Groundwater Level Prediction Using Multiple Linear Regression

1. Scenario

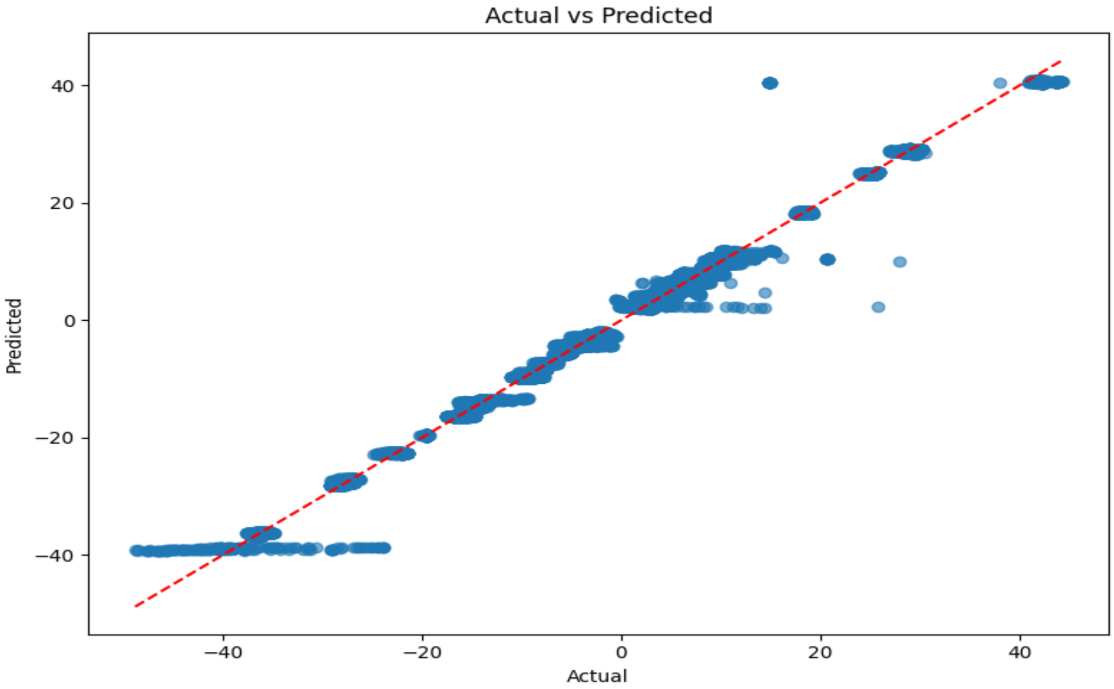
- Delhi NCR
- Objective: Identify key drivers of groundwater depletion and predict groundwater levels at unsampled locations.

