

Land use intensity is one of the most significant forms of land cover modification, and can have a major detrimental impact on terrestrial and aquatic ecosystems. Amongst the renewable natural resources groundwater commands a predominant position. About 70 per cent of the net irrigated area of Punjab is irrigated using groundwater. This has resulted in rapid pace of development of groundwater leading to groundwater depletion thereby creating declining water level conditions in about 77 per cent area of the state. Water table is declining at the rate of 17 cm to 59 cm per year (Takshi and Chopra, 2004), in fact its excessive withdrawal for irrigation has raised the issue of sustainability of irrigated agriculture. Groundwater appears to be under threat of exhaustion from its current exploitable zone because of excessive withdrawal for irrigation in Punjab. Unless the existing level of groundwater exploitation is brought within safer limits, the present productivity gains may turn into irreversible decline in the near future.

In Ludhiana district the tubewell irrigated area increased from 2.04 lakh ha in 1969-70 to 2.97 lakh ha in 2002-03 and accounts for 97 per cent of the net irrigated area (Anonymous 2003). This has been made possible due to increase in number of tubewells from 35,257 in 1969-70 to 1,19,060 in 2002-03 which has resulted in over exploitation of groundwater.

The excessive exploitation of groundwater in Ludhiana district is also associated with particular land use activity. Historically, wheat has been and continues to be, the dominant crop activity in the district. It continues to account for about 44 per cent of the cropped area of the district. The second major crop activity is rice. By displacing maize and groundnut, rice has consolidated its base in the last few decades. Consequently the share of land under rice crop in the district has increased from less than one per cent in 1969-70 to 40.4 per cent of total cropped area in 2002-03. Thus, there is a need to analyze the relationship between excessive exploitation of groundwater and cultivation of wheat and paddy crops in Ludhiana district. In this study a statistical model has been developed to predict water table behavior for district Ludhiana.

MATERIALS AND METHODS

Study Area

The study has been carried out for district Ludhiana comprising eleven blocks namely Ludhiana, Mangat, Sidhwanbet, Jagaron, Sudhar, Pakhowal, Dehlon, Doraha, Khanna, Samarala and Machiwara. Information on area under paddy, wheat, total cropped area, rainfall and number of tubewell for 20 years (1983–2003) were used for development of statistical model for water table behaviour. Model is used to analyze the impact of land use activities for the district.

Assessment of Water Resources

From the daily records of the water released into the canal system, the annual releases of water during the period 1983-84 to 2002-03 were estimated. Water level records of observation points in Ludhiana district for the years 1983-84 to 2002-03 were collected from Groundwater Cell, Department of Agriculture and Water

Resources and Environment Directorate, Punjab and were used for analysis.

The annual ground water recharge (June to May) for the period 1983-84 to 2002-03 has been estimated using following relationship:

$$P_g = P_{erc} + Q_{erc} + P_w + P_c - E_t \pm Q_g \qquad (1)$$

Where,
P_g = Total groundwater recharge, ha-m
P_{erc} = Recharge to groundwater from percolation of rainfall, ha-m
Q_{per} = Percolation of water through canal distribution system, ha-m
P_c = Percolation from canal irrigated areas, ha-m
P_w = Percolation of water from areas irrigated by wells, ha-m
E_t = Evaporation from shallow water table areas, ha-m
Q_g = Groundwater inflow/outflow from the area to neighboring areas, ha-m

The value of 25 per cent of total rainfall as groundwater recharge has been used for the study (CGWB, 1997). The seepage factor for seepage from unlined main canals, branches, distributaries, and minors has been assumed as 18 ha-m/day/10^6 sq. m. of the wetted area. For lined canals, seepage losses are taken as 20 per cent of above value. In order to account for deep percolation of water from canal irrigated area, the return flow factor for paddy area is taken as 0.6 and for non paddy area it is taken as 0.3. In order to account for deep percolation of water from canal irrigated area the return flow factor for paddy area is taken as 0.5 and for non paddy area it is taken as 0.3. The loss of ground water as direct evaporation is considered negligible due to very small water table area within 1.5 to 2.0m. Inflow/outflow was calculated from water balance studies.

