



DEVELOPMENT OF FUZZY MODEL FOR DIFFERENT FLOOD CONDITION

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Abstract: Floods are among the most frequent and destructive natural disasters, causing significant damage to infrastructure, economy, and human life. Accurate flood prediction is challenging due to uncertainties in rainfall patterns, river discharge, and environmental conditions. This study presents the development of a flood prediction model using Fuzzy Logic, which effectively handles imprecise and uncertain data.

The proposed model considers key input parameters such as Rainfall, slope, elevation and infiltration to classify flood situations into categories like Low, Medium and High. A fuzzy inference system is designed using membership functions and rule-based logic to simulate real-world decision-making processes. The implementation of the model is carried out using MATLAB, where MATLAB coding is used to define fuzzy sets, develop rule bases, and perform simulation and testing of flood scenarios. The results demonstrate that the fuzzy model provides reliable and accurate flood risk prediction under varying conditions. The use of MATLAB enhances computational efficiency and visualization of the model through rule surfaces and membership functions. This approach offers a practical and cost-effective solution for flood forecasting and disaster management, supporting early warning systems and improving decision-making in flood-prone regions.

Index Terms - Flood Prediction, Fuzzy Logic, MATLAB, GIS, Mamdani FIS, Flood Risk Assessment.

I. INTRODUCTION

Floods are one of the most frequent and devastating natural disasters worldwide, causing severe damage to infrastructure, agriculture, economy, and human life. Globally, floods account for more than 40% of all natural disasters, affecting millions of people every year. In countries like India, the impact is even more significant due to high population density, rapid urbanization, inadequate drainage systems, and changing climatic conditions. Recent trends show an increase in the frequency and intensity of floods due to climate change, erratic rainfall patterns, and unplanned development in flood-prone areas.

Accurate flood prediction and management remain a major challenge because hydrological processes involve high uncertainty. Parameters such as rainfall intensity, river discharge, soil moisture, and inflow rates are highly variable and difficult to measure precisely. Traditional flood prediction methods, including statistical and regression-based models, often require exact data and may not perform effectively under uncertain and dynamic conditions.

To overcome these limitations, this study focuses on the development of a flood prediction model using Fuzzy Logic. Fuzzy logic is particularly suitable for handling imprecise and uncertain data by using linguistic variables such as low, medium, and high, which closely resemble human reasoning. The proposed

This study aims to develop a robust and interpretable model that can assist engineers, policymakers, and disaster management authorities in improving early warning systems and reducing flood-related risks under different environmental conditions.

For Study Area Description model considers key input parameters like rainfall, slope, infiltration and elevation and inflow conditions to classify flood situations into different categories such as Low, Medium and High.

The model is implemented using MATLAB, which provides an efficient platform for developing fuzzy inference systems, defining membership functions, and simulating various flood scenarios. By integrating fuzzy logic with MATLAB coding, the system is capable of generating reliable predictions and supporting effective decision-making in flood management.

II. Study Area

Two flood-affected areas were selected for the study:

