

# Mapping The Risk Levels and Distribution of Dengue Fever (Df) in The City of Pontianak Using Choropleth Maps and Point Mapping

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## Abstract.

*Dengue Hemorrhagic Fever (DHF) remains a critical public health challenge in tropical regions, with Indonesia recording approximately 143,000 cases in 2022 alone, yet most local health authorities lack spatially explicit decision-support tools. This study aimed to design and develop a web-based Geographic Information System (GIS) capable of mapping DHF vulnerability levels and case distribution in Pontianak City, West Kalimantan, in real time. A research and development approach was employed, involving field observation, structured interviews with Pontianak City Health Office officials, and secondary data collection comprising 120 confirmed DHF patient records obtained from the health office for the period 2024 to May 2025. The system integrated real-time environmental data retrieved via the OpenWeatherMap API alongside population density data from the Central Bureau of Statistics (BPS). Vulnerability levels were calculated using a scoring method applied to four parameters — air temperature, rainfall, humidity, and population density — and visualized through dual-layer spatial techniques: Choropleth Maps to represent sub-district vulnerability gradations and Point Mapping to display precise case locations based on patient geographic coordinates. System validation was conducted through Black Box Testing, which confirmed full functional compliance, and User Acceptance Testing (UAT) with health office representatives, yielding a Strongly Agree score of 88.23%. The developed system successfully classified DHF vulnerability into three categories (High, Moderate, Low) and provided interactive, real-time spatial visualization, offering the Pontianak City Health Office a data-driven instrument for targeted DHF prevention and control.*

**Keywords:** *Choropleth Map; Dengue Hemorrhagic Fever; Geographic Information System; Point Mapping and Scoring Method.*

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## I. INTRODUCTION

Dengue hemorrhagic fever (DHF) remains one of the most pressing vector-borne diseases threatening public health systems across tropical and subtropical regions worldwide. The World Health Organization (WHO) estimates that approximately 390 million dengue infections occur annually, of which around 96 million manifest clinically, placing half the global population at risk within endemic zones (Brady et al., 2012, as cited in Wijayanti et al., 2023; Prabowo et al., 2025). Over the past decade, the geographic range of *Aedes aegypti*—the primary vector of dengue virus serotypes DENV-1 through DENV-4—has expanded dramatically due to accelerating urbanization, climate change, and increased international travel, further complicating disease containment efforts (Sasmito et al., 2024; Delita & Nurhayati, 2022). In Indonesia, the epidemiological burden of DHF is particularly severe; national surveillance data recorded approximately 143,000 confirmed cases in 2022 alone, positioning Indonesia among the highest-burden countries in the Southeast Asian region (Virdayanti et al., 2025; Wijayanti et al., 2023). The disease is transmitted when an infected female *Aedes* mosquito bites a susceptible human host, causing clinical manifestations including sustained high fever lasting 2–7 days, haemorrhagic episodes, severe myalgia, and, in critical cases, dengue shock syndrome that can rapidly progress to mortality if not promptly managed (Delita & Nurhayati, 2022). Several environmental parameters—particularly mean air temperature (25–30°C), relative humidity (70–90%), and precipitation patterns that produce standing water—have been consistently identified as determinants of vector breeding activity and viral replication efficiency, thereby modulating transmission intensity across space and time (Wijayanti et al., 2023; Wahyuni et al., 2021).

Within the Indonesian context, Pontianak City—the provincial capital of West Kalimantan—presents a particularly challenging epidemiological landscape for DHF control. Situated at the confluence of the Kapuas River and its numerous tributaries, the city's low-lying, wetland-dominated topography generates

persistently elevated humidity levels and widespread waterlogging, creating near-ideal ecological conditions for perennial *Aedes aegypti* proliferation (Natalia et al., 2015). Population data from Badan Pusat Statistik (BPS) Kota Pontianak (2024) indicate that the city's total population reached 687,031 inhabitants, with the highest concentrations recorded in Pontianak Barat sub-district (152,880 persons) and Pontianak Utara (149,693 persons)—precisely the densely settled areas where vector-host contact probability is greatest. A correlational study conducted by Virdayanti et al. (2025) in Kendari City further confirmed that population density and rainfall patterns are the most statistically significant spatial predictors of DHF incidence distribution, underscoring the epidemiological relevance of these variables in equatorial Indonesian cities comparable to Pontianak. These findings align with Istiqlala's (2024) investigation in Kediri Regency, which demonstrated that geography-based case mapping can uncover high-risk spatial clusters that conventional administrative surveillance systems systematically fail to detect, highlighting a critical gap in current disease reporting infrastructure (Istiqlala, 2024; Virdayanti et al., 2025).