1) Water Balance of Ludhiana District

The following form of water balance equation has been used for this study,

$$(P + I) - (ET + E + Q_p + Q_g + Q_s + \Delta S_m \pm \Delta S_s) = \pm \Delta S_g \qquad (2)$$

Where,
P = Total precipitation over the area, ha-m
I = Irrigation water applied over the area from all sources, ha-m
ET = Evapotranspiration, ha-m
E = Evaporation from bare soil, ha-m
Q_p = Quantity of groundwater pumped (draft), ha-m
Q_g = Outflow of groundwater across the basin boundaries, ha-m
Q_s = Surface run-off from the area, ha-m
ΔS_m= Change in soil moisture storage, ha-m
ΔS_s= Change in surface storage in distribution system, ha-m
ΔS_g = Change in groundwater storage, ha-m

By using Thiessen Polygon method the weighted average rainfall value for the study area was calculated from four raingauge stations namely Ludhiana, Jagraon, Samarala and Khanna for the period 1983-84 to 2002-03. From the daily canal water releases records, the monthly canal water releases were estimated. The monthly crop evapotranspiration of each crop has been computed using following relationship (Doorenbos and Pruitt, 1977 and Kaushal M P, 1988).

$$ET_{crop} = K_c \times ET_0 \qquad (3)$$

Where,
ET_{crop} = Crop evapotranspiration, mm/day
K_c = Crop coefficient, a fraction
ET_0 = Reference crop evapotranspiration, mm/day

The groundwater draft is calculated from number of tubewells in the area and draft norms. The draft values were increased/decreased by 10 per cent whenever the annual rainfall was usually low/high. The surface runoff has been taken as 34 per cent of the annual rainfall. As the water balance is being considered on annual basis, it is assumed that there is no significant change in soil moisture storage. Change in surface water storage on an annual basis is considered to be negligible. The volume of storage/mining was computed by using an average value of 0.15 as specific yield. The groundwater inflow/outflow has been computed as a residual of water balance equation. The net change in groundwater storage was calculated as

Net change in groundwater storage =Gross recharge to groundwater + groundwater inflow/outflow – groundwater draft (4)

Statistical Model to Predict Water Table Behaviour

Regression analysis is one of the most popular statistical tools and it allows us to model complicated relations between variables. Twenty year data of area under paddy, wheat, total cropped area in thousand hectare, number of tubewells in hundred and rainfall in hundred mm for district Ludhiana were selected as the variables X_1, X_2, X_3, X_4 and X_5 respectively. A multilinear regression analysis was carried out by using following equation

$$Y = b_o + b_1 X_1 + b_2 X_1^2 + b_3 X_2 + b_4 X_2^2 + b_5 X_3 + b_6 X_3^2 + b_7 X_4 + b_8 X_4^2 + b_9 X_5 + b_{10} X_5^2$$
(5)

Where Y is the dependent variable (Water table in metre) in analysis, while b_o is the intercept; b_i represents the regression coefficients for the second order polynomial and X_i represents the levels of independent variables.

