IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Flood Susceptibility Mapping

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Abstract: Flood susceptibility mapping is essential for disaster risk management, especially as climate change increases flooding. Recent studies show that combining machine learning (ML) with GIS greatly improves prediction accuracy. Interpretable ML models, along with socioeconomic data, help clearly identify vulnerable areas. For example, in Hefei, China, fine-scale mapping supported better local decision-making. Many modern approaches also use multidimensional assessments that integrate physical flood data with factors like population, infrastructure, and climate. This results in accurate, transparent, and community-focused risk evaluations that strengthen urban planning and disaster preparedness.

Keywords:*Flood susceptibility mapping,Disaster risk management,Climate change,Machine learning (ML),Geographic Information Systems (GIS),Interpretable ML models.*

1 INTRODUCTION

1.1 GENERAL

Flooding is one of the most destructive natural disasters, made worse by climate change, rapid urbanization, and land-use changes. This increases the need for accurate flood risk assessment. Traditional prediction methods often struggle to analyze the complex interaction of environmental and human factors.Flood susceptibility mapping helps identify areas likely to flood by analysing rainfall, elevation, soil, vegetation, and land-use data. GIS tools and machine learning improve the accuracy of these maps by using past flood patterns to predict future risks.In regions with limited data, expert judgment and simple statistical methods can still produce reliable maps to support disaster planning. These maps not only protect communities and infrastructure but also help conserve ecosystems by identifying vulnerable habitats and guiding environmental protection efforts.

1.2 IMPORTANCE IN URBAN PLANNING, DISASTER RISK REDUCTION, BIODIVERSITY CONSERVATION

Flood susceptibility maps guide safer urban growth by identifying high-risk areas, helping planners design better drainage, protect homes, and place infrastructure wisely. They aid emergency response by prioritizing evacuation routes and rescue efforts, reducing loss of life and damage. These maps also support nature, showing where floods threaten habitats, so conservation efforts can protect ecosystems that, in turn, benefit humans through clean water, soil protection, and climate balance.

1.3 EVOLUTION FROM TRADITIONAL TO MODERN TECHNIQUES

Flood susceptibility mapping has evolved from relying on local knowledge and historical records to using advanced GIS and machine learning techniques. Traditional methods were limited and subjective, but GIS allows layering of factors like elevation, slope, soil, rainfall, and land use for accurate, data-driven maps. Machine learning further improves predictions by identifying complex patterns in historical data. In data-scarce regions, hybrid approaches like AHP and Frequency Ratio combined with GIS still provide reliable flood risk assessments.

1.4 HUMAN RELEVANCE: HOW MAPPING HELPS PROTECT LIVES, HABITATS, AND INFRASTRUCTURE

Flood susceptibility mapping protects lives, infrastructure, and ecosystems. It enables early warnings, guiding evacuations and reducing casualties. For infrastructure, maps help design resilient roads, bridges, and water systems, preventing costly damage. They also aid conservation by identifying vulnerable habitats, preserving biodiversity, and maintaining natural flood buffers. Overall, flood mapping supports safer urban planning, emergency preparedness, and ecosystem resilience.

2 ROLE OF GIS IN FLOOD SUSCEPTIBILITY MAPPING

2.1 GENERAL

GIS helps identify flood-prone areas by integrating spatial data like rainfall, elevation, slope, soil, and land use. By layering this information, it produces detailed maps that improve flood prediction, planning, and disaster preparedness.

2.2 GIS AS A CORE FRAME WORK FOR SPACIAL FLOOD ANALYSIS

GIS is an advanced digital mapping tool that combines information like land shape, water flow, rainfall, soil, land use, and past flood events to understand and predict flood risks. By layering these datasets, GIS shows which areas are vulnerable and why. When paired with machine learning models like Random Forest, it becomes even more accurate in forecasting future floods. Beyond prediction, GIS supports decision-making by identifying at-risk roads, homes, and natural areas, helping planners improve drainage and emergency teams plan safe evacuation routes.