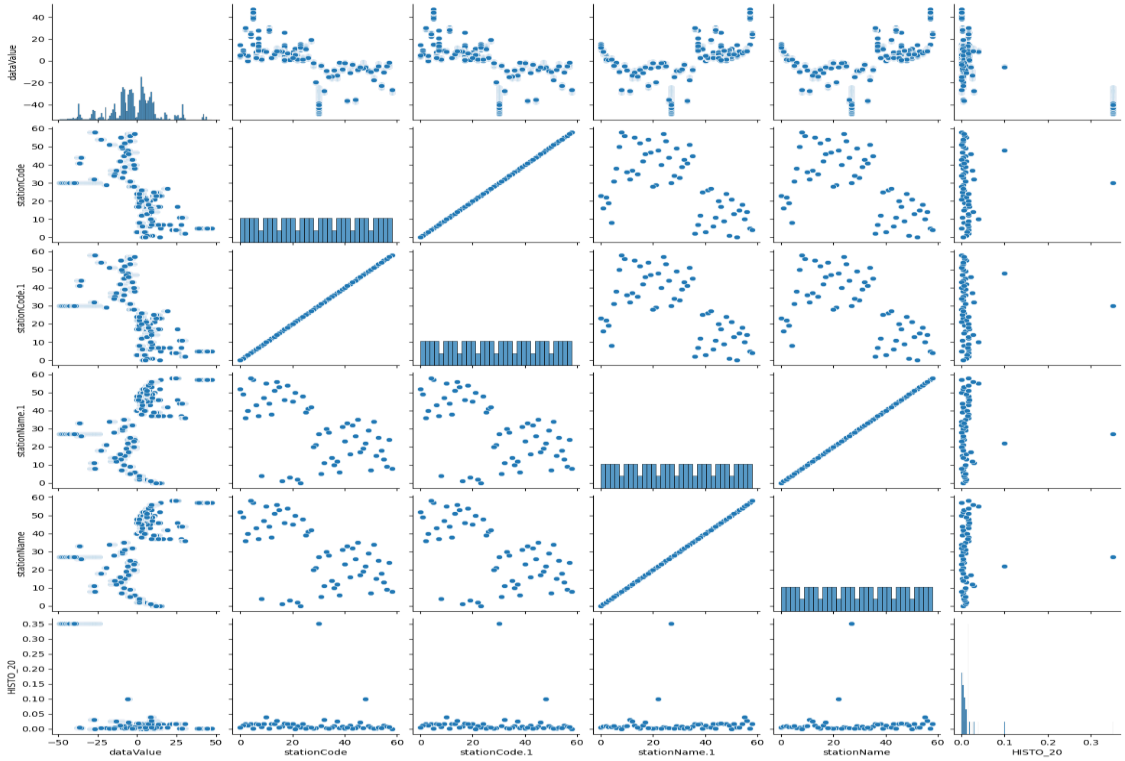
2. Methodology

- **Data:** Preprocessed groundwater dataset with 175 columns including the target 'data Value'.
- **Dependent variable**: dataValue
- **Independent variables**: 58 selected features (BIC criterion)
- **Spatial unit**: District
- **Temporal unit**: Daily
- **Model equation**: Multiple Linear Regression (OLS)
- **Data Acquisition**: Data acquired from India WRIS, Bhuvan ISRO, Copernicus Climate Data Store, NICES Portal, SHRUG Atlas.
- **Data Merging**: Merged datasets on district and date.
- **Data Preprocessing**: Missing values handled, outliers removed, data merged appropriately.
- **Model Specification**: Defined model structure and selected features.
- **Model Training**: Trained the model using the training dataset.
- **Model Evaluation**: Evaluated model performance using test dataset and metrics like R^2, RMSE.
- **Model Diagnostics**: Residuals analyzed for patterns.
- **EDA**: Scatter plots, pair plots, and spatial-temporal plots analyzed to observe trends.

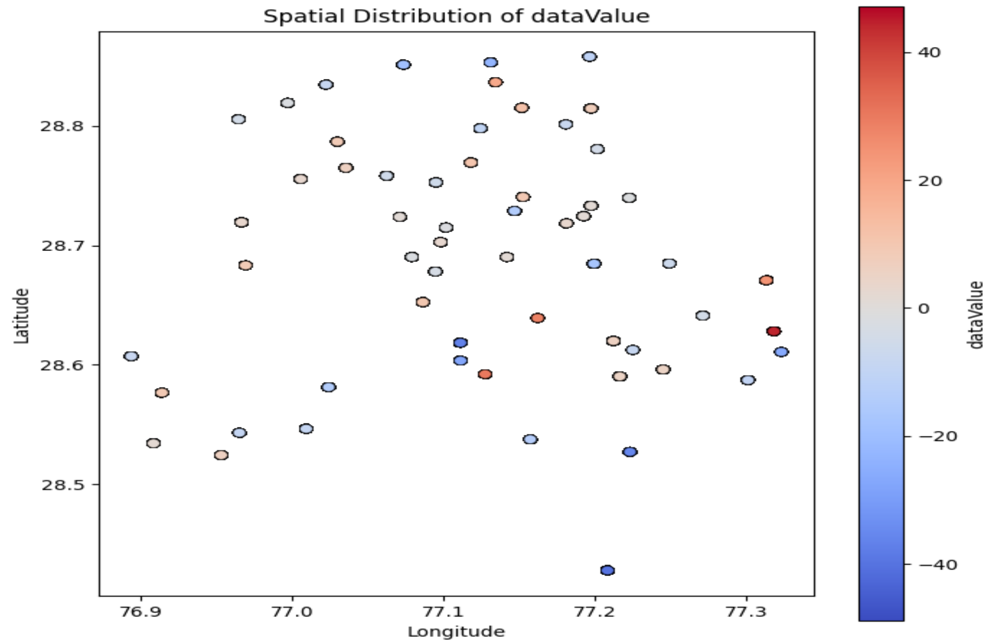
3. Exploratory Data Analysis (EDA)