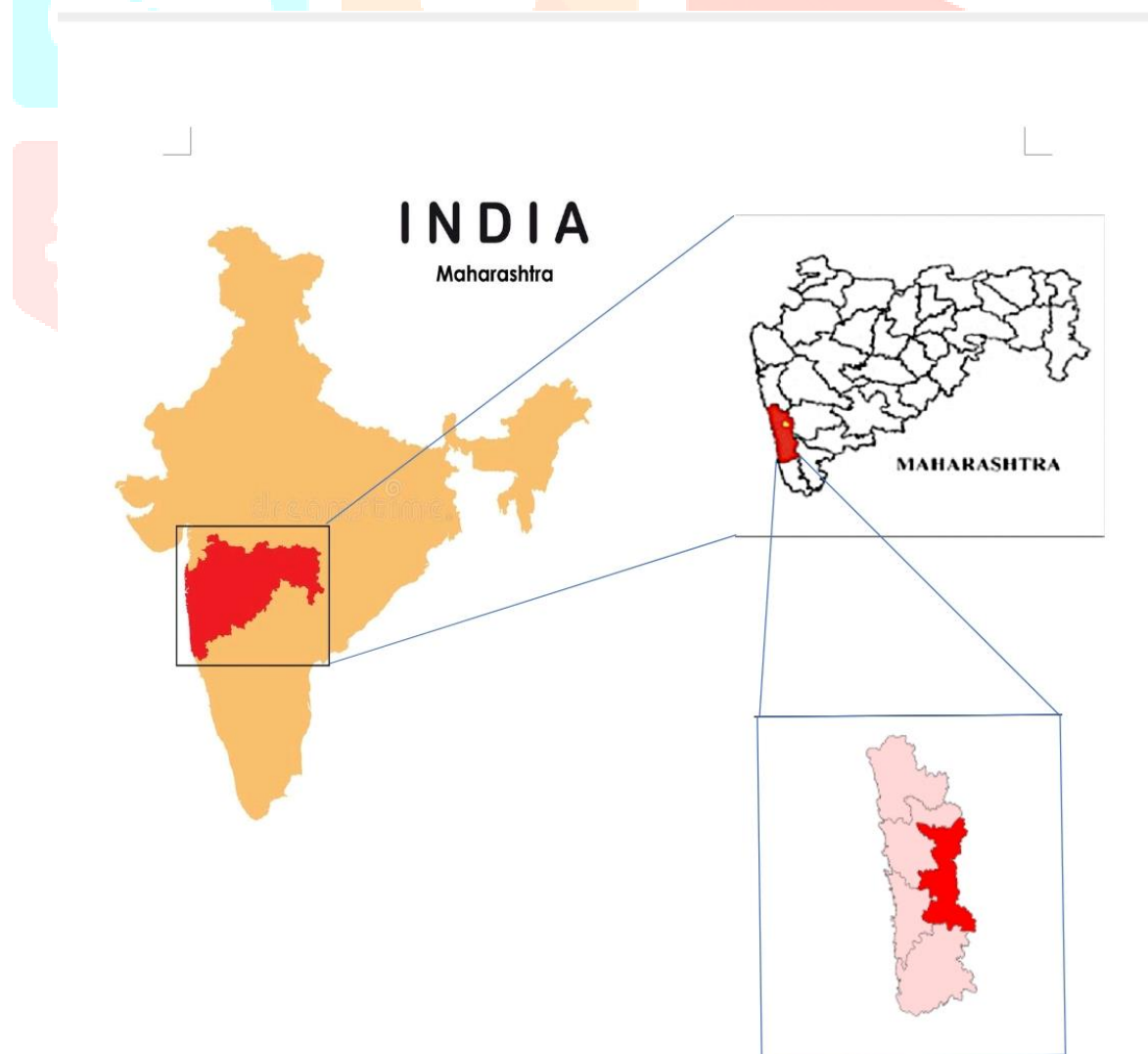
1. Chiplun, Ratnagiri District, Maharashtra India

Latitude:- 17.5333° N

Longitude:- 73.5167° E

A) Vashishti River – Chiplun

- * Located in Ratnagiri district, Maharashtra.
- * Highly affected during the 2021 Maharashtra floods.
- * Heavy rainfall due to Western Ghats influence.
- * Low-lying areas near riverbanks experience severe flooding.



2.Sinhagad road,Dattanagar ,Pune District ,Maharashtra

Latitude:- 18.48207° N

Longitude:- 73.82268 ° E

B) Mutha River – Datta Nagar, Sinhagad Road, Pune

- * Located in Pune city, Maharashtra.
- * Urbanized region with high runoff generation.
- * Frequently affected during heavy monsoon rainfall.
- * Presence of encroachments and drainage issues.



The present study focuses on two flood-prone regions in Maharashtra, namely the Mutha River basin along Sinhagad Road and Dattanagar in Pune, and the Vashishti River basin in Chiplun. These areas were selected due to their contrasting hydrological and topographical characteristics, which make them suitable for analyzing flood behavior under different environmental conditions.