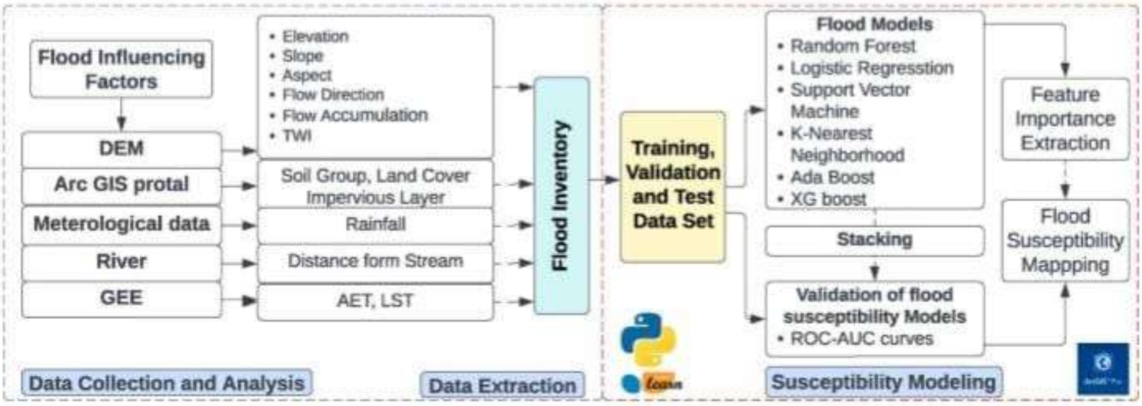

Fig 2.1 Overall methodological framework, (Zelalem Demissie et al. (2024))

2.3 TYPES OF SPATIAL DATA USED (ELEVATION, RAINFALL, SOIL, LAND USE, SLOPE)

In flood susceptibility mapping, accurate spatial data is essential because it shows what is happening, where it happens, and how different features interact. Studies using GIS with models like AHP, Frequency Ratio, and Random Forest highlight four key datasets: elevation, rainfall, soil, and land use, along with slope.

Elevation: DEMs identify low-lying areas, slopes, and water flow paths. Low elevations and valleys are more flood-prone.

Rainfall: High or extreme rainfall increases pressure on drainage systems, raising flood risk.

Soil: Sandy soils drain quickly, while clay soils retain water, causing runoff and pooling.

Land Use: Urban areas with concrete surfaces increase runoff; forests and farmland reduce it.

Slope: Steeper slopes create faster runoff; flat areas allow water to accumulate.

2.4 REAL-WORLD EXAMPLES OF GIS AIDING LOCAL FLOOD PREDICTION

In flood-prone regions, GIS is widely used not just for analysis but for practical action. In hilly and river basin areas, DEMs help identify low-lying and steep zones where flash floods may occur, allowing local authorities to plan early warnings, improve drainage, and guide safer housing development. Agricultural communities use GIS by combining rainfall, soil, and land use data to predict waterlogging risks, helping farmers choose suitable crops and planting seasons. In rapidly growing urban areas, GIS detects land cover changes and simulates water flow, leading to better drainage designs and zoning rules that reduce unexpected urban flooding.

2.5 IMPORTANCE OF REMOTE SENSING DATA FOR CONTINUOUS MONITORING

Remote sensing collects satellite or aerial data without touching the ground, allowing continuous monitoring of large and hard-to-reach areas. It provides up-to-date information on vegetation, soil moisture, land temperature, and rainfall factors that change quickly and influence flood risk. By tracking these changes, remote sensing helps identify reduced vegetation or expanding urban areas that increase runoff. It also validates GIS and machine learning flood models by comparing predictions with actual flood events. In fast-developing flash floods, frequently updated satellite data supports real-time forecasting and early warning systems.

3 MACHINE LEARNING APPROACHES IN FLOOD SUSCEPTIBILITY MAPPING

3.1 GENERAL

Machine learning has become a powerful tool in flood susceptibility mapping because it can analyse complex relationships among factors like elevation, rainfall, soil, land use, and drainage. Models such as Random Forest, SVM, and Logistic Regression learn patterns from large datasets to accurately predict flood-prone areas. These data-driven approaches improve decision-making, helping planners develop better flood mitigation and management strategies.

3.2 INTRODUCTION TO ML MODELS: RANDOM FOREST, SVM, DECISION TREES, ANN

Machine learning models are widely used in flood susceptibility mapping because they can analyse large, complex environmental datasets and identify hidden patterns. The most effective models include Decision Trees, Random Forest, SVM, and ANN.

- Decision Trees classify areas by asking simple questions about factors like elevation or land use.
- Random Forest uses many decision trees and combines their results for more reliable predictions.
- SVM separates flood-prone and non-flood-prone areas by finding the best dividing boundary in the data.
- ANN mimics the human brain, learning complex nonlinear patterns among multiple flood-related factors.

