IJARCCE
ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026

DOI: 10.17148/IJARCCE.2026.155235

Smart Flood Detection and Impact Mapping System: An IoT-Driven Framework for Real-Time Early Warning and Spatial Risk Visualisation

Mrs. Vidya V Patil[1], Amar[2], Divit V[3], Hari Narayana S[4], Kiran S[5]

Assistant Professor, Department of Computer Science and Engineering,
K. S. School of Engineering and Management (KSSEM), Bengaluru, Karnataka, India[1]

Students, Department of Computer Science and Engineering, K. S. School of Engineering and Management (KSSEM),
Bengaluru, Karnataka, India[2-5]

Abstract: Year after year, floods establish themselves as one of nature's most relentless and costly hazards — stripping communities of lives, agricultural stability, and infrastructure built over generations. Much of this destruction is not unavoidable; a substantial share of it can be traced directly to the failure of existing warning systems to reach at-risk populations quickly enough, and reliably enough, when conditions deteriorate. This paper presents the Smart Flood Detection and Impact Mapping System, a hardware-first, internet-independent platform that integrates IoT environmental sensing, embedded microcontroller processing, and GSM cellular communication to deliver autonomous real-time flood alerts without relying on cloud infrastructure. The system continuously measures water level, rainfall intensity, temperature, and humidity through field-deployed sensor arrays; evaluates incoming readings against pre-calibrated safety thresholds; and immediately dispatches SMS warnings to residents, farmers, local authorities, and emergency management teams the moment dangerous conditions are detected. Because alert delivery travels through the GSM cellular network rather than the internet, the system remains fully operational during the network outages that characteristically accompany severe weather events. A complementary Python-based visualisation pipeline converts accumulated sensor telemetry into colour-indexed spatial heat maps, providing disaster coordinators with a structured, geographically explicit picture of inundation severity that supports evidence-based evacuation planning and rescue resource allocation. The resulting system is low-cost, energy-efficient, portable, and suited for deployment across both urban centres and the remote rural communities where the gap between flood risk and monitoring capability is widest.

Keywords: Flood Monitoring, IoT, GSM Module, Early Warning System, Heat Mapping, Disaster Management, Real-Time Monitoring, Embedded Systems, Arduino, Edge Computing, Environmental Sensing, SMS Alert, SIM800L.

I. INTRODUCTION

Flooding is not merely a meteorological event — it is a cascading humanitarian emergency. When rivers exceed their natural capacity, when drainage systems buckle under sustained rainfall, or when ageing dam infrastructure finally yields to hydraulic pressure, the con-sequences propagate through communities with a speed and breadth that leaves affected populations very little time to react. Millions of people face this reality every single year, and the situation is worsening: shifting climate patterns, the expansion of human settlements into flood-prone terrain, and the progressive degradation of natural flood buffers such as forests and wetlands are collectively increasing both the frequency and the severity of flood events worldwide [1].

The most consequential dimension of flood risk is often not the flood itself but the warning gap — the interval between when dangerous conditions begin to develop and when the communities in harm's way receive actionable information about them. In many regions, particularly rural and semi-urban areas, this gap is enormous. Monitoring depends on manual water-gauge inspection conducted at infrequent intervals, or on generalisedweather bulletins that describe regional conditions rather than the specificsituation at a given river-bank or drainage outflow. Both approaches are structurally too slow, too broad, and too reliant on communication channels that tend to fail under the exact conditions that make rapid alerting essential [2]. The proliferation of IoT-based monitoring systems has introduced promising alternatives, but a critical design flaw has emerged in many of these implementations: they route alert data through cloud platformsand mobile applications that require stable internet connectivity. This dependency creates a fundamental operational paradox: the systems are designed to help during severe weather, but severe weather is precisely when internet access is most likely to be disrupted. A flood warning platform that goes silent at the height of a storm provides no safety benefit whatsoever [3].

