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Assessment of relationship between selected weather parameters and groundwater level in Dharwad district of Karnataka

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Abstract
Groundwater is a very important natural resource and has a significant role in the economy. It is the main source of water for irrigation and the food industry. In general, groundwater is a reliable source of water for agriculture and can be used in a flexible manner. The present study was undertaken in the 24 observation wells of the Dharwad district of Karnataka. To assess the relationship between selected weather parameters and groundwater level, the techniques of correlation and regression analysis were employed, and the results obtained by correlation and regression analysis, which were used to study the relationship between selected weather parameters and groundwater levels, showed that groundwater levels are negatively correlated with rainfall and positively correlated with temperature and both rainfall and temperature were found to contribute significantly to the variation in groundwater levels in most of the wells.

Keywords: Groundwater level, correlation and regression analysis, rainfall and temperature

Introduction
Groundwater is a very important natural resource and has a significant role in the economy. It is the main source of water for irrigation and the food industry. Among the various forms of water resources, groundwater has become an essential and most reliable source due to its several inherent qualities, such as widespread and continued availability, outstanding quality, limited susceptibility, cheap, drought dependability and so on. To keep up with the increased demand for water caused by rapid development, it is necessary to assess the quality and quantity of groundwater. Sustainable management of groundwater resources is a fundamental task.

Correlation measures the degree of closeness or association between two variables and the strength of the relationship between different parameters. A regression study tells about the contribution of independent variable to the dependent variable.

Material and Methods
Dharwad district is situated in the western sector of the northern half of Karnataka state. The district encompasses an area of 4263 square kilometers lying between the latitudinal parallels of 15°02' and 15°51' north and longitudes of 73°43' and 75°35' east. The district lies approximately about 800 meters above the sea level. The total geographical area of the district is 8, 38,600 ha. Of this, the total cultivable area is 6, 22,853 ha, which constitutes 78.27 per cent of the total geographical area. Agriculture is the main occupation in the district, which uses both surface and groundwater resources and employs the flood irrigation method. The major crops grown are jowar, paddy, wheat, maize, cotton, soybeans, chilli, onion and green gram. The south-west monsoon is most crucial for Dharwad district. Average annual rainfall of the district was 864 mm. The average temperature is 24.1 ^{0}C.

The climate is mildly hot during the summer (April–May) and pleasant during rest of the year. The hot season begins from March with the maximum temperature of 38 ^{0}C and minimum temperature of Dharwad is 14 ^{0}C during the month of December, which is the coldest month.

Figure 1 shows the study area map with 24 observation well locations. The secondary data pertaining to groundwater level was collected from the Department of Mines and Geology, Dharwad from 2010 to 2020 (for some wells, data was available from 2010 to 2020 and for some wells from 2012 to 2020) and weather parameters (rainfall and temperature) were collected from the Karnataka State Natural Disaster Monitoring Center (KSNDMC), Bengaluru from 2010 to 2020. The description of the Twenty four observation wells are shown in Table 1.