Together, these models help create accurate flood susceptibility maps that support better planning and disaster protection.

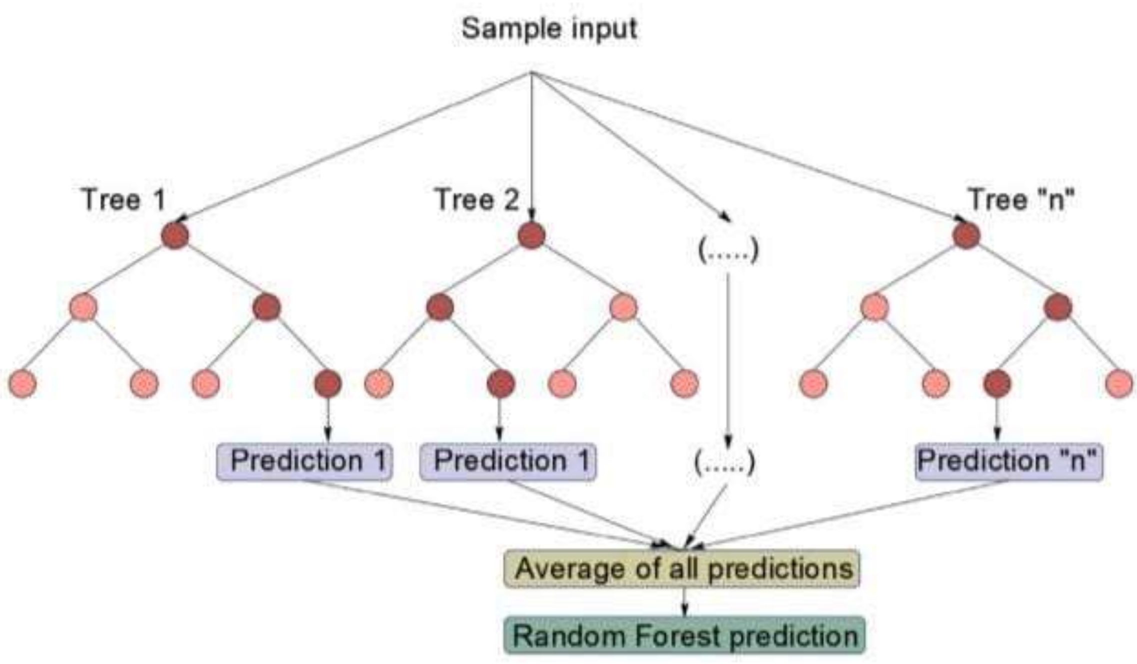

Fig 3.1 Schematic structure of the random forest regression model (Mohamed Wahba et al.(2024))

3.3 HOW ML OUTPERFORMS TRADITIONAL STATISTICAL MODELS IN PREDICTION ACCURACY

Traditional statistical models like Logistic Regression and Frequency Ratio have long been used for flood susceptibility mapping, but they often fail to capture the complex, non-linear interactions among factors such as rainfall, elevation, soil, and slope. Machine learning overcomes these limitations by learning patterns directly from data without strict assumptions. Models like Random Forest, SVM, ANN, and Decision Trees can recognize hidden relationships, handle multicollinearity, and work effectively with high-dimensional data. ML models are also adaptable they improve with new data and can be applied to different regions with similar conditions. Research shows that ML consistently outperforms traditional methods in accuracy and prediction quality. Instead of replacing older models, ML enhances them, making flood mapping more precise and helping communities prepare and respond more effectively.

3.4 CASE EXAMPLES OF ML APPLIED TO FLOOD ZONES WITH GIS LAYERS

ML combined with GIS is widely used in real flood-prone regions to produce accurate flood susceptibility maps. By integrating spatial data such as elevation, slope, rainfall, soil, and land use with models like Random Forest, ANN, SVM, and Decision Trees, predictions become far more reliable than traditional methods.

Random Forest effectively identifies complex interactions such as how certain soil types and low slopes increase flood risk during heavy rain outperforming models like frequency ratio and logistic regression. ANN has been successful in river basins by learning from limited historical flood data and predicting risk even in areas with poor documentation. SVM has been used in flash-flood regions to classify flooded and non-flooded zones using drainage density, rainfall intensity, and distance from rivers, producing high-resolution maps validated with real flood points.