The Mutha River, a tributary of the Bhima River, flows through the rapidly urbanizing city of Pune. The study stretch near Sinhagad Road and Dattanagar is highly vulnerable to urban flooding due to increased impervious surfaces, encroachment along riverbanks, and inadequate drainage infrastructure. The region lies at an elevation ranging approximately from 550 m to 700 m above mean sea level, with surrounding hilly terrain influenced by features such as Sinhagad Fort. The upper catchment areas exhibit moderate to steep slopes, facilitating rapid runoff, while the downstream urban sections have relatively gentle slopes, leading to water accumulation and localized flooding. The area receives an average annual rainfall between 700 mm and 900 mm, primarily during the monsoon season, with recent trends indicating an increase in high-intensity, short-duration rainfall events.

In contrast, the Vashishti River basin in Chiplun represents a typical coastal and high rainfall region of the Konkan belt. The river originates in the Western Ghats and flows through low-lying areas before draining into the Arabian Sea. The elevation in this region varies from about 10 m to 300 m above mean sea level, with steep slopes in the upstream ghats and very gentle slopes in the downstream floodplains. This topographical variation causes rapid runoff from the steep catchment areas, which accumulates in the flatter regions of Chiplun, resulting in severe flooding. The area experiences extremely high annual rainfall ranging from 3000 mm to 4000 mm, making it one of the most flood-affected regions in Maharashtra. The combination of intense rainfall, low elevation, and limited drainage capacity significantly increases flood vulnerability.

The comparative analysis of these two study areas highlights the influence of slope, elevation, and rainfall on flood behavior. While the Mutha River basin is more prone to urban flooding due to anthropogenic factors, the Vashishti River basin is primarily affected by natural factors such as heavy rainfall and terrain. These variations provide a comprehensive basis for developing and testing the fuzzy logic-based flood prediction model under different flood conditions

1. Data Collection

Different types of data were collected from government reports, satellite imagery, GIS databases, and rainfall records.

1.1 Rainfall Data

- * Daily and annual rainfall records were collected.
- * Rainfall intensity data for monsoon season was considered.
- * IMD (Indian Meteorological Department) data was used.

1.2 Elevation Data

- * DEM (Digital Elevation Model) data was collected.
- * Elevation information helps identify low-lying flood-prone areas.

1.3 Slope Data

- * Slope maps were generated using DEM data in GIS.
- * Low slope areas are more vulnerable to water accumulation.

1.4 Infiltration Data

- * Infiltration data was collected based on soil and land surface conditions.
- * Infiltration rate helps identify areas with high surface runoff and flood vulnerability.
- * Low infiltration areas are more prone to water accumulation and flooding.

III. RESEARCH METHODOLOGY

The methodology adopted for this study focuses on flood prediction and flood risk assessment using a Fuzzy Logic-based model. The study has been carried out for two flood-prone regions: Datt Nagar area near Sinhagad Road, Pune along the Mutha River and Chiplun region along the Vashishti River. The methodology

includes collection of hydrological and geographical data, preprocessing of data, GIS analysis, development of fuzzy inference rules, flood susceptibility mapping, and validation of results.

The proposed methodology helps in identifying flood-prone zones by integrating multiple parameters such as rainfall, elevation, slope, drainage characteristics, river water level, and land use conditions.