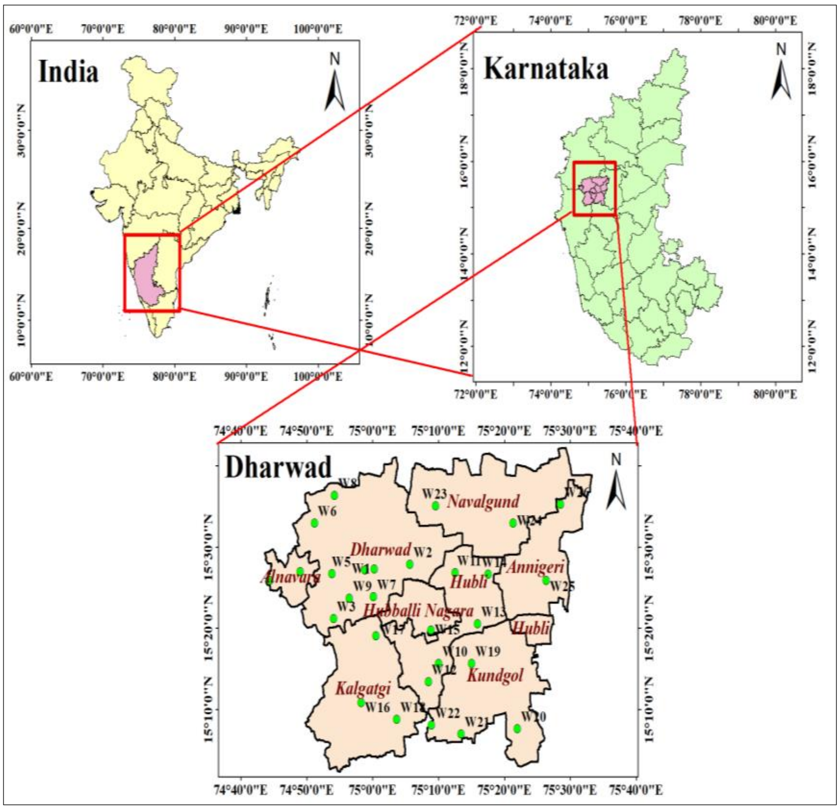

Fig 1: Location map of study area

Table 1: Observation wells of study area

Taluk	Well No	Well location	Well type
Dharwad	W1	Dharwad	Bore well
	W2	Somapur	Bore well
	W3	Banaduru	Bore well
	W4	Amminabhavi	Bore well
	W5	Mandihala	Bore well
	W6	Guledhakoppa	Bore well
	W7	Yarikoppa	Bore well
	W8	Thadakoda	Bore well
Hubbali	W9	Byahatti	Bore well
	W10	Chabbi	Bore well
	W11	Mantur	Bore well
	W12	Kiresur	Bore well
Hubbali Nagara	W13	Bidanala	Bore well
Kalaghatagi	W14	Kalaghatgi	Bore well
	W15	Dhummawad	Bore well
	W16	Tabakad Honnalli	Bore well
Kundagol	W17	Gudageri	Bore well
	W18	Hirebudihal	Bore well
	W19	Jigalur	Bore well
Navalagunda	W20	Navalagund	Bore well
Annigeri	W21	Annigeri	Bore well
	W22	Shelavadi	Bore well
Alnavara	W23	Alnavara	Bore well
	W24	Aravatagi	Bore well

Correlation analysis

Correlation measures the degree of closeness or association between two variables and the strength of the relationship between different parameters.

Correlation coefficient

The index of the degree of relationship between two variables is known as correlation coefficient. It measures the strength of the linear relationship between two variables X and Y.

It is calculated by using following formula,

$$r = \frac{n\sum X_i Y_i - \sum X_i \sum Y_i}{\sqrt{(n\sum X_i^2 - (\sum X_i)^2 (n\sum Y_i^2 - (\sum Y_i)^2)}}$$

Where,

r = Correlation coefficient.

X = Independent variable (Weather parameters).

Y=Dependent variable (Groundwater level).

i=1, 2, 3… n.

Testing correlation coefficient

The significance of Correlation coefficient (r) is tested using t-test.

Hypothesis is set as

H_0: ρ= 0.

H_1: ρ≠0.

Test statistic is as follows,

$$t = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}}$$

Where,

r = Correlation coefficient.

n = Number of observations.

Calculated t-value is compared with critical t-value for (n-2) degrees of freedom for drawing the significant inference.

Multiple regression models

When the numbers of variables which explain the dependent variable are more than one, multiple linear regression models can be used. Here, the model is,

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots + \beta_p X_p$$

Where,

Y = Groundwater level.

X_i = weather parameters *viz.*, rainfall and temperature.

β_i = partial regression coefficients of Y on X_i's, where i=1, 2… P.