3.5 CHALLENGES IN TRAINING DATASETS & MODEL VALIDATION

Machine learning greatly improves flood susceptibility mapping, but its accuracy depends heavily on data quality and model validation. In many regions, historical flood records are incomplete or poorly geo-referenced, making it difficult to train models reliably. Datasets are often unbalanced, with far fewer flood points than non-flood points, which can bias models like Random Forest or SVM. Spatial data layers rainfall, soil, land use, slope, elevation may also differ in resolution or accuracy, introducing errors. Validation is another challenge; limited or uneven field-verified flood points can misrepresent model performance. Even strong metrics like AUC depend on how reliable the validation data is.

3.6 HUMAN PERSPECTIVE: HOW AI HELPS MAKE QUICKER AND DATA-DRIVEN EVACUATION DECISIONS

AI models like Random Forest, SVM, and ANN can analyse real-time environmental data rainfall, soil moisture, river levels, and terrain to predict where floods may occur with high accuracy. These fast, dynamic predictions help disaster teams identify high-risk areas early, allowing better evacuation planning and quicker responses. AI-powered maps guide officials in prioritizing vulnerable communities, giving people more time to reach safety. As machine learning improves with new data, predictions become even more reliable. Combined with GIS, AI turns flood risk into clear, easy-to-understand maps, making flood response proactive, precise, and focused on protecting lives.

4 HYBRID MODELS: ANALYTICAL HIERARCHY PROCESS (AHP) AND FREQUENCY RATIO (FR)

4.1 GENERAL

Hybrid models like AHP and Frequency Ratio combine expert judgment with statistical analysis to improve flood susceptibility mapping. AHP assigns importance to flood-related factors, while FR uses historical flood data to estimate risk. Together, they produce more accurate and reliable flood maps, especially in data-limited regions, supporting better planning and disaster risk reduction.

4.2 THE PRINCIPLE OF AHP: EXPERT BASED DECISION-MAKING THROUGH PAIRWISE COMPARISION

AHP is a decision-making method that uses expert knowledge to rank the importance of factors affecting flooding. It works through pairwise comparisons, where experts judge which factor like slope, rainfall, soil, or land use is more important. These judgments are given numerical scores, which are then converted into weights. The weights are applied to GIS layers to create a flood susceptibility map.

AHP is especially useful in areas with limited flood data because it turns expert opinion into a clear, consistent, and objective framework. It includes a built-in consistency check and is well suited for local or regional flood studies where expert insight is crucial.

4.3 FREQUENCY RATIO: USING HISTORICAL FLOOD EVENT DATA FOR STASTICAL PREDICTION

The Frequency Ratio (FR) method is a simple statistical technique that predicts flood-prone areas by analysing past flood events. It compares how often floods occurred under specific conditions such as certain slopes, soil types, rainfall levels, or land use with how much of the region has those conditions. The resulting ratio shows how strongly each factor contributes to flooding. FR is easy to compute and interpret, making it useful for planners and researchers. When combined with GIS, it produces clear flood susceptibility maps that help guide safer infrastructure planning and early warning systems.

4.4 INTEGRATION OF AHP AND FR FOR ROBUST MAPPING

Since no single method can perfectly identify flood-prone areas, combining AHP and FR creates a stronger and more reliable flood susceptibility map. AHP provides expert-based weights for factors like rainfall, slope, soil, and land use, while FR uses historical flood data to show how strongly each condition contributes to flooding.

By integrating both, AHP offers structured judgment and FR adds data-driven validation. AHP sets the overall factor importance, and FR fine-tunes the influence of each category. This hybrid approach produces more accurate, region-specific maps, especially useful in data-limited areas, helping communities plan safer and make informed flood management decisions.

4.5 CASE STUDIES AND EFFECTIVENESS IN HILLY AND URBAN TERRAIN

Flood susceptibility mapping is especially important in hilly and urban regions where terrain and human activities increase flood risk. Case studies show that GIS-based models, machine learning, and hybrid methods like AHP and Frequency Ratio are highly effective in these areas. In hilly terrains, factors such as slope, elevation, soil type, and rainfall strongly influence flood occurrence. RF models have accurately identified vulnerable valleys and settlements, even without recorded flood history, helping authorities improve drainage and regulate construction. In urban areas, impervious surfaces create rapid runoff during heavy rains. Studies using combined AHP–FR models successfully mapped flood-prone zones by integrating expert rankings of factors like land use, drainage density, and river proximity with historical flood data. This helps track rising flood risks linked to rapid urban growth and poor planning.