### **State of the Art**

Growing recognition of spatial heterogeneity in DHF transmission has spurred a body of research applying Geographic Information Systems (GIS) to disease mapping across Indonesian cities. Nuhgroho et al. (2023) conducted a landmark multi-parameter study in Bandung City that integrated physical environmental indicators and population density into a GIS-based vulnerability framework, ultimately identifying fifteen sub-districts at high risk and demonstrating that multi-criteria spatial approaches substantially outperform single-variable models in risk stratification accuracy. Similarly, Yuliana et al. (2022) employed a GIS spatial analysis in Padang City, successfully classifying 11 of 104 urban kelurahan as high-vulnerability zones, with Kuranji designated as the top-priority area for targeted health intervention based on composite environmental and demographic scoring. In the realm of web-based operational systems, Saputra et al. (2024) developed a web-hosted GIS platform for DHF monitoring in the Wanasari Primary Health Centre catchment area, reporting that the system measurably accelerated outbreak response times and improved the spatial precision of public health interventions (Saputra et al., 2024; Nuhgroho et al., 2023). Complementary evidence from a meta-analytical review by Wijayanti et al. (2023) further validated that the integration of climatic and demographic parameters into GIS-enabled surveillance models yields substantially improved predictive accuracy compared to passive case-notification systems alone, reinforcing the scientific rationale for spatially explicit approaches to DHF management (Wijayanti et al., 2023; Yuliana et al., 2022).

### **Methodological Limitations**

Despite these advances, a careful examination of the extant literature reveals persistent and consequential methodological limitations. The spatial mapping systems examined in studies such as Roziqin and Hasdiyanti (2017), though incorporating larval density and population distribution as explanatory variables, remain fundamentally static—anchored to historical datasets that are incapable of reflecting the dynamic interplay between real-time environmental fluctuations and vector activity. This limitation is compounded in Saputra et al.'s (2024) GIS-based forest fire vulnerability model in West Kalimantan, which employed a scoring method with historical hotspot data but lacked integration of live environmental feeds, thereby restricting the system's operational utility for real-time decision support. A systematic analysis by Prabowo et al. (2025) further exposed that the majority of conventional DHF surveillance systems remain dependent on passive case detection and administratively aggregated reporting, rendering them structurally vulnerable to underreporting bias, spatial misclassification, and reporting delays—all of which fundamentally impair the timely identification of transmission hotspots. Corroborating this assessment, a spatial vulnerability analysis of DHF across Indonesian settings (Sasmito et al., 2024) demonstrated that incorporating socio-economic and environmental variables into GIS-based risk models yields substantially more comprehensive risk profiles; however, the majority of municipality-level studies reviewed had yet to implement a fully integrated, multi-criteria approach underpinned by real-time environmental data streams (Prabowo et al., 2025; Sasmito et al., 2024).

### **Research Gap & Problem Statement**

Taken together, the evidence reveals a clear and consequential research gap: no web-based GIS system currently exists for Pontianak City that is capable of integrating dynamic, real-time multi-parameter vulnerability scoring with interactive spatial visualization of DHF case distribution. This absence is not

merely an academic observation—it has direct operational consequences. Interviews conducted with officials from the Pontianak City Health Office (Dinas Kesehatan Kota Pontianak) confirmed that the institution currently lacks any dedicated digital application capable of visualizing DHF case distribution at a geographically granular level, meaning that prevention and control decisions continue to be formulated on the basis of aggregated, spatially imprecise data. This situation is particularly alarming given the city's documented ecological risk profile and the demonstrated association between delayed spatial intelligence and suboptimal outbreak response (Virdayanti et al., 2025; Wahyuni et al., 2021). Furthermore, Wijayanti et al.'s (2023) meta-analysis of DHF risk factors in Indonesia underscores that the complexity of vector-environment-host interactions demands adaptive, continuously updated spatial data infrastructure—an infrastructure that Pontianak presently lacks. Addressing this gap is therefore not only scientifically imperative but also practically urgent for the city's public health governance capacity (Wijayanti et al., 2023; Nuhgroho et al., 2023).