Following is the code used in our project.

```
%% Fuzzy Flood Risk Prediction with Graph Output
clear; clc; close all;

% Step 1: Create Mamdani FIS
fis = mamfis('Name', 'FloodRiskModel');

% Step 2: Add Inputs & Membership Functions
fis = addInput(fis, [0 200], 'Name', 'Rainfall');
fis = addMF(fis, 'Rainfall', 'trimf', [0 0 60], 'Name', 'low');
fis = addMF(fis, 'Rainfall', 'trimf', [40 100 150], 'Name', 'medium');
fis = addMF(fis, 'Rainfall', 'trimf', [120 200 200], 'Name', 'high');

fis = addInput(fis, [0 40], 'Name', 'Slope');
fis = addMF(fis, 'Slope', 'trimf', [0 0 8], 'Name', 'flat');
fis = addMF(fis, 'Slope', 'trimf', [5 15 25], 'Name', 'moderate');
fis = addMF(fis, 'Slope', 'trimf', [20 40 40], 'Name', 'steep');

fis = addInput(fis, [0 1000], 'Name', 'Elevation');
fis = addMF(fis, 'Elevation', 'trimf', [0 0 200], 'Name', 'low');
fis = addMF(fis, 'Elevation', 'trimf', [100 400 700], 'Name', 'medium');
fis = addMF(fis, 'Elevation', 'trimf', [500 1000 1000], 'Name', 'high');

fis = addInput(fis, [0 5], 'Name', 'Infiltration');
fis = addMF(fis, 'Infiltration', 'trimf', [0 0 1], 'Name', 'low');
fis = addMF(fis, 'Infiltration', 'trimf', [0.5 2 3.5], 'Name', 'medium');
fis = addMF(fis, 'Infiltration', 'trimf', [2.5 5 5], 'Name', 'high');

% Step 3: Add Output & Membership Functions
fis = addOutput(fis, [0 100], 'Name', 'FloodRisk');
fis = addMF(fis, 'FloodRisk', 'trimf', [0 0 40], 'Name', 'low');
fis = addMF(fis, 'FloodRisk', 'trimf', [20 50 80], 'Name', 'medium');
fis = addMF(fis, 'FloodRisk', 'trimf', [60 100 100], 'Name', 'high');

% Step 4: Add Rules
rules = [
    3 3 1 1 3 1 1;
    3 2 1 1 3 1 1;
    2 3 1 2 3 1 1;
    2 2 2 2 2 1 1;
    1 1 3 3 1 1 1
];
fis = addRule(fis, rules);

% Step 5: Take user input
fprintf('\nEnter values for Flood Risk Prediction:\n');
fprintf('-----\n');

rain = input('Enter Rainfall (0 to 200 mm/hr): ');
slope = input('Enter Slope (0 to 40 deg): ');
elev = input('Enter Elevation (0 to 1000 m): ');
infil = input('Enter Infiltration (0 to 5 cm/hr): ');
```

```

inputVec = [rain slope elev infil];

% Step 6: Evaluate flood risk
risk = evalfis(fis, inputVec);
level = ternaryClass(risk);

% Step 7: Show result in Command Window
fprintf('\nINPUT VALUES:\n');
fprintf('Rainfall    = %.2f mm/hr\n', rain);
fprintf('Slope      = %.2f deg\n', slope);
fprintf('Elevation    = %.2f m\n', elev);
fprintf('Infiltration = %.2f cm/hr\n', infil);

fprintf('\nOUTPUT:\n');
fprintf('Flood Risk    = %.2f\n', risk);
fprintf('Risk Level    = %s\n', level);

% Step 8: Bar Graph for final flood risk
figure('Name', 'Final Flood Risk Result', 'NumberTitle', 'off');
bar(risk, 'FaceColor', [0.2 0.6 0.8]);
ylim([0 100]);
ylabel('Flood Risk');
title(['Final Flood Risk = ' num2str(risk, '%.2f') ' (' level ')']);
grid on;
set(gca, 'XTickLabel', {'Current Input'});

% Step 9: Output membership graph with result marker
figure('Name', 'Flood Risk Membership Graph', 'NumberTitle', 'off');
plotmf(fis, 'output', 1);
hold on;
xline(risk, 'r', 'LineWidth', 2);
title(['Flood Risk Membership Functions, Result = ' num2str(risk, '%.2f')]);
xlabel('Flood Risk');
ylabel('Degree of Membership');
legend('Low', 'Medium', 'High', 'Calculated Risk');
grid on;
hold off;

% Step 10: Surface graph of output
figure('Name', 'Flood Risk Surface', 'NumberTitle', 'off');
gensurf(fis);
title('Flood Risk Surface vs Rainfall and Slope');

%% Helper function
function label = ternaryClass(score)
    if score < 30
        label = 'Low';
    elseif score < 70
        label = 'Medium';
    else
        label = 'High';
    end
end
end

```

1. Data Pre-processing

Collected data was processed before analysis.

2. GIS Analysis

Geographical Information System (GIS) software was used for spatial analysis.

GIS Layers Prepared

- * Rainfall Map
- * Elevation Map
- * Slope Map

Purpose of GIS Analysis

GIS helps in:

- * Spatial visualization of flood-prone regions.
- * Identification of vulnerable zones.
- * Overlay analysis of different flood factors.