4.6 HUMAN ASPECT: COMMUNITY-DRIVEN DATA IMPROVES LOCAL ADAPTATION AND PREPAREDNESS

Effective flood management relies not only on technology but also on community involvement. Local residents reporting floods, water levels, damaged infrastructure, and rainfall provide critical data that satellites or official records may miss, especially in remote or informal areas. When combined with GIS and machine learning, this information improves the accuracy of flood susceptibility maps.

Community participation also fosters ownership, motivating people to follow warnings, adopt safer practices, and engage in preparedness activities. It allows solutions to be tailored to local realities, enhances the timeliness of alerts, improves emergency response, and supports educational programs. By bridging high-tech mapping with local knowledge, community-driven data makes flood management more effective, empowering residents to protect their homes and livelihoods.

5 MAPPING FLOOD SUSCEPTIBILITY FOR ECOLOGICAL APPLICATIONS

5.1 GENERAL

Flood susceptibility mapping helps protect both people and ecosystems. Many flood-prone areas coincide with sensitive habitats like wetlands and riverbanks. By combining flood risk data with species distribution models, these maps identify vulnerable habitats, guiding conservation efforts and supporting sustainable land and water management.

5.2 HOW FLOOD-PRONE AREAS OVERLAP WITH ECOLOGICALLY SENSITIVE HABITATS

Flood-prone areas often overlap with ecologically sensitive habitats like wetlands and riverbanks, creating challenges for both disaster management and conservation. These habitats, prone to flooding due to low elevation and proximity to water, also act as natural buffers. GIS-based flood mapping combined with species distribution data helps identify zones where high flood risk and biodiversity hotspots coincide. This allows planners to design strategies like preserving floodplains, creating wildlife corridors, or controlled flooding that protect both communities and ecosystems. Integrating flood and habitat management promotes sustainable development, ensuring resilient landscapes for people and nature.

5.3 IMPORTANCE OF INTEGRATING FLOOD MAPS WITH SPECIES DISTRIBUTION TO PROTECT BIODIVERSITY

Protecting biodiversity in flood-prone areas requires understanding how flood risks overlap with species habitats. Integrating flood maps with species distribution data identifies which habitats and species such as wetlands and riverbanks are most vulnerable. This approach distinguishes harmful floods from those ecosystems rely on and supports measures like wildlife corridors and sustainable land use. By combining flood risk management with conservation planning, communities can safeguard lives while preserving biodiversity in flood-affected landscapes.

5.4 TECHNIQUES USED TO OVERLAY SPECIES DATA AND FLOOD MODELS

Overlaying species distribution data with flood susceptibility models helps assess how flooding affects biodiversity and guides conservation. GIS techniques like spatial overlay highlight areas where high flood risk overlaps critical habitats. Species distribution models (SDMs) predict potential habitats, which, combined with flood models, show how floods may shift or fragment ecosystems. Methods like AHP, Random Forest, or SVM integrate multiple ecological and flood factors into composite maps. Buffer and temporal analyses further assess indirect impacts and seasonal changes. Together, these approaches provide a dynamic, multi-layered understanding of flood–biodiversity interactions for sustainable planning.

5.5 PRACTICAL IMPLICATIONS FOR HABITAT RESTORATION AND CONSERVATION

Integrating flood maps with species and habitat data enables practical conservation and flood management. Planners can prioritize restoring wetlands and floodplains that absorb water, reduce flood peaks, and provide critical habitat. Wildlife corridors can be designed to maintain connectivity during floods, preventing habitat fragmentation. Integrated maps also guide sustainable land use, protecting natural areas from urban or agricultural conversion. Tailored restoration strategies improve success and reduce costs, while community involvement ensures both biodiversity protection and reduced flood risk creating benefits for people and nature alike.

5.6 HUMANIZED OUTLOOK: SAFEGUARDING NATURE ALSO SAFEGUARDS HUMAN LIVELIHOODS

Floods impact both human communities and the natural ecosystems that support them. Wetlands, floodplains, and forests act as natural buffers, absorbing water and reducing flood severity downstream. Protecting these habitats not only lowers flood risk but also preserves vital resources clean water, fertile soil, and food that communities rely on. Integrating flood management with biodiversity conservation creates mutual benefits: safer lives, stable livelihoods, and healthier ecosystems.