### **Research Purpose & Contribution**

In response to the documented gap, this study aims to design and develop a web-based Geographic Information System capable of mapping DHF vulnerability levels and case distribution in Pontianak City in real time, through the integrated application of Choropleth Map and Point Mapping techniques. Specifically, the system employs a multi-parameter scoring method that dynamically weights four key environmental and demographic variables—air temperature, precipitation, relative humidity, and population density—sourced via real-time API integration with OpenWeatherMap and official BPS population datasets, thereby enabling continuous and geographically granular vulnerability assessment. The urgency of this research is underscored by the Pontianak City Health Office's confirmed absence of a spatially-enabled decision support tool, a gap that leaves one of Indonesia's highest-risk urban environments without the analytical infrastructure necessary for evidence-based vector control programming (Saputra et al., 2024; Wahyuni et al., 2021). The novelty of this work lies in its unique methodological architecture: the simultaneous deployment of dual-layer spatial visualization—choropleth mapping for administrative-unit vulnerability gradients and point mapping for individual case geolocation—within a single integrated real-time web platform represents a contribution not previously documented in the DHF-GIS literature for this geographic context (Yuliana et al., 2022; Prabowo et al., 2025). Theoretically, this study advances the understanding of adaptive GIS-based disease surveillance frameworks applicable to high-density tropical urban environments. Practically, the resulting system is designed to serve as an operational reference tool for the Pontianak City Health Office, enabling data-driven, spatially targeted prevention and control strategies that more effectively allocate public health resources and reduce the city's structural vulnerability to recurring DHF outbreaks (Nuhgroho et al., 2023; Virdayanti et al., 2025).

## **II. METHODS**

### **Research Design**

This study adopts a mixed-methods research design that integrates quantitative analysis with applied system development, following the Research and Development (R&D) paradigm as articulated by Sugiyono (2019), who defines this approach as a systematic scientific procedure for both investigating existing phenomena and producing validated technological artifacts. Within this framework, the research is classified as applied developmental research, oriented toward engineering a functional Geographic Information System (GIS) platform rather than testing a pre-specified hypothesis. This categorization aligns with Sudaryono's (2018) typology of Information Technology research, which distinguishes studies aimed at producing operational systems from purely explanatory inquiries. The quantitative dimension manifests in the scoring method used to compute district-level DHF vulnerability indices from four parametric inputs, while the developmental dimension encompasses the full software lifecycle from requirements analysis through user acceptance validation. Such dual-orientation designs are increasingly recognized in health-informatics literature as particularly appropriate when the research objective is simultaneously diagnostic and prescriptive (Saputra et al., 2024; Prabowo et al., 2025), because they allow empirical evidence about disease determinants to be directly translated into functional decision-support tools.

### Population, Sample, and Data Sources

The spatial unit of analysis in this study is the six administrative districts (*kecamatan*) of Pontianak City, namely Pontianak Barat, Pontianak Utara, Pontianak Kota, Pontianak Timur, Pontianak Selatan, and Pontianak Tenggara, collectively constituting the entire administrative boundary of the city and rendering probabilistic sampling unnecessary given the census-level spatial scope. Patient-level data were obtained from the Pontianak City Health Office (*Dinas Kesehatan Kota Pontianak*) and cover confirmed DHF cases recorded from January 2024 through May 2025, yielding a dataset of 120 patient records. Each record includes patient name, sex, age, residential address, and geographic coordinates (latitude and longitude), the latter having been validated against Google Maps to ensure spatial accuracy. Population density figures for each district were sourced from the 2024 Statistical Yearbook of the Pontianak City Central Bureau of Statistics (BPS, 2024), which places the total municipal population at 687,031 inhabitants, with Pontianak Barat (152,880) and Pontianak Utara (149,693) recording the highest densities. Environmental parameters — air temperature, rainfall, and relative humidity — are retrieved in real-time via the OpenWeatherMap API, which aggregates data from meteorological broadcasting services and official weather stations, thereby ensuring that vulnerability calculations always reflect current atmospheric conditions (Virdayanti et al., 2025; Delita & Nurhayati, 2022). This multi-source data strategy mirrors the approach recommended by Nuhgroho et al. (2023) for achieving robust multi-parameter vulnerability assessments.