- Scatter plots and pair plots were used to explore relationships between features and groundwater levels.
- Spatial and temporal trends were observed.
- Data was cleaned and outliers removed.





Pair-plots of features with GWL Values



4. Model Assumptions

- Linearity: Relationships between predictors and target are linear.
- No Perfect Multicollinearity: Checked correlations among predictors.
- Exogeneity: Residuals uncorrelated with predictors.
- Homoscedasticity: Residuals have constant variance.

5. Model Selection

- Compared models using AIC and BIC.
- BIC-selected model (58 predictors) was chosen for analysis.

6. Model Estimation & Diagnostics

- Top 12 Coefficients:

Feature	Coefficient	Std_Error	t_value	p_value
stationCode.1	-0.22627	0.000746	-303.44491	0.0
HISTO_20	-81.591015	1.554332	-52.49266	0.0
Rainfall(mm)_2024	-0.539686	0.003682	-146.55966	0.0

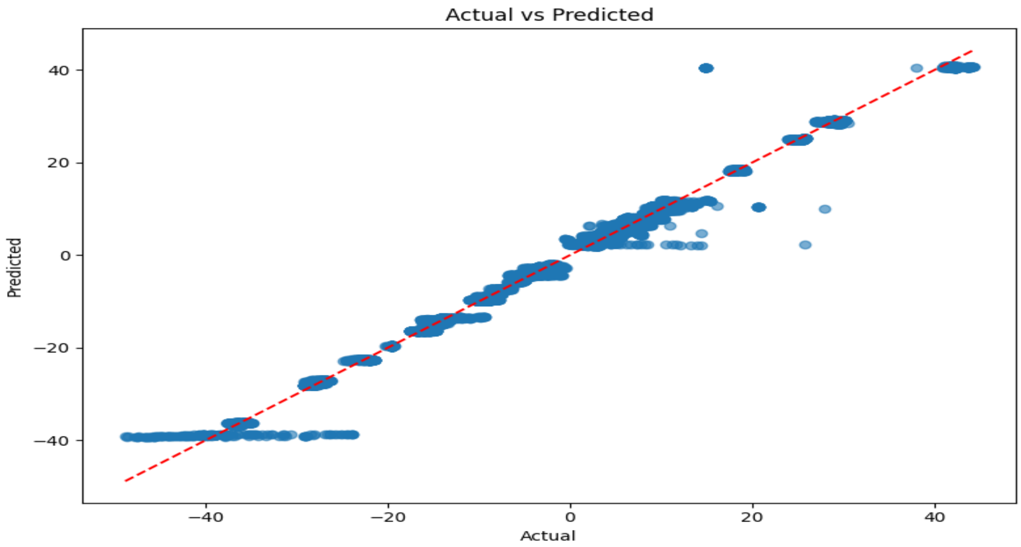
_count	-5.4e-05	0.0	-377.401993	0.0
HISTO_80	574.507576	9.251323	62.100043	0.0
shape_leng	-0.002849	1e-05	-273.703361	0.0
Pre Monsoon of GW Trend_2024	47.434549	0.648234	73.175021	0.0
stationName	0.592188	0.002755	214.934334	0.0
Categorization of Assessment Unit_2023	-33.680615	0.38376	-87.764782	0.0
sand_5-15cm_mean	1.608464	0.01368	117.575387	0.0