6 FACTORS INFLUENCING FLOOD SUSCEPTIBILITY

6.1 GENERAL

Flood susceptibility depends on natural and human factors such as rainfall, slope, elevation, soil, drainage, land use, and vegetation. These factors influence water flow and accumulation, and understanding them is crucial for identifying high-risk areas and planning effective mitigation.

6.2 HOW THESE FACTORS INTERACT TO DEFINE SUSCEPTIBILITY ZONES

Flood susceptibility results from the interaction of multiple natural and human factors. Elevation, slope, rainfall, soil type, land use, and drainage all influence how water flows and accumulates. Low-lying or steep areas, poorly drained soils, and urban surfaces increase flood risk, while forests and wetlands reduce it. GIS and ML models combine these layers to identify zones where risks converge, helping pinpoint the most vulnerable areas for effective flood management.

6.3 USE OF THEMATIC LAYERS AND THEIR WEIGHTAGE IN MODELS

In flood susceptibility mapping, thematic layers such as elevation, slope, rainfall, soil, land use, and distance from rivers combine to reveal flood risk. Not all layers have equal influence, so weighting is essential. AHP uses expert judgment to assign weights, FR relies on historical flood data, and ML models learn layer importance from patterns in the data. Proper weighting ensures flood maps accurately reflect real-world risk, helping decision-makers prioritize protection for people and the environment.

6.4 EXAMPLES OF LOCATION-BASED FACTOR PRIORITIZATION

Flood susceptibility varies by location, so factor prioritization is essential. In hilly areas, slope and elevation are most important due to rapid runoff, while in lowland urban or coastal regions, elevation and land use matter more. In semi-arid zones, soil type and drainage take priority. AHP assigns weights based on expert judgment, FR uses historical flood data, and ML models like Random Forest adapt automatically to local conditions, ensuring flood maps reflect regional risks accurately.

6.5 HUMAN ANGLE: WHY UNDERSTANDING THESE FACTORS HELPS PEOPLE PREPARE BETTER

When communities understand local flood factors like rainfall, drainage, elevation, and vegetation they can act before disasters occur. GIS and models like AHP, FR, or Random Forest analyse these risks at a local level, helping decision-makers prioritize defences and farmers adjust practices. By revealing patterns in past floods, these tools empower communities to prepare, adapt, and build resilience, showing that understanding flood risks is key to protecting lives.

7 MODEL VALIDATION AND ACCURACY ASSESSMENT

7.1 GENERAL

Model validation and accuracy assessment are crucial for reliable flood susceptibility mapping. Validation checks if predictions match real conditions, while accuracy metrics like confusion matrix, ROC curve, AUC, or Kappa measure performance, guiding improvements and ensuring practical usefulness.

7.2 IMPORTANCE OF MODEL VALIDATION USING FIELD DATA OR PAST EVENT MAPPING

Creating flood maps with GIS and ML is powerful, but validation is essential to ensure predictions reflect reality. Comparing model outputs with historical floods, field surveys, and community-reported data helps identify true high-risk areas and avoid false alarms. Validated models, like Random Forest or AHP-FR, improve planning, guide zoning, drainage, and evacuation decisions, build trust, and ultimately protect lives.

7.3 COMPARISON OF AHP-FR VS ML MODELS IN PERFORMANCE

Flood prediction uses two main approaches: AHP-FR and machine learning models like Random Forest, SVM, Decision Trees, and ANN. AHP-FR combines expert judgment and historical data, offering transparency and ease of interpretation, ideal for data-scarce areas. ML models learn from large datasets, detect complex patterns, and often achieve higher accuracy (AUC, ROC, Kappa), making them effective where extensive geospatial data exists.

7.4 TRANSPARENT MODELLING IMPROVE TRUST AMONG DECISION-MAKERS AND PUBLIC

In flood mapping, transparency is as important as accuracy. Clear disclosure of data layers, factor weights, and methods like AHP's expert-based weightinghelps decision-makers and the public understand and trust the results. Transparent models build confidence, improve cooperation, and ensure flood maps guide effective planning, emergency response, and community resilience.

8 APPLICATIONS IN URBAN AND RURAL PLANNING

8.1 GENERAL

Flood susceptibility mapping guides urban and rural planning by identifying high-risk areas. It helps design safe infrastructure, manage land use, plan drainage and emergencies, protect agriculture, and enhance community resilience.