The *Smart Flood Detection and Impact Mapping System* proposed in this paper is built around an explicit rejection of this dependency. Internet connectivity is treated as a useful supplement rather than an operational requirement. All detection logic executes locally on an embedded microcontroller positioned at the sensing site. All alert communications are routed through a GSM cellular module that operates independently of internet infrastructure. The system is designed to perform most reliably under the conditions that most systems fail: severe weather, network congestion, and power disruption. A Python-driven spatial visualisation component complements the alerting mechanism by producing colour-indexed heat maps that give emergency management authorities a geographically structured picture of inundation risk, enabling better-targeted and faster rescue operations.

This paper is organised as follows: Section II surveys related work and identifies recurring gaps; Section III defines the problem; Section IV describes the proposed system; Section V presents the architecture; Section VI details the methodology; and Section VII concludes with contributions and future directions.

II. LITERATURE SURVEY

A review of six peer-reviewed IoT flood monitoring studies published in 2025 reveals consistent technical progress alongside a set of structural limitations that the proposed system is designed to resolve.

A. *IoT Integrated Flood Detectionand Avoidance*[1]

Manoharan *et al.* combined sensor networks with cloud analytics to construct a real-time water level monitoring platform. The work successfully demonstrated that cost-effective environmental sensing is technically achievable, but the system's reliance on contin-uous internet connectivity created an operational vulnerability: under the network degradation conditions that accompany severe storms, alert delivery became unreliable. Sensor precision and power supply continuity were also flagged as areas requiring further development.

B. *Flash Flood Monitoringwith Mobile Alerts* [2]

This implementation delivered flood notifications through a smart-phone application, providing users with an accessible and familiar interface for receiving sensor-triggered warnings. The user experience was effective under standard operating conditions, but the dependence on both internet access and smartphone availability fundamentally limited the system's reliability during emergency conditions — precisely the situations in which rapid, dependable alerting is most critical.

C. *Flood Monitoringand Control System* [3]

Ankit *et al.* expanded the conventional monitoring paradigm by incorporating automated water flow control mechanisms, enabling the system to actively respond to detected flood conditions rather than merely reporting them. The approach demonstrated strong potential, but the resulting architectural complexity increased imple-mentation and maintenance costs in ways that restrict deployability in low-resource community settings.

D. *Automated Water Level Monitoring*[4]

This work applied threshold-based IoT sensing to automate water level monitoring and alert generation. Two persistent challenges emerged: sensor measurement inaccuracies attributable to environ-mental interference such as turbulence and floating debris, and com-munication latencies that reduced the effective lead time that early warning systems are intended to provide.

E. *Real-Time Flood Monitoringvia IoT* [5]

Myint and Thein developed a cloud-integrated monitoring frame-work capable of continuous multi-node data processing and real-time analysis. While analytically capable, the system's cloud dependency caused performance degradation in areas with unreliable internet connectivity — a category that encompasses many of the communities most frequently and severely affected by flood events.

F. *Smart IoT Flood Detectionwith Data Logging* [6]

Ma'ti *et al.* constructed an around-the-clock monitoring platform with immediate alarm generation upon threshold breach detection. The identified limitation was that sensor hardware failures or periods of degraded network coverage could interrupt or delay alert delivery. The proposed system addresses this through multi-sensor redundancy, backup power provisions, and multi-pathway communication.

Gap Analysis: Three structural limitations recur consistently across the surveyed literature: internet dependency in alert delivery path-ways; purely reactive operation without predictive capability; and limited applicability in rural and low-resource environments due to cost and architectural complexity. All three are directly addressed in the proposed system.

DOI: 10.17148/IJARCCE.2026.155235

III. PROBLEM STATEMENT

The problem at the centre of this research can be stated plainly: in flood-prone communities, the information that would allow people to protect themselves and their livelihoods consistently arrives too late to be useful.
This failure is not attributable to any single cause. In many areas,no monitoring infrastructure exists at all, leaving communities entirely dependent on visual observation of rising water and informal neighbourhood communication. In areas where some infrastructure does exist, it typically communicates through internet-dependent channels — cloud dashboards, mobile applications, centralised broad-cast systems — that become unavailable under severe weather conditions. And where warnings are generated, they tend to be generalised across large geographic areas rather than targeted to the specific localities and individuals most immediately at risk [4].