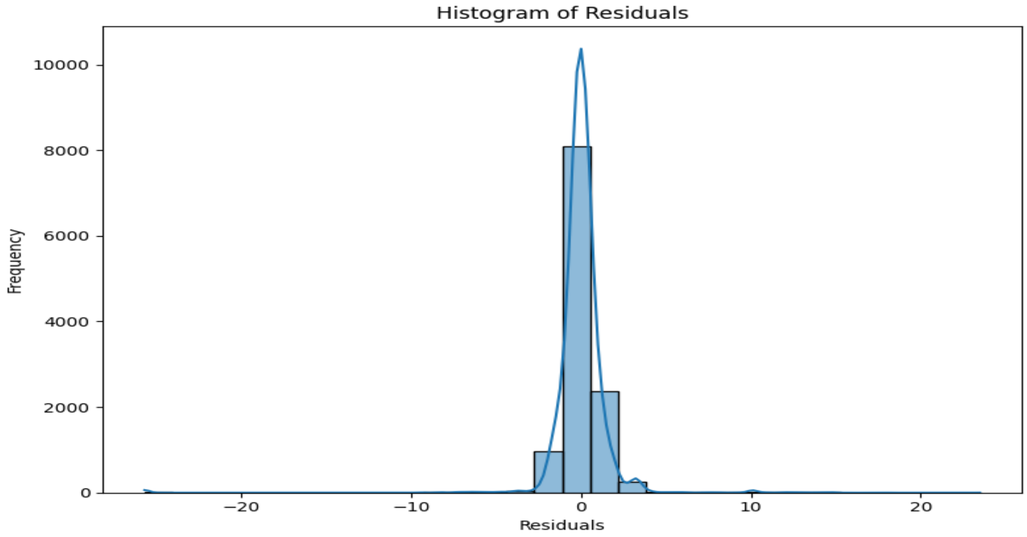
Model Fit Metrics:

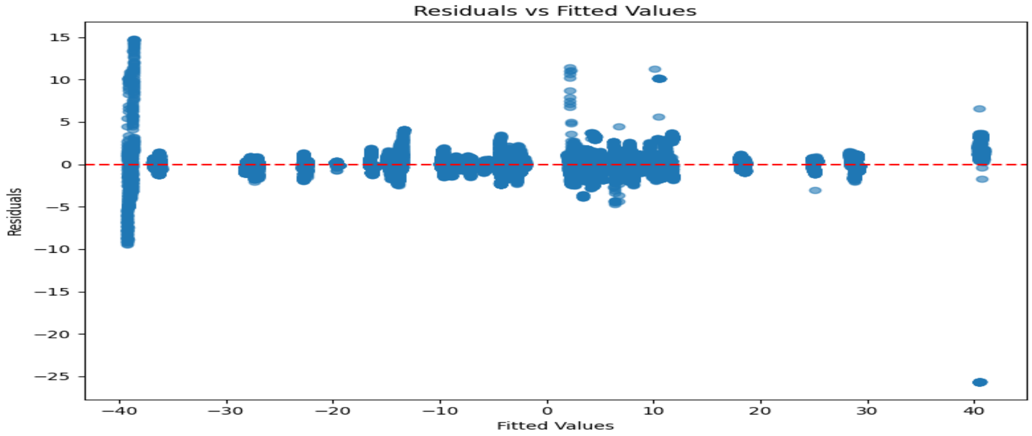
- R_squared(training): 0.9904
- Adj_R_squared: 0.9904
- F_stat: 49925.6491
- F_pvalue: 0.0000
- Num_Predictors: 58.0000