3. Development of Fuzzy Logic Model

Fuzzy Logic technique was used because flood conditions are uncertain and depend on multiple parameters.

3.1 Input Parameters

The following input parameters were used in the fuzzy model:

- * Rainfall
- * Elevation
- * Slope
- * Infiltration

4. Input Membership Functions

The fuzzy flood prediction model uses four input parameters: Rainfall, Slope, Elevation, and Infiltration. Each input is classified into three linguistic categories — Low, Medium, and High — using Triangular Membership Functions .

- Rainfall (0–200 mm)
 - Low: [0 0 60]
 - Medium: [40 100 150]
 - High: [120 200 200]
- Slope (0–40°)
 - Flat: [0 0 8]
 - Moderate: [5 15 25]
 - Steep: [20 40 40]
- Elevation (0–1000 m)
 - Low: [0 0 200]
 - Medium: [100 400 700]
 - High: [500 1000 1000]
- Infiltration (0–5 cm/hr)
 - Low: [0 0 1]
 - Medium: [0.5 2 3.5]
 - High: [2.5 5 5]

5. Fuzzy Membership Functions

Each parameter was divided into categories such as:

- * Low
- * Medium
- * High

Example:

- * High rainfall → High flood possibility
- * Low elevation → High flood possibility
- * Steep slope → Low water accumulation

5.1 Fuzzy Rule Base

Rules were developed using expert knowledge.

Example Rules

1. IF rainfall is high AND elevation is low THEN flood risk is very high.
2. IF slope is low AND drainage is poor THEN flood risk is high.
3. IF rainfall is medium AND elevation is medium THEN flood risk is moderate.

5.2 Fuzzy Inference System

The Mamdani Fuzzy Inference System was used to process the rules and generate flood risk outputs.

6. MATLAB Implementation

MATLAB Fuzzy Logic Toolbox was used for model development.

7. Flood Hazard Mapping

The outputs from GIS and fuzzy analysis were combined to generate flood hazard maps.

7.1 Flood Risk Categories

- * Low Risk
- * Medium Risk
- * High Risk

These maps help identify areas vulnerable to flooding in Pune and Chiplun.

8. Final Outcome of the Study

The study provides:

- * Flood vulnerability assessment
- * Identification of flood-prone regions
- * Decision support for disaster management
- * Better planning for flood mitigation
- * GIS-based flood hazard maps
- * Fuzzy Logic-based prediction model