The agricultural community bears a disproportionate share of this burden. An unexpected inundation event can annihilate an entire growing season, compromise the structural integrity of irrigation systems that represent years of investment, and endanger livestock that households depend on for both income and sustenance. In rural economies where farming is the primary source of livelihood, the cumulative impact of repeated unwarned flood losses generates cycles of debt, displacement, and diminishing agricultural capacity.

At the emergency management level, delayed warnings cascade into delayed evacuations, misallocated rescue resources, over-whelmed temporary shelters, and in the most severe cases, preventable deaths. Every hour by which the warning gap can be reduced represents a measurable improvement in safety outcomes for affected communities.
The proposed system is designed to close this gap through three governing design principles: *resilience* (operational continuity when conventional infrastructure has failed), *locality* (warnings targeted to specific at-risk individuals rather than regional authorities alone), and *affordability* (a cost structure compatible with deployment in com-munities and administrations with severely constrained resources).

IV. PROPOSEDSYSTEM

A. System Overview

The Smart Flood Detection and Impact Mapping System integrates four technology layers into a unified, internet-independent real-time monitoring and alerting platform: environmental sensing, embedded edge processing, GSM cellular communication, and Python-based spatial visualisation.

B. Hardware Components

The physical sensing and processing infrastructure comprises the following components:

- **Water Level Sensor:** Continuously measures water height in rivers, channels, and adjacent water bodies, providing the primary quantitative indicator of flood risk escalation.
- **Rainfall Sensor:** Captures precipitation intensity in real time, en-abling the system to anticipate downstream water accumulation before it manifests as observable water level rises.
- **Temperature Sensor:** Logs ambient temperature readings to pro-vide environmental context for multi-parameter risk evaluation.
- **Humidity Sensor:** Monitors atmospheric moisture levels as a sec-ondary flood risk indicator, with particular relevance in regions where high soil saturation amplifies the flood impact of a given rainfall event.
- **Arduino UNO Microcontroller:** Functions as the embedded pro-cessing core, executing continuous sensor polling, real-time thresh-old comparison, risk classification, and alert triggering, entirely on-device without external computation.
- **GSM SIM800L Module:** Transmits pre-configured SMS warning messages to registered recipients via the cellular network, indepen-dently of internet connectivity.
- **Buzzer and LED Indicators:** Provide immediate localised audio-visual alerts at the sensing node location for the benefit of field personnel.
- **Python Heat Mapping Module:** Processes logged telemetry data to produce colour-coded spatial heat maps representing the geo-graphic distribution of flood risk intensity.

C. Working Principle

System operation follows a continuously executing closed-loop detection and response cycle. Environmental sensors sample con-ditions at regular intervals and transmit readings to the Arduino microcontroller. The microcontroller evaluates each incoming read-ing against pre-calibrated safety thresholds for the corresponding parameter. When all monitored values remain within safe bounds, readings are logged for trend analysis and transmitted to the data storage pipeline.

When any monitored parameter breaches its threshold, the follow-ing automated response sequence is initiated:

1. The flood risk condition is flagged and recorded with a precise timestamp.
2. The GSM module dispatches SMS alerts to pre-registered recipi-ents: nearby residents, farmers, local administrative officers, and district disastermanagement coordinators.
3. The onboard buzzer and LED indicators activate to provide imme-diate physical alerting at the node location.
4. All sensor readings are logged comprehensively for post-event analysis and accountability.
5. The Python visualisation pipeline generates updated spatial heat maps identifying high-risk zones and comparatively safer areas within the monitored region.

The complete critical path from hazard detection to alert delivery involves no internet dependency at any point, ensuring operational continuity during network disruptions.

V. SYSTEM ARCHITECTURE

The system architecture is structured into four sequential, func-tionally distinct layers that together form the complete detection-to-response pipeline.