8.2 INFRASTRUCTURE DEVELOPMENT: ROADS, BRIDGES, AND HOUSING BASED ON FLOOD RISK

Flood susceptibility mapping helps plan safer, resilient infrastructure. Using GIS, AHP, FR, and ML models, planners can design roads, bridges, and housing in flood-safe zones, improve drainage, and use flood-resistant materials. This reduces damage, ensures connectivity, guides zoning, and supports resilient urban and rural communities.

8.3 AGRICULTURE PLANNING: PREDICTING CROP LOSS ZONES

Flood susceptibility mapping helps protect agriculture by identifying areas at risk of waterlogging and soil erosion. Using GIS, AHP, FR, and ML models like Random Forest, farmers and planners can anticipate high-risk zones, adjust crop cycles, choose flood-resistant crops, and implement preventive measures. This supports early warnings, crop insurance, and adaptive farming, reducing losses and enhancing resilience against climate uncertainties.

8.4 HUMAN IMPACT: MINIMIZING LOSS OF LIVES AND ASSETS THROUGH PLANNED DEVELOPMENT

Flood susceptibility mapping is a vital tool for saving lives and protecting property. Using GIS and models like AHP, FR, and Random Forest, planners can identify high-risk areas, guide safer housing, design resilient infrastructure, and implement early warning systems. This enables communities to prepare, evacuate, and reduce flood damage, creating safer, more resilient towns and rural areas.

9 LIMITATIONS, CHALLENGES, AND ETHICAL CONSIDERATIONS

9.1 GENERAL

Flood susceptibility mapping is valuable but faces challenges like limited or outdated data, model uncertainties, and difficulty capturing real-time flood dynamics. Ethical issues also arise, as maps can impact land use, resettlement, or resources, making transparency, privacy, and equity essential.

9.2 DATA AVAILABILITY AND QUALITY ISSUES

Flood susceptibility mapping depends on high-quality, detailed data, but many regions face gaps, outdated records, or inconsistent datasets. This limits the accuracy of AHP, Frequency Ratio, and machine learning models, leading to potential mispredictions. Improving data quality, open-data sharing, and real-time monitoring is essential for reliable flood risk maps.

9.3 BIAS IN EXPERT-BASED MODELS LIKE AHP

AHP is valuable for flood mapping, especially in data-scarce regions, by weighting factors like slope, rainfall, soil, and land use based on expert judgment. However, it can introduce subjective bias due to experts' backgrounds, recent experiences, or regional generalizations. Inconsistencies may arise in pairwise comparisons, affecting reliability. To reduce bias, multidisciplinary experts, updated field data, and cross-checking with data-driven methods like Frequency Ratio or machine learning improve accuracy and credibility.

9.4 OVERFITTINGIN ML MODELS

ML models like Random Forest, Decision Trees, and ANN offer high flood prediction accuracy but are prone to overfitting performing well on training data but poorly on new data. Overfitting occurs when models memorize noise instead of learning true patterns, especially with small, unbalanced, or low-diversity datasets. To prevent this, techniques like cross-validation, feature selection, model simplification, and comparison with methods like AHP or Frequency Ratio improve reliability and generalization.

9.5 HUMAN REFLECTION: BALANCING TECHNOLOGICAL POWER WITH INCLUSIVE AND JUST POLICIES

Advanced flood mapping with GIS and ML (e.g., Random Forest, SVM, AHP) offers powerful prediction tools, but ethical use is crucial. If only accessible to experts or tech-savvy users, vulnerable communities may be left unprotected. Fair, transparent models, inclusive data, and community participation ensure equitable, actionable flood risk management.

10 FUTURE PROSPECTS AND INNOVATIONS

10.1 GENERAL

The future of flood mapping lies in combining advanced technologies and real-time data. Machine learning, remote sensing, IoT sensors, and cloud GIS improve prediction accuracy and speed. High-resolution imagery, AI, and community data enable adaptive, sustainable flood management, supporting early warnings, proactive planning, and climate-resilient infrastructure.

10.2 INTEGRATING IOT SENSORS WITH FLOOD MODELS IN REAL- TIME

IoT sensors beside rivers and drains can send real-time data on water levels, rainfall, and soil moisture to GIS-based flood models powered by machine learning. This transforms static maps into dynamic tools, enabling timely, adaptive predictions. Real-time data improves early warnings, guides targeted evacuations, and keeps models accurate over time, while GIS dashboards make the information accessible to planners and communities.