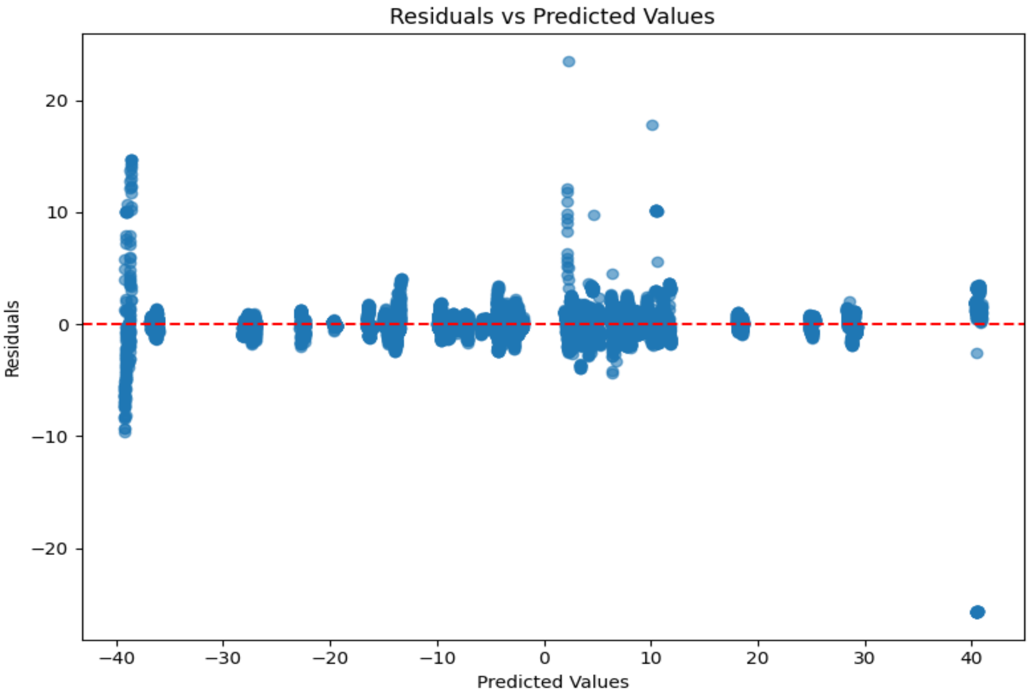
7. Predictions & Evaluation

- R-squared(testing data): 0.9868
- RMSE: 1.7404
- MSE: 3.0291
- Plots:


Actual vs Predicted
Predicted
40
20
0
−20
−40
Actual
−40
−20
0
20
40

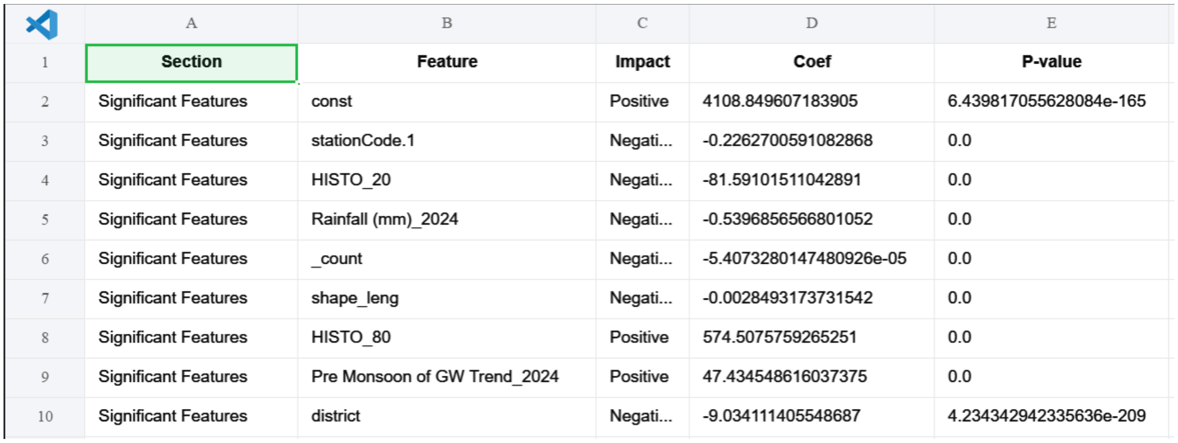

Histogram of Residuals
Frequency
10000
8000
6000
4000
2000
0
Residuals
−20
−10
0
10
20