1) Data Acquisition Layer

Field-deployed environmental sensors positioned at riverbanks, drainage outflows, dam proximity zones, and historically flood-prone agricultural areas continuously capture real-time measurements across the four monitored parameters: water level, rainfall intensity, atmospheric humidity, and ambient temperature. This layer operates passively and without interruption, requiring neither human oversight nor network connectivity for sustained function.

2) Embedded Processing Layer

The Arduino UNO microcontroller receives raw sensor measure-ments and applies threshold evaluation logic to classify the current environmental state — safe, watch, or alert — at each evaluation cycle. All computation is local and autonomous. The processing layer retains full functionality regardless of the availability of cloud services or external network access.

3) Communication and Alerting Layer

Upon threshold breach detection by the processing layer, the GSM SIM800L module activates and transmits warning SMS messages to the pre-configured recipient registry. The cellular communication pathway represents the critical resilience contribution of the system architecture: it remains active and functional when internet-based alert channels have failed. Concurrent audio-visual indicators at the node level provide immediate physical notification for field person-nel.

4) Visualisation and Decision Support Layer

Accumulated sensor telemetry is continuously fed into the back-end Python visualisation pipeline, which employs the Matplotlib and Seaborn libraries to render colour-indexed heat maps of the monitored geographic region. These maps provide emergency management au-thorities with a spatially explicit, continuously updated picture of flood severity distribution, directly supporting the prioritisation of evacuation routes, rescue resource deployment, and relief operation coordination.

VI. METHODOLOGY

System development and validation followed a structured six-step methodology designed to ensure reliable performance under realistic field conditions across all operational scenarios.

1) Sensor Deployment and Data Collection

Sensing nodes were installed at locations identified as flood-vulnerable through a combination of historical inundation records, topographic analysis, and direct community consultation. Deploy-ment sites included riverbanks, drainage outflows, agricultural land perimeters, and areas in proximity to water storage and dam infras-tructure. Each sensor node was configured for continuous sampling with regular-interval data transmission to the microcontroller.

2) Threshold Calibration and Data Processing

Safety threshold values for each monitored environmental parame-ter were established through a combination of published hydrological reference data and empirical calibration conducted under controlled laboratory and field conditions. The microcontroller firmware was configured to perform continuous threshold comparison, classifying the environmental state in real time and maintaining a persistent record of state transitions for trend analysis.

3) Flood Risk Detection

The risk classification logic was designed to respond not only to individual parameter threshold breaches but also to multi-parameter correlation patterns that signal elevated compound risk. For example, concurrent high rainfall intensity and elevated atmospheric humidity indicates a condition of greater immediate flood risk than elevated rainfall alone, enabling more accurate and nuanced risk assessment than single-parameter threshold systems can provide.

4) Automated Alert Generation

On transitioning to an alert state, the GSM module transmits pre-composed SMS messages to recipients organised by functional cate-gory: local residents, agricultural community members, municipal administrative officers, and district disaster management coordinators. Message content was specifically designed to communicate action-able information — what is happening, where, and what protective action is recommended — rather than generic severity notifications.

5) Heat Map Generation

Sensor telemetry accumulated across monitoring periods is period-ically processed by the Python pipeline to produce updated regional heat maps. The visualisation employs a colour gradient progressing from green (low risk) through amber (elevated risk) to red (critical risk), rendering the geographic distribution of flood severity in a format readily interpretable by emergency responders without spe-cialised technical background.

6) Testing and Validation

The complete integrated system was subjected to a structured series of simulated flood scenarios, each targeting a specific perfor-mance dimension. Evaluation metrics included:

- **Detection Accuracy:** Rate of correct threshold breach identification against simulated environmental ground truth.
- **Alert Delivery Latency:** Elapsed time from threshold breach detection to confirmed SMS receipt at registered devices.
- **Communication Reliability:** Alert delivery success rate under conditions of degraded cellular network availability.
- **System Uptime:** Sustained operational duration under simulated field stress conditions, including battery interruption and sensor recovery scenarios.

VII. CONCLUSION

The Smart Flood Detection and Impact Mapping System demon-strates that an affordable, community-deployable flood early warning platform can be built without accepting the internet dependency that has become the defining vulnerability of most modern monitoring solutions.