10.3 CLOUD-BASED GIS AND AI DEPLOYMENT FOR LIVE RISK UPDATE

Cloud-based GIS platforms powered by AI, like GEE, enable real-time flood mapping that updates with rainfall, land-use changes, and sensor data. Machine learning models such as Random Forest process spatial layers instantly, producing dynamic, accurate risk maps. These systems allow continuous validation, accessible dashboards, and near-instant updates for planners and communities, turning flood mapping into a responsive, action-oriented tool.

10.4 HUMANIZED VISION: CREATING FLOOD-RESILIENT AND CLIMATE-SMART COMMUNITIES

Building flood-resilient communities starts with understanding risks through tools like GIS, machine learning (Random Forest, SVM), and AHP-FR. These technologies map flood-prone areas and critical habitats, guiding safe infrastructure, ecosystem protection, and early warning systems. When combined with local knowledge and community involvement, flood mapping becomes human-centered, empowering people to prepare, adapt, and reduce loss of life and livelihood.

11 CASE STUDY

This case study assessed flood vulnerability in the Lower Keleghai River Basin, West Bengal, using AHP and GIS. Key factors like elevation, slope, rainfall, land use, soil type, river proximity, and TWI were weighted via expert-based AHP pairwise comparisons. Weighted layers were combined in GIS to produce a flood susceptibility map classifying areas from very low to very high risk. Validation with SAR imagery showed strong agreement between predicted high-risk zones and actual floods, demonstrating that AHP-GIS integration is an effective method for flood mapping.

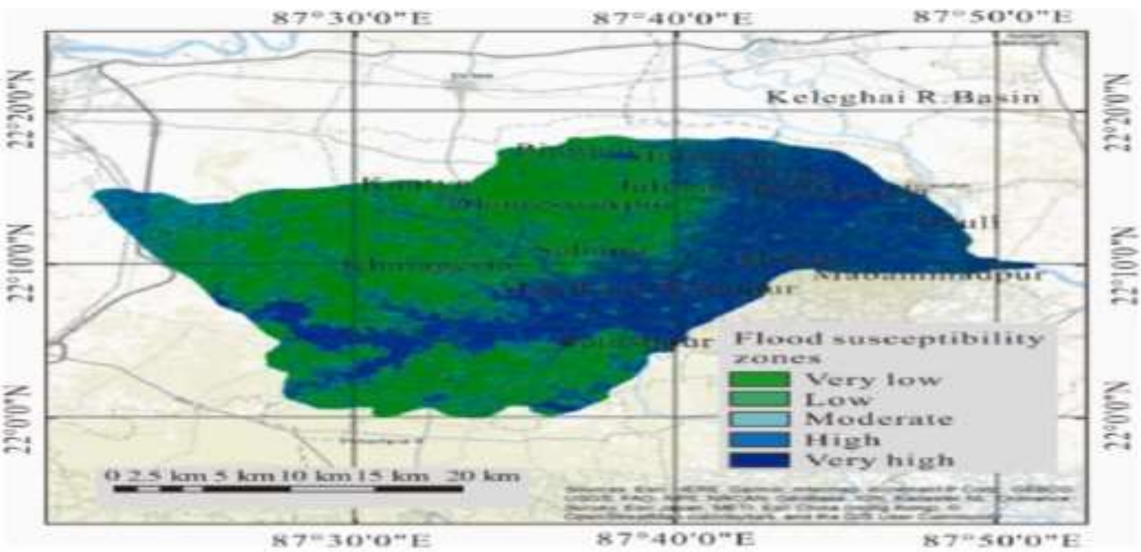

Fig 11.4 Flood susceptibility map based on AHP model (Nityananda Sar et al.(2024))

ACKNOWLEDGEMENT

It is the great enthusiasm and learning spirit that I bring out this seminar report. I also feel that it is the right opportunity to acknowledge for the support and guidance from all those who helped me during the course of completion of myself. I am extremely grateful to our Principal Dr. Benny Joseph, Vimal Jyothi Engineering College for providing the necessary facilities for the completion of the report. With immense pleasure and gratitude, I owe myself thanks to Dr. Biju Mathew, Head of the Department of Civil Engineering, for his valuable suggestion and guidance during the course. I am thankful to the seminar coordinator Ms. Hridya P, Assistant Professor in Civil Engineering as well as my seminar guide Ms. Anitha Babu, Assistant professor in Civil Engineering for her suggestion and guidance. I also thank all my friends for their valuable support and cooperation. My acknowledgement would not be complete without thanking my beloved parents and above all, I would like to express my sincere gratitude to God almighty for showering his blessing upon me.

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