RESULTS AND DISCUSSION

Annual Water Balance of Study Area

Depth of water table in year 1983 and rise or fall from 1983-84 to 2002-03 was calculated and the average fall of water table was maximum in Sudhar block i.e. 0.32 m per year and the lowest fall of water level was 0.05 m per year in Doraha block. The average annual rainfall was found to vary between 212.36 mm to 1100.87 mm during the study period with an average value of 511.98 mm. The canal irrigation water applied over the area for the study period vary from 151.65 mm to 237.66 mm and tubewell water vary from 429.62 mm to 802.40 mm. The evapotranspiration for the district Ludhiana varied between 225454.95 ha-m to 284724.93 ha-m. Average value per unit area works out to be 661.67 mm. The annual ground water draft varied from 161837.85ha-m to 287561.48 ha-m with an average value of 237049.78 ha-m. Average value per unit area works out to be 629.28 mm. The average annual surface runoff over these years was 65572.17 ha-m. The runoff varied from 37135.09 ha-m to 140998.81 ha-m with an average value of 65572.17 ha-m. Average value per unit area works out to be 174.07 mm. The change in groundwater storage varied from -70827.13 ha-m to +96009.53 ha-m with an average value of –9926.05 ha-m. Average value per unit area works out to be -26.35 mm. The groundwater outflow has been estimated as the residual of water balance equation and its computation is given in Table 1. From this Table, it is observed that the groundwater outflow varied from a minimum value of –94529.10 ha-m (inflow) to a maximum of 12826.64 ha-m with an average of –39617.54 ha-m during the period of study. Average value per unit area works out to be -105.17 mm. The values for different recharge components (in mm of water) are tabulated in Table 2. By taking 25 percent of the annual rainfall the average annual rainfall recharge over the years 1983-84 to 2002-03 works out to be 48217.6 ha-m. Average value per unit area works out to be 128 mm. The average annual recharge from canal network over the years 1983-84 to 2002-03 works out to be 18104.20 ha-m. Average value per unit area works out to be 48.06 mm. The percolation from canal irrigated areas plus deep percolation from paddy fields varied between 20096.95 ha-m to 30855.50 ha-m during the period 1983-84 to 2002-03 with an average value of 24636.18 ha-m. Average value per unit area works out to be 65.40 mm. The average annual recharge from tubewell irrigated areas during the years 1983-84 to 2002-03 comes out to be 90901.48 ha-m. Average value per unit area works out to be 241.31 mm. Based on the computation of groundwater recharge, the percentage of groundwater recharge works out to be 26.51 per cent, 9.96 per cent and 63.53 per cent by rainfall, canal seepage and return flow from irrigated areas respectively. The results of water balance study were checked by comparing observed and predicted annual rise/fall of water table and is given in Table 2. From the Table 2, it is observed that the trend of computed annual rise/fall in water table is matching and the values compare well with observed values of rise and fall with an average difference of 10 cm.

Development of Model to Predict Water Table Behaviour in district Ludhiana

The linear, exponential, power and multiple regression models were used to develop a model for water table behaviour in study area. The independent parameters were paddy, wheat, total cropped area, rainfall and number of tubewells and evapotranspiration. It was observed that out of all statistical models polynomial of degree two was having the higher correlation coefficient. The Table 3 shows the correlation matrix of independent parameters with water table. It was observed that the area under paddy, total cropped area and number of tubewells are most significant at 5% level of significance and they are the most dominant parameters contributing to declining water table in the study area. The correlation coefficient (R^2), standard error and the F value are given in the Table 4. It was observed that R^2 was maximum (0.9125) in Ludhiana block having standard error as 0.47 where as it was minimum i.e. 0.65 in Dehlon block with the standard error of 0.90. The correlation coefficient (R^2) was higher i.e. 0.93 for Ludhiana district with the standard error of 0.39. Using the multiple regression model water level for the year 2002-03 and 2003-04 was determined. The Fig.1 and 2 shows the graph of the predicted and observed water table for the year 2002-03 and 2003-04 respectively for different blocks of Ludhiana district.

Groundwater Management Strategies in District Ludhiana

It has been observed that the water table is declining every year in district Ludhiana. If the same trend of cropping pattern continues, the water level will decline from 10.96 m in 2002-03 to 15.92 m in 2020-21 (Fig.3). Thus there is need to reduce the stress on the groundwater reservoir. This can be done by shifting the cropping pattern in such a way so as to reduce the area under crops having high water requirements thus helping to reduce the demand for irrigation.

After analyzing the cropping pattern, it is observed that major crops of Ludhiana district in the Kharif season are Paddy, maize, groundnut, pulses, vegetables and oilseeds. The area under these crops in the study area for the year 2003-04 is given in Table 5. The water requirement for the paddy is 124.40 cm, whereas the water requirement of maize, pulses, groundnut, vegetable and oilseeds for the district Ludhiana was calculated as 29.12 cm, 29.06 cm, 34.28 cm, 26.28 cm and 34.28 cm respectively. Since the paddy crop is having higher water requirement, different percentages of the area under paddy was shifted to the other crops viz., maize, groundnut, pulses, vegetables and oilseeds in the ratio of 1:1:1:1:1 and 3:1:1:1:1 respectively.

Based on the blockwise area of these crops and using the water requirements of the crops, the reduction in draft values for 5 per cent, 10 per cent, 15 per cent, 20 per cent, 25 per cent reduction of the paddy area were calculated. Table 6 shows the reduction in draft value for different blocks of the Ludhiana district.

The values of rise/fall of water table in Ludhiana district with 5, 10, 15, 20 and 25 per cent reduction in paddy area are given in Table 7. The recharge from rainfall and canal network as well as groundwater outflow was taken as expected value, which was computed taking average of these values for the year 1983-84 to 2002-03. The groundwater draft was taken as increasing at the rate of 1 per cent, 1.5 per cent and 2 per cent per year over the average value of draft for the year 1983-84 to 2002-03.

