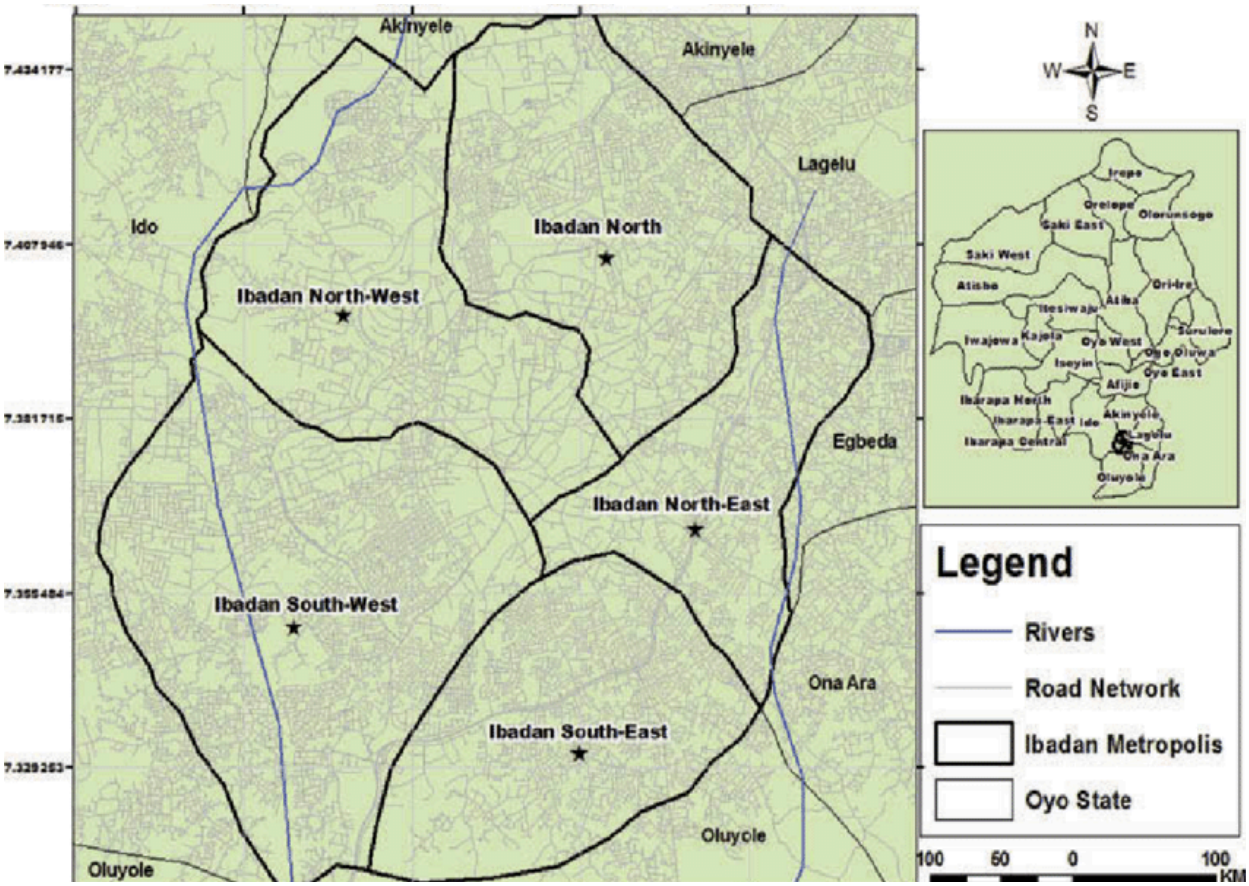

Flood Area Extent prediction in Ibadan Metropolis using GIS and Machine Learning Models

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Introduction

Natural disasters rank among the most devastating phenomena affecting humanity. Events such as tsunamis, volcanic eruptions, hurricanes, sandstorms, hailstorms, and floods inflict tremendous human and economic losses worldwide. According to the United Nations Office for Disaster Risk Reduction (UNDRR), the economic impact of natural disasters has escalated dramatically. Direct losses from disasters, estimated at US$70–80 billion annually between 1970 and 2000, surged to approximately US$180–200 billion per year during 2001–2020. When indirect costs and cascading effects are factored in, the true global cost may exceed US$2.3 trillion annually [1].

While Nigeria does not face certain hazards such as tsunamis or volcanic eruptions, the nation remains highly vulnerable to natural disasters, particularly flooding. Coastal areas like Lagos and the Niger Delta, as well as the Niger and Benue River basins experience frequent flood events. Contrary to the common assumption that upland areas are less susceptible to flooding, recent catastrophic events have demonstrated that elevated terrain is equally vulnerable when inadequate infrastructure meets extreme rainfall.

In August 2011, a major flood disaster devastated the ancient city of Ibadan, claiming multiple lives and causing extensive property damage [2]. More recently, in September 2024, one of Nigeria's most devastating floods struck Maiduguri after the Alau Dam breached due to structural failure exacerbated by heavy rainfall [3]. The floodwaters submerged vast areas of the city, displaced thousands and resulted in significant casualties. Most recently, in early 2025, torrential rains overwhelmed Mokwa town in Niger State, where inadequate drainage systems caused entire communities to be submerged. The disaster destroyed thousands of homes, submerged farmlands, displaced over 3,000 people, and resulted in approximately 200 deaths [4].