### Research Instruments

The primary instrument of this study is the web-based GIS application developed by the researcher, which operationalizes three interrelated technical components. First, the scoring method (*metode skor*) instrument quantifies DHF vulnerability by assigning weighted scores to four environmental and demographic parameters: air temperature (optimal range 25–30°C, score 3; near-optimal 20–24°C or 31–35°C, score 2; outside range, score 1), relative humidity (optimal 70–90%, score 3; 50–69% or 91–100%, score 2; below 50%, score 1), rainfall intensity (optimal 5–10 mm/hour, score 3; 1–4 mm/hour, score 2; outside range, score 1), and population density (above 8,000 persons/km<sup>2</sup>, score 3; 4,000–8,000 persons/km<sup>2</sup>, score 2; below 4,000 persons/km<sup>2</sup>, score 1). The aggregate score then determines a district's vulnerability category: High ( $\geq 10$ ), Moderate (7–9), or Low ( $< 7$ ). This parameterization is grounded in established entomological evidence on *Aedes aegypti* ecology (Delita & Nurhayati, 2022) and aligns with scoring frameworks validated in analogous GIS-based DHF studies (Wahyuni et al., 2021; Saputra et al., 2024). Second, a User Acceptance Testing (UAT) questionnaire instrument employing a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) was administered to evaluate the system's functional suitability and usability from the end-user perspective. Content validity of the questionnaire was assured through expert review by system engineers and public health practitioners at the Pontianak City Health Office, and internal consistency was assessed prior to deployment, consistent with the validation procedures described by Sudaryono (2018) and Emzir (2019). Third, Black Box Testing was applied as a functional verification instrument to confirm that each system module performs its specified operations correctly regardless of internal code structure, a methodology well-established in software quality assurance literature (Roziqin & Hasdiyanti, 2017).

### Research Procedure

The research was executed in seven sequential stages that collectively constitute a structured Systems Development Life Cycle (SDLC). In the first stage, problem identification, a gap analysis was conducted through document review and a structured interview with the DHF coordinator (*PJ DBD*) at the Pontianak City Health Office. This confirmed the absence of any spatially explicit decision-support tool within the institution and established the functional requirements for the system to be developed. The second stage, data collection, involved three parallel sub-activities: a systematic literature review of peer-reviewed GIS and DHF studies to establish the theoretical and methodological framework; direct observation at the Health Office to understand existing data workflows; and a formal interview with the DHF coordinator to obtain the patient dataset along with permission for its use in research. The third stage, requirements analysis, translated the

findings from stages one and two into formal functional requirements — including real-time choropleth vulnerability mapping, point-mapped case distribution, and administrative patient data management — and non-functional requirements encompassing browser accessibility, interface intuitiveness, and interactive spatial query functionality. The fourth stage, system design, produced a complete architectural specification comprising a client-server model, Entity Relationship Diagrams (ERD), Use Case and Activity Diagrams drawn in UML notation, database schema definitions in MySQL, and interface wireframes. The fifth stage, implementation, involved the full-stack development of the system: the backend was developed in native PHP with XAMPP as the local server environment, while the frontend was built using HTML5, CSS3, and JavaScript; geospatial visualization was realized through the Leaflet.js open-source library using GeoJSON boundary data for district polygons; and real-time environmental parameters were fetched via the OpenWeatherMap API. The sixth stage, system testing, applied Black Box Testing across all functional modules, followed by UAT. The seventh stage, conclusion and documentation, synthesized all findings and produced system and research documentation in accordance with academic reporting standards (Sugiyono, 2019; Emzir, 2019).

### **Data Analysis Technique**

Data analysis in this study operates across two complementary levels. At the computational level, vulnerability scoring is performed by a PHP function (`calculateRiskLevel`) that accepts the four real-time and static parameters as arguments, computes the aggregate risk score through conditional scoring logic, and returns a categorical output (High, Moderate, or Low) stored in the `region_daily_data` table of the MySQL database. This programmatic analysis is executed server-side upon each system refresh cycle, ensuring that the choropleth layer continuously reflects current environmental conditions. The spatial distribution of DHF cases is rendered client-side through Leaflet.js by reading latitude–longitude records from the `pasien` database table and instantiating interactive map markers, enabling users to visually identify geographic clustering patterns consistent with the spatial analysis approaches applied by Nuhgroho et al. (2023) and Yuliana et al. (2022). At the evaluative level, Black Box Testing results were analyzed by comparing actual system outputs against expected outputs for each defined test case, with overall functional correctness expressed as a pass/fail ratio across all tested features. UAT data were analyzed using the Likert percentage formula, wherein the total weighted score is divided by the maximum achievable score and multiplied by 100, yielding a usability percentage that is then interpreted against a five-tier classification table (0–19.99% = Strongly Disagree; 20–39.99% = Disagree; 40–59.99% = Neutral; 60–79.99% = Agree; 80–100% = Strongly Agree). This quantitative usability evaluation framework follows the protocol described by Sudaryono (2018) and has been adopted in comparable GIS acceptance studies (Saputra et al., 2024; Istiqlala, 2024).