Using the predicted water table from the water balance for the year 2002-03, the water table behaviour at 5, 10, 15, 20 and 25 per cent reduction in area under paddy crop with increasing groundwater draft from 1, 1.5 and 2 per cent for year 2003-04 to 2020-21 is carried out. The average water table in Ludhiana district was at 10.96 m in year 2002-03. The analysis shows that by shifting 20 per cent paddy area with other crops the water table is predicted to be 2.06 m at 1 per cent increase in groundwater draft (Fig.4), 5.50 m at 1.5 per cent (Fig.5) and 8.55 m at 2 per cent (Fig.6) in the year 2020-21. Figures clearly show that shifting of 20 per cent paddy area with maize, groundnut, pulses, vegetables and oilseeds would help in arresting the falling water table conditions in district Ludhiana.

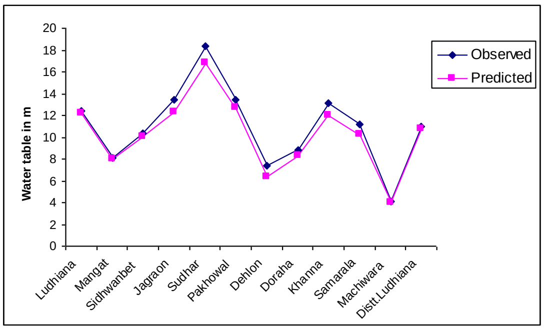

Fig. 1 Observed and predicted water table in district Ludhiana for the year 2002-03

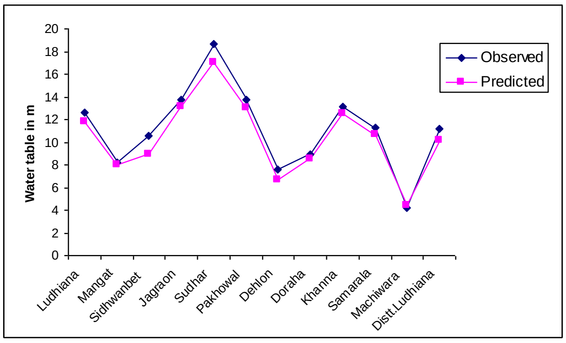

Fig.2 Observed and predicted water table in district Ludhiana for the year 2003-04

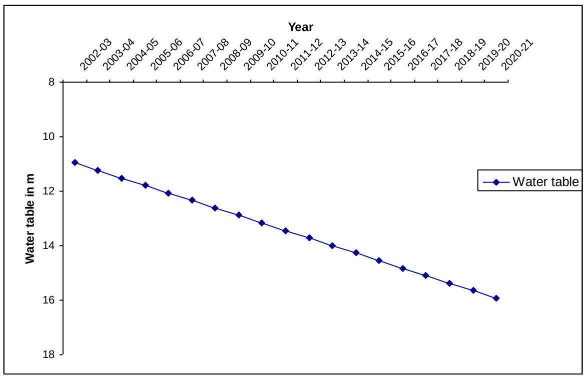

Fig. 3 Water level behaviour in district Ludhiana for the year 2002-03 to 2020-21 without any change in cropping pattern

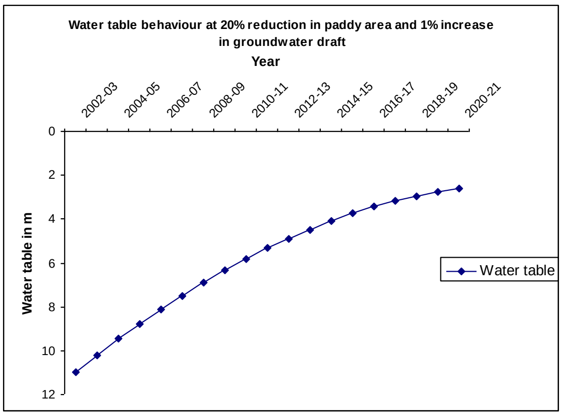

Fig.4 Water table behaviour at 20% reduction in paddy area and increasing 1% groundwater draft