IV. RESULTS AND DISCUSSION

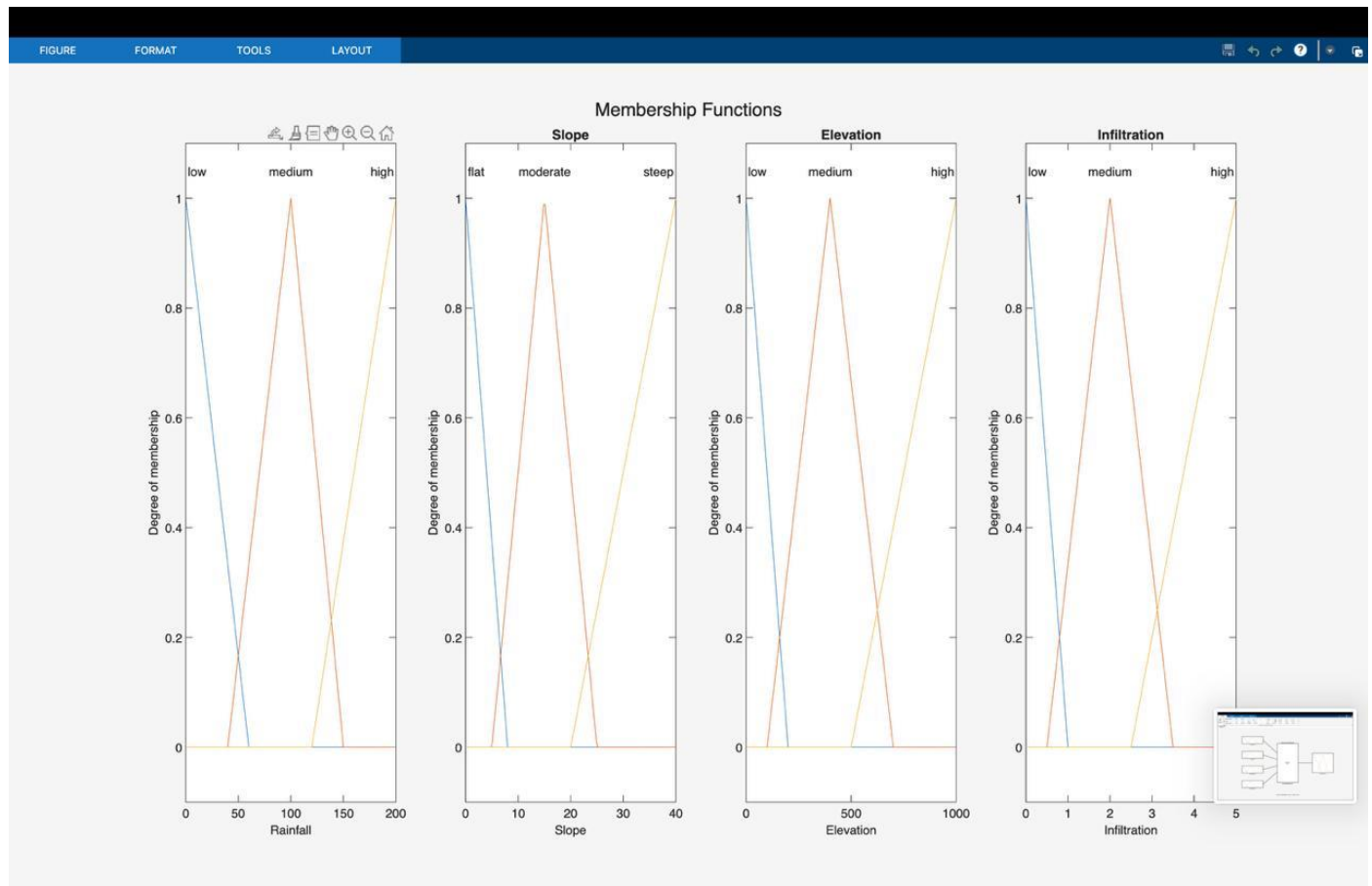


Figure 1: Flood Risk Output Graph

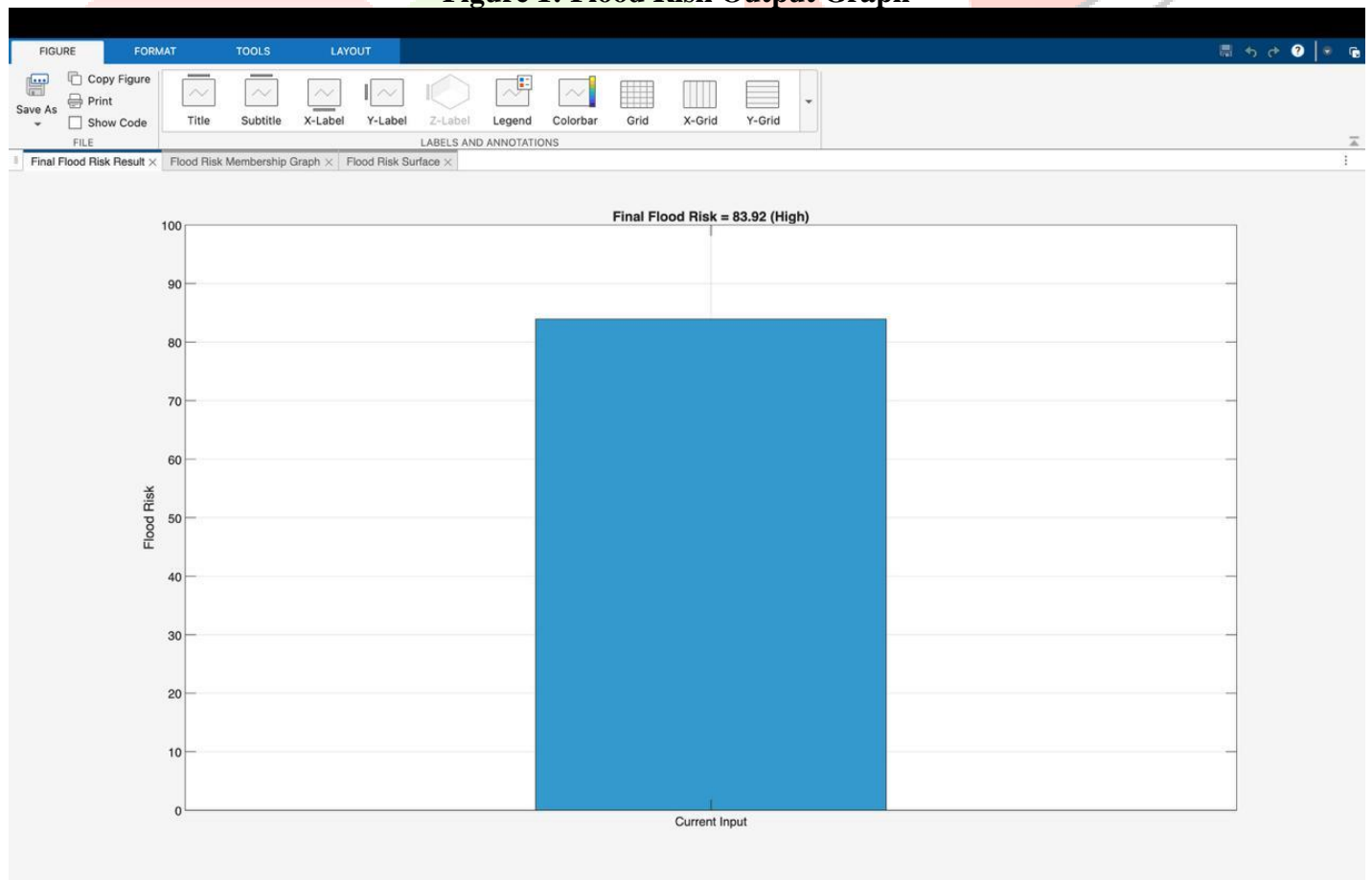


Figure 2: Flood Risk Membership Functions

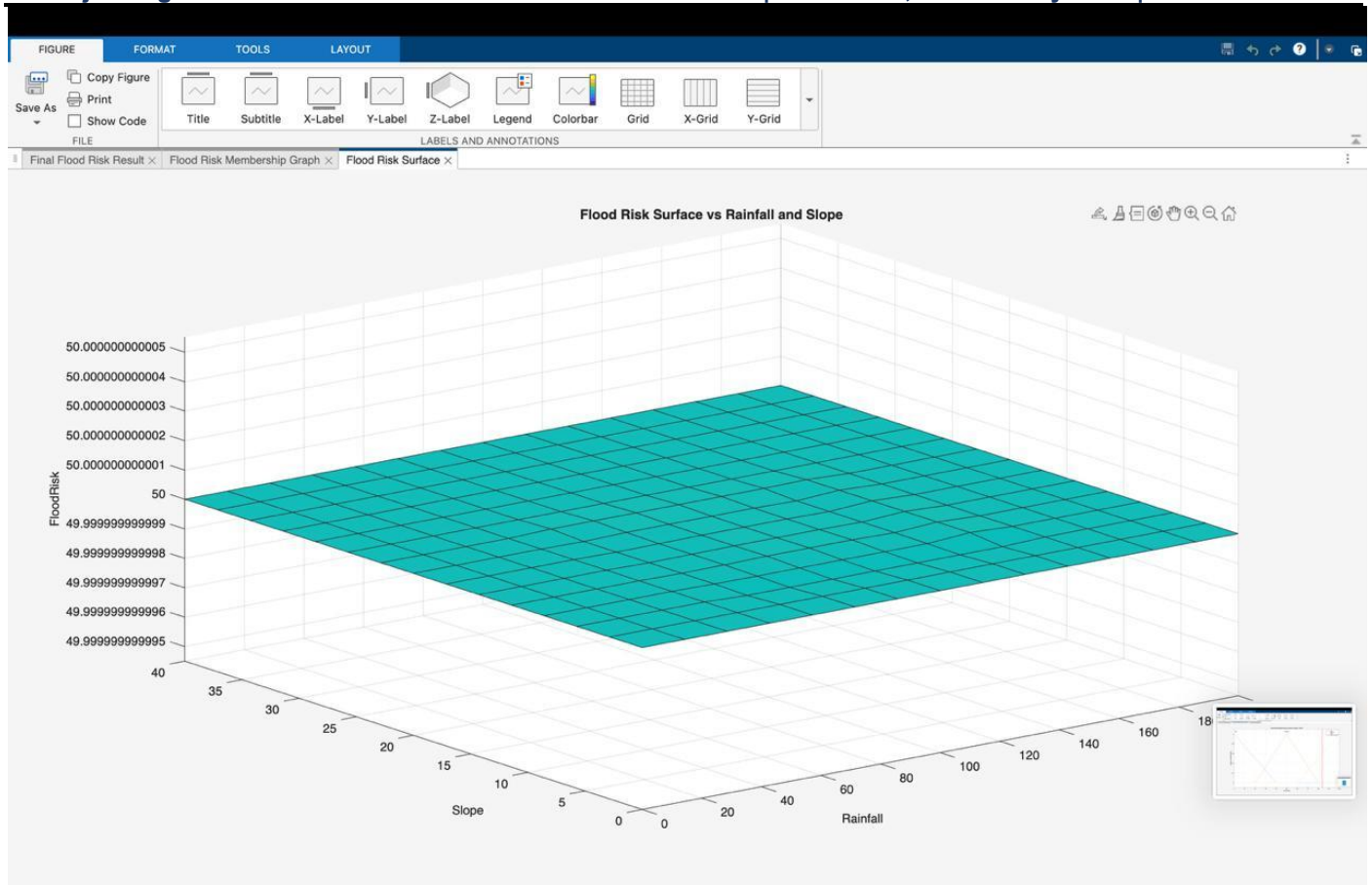


Figure 3: Flood Risk Surface Plot

The fuzzy logic flood prediction model was developed in MATLAB to identify flood risk in Datta Nagar near the Mutha River and Chiplun near the Vashishti River. The model used four important parameters: rainfall, slope, elevation, and infiltration rate.

A Mamdani Fuzzy Inference System (FIS) was created using MATLAB Fuzzy Logic Toolbox. All input values were divided into low, medium, and high categories using membership functions. Fuzzy IF-THEN rules were used to predict flood risk under different conditions.

The results showed that high rainfall, low infiltration, low elevation, and flat slope areas have higher chances of flooding. Areas near riverbanks