### **Ethical Considerations**

This research was conducted in full compliance with applicable research ethics principles governing the collection, use, and storage of personally identifiable health data. Prior to data collection, formal written permission was obtained from the Pontianak City Health Office, which constitutes the institutional data custodian for all DHF case records used in this study. The DHF coordinator who participated in the structured interview provided informed consent and was made aware of the study's objectives, scope, and intended use of the data. Patient data — including names, ages, sex, residential addresses, and geographic coordinates — were used exclusively for the purposes of spatial visualization within the system and were not disclosed to any third party or used for individual-level clinical inference. Access to patient records within the system is restricted through role-based authentication, ensuring that sensitive data are accessible only to authorized personnel of the Health Office. These ethical safeguards align with the data governance principles outlined by Emzir (2019) for applied research involving secondary health data, and reflect the transparency and participant protection standards expected in Scopus-indexed health informatics publications (Wijayanti et al., 2023; Virdayanti et al., 2025).

### III. RESULT AND DISCUSSION

#### System Implementation

The developed web-based Geographic Information System (GIS) integrates a multi-layer client-server architecture comprising a PHP backend, MySQL database, JavaScript-powered frontend rendered via Google Chrome, and a Leaflet.js interactive mapping library overlaid on OpenStreetMap base tiles. The system encompasses ten distinct functional interface modules: Login, Registration, Admin Dashboard, Staff Dashboard, User Profile, Historical Statistics, Patient Data Management, Add Patient, Edit Patient, and User Management. Each module was constructed to address specific operational requirements identified during the needs analysis phase. The Admin Dashboard serves as the primary operational interface, automatically fetching real-time environmental data via the OpenWeatherMap API and presenting an integrated dual-layer spatial visualization encompassing Choropleth Map and Point Mapping overlays alongside a panel displaying current meteorological and demographic summaries for each sub-district. The Staff Dashboard mirrors the core visualization functionality of the Admin Dashboard while restricting data management privileges, ensuring role-based access control aligned with the operational hierarchy of the Pontianak City Health Office.

#### Implementation of the Scoring Method for Vulnerability Level Calculation

The vulnerability level of each administrative sub-district (kecamatan) in Pontianak City was quantified using a scoring method operationalized through the PHP function `calculateRiskLevel()`. The function accepted four real-time environmental parameters retrieved via the OpenWeatherMap API, specifically air temperature, air humidity, and rainfall, supplemented by population density data sourced from the Badan Pusat Statistik (BPS) Pontianak City 2024. Each parameter was scored on a three-point scale according to its proximity to the ecological optimum for *Aedes aegypti* propagation, as summarized in Table 1.

**Table 1.** Scoring Criteria for DHF Vulnerability Parameters

Parameter	Score 3 (Optimal)	Score 2 (Near-Optimal)	Score 1 (Sub-optimal)
Air Temperature	25–30°C	20–24°C or 30–35°C	<20°C or >35°C
Air Humidity	70–90%	50–70% or 90–100%	<50%
Rainfall	5–10 mm/hr	1–5 mm/hr	<1 mm or >10 mm
Population Density	>8,000 persons/km <sup>2</sup>	4,000–8,000 persons/km <sup>2</sup>	<4,000 persons/km <sup>2</sup>

The cumulative risk score derived from the four parameters was classified into three vulnerability categories: High (total score  $\geq 10$ ), Moderate (score 7–9), and Low (score  $< 7$ ). The resulting risk level for each sub-district was stored daily in the `regiondailydata` table within the MySQL database, enabling both real-time visualization and longitudinal historical tracking. The scoring algorithm was successfully executed for all six administrative sub-districts of Pontianak City, with the output directly feeding into the Choropleth Map visualization layer.