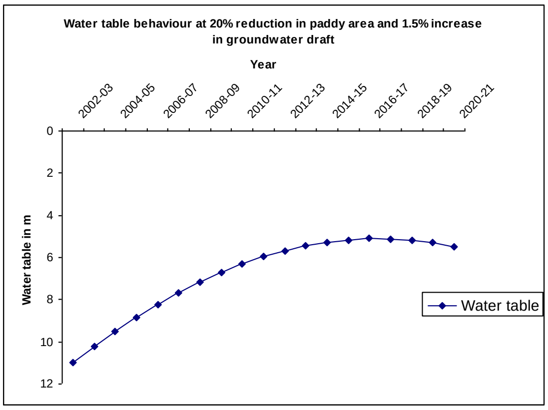

Fig.5 Water table behaviour at 20% reduction in paddy area and increasing 1.5% groundwater draft

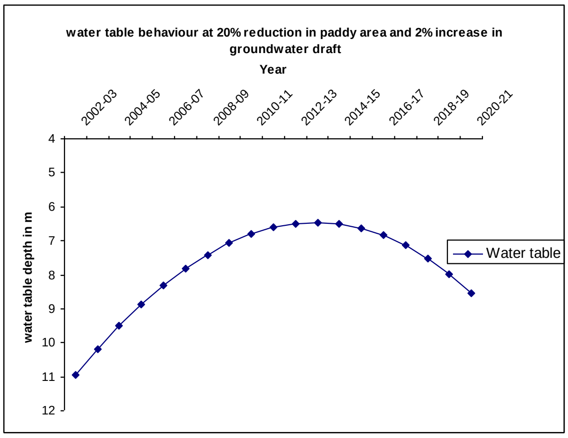

Fig.6 Water table behaviour at 20% reduction in paddy area and increasing 2% groundwater draft

Table 1 Water Balance of District Ludhiana (mm)

Year	Canal Water Input	Rainfall	Tubewell Draft	Evapotranspiration	Tubewell Draft	Runoff	Storage	OUTFLOW
1	2	3	4	5	6	7	8	9
1983-84	184.70	735.73	485.58	663.98	485.58	250.15	-27.75	34.05
1984-85	226.51	568.78	503.19	637.53	503.19	193.39	-46.54	10.91
1985-86	209.15	789.00	452.74	643.96	452.74	268.26	58.03	27.90
1986-87	227.06	471.82	546.56	687.17	546.56	160.42	-79.28	-69.44
1987-88	220.87	212.36	802.40	755.84	802.40	72.20	-188.02	-206.79
1988-89	182.16	1100.87	429.62	668.58	429.62	374.30	254.87	-14.71
1989-90	218.45	485.18	630.21	698.84	630.21	164.96	-74.12	-86.05
1990-91	209.89	561.30	589.71	629.75	589.71	190.84	142.08	-191.48
1991-92	237.66	490.51	642.56	691.49	642.56	166.77	-82.26	-47.83
1992-93	221.76	386.02	658.29	651.98	658.29	131.25	-152.12	-23.32
1993-94	188.20	493.65	664.03	685.36	664.03	167.84	-47.07	-124.28
1994-95	200.31	430.38	670.25	671.19	670.25	146.33	-13.13	-173.70
1995-96	154.31	572.87	670.05	663.28	670.05	194.78	117.38	-248.25
1996-97	180.82	440.06	680.11	669.10	680.11	149.62	-50.77	-147.07
1997-98	165.05	509.49	602.58	598.50	602.58	173.23	-15.10	-82.09
1998-99	151.65	635.55	572.16	627.64	572.16	216.09	25.77	-82.30
1999-00	157.25	324.27	699.95	627.73	699.95	110.25	-5.52	-250.94
2000-01	177.36	336.53	759.54	650.13	759.54	114.42	-150.81	-99.85
2001-02	179.19	405.33	762.79	660.23	762.79	137.81	-43.11	-170.42
2002-03	152.60	289.93	763.37	651.12	763.37	98.58	-149.46	-157.71
AVERAGE	192.25	511.98	629.28	661.67	629.28	174.07	-26.35	-105.17

{(9) = (2) + (3) + (4) - (5) - (6) – (7) – (8)}

Table 2 Comparison of computed and observed water table rise/fall in the District Ludhiana