Given the increasing frequency and severity of these events, coupled with their substantial socio-economic impacts, there is an urgent need to develop reliable predictive methods for flood extent mapping and susceptibility assessment in Nigeria.

Problem Statement

Despite efforts by government agencies and humanitarian organizations, response strategies are often reactive rather than proactive due to limited predictive insights into where and to what extent floods may occur. Current flood risk assessments are often based on outdated hydrological

models, manual mapping, or incomplete field surveys, making them inadequate for timely disaster preparedness and mitigation.

Thus, there is a pressing need for an integrated, data-driven approach that combines Geographic Information Systems (GIS) with Machine Learning models to accurately predict the spatial extent and severity (degree) of floods in South Western Nigeria. This would provide early warning systems, aid resource allocation, and support evidence-based decision-making for disaster risk reduction.

Project Scope and Methodology

Initially, this project proposed to analyze flood patterns across Northern Nigeria. However, due to data availability constraints and time limitations, the scope has been refined to focus on Ibadan Metropolis in Oyo State, Southwest Nigeria, a region with documented flood history and accessible datasets. The study utilizes pluvial flood data sourced from Kaggle, along with geospatial and climatic data obtained from the United States Geological Survey (USGS) and the Copernicus Climate Data Store.

Existing Solutions

Flood management in Nigeria has seen the use of hydrological and hydraulic models like HEC-RAS and SWAT [5], remote sensing and GIS mapping [6], machine learning methods such as Random Forest, SVM, and Neural Networks [7], and early warning systems from agencies like NEMA and NiMet [8]. While these approaches are useful, they often struggle with missing hydrological data, focus more on mapping after floods than actually predicting, rely on poorly calibrated models, and provide alerts that are too broad to help communities directly.

Our Contribution

Our methodology combines advanced machine learning techniques to spatially map flood extents and predict degrees of susceptibility, with exploratory data analysis that generates evidence-based insights characterizing the flood risk patterns of Ibadan Metropolis in Oyo State, Southwest Nigeria.

Objectives

The project aims to:

1. Model and forecast flood extents across Ibadan Metropolis using historical and current geospatial data

2. Map flood susceptibility zones to identify high-risk areas requiring priority intervention

3. Integrate multi-source datasets (rainfall, elevation, river networks, soil types, land use/land cover, historical flood records, and remote sensing imagery) for accurate flood modeling.

4. Compare and evaluate multiple Machine Learning algorithms (e.g., Decision Trees, Random Forest, Gradient Boosting, SVM, Neural Networks) to identify the most effective model for local conditions.

5. Provide actionable insights to government agencies, NGOs, and local communities for proactive flood management, disaster preparedness, and sustainable urban and agricultural planning.

Proposed Data Sources

The data is downloaded from Kaggle. The flood dataset generation was based on the identified conditioning variables related to pluvial flood, a Shuttle Radar Topography Mission (SRTM DEM) Digital Elevation Model land imagery gathered from the United States Geological Survey (USGS) and Copernicus Climate Data Store website.

Proposed Methodology

Data collection: The data covers Ibadan metropolis, which comprises 5 local government areas in the urban areas, which are: Ibadan North LG, Ibadan North-East LG, Ibadan North-West LG, Ibadan South-West LG and Ibadan South-East LG Areas. A total of 144,401 records and eight conditioning variables out of 53 were gathered.

Flood occurrence data extraction: This includes flood points extraction These points were derived through the combination of Sentinel-1 and Landsat-8 satellite images, utilizing advanced image processing techniques and flood detection algorithms.

Data preprocessing and preparation: This step is important for quality and suitability of the data for modeling. This involved performing a multicollinearity test to assess the dependence between independent variables, and employing the step-wise weight assessment ratio analysis to determine the weights of the criteria.

Model selection and optimization: This step selects the non-parametric DT algorithm as the base model for flood-prone areas mapping. It also uses other algorithms like Random Forest, Gradient Boosting, SVM, Neural Networks.

Model validation and performance evaluation: The trained and optimized model is validated using independent validation data. Various evaluation metrics are employed to assess the performance of the model. These metrics include root mean square error (RMSE) and mean absolute error (MAE) to measure prediction accuracy, coefficient of determination (R2) to determine the goodness of fit.

Expected Outcomes

1. A geospatial map identifying and visualizing areas at risk of flooding in Ibadan, Southwestern part of Nigeria.
2. A robust machine learning model capable of accurately predicting flood degrees under varying conditions.
3. Analytical insights into the environmental and hydrological drivers of flooding in Ibadan, Southwestern part of Nigeria.

Community Impact

This project aims to empower communities across Ibadan Metropolis by providing actionable flood predictions that can save lives, protect livelihoods, and guide sustainable development. By delivering accurate, localized flood risk maps and early warnings, we hope to support farmers, local governments, and emergency responders in making informed decisions. Ultimately, our goal is to reduce vulnerability, enhance preparedness, and contribute to a safer, more resilient future for the people of Ibadan.

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