Water Resource Monitoring and Future Water Condition Forecasting using NDWI and Climate Prediction with Machine Learning

Abstract

Water scarcity, floods, and droughts are increasing due to climate change and environmental degradation. This project presents a data-driven approach to forecast future water conditions (Flood, Drought, Normal) using remote sensing and climate data. By integrating **NDWI (Normalized Difference Water Index)** and climate parameters (Rainfall, Temperature), and applying **LSTM and Prophet models**, we generate accurate forecasts. The future water condition is then classified using intelligent rules based on predicted NDWI and Rainfall. The system is interactive and user-driven, capable of providing flood or drought warnings for any specified number of future months.

Problem Statement

Uncertainty in water availability, combined with insufficient monitoring, often leads to delayed response to droughts and floods. Manual assessment and poor forecasting accuracy hinder preparedness. The main problems include:

- No automated mechanism to monitor water content using satellite data.
- Lack of early warning system integrating both **hydrological** and **meteorological** predictions.
- Region-specific future water condition forecasting is absent in most models.

Project as a Solution

We developed an integrated forecasting model using:

- **Google Earth Engine (GEE)** for retrieving NDWI data from satellite imagery.
- **Prophet (by Facebook)** for forecasting Rainfall, Maximum, and Minimum Temperature.
- **LSTM (Long Short-Term Memory)** model for forecasting NDWI values.
- A **rule-based classifier** to predict water condition: Drought, Flood, or Normal.

Key Features:

- Real-time climate and NDWI data handling.
- Predictive accuracy using advanced ML algorithms.
- Region-specific monitoring (Jharkhand, India).
- Interactive input for forecasting horizon (e.g., forecast for next 12 months).

Region

Defined in Google Earth Engine (GEE):

```
var region = ee.Geometry.Point([85.324, 23.344]).buffer(5000);
```

Region Details:

- **Latitude**: 23.344° N
- **Longitude**: 85.324° E
- **Location**: Near Ranchi/Hazaribagh, Jharkhand, India
- **Area**: Circular buffer with **5 km radius**

This area is used to:

- Collect NDWI values monthly.
- Analyze vegetation water content.
- Observe rainfall and temperature trends for localized prediction.

Dataset Collection and Duration

Parameter	Source	Platform	Duration
NDWI	Landsat (via Google Earth Engine)	Remote Sensing	Jan 2010 – Nov 2024
Rainfall	CHIRPS or IMD (CSV Format)	Climate Archive	Jan 2010 – Nov 2024
Tmax / Tmin	ERA5 / IMD	Climate Archive	Jan 2010 – Nov 2024

- Collected and preprocessed in **monthly intervals**.
- Final merged dataset contains aligned **monthly NDWI, Rainfall, Tmax, Tmin** for training and prediction.
- Dataset - NDWI Dataset & Rainfall & Temperature Dataset

Procedure (Pipeline)

1. Data Preprocessing

- NDWI values extracted using GEE and saved.
- Rainfall & Temperature CSVs were cleaned, nulls removed.
- Monthly aggregation performed.
- Merged into one DataFrame.

2. Exploratory Data Analysis (EDA)

- Line plots of NDWI, Rainfall, Tmax, Tmin over time.
- Boxplots and Histograms with KDE for distribution insights.
- Correlation matrix to check interdependency.

3. Classification (Historical Labeling)

```
if NDWI < -0.2 and Rainfall < 30 ➜ Drought
if NDWI > -0.1 and Rainfall > 200 ➜ Flood
Else ➜ Normal
```

4. Forecasting

- **NDWI Prediction** using **LSTM** model (trained on past NDWI).
- **Rainfall, Tmax, Tmin Prediction** using **Prophet** (Facebook) model.

5. Future Condition Classification

- Merge NDWI and Climate forecasts by month.
- Apply classification logic on future predictions:

```
if NDWI < -0.15 and Rainfall < 50 ➜ Drought
if NDWI > -0.17 and Rainfall > 200 ➜ Flood
Else ➜ Normal
```

6. User Interaction

- User inputs number of future months (e.g., 6, 12, or 24).
- Predicted water condition displayed month-wise.
- A **forecast visualization** shows NDWI, Rainfall, and condition regions (colored bands).