Year	Rainfall recharge	Canal Seepage	Percolation From Canal irrigated Area	Percolation From Well irrigated Area	Groundwater Outflow	Groundwater Draft	Net Recharge	Computed Equivalent Rise/Fall in water Table	Observed Equivalent Rise/Fall in water able	Difference
1	2	3	4	5	6	7	8	9	10	11
1983-84	183.93	46.18	58.71	172.24	34.05	485.58	-58.56	-0.39	-0.18	0.21
1984-85	142.20	56.63	72.90	180.08	10.91	503.19	-62.31	-0.42	-0.31	0.11
1985-86	197.25	52.29	68.32	181.97	27.90	452.74	19.20	0.13	0.39	0.26
1986-87	117.96	56.77	74.34	198.03	-69.44	546.56	-30.03	-0.20	-0.53	0.33
1987-88	53.09	55.22	72.47	242.67	-206.79	802.40	-172.17	-1.15	-1.25	0.11
1988-89	275.22	45.54	59.66	222.45	-14.71	429.62	187.96	1.25	1.70	0.45
1989-90	121.30	54.61	73.69	233.36	-86.05	630.21	-61.21	-0.41	-0.49	0.09
1990-91	140.33	52.47	70.76	218.27	-191.48	589.71	83.59	0.56	0.95	0.39
1991-92	122.63	59.42	81.91	241.70	-47.83	642.56	-89.08	-0.59	-0.55	0.05
1992-93	96.51	55.44	76.91	248.77	-23.32	658.29	-157.34	-1.05	-1.01	0.03
1993-94	123.41	47.05	65.46	251.47	-124.28	664.03	-52.36	-0.35	-0.31	0.04
1994-95	107.60	50.08	71.35	258.32	-173.70	670.25	-9.21	-0.06	-0.09	0.03
1995-96	143.22	38.58	53.52	253.20	-248.25	670.05	66.72	0.44	0.78	0.34
1996-97	110.02	45.21	64.18	261.44	-147.07	680.11	-52.20	-0.35	-0.34	0.01
1997-98	127.37	41.26	57.54	253.99	-82.09	602.58	-40.32	-0.27	-0.10	0.17
1998-99	158.89	37.91	53.35	273.11	-82.30	572.16	33.39	0.22	0.17	0.05
1999-00	81.07	39.31	54.89	265.77	-250.94	699.95	-7.97	-0.05	-0.04	0.02
2000-01	84.13	44.34	62.26	289.59	-99.85	759.54	-179.38	-1.20	-1.01	0.19
2001-02	101.33	44.80	62.49	289.44	-170.42	762.79	-94.32	-0.63	-0.29	0.34
2002-03	72.48	38.15	53.40	290.40	-157.71	763.37	-151.22	-1.01	-1.00	0.01
AVERAGE	128.00	48.06	65.40	241.31	-105.17	629.28	-41.34	-0.28	-0.18	0.10

* Specific value taken as 0.15
** {(8) = (2) + (3) + (4) + (5) – (6) – (7)}

{(2) to (8) values are in milli-meters}
{(9) to (11) values are in meters}

Table 3 Correlation matrix of different parameters for district Ludhiana

	Paddy	Wheat	Total cropped Area	Rainfall	Number of Tubewells	Evapotranspiration
Wheat	-0.628					
Total cropped Area	-0.038	0.408				
Rainfall	-0.462	0.306	0.145			
Number of Tubewells	0.834	-0.739	-0.133	-0.407		
Evapotran-spiration	-0.257	0.105	0.353	-0.221	-0.78	
Water level	0.504	-0.679	0.559	-0.661	0.619	0.073

Number of variables = 7

Number of observations = 20

Critical value at 5% level of significance = 0.444

Table 4 Statistical Analysis

Block	R^2	Standard Error	F Value
Ludhiana	0.9125	0.4787	9.3923
Mangat	0.8857	0.3605	6.9739
Sidhwanbet	0.8535	0.5967	5.2452
Jagraon	0.8507	0.7158	11.8298
Sudhar	0.8988	0.8757	7.9953
Pakhowal	0.8658	0.7596	5.8099
Dehlon	0.6546	0.9012	1.7059
Doraha	0.8028	0.549	3.6657
Khanna	0.6757	0.7669	1.8755
Samarala	0.7911	0.6234	3.4095
Machiwara	0.9017	0.249	8.2646
District Ludhiana	0.9345	0.3917	8.323