In this model, the estimates of coefficients (β_i's and α) are to be computed using the method of least squares. The final relation can be represented in matrix form as follows.

$$\begin{bmatrix}\beta_1\\ \beta_2\\ \vdots\\ \beta_p\end{bmatrix} = \begin{bmatrix}\sum X_1^2 & \sum X_1X_2 & \cdots & \sum X_1X_p\\ \sum X_2X_1 & \sum X_2^2 & \cdots & \sum X_2X_p\\ \vdots & \vdots & \ddots & \vdots\\ \sum X_pX_1 & \sum X_pX_2 & \cdots & \sum X_p^2\end{bmatrix}^{-1} \begin{bmatrix}\sum X_1Y\\ \sum X_2Y\\ \vdots\\ \sum X_pY\end{bmatrix}$$

And

$$\hat{\alpha} = \bar{Y} - (\beta_1\bar{X}_1 + \beta_2\bar{X}_2 + \ldots + \beta_p\bar{X}_p)$$

The model was tested by using F test with statistic defined as.

$$F = \frac{\text{Regression mean sum of square}}{\text{Error mean sum of square}}$$

Coefficients of determination (R^2)

Coefficient of determination (R^2) was used as the measure the goodness of fit.

$$R^2 = \frac{\textit{regression sum of squares}}{\textit{total sum of squares}} = \frac{b\sum(X_i-\bar{x})(Y_i-\bar{y})}{\sum(Y_i-\bar{y})^2}.$$

Results and Discussion

Correlation studies allowed researchers to learn more about the relationship that exists between groundwater level and weather parameters. In view of this, an attempt to compute the correlation between groundwater level and weather parameters has been made and the results are discussed (Table 2).

The result of correlation analysis reveals that groundwater levels are negatively correlated with rainfall, which means that as rainfall increases, groundwater level depths decrease. The highest correlation was exhibited by the W10 located in Chabbi, which was found to be -0.539. The groundwater levels showed no correlation with rainfall in W3, W7, W15 and W19. It might be due to the fact that in these regions the groundwater levels may be affected by other factors like runoff, infiltration rate, land use pattern, cropping system and so on.

A positive correlation existed between the groundwater levels and temperatures in the study area. The highest correlation was exhibited by the W24 located at Aravatagi, which was found to be 0.475. The groundwater levels showed no correlation with temperature in W2, W3, W6, W8, W9, W11, W12, W15 and W20. It might be due to the fact that in these regions the groundwater levels may be affected by other factors like runoff, infiltration rate, land use pattern, cropping system and so on. Similar results were obtained from the study conducted by Tabari *et al.* (2012) [9], who observed that there was a significant positive correlation between average groundwater level and maximum and minimum air temperatures, whereas groundwater level had negative correlations with precipitation and relative humidity.

Regression studies allowed researchers to learn more about the contribution of each weather parameter to the groundwater level. In the case of multiple regressions, the dependent variable is groundwater level and the independent variables are rainfall and temperature. The multiple regression models were fitted to 24 observation wells and presented in Table 3.

Only rainfall contributed significantly to the total variation in groundwater levels in W2, W8, W9, W11, W12, W13, and W20, accounting for approximately 16,15,7,11,22,20, and 12 per cent, respectively. In W21, only temperature was found to contribute significantly, about 8 per cent, to the total variation in the groundwater levels. Rainfall and temperature were found to contribute significantly to about 39,11,15,36,16,18,10,13 and 42 per cent of the total variation in groundwater levels in W1, W4, W5, W10, W16, W17, W18, W22, W23 and W24, respectively. The W24 located at Aravatagi showed highest R^2 value of 0.42 and the R^2 value was significant and higher, which represents the true relationship between groundwater level and weather parameters.

Though the temperature was significantly correlated in W7 and W9, the rainfall and temperature were significantly correlated in W14. It is not significant in regression, indicating that in these wells, the relationship between groundwater level, rainfall, and temperature is not linear. The contribution of rainfall to the groundwater level is significant in the majority of the wells than the temperature in the study area. Similar results were found from the study conducted by Swetha (2009) [8], who concluded that out of four weather parameters, only rainfall contributed significantly to the groundwater level and the multiple regression model fit was found highly significant for the data with an R^2 value of 0.44.

Conclusion

Groundwater level trends of 24 observation wells were investigated. The present study concludes that, groundwater levels are negatively correlated with rainfall and positively correlated with temperature.

Rainfall was found to contribute significantly to the variation in groundwater levels in seven wells, while temperature was found to contribute significantly to the variation in groundwater levels in one well and both rainfall and temperature were found to contribute significantly to the variation in groundwater levels in ten wells.

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