were found to be more flood-prone because water accumulates easily there. The surface plots also showed that flood risk increases when heavy rainfall occurs in flat regions with poor drainage.

The model successfully classified flood conditions into low, medium, and high-risk categories. It handled uncertainty better than traditional mathematical methods and gave reliable flood predictions.

The graphs and outputs generated in MATLAB proved that fuzzy logic is useful for flood risk assessment. This model can help government agencies and planners identify flood-prone areas and improve flood management in the future.

V. CONCLUSION

The study developed a fuzzy logic-based flood prediction model using MATLAB for flood-prone areas of Datta Nagar near the Mutha River and Chiplun near the Vashishti River. The model used important parameters such as rainfall, slope, elevation, and infiltration to study flood risk.

A Mamdani Fuzzy Inference System was created in MATLAB using membership functions and fuzzy IF-THEN rules. The model classified flood risk into low, medium, and high categories and generated graphs and surface plots for analysis.

The results showed that heavy rainfall, low elevation, flat slopes, and low infiltration increase flood chances. MATLAB coding helped in creating the fuzzy model, reducing manual errors, automating calculations, and visualizing flood conditions easily.

The developed model can help planners and disaster management authorities identify flood-prone areas and improve flood control measures. In future, the model can be improved using real-time rainfall data, GIS, remote sensing, and machine learning techniques.

Overall, the study shows that fuzzy logic with MATLAB is an effective and reliable method for flood prediction and flood risk assessment.

VI. REFERENCES

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