Table 5 Area under major *Kharif* crops (ha) for the year 2003-04

BLOCK	PADDY	MAIZE	PULSES	GROUNDNUT	VEGETABLE	OILSEEDS
Ludhiana	15486	235	94	0	109	2
Mangat	28870	282	152	31	355	4
Pakhowal	20479	311	213	1	86	4
Dehlon	19504	262	65	0	26	0
Sudhar	26719	215	508	4	39	2
Jagraon	29792	140	385	0	33	0
Sidhwanbet	28852	287	1150	6	87	27
Samarala	12762	258	17	1	221	0
Machiwara	21530	553	8	5	54	1
Khanna	18456	296	22	0	573	0
Doraha	18542	154	29	0	19	0
TOTAL	240992	2993	2643	48	1602	40

Table 6 Reduction in draft values (ha-m) for different blocks

BLOCK	5%	10%	15%	20%	25%
Ludhiana	726.2678	1452.54	2178.80	2905.07	3631.34
Mangat	1353.955	2707.91	4061.87	5415.82	6769.78
Pakhowal	960.4313	1920.86	2881.29	3841.73	4802.16
Dehlon	914.7054	1829.41	2744.12	3658.82	4573.53
Sudhar	1253.077	2506.15	3759.23	5012.31	6265.39
Jagraon	1397.196	2794.39	4191.59	5588.78	6985.98
Sidhwanbet	1353.111	2706.22	4059.33	5412.44	6765.56
Samarala	598.5167	1197.03	1795.55	2394.07	2992.58
Machiwara	1009.721	2019.44	3029.16	4038.89	5048.61
Khanna	865.5559	1731.11	2596.67	3462.22	4327.78
Doraha	869.5892	1739.18	2608.77	3478.36	4347.95
TOTAL	11302.13	22604.25	33906.38	45208.51	56510.64

Table 7 Rise/Fall of water table under normal conditions (mm) for 5, 10, 15, 20 and 25 per cent reduction in paddy area

Percent reduction in paddy area	Rainfall Recharge (mm)	Canal Seepage (mm)	Percolation from C.I.A. (mm)	Percolation From T.I.A. (mm)	Groundwater Outflow (mm)	Groundwater Draft (mm)	Net Recharge (mm)	Computed Equivalent Rise/Fall in Water Table (m)
5	127.995	48.062	52.704	287.592	-105.168	629.284	-7.763	-0.0518
10	127.995	48.062	51.935	284.509	-105.168	629.284	-11.615	-0.0774
15	127.995	48.062	51.166	281.425	-105.168	629.284	-15.468	-0.1031
20	127.995	48.062	50.396	278.342	-105.168	629.284	-19.320	-0.1288
25	127.995	48.062	49.627	275.259	-105.168	629.284	-23.173	-0.1545

C.I.A. is the Canal Irrigated Area
T.I.A. is the Tubewell Irrigated Area

3. CONCLUSIONS

Land use/land cover management, particularly high-input agriculture, is considered to be an important source. It has been observed that the water table is declining every year in district Ludhiana. If the same trend of cropping pattern continues, the water level will decline from 10.96 m in 2002-03 to 15.92 m in 2020-21 (Fig. 3). This can be done by shifting the cropping pattern in such a way so as to reduce the area under crops having high water requirements thus helping to reduce the demand for irrigation. The water table behaviour of the Ludhiana district indicates that there is a declining trend of water level and the average rate of fall of water table is 18 cm per year for the years 1983-84 to 2002-03. The groundwater recharge from rainfall, canal seepage and return flow from irrigated area was found to be 26.51 per cent, 9.96 per cent and 63.53 per cent respectively. Multiple regression model fits well to the data on water level verses area under paddy, wheat, total cropped area, number of tubewells and rainfall. The observed and predicted water levels for all the blocks of Ludhiana district has been found in close agreement with each other. The analysis shows that by shifting 20 per cent paddy area with other crops the water table is predicted to be 2.06 m at 1 per cent increase in groundwater draft, 5.50 m at 1.5 per cent and 8.55 m at 2 per cent in the year 2020-21. Figures clearly show that shifting of 20 per cent paddy area with maize, groundnut, pulses, vegetables and oilseeds would help in arresting the falling water table conditions in district Ludhiana.

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