By routing all alert communications through a GSM cellular mod-ule rather than cloud services or mobile applications, the system ensures that warning delivery is most reliable precisely when condi-tions are most dangerous — inverting the failure pattern that charac-terises the majority of internet-dependent implementations surveyed in the literature. The spatial heat-mapping capability complements this resilient alerting mechanism by providing emergency manage-ment authorities with structured, geographically indexed situational awareness that enables faster targeting of rescue resources and more effective coordination of evacuation operations.

The convergence of these two capabilities addresses the fundamen-tal challenge that motivates this work: narrowing the gap between when a flood begins and when the communities in its path receive information that allows them to act. For the rural residents, farmers, and under-served communities who face flood risk without access to sophisticated monitoring infrastructure, that narrowing represents a direct and meaningful improvement in safety and livelihood protec-tion.

Future developmentwill pursue four primary directions:

(1) Integration of lightweight on-device machine learning models to enable proactive flood forecasting rather than purely reactive threshold detection.

(2) Supplementation of the GSM communication layer with Lo-RaWAN hardware for extended range and operation during cel-lular tower downtime.

(3) Incorporation of photovoltaic solar energy harvesting to support maintenance-free indefinite operation in remote field deploy-ments.

(4) Scaling of the heat-mapping module into a cloud-hosted, web-accessible GIS dashboard for real-time multi-agency disaster coordination.

ACKNOWLEDGMENT

The authors gratefully acknowledge K. S. School of Engineering and Management, Bengaluru, for the institutional infrastructure, lab-oratory facilities, and academic environment that supported this work from conception through completion. Deep appreciation is extended to the project guide, Mrs. Vidya V Patil, whose mentorship, domain expertise, and sustained personal encouragement were indispensable at every stage of the project.

The authors also thank the local residents and farming commu-nity members in flood-affected localities near Bengaluru who shared their direct experiences of flood risk and warning system failure. Their perspectives shaped the design of this system in ways that technical requirements alone could not have accomplished, and their cooperation is gratefully acknowledged.

REFERENCES

[1]. L. Manoharan, K. S. Vignesh, M. Saravanapandian, B. Ajay, R. K. Dwibedi and K. U. Kalyani, “IoT Integrated Flood Detec-tion and Avoidance,” *Int. Journal of Engineering Research and Technology*, vol. 14, no. 3, pp. 101–108, 2025.

[2]. Z. Zulkapli, Z. Janin, M. Zolkapli, N. Burham, M. Masrie and S. Shahbudin, “IoT-Based Flash Flood Monitoring with Mo-bile Notification Alerts for Urban Areas,” *Journal of Sensor Networks and IoT Applications*, vol. 8, no. 1, pp. 45–57, 2025.

[3]. T. Ankit, K. Kumar, G. Pal, A. Kumar, M. P. Ankit and S. M. Tyagi, “IoT Based Flood Monitoring and Control System,” in *Proc. Int. Conf. on Embedded Systems and Smart Technologies*, 2025, pp. 112–118.

[4]. D. M. K. Selvi, P. Sharmila, E. Manchinella, P. P. J. Pavani and P. Sadhvika, “Internet of Things Based Automated Water Level Monitoring and Alert System,” in *Proc. IEEE Int. Conf. on IoT and Disaster Management*, 2025, pp. 78–85.

[5]. M. M. Myint and T. L. L. Thein, “Real-Time Flood Monitor-ing System Using Internet of Things in Urban Environments,” *Int. Journal of Computer Applications in Engineering*, vol. 11, no. 2, pp. 23–31, 2025.

[6]. M. A. N. Ma’ti, R. M. Isa, F. A. M. Kasran, S. L. M. Hassan, W.N. W. Zakaria and M. H. N. Ismadi, “Smart IoT-Based Flood Detection and Alert System with Real-Time Data Logging,” *Journalof Applied IoT Systems and Safety Engineering*, vol. 6, no. 1, pp. 91–102, 2025.