Residuals vs Fitted Values
Residuals
15
10
5
0
−5
−10
−15
−20
−25
Fitted Values
−40
−30
−20
−10
0
10
20
30
40



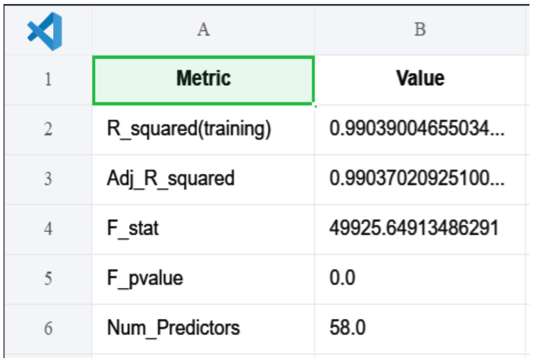
- Residual Plot
- The residual plot shows the difference between observed and predicted values. It helps in diagnosing the model fit.
- Interpretation: No clear pattern suggests a good fit.
- Action: Consider refining the model if patterns are detected.

8. Significant Features & Interpretation



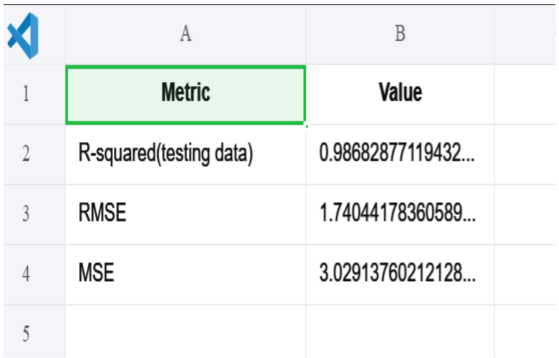
Section	Feature	Impact	Coef	P-value
Significant Features	const	Positive	4108.849607183905	6.439817055628084e-165
Significant Features	stationCode.1	Negati...	-0.2262700591082868	0.0
Significant Features	HISTO_20	Negati...	-81.59101511042891	0.0
Significant Features	Rainfall (mm)_2024	Negati...	-0.5396856566801052	0.0
Significant Features	_count	Negati...	-5.4073280147480926e-05	0.0
Significant Features	shape_leng	Negati...	-0.0028493173731542	0.0
Significant Features	HISTO_80	Positive	574.5075759265251	0.0
Significant Features	Pre Monsoon of GW Trend_2024	Positive	47.434548616037375	0.0
Significant Features	district	Negati...	-9.034111405548687	4.234342942335636e-209

Model Fit Metrics:



Metric	Value
R_squared(training)	0.99039004655034...
Adj_R_squared	0.99037020925100...
F_stat	49925.64913486291
F_pvalue	0.0
Num_Predictors	58.0

Model Prediction Metrics:



Metric	Value
R-squared(testing data)	0.98682877119432...
RMSE	1.74044178360589...
MSE	3.02913760212128...

Confidence in Interpretation:

- Description: The model explains most of the variability in groundwater levels (high R-squared).
- Significant features with p < 0.05 are likely reliable predictors.
- Prediction metrics (RMSE for regression and Accuracy/F1 for categorized classes) indicate reasonable predictive power.

9. Conclusion & Policy Implications

- The model identifies key factors affecting groundwater levels.
- Predictions can guide water resource planning.
- Recommendations: Monitor significant drivers and use the model for short-term planning and risk assessment.

10. References

- India WRIS: https://indiawris.gov.in/wris/
- Bhuvan ISRO: https://bhuvan-app1.nrsc.gov.in/2dresources/bhuvanstore2.php
- Copernicus Climate Data Store: https://cds.climate.copernicus.eu/#!/home
- NICES Portal: https://nices.nrsc.gov.in/
- SHRUG Atlas: https://www.devdatalab.org/atlas