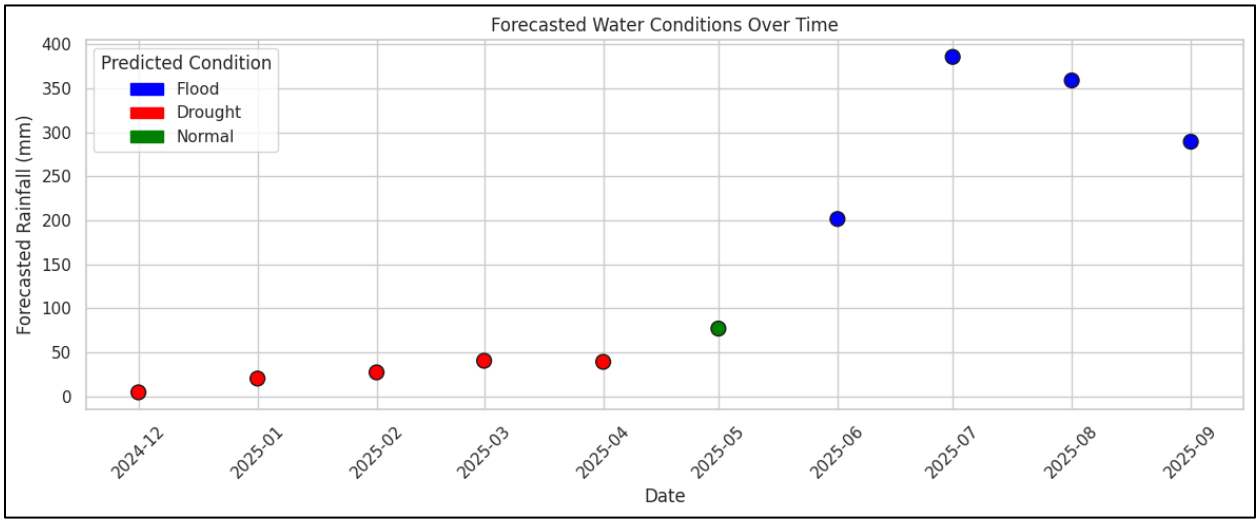
Output

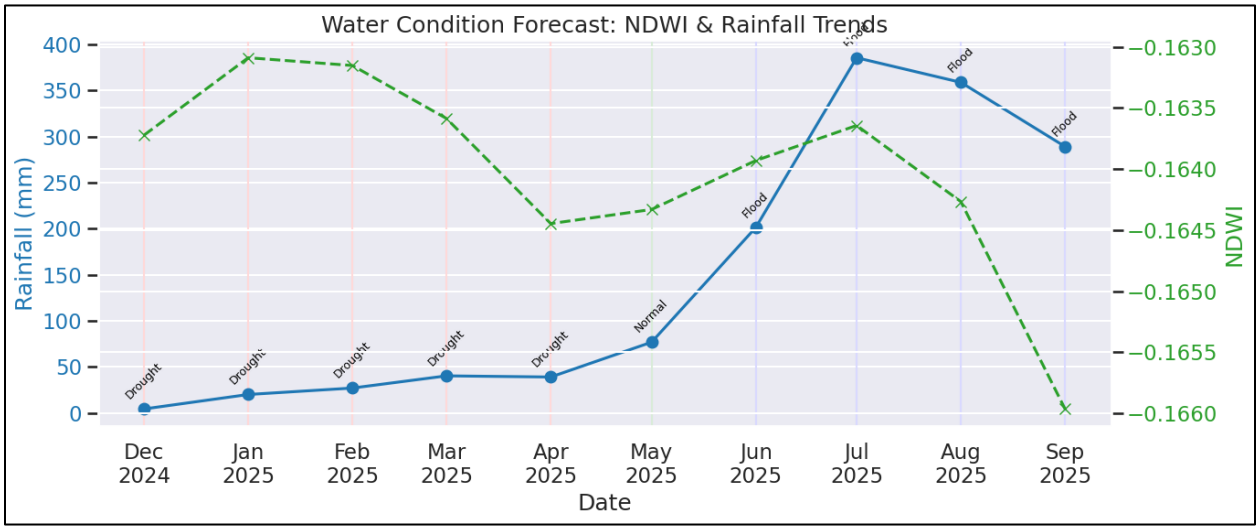
Sample Output Table

Date	Predicted NDWI	Rainfall (mm)	Predicted Condition
2024-12-01	-0.1637	4.40	Drought
2025-01-01	-0.1631	20.10	Drought
2025-06-01	-0.1639	201.44	Flood
2025-09-01	-0.1660	289.26	Flood
2025-11-01	-0.1672	11.18	Drought

Forecast Graph

- NDWI and Rainfall plotted with twin axes.
- Shaded regions:
  - Flood (blue)
  - Drought (red)
  - Normal (green)





Project link: - [Water Resource Monitoring & Prediction]

9. Conclusion This project delivers a reliable and intelligent water condition forecasting system using:

- Remote sensing (NDWI)
- Climate time series forecasting (Rainfall, Temperature)
- Hybrid modeling (LSTM + Prophet)
- Transparent rule-based classification