#### Choropleth Map Visualization

The Choropleth Map was implemented using the Leaflet.js library on the client side, utilizing GeoJSON boundary data for the six sub-districts of Pontianak City. The `createChoropleth()` JavaScript function retrieved the vulnerability risk levels stored in the database and mapped them to a color gradient scheme: dark red (#D32F2F) for High risk, amber (#FFB300) for Moderate risk, and green (#66BB6A) for Low risk. Each polygon representing a sub-district was rendered with its corresponding color on the interactive map. Upon user interaction, clicking a sub-district polygon triggered a popup displaying the sub-district name, risk level, air temperature, humidity, average rainfall, and population density in real time. The visualization further supported toggle controls enabling users to activate or deactivate the choropleth layer and patient markers independently, enhancing analytical flexibility for the health office personnel (Figure 5.12).

#### Point Mapping Visualization

The Point Mapping technique was implemented to spatially represent the geographic distribution of individual DHF cases. Patient data comprising 120 records collected from the Pontianak City Health Office covering the period 2024 to May 2025 were stored in the MySQL `pasien` table together with georeferenced coordinates (latitude and longitude) obtained through direct observation and cross-validation with Google Maps. On the client side, Leaflet.js rendered each case as a discrete marker on the base map of Pontianak

City. Each marker was equipped with an interactive popup presenting patient-specific information upon click. **System Testing: Black Box Testing.** Functional correctness of the system was evaluated using Black Box Testing, in which predefined input scenarios were executed and outputs were compared against expected system behavior. A total of nine functional features were tested across multiple scenarios, as presented in Table 2.

**Table 2.** Summary of Black Box Testing Results

No.	Feature Tested	Scenarios Tested	Outcome
1	User Login	Valid credentials; invalid credentials	Pass
2	User Registration	Valid new data; duplicate email/username	Pass
3	Admin Dashboard	Dashboard load; toggle patient markers; toggle choropleth layer	Pass
4	Profile Management	Update name/email; update password; incorrect current password	Pass
5	Historical Statistics	Access statistics page with 30-day trend charts	Pass
6	Patient Data Management	View patient list with edit/delete options	Pass
7	Add Patient	Submit valid patient form with coordinates	Pass
8	Edit Patient	Modify existing patient record	Pass
9	User Management	Admin access to manage user accounts	Pass

All tested functional features produced outputs consistent with the expected behavior defined in the functional requirements specification. No functional failures were recorded across all scenarios, indicating that the system operates correctly under the tested conditions.

#### **User Acceptance Testing (UAT)**

User Acceptance Testing (UAT) was conducted with a representative of the Pontianak City Health Office, specifically the DHF Program Officer (PJ DBD), to evaluate the system's suitability for operational use. The instrument comprised 14 statement items assessed on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The items covered key dimensions including map display quality, system usability, the clarity of vulnerability level and patient location information, reliability of patient data management functions, and the overall utility of the system for supporting decision-making. The complete UAT results are presented in Table 3.

**Table 3.** User Acceptance Testing (UAT) Results

No.	Statement	Response	Score
1	The system interface is visually clear and easy to understand	Strongly Agree (SS)	5
2	The vulnerability level information displayed is easy to comprehend	Strongly Agree (SS)	5
3	The choropleth map accurately reflects sub-district vulnerability levels	Strongly Agree (SS)	5
4	The color differentiation between risk levels on the map is clear	Strongly Agree (SS)	5
5	The map correctly displays all patient case locations and is operable (pan/zoom)	Strongly Agree (SS)	5
6	The popup information when clicking a patient marker is clear and informative	Strongly Agree (SS)	5

No.	Statement	Response	Score
7	The toggle feature for patient markers and vulnerability layers works correctly	Agree (S)	4
8	The process of adding new patient data via the form runs smoothly	Agree (S)	4
9	Searching and viewing patient detail information is easy	Strongly Agree (SS)	5
10	The edit patient function operates as expected	Strongly Agree (SS)	5
11	The patient deletion process is secure and clear	Strongly Agree (SS)	5
12	The system is highly helpful in visualizing DHF distribution and vulnerability levels	Strongly Agree (SS)	5
13	The information presented is relevant for supporting DHF prevention decision-making	Strongly Agree (SS)	5
14	The system is reliable and I would recommend its use for the Health Office	Strongly Agree (SS)	5
<b>Total Score</b>			<b>68</b>

The Likert-based percentage calculation yielded the following distribution: Strongly Agree (SS) = 88.23% (score 60 out of 68), and Agree (S) = 11.77% (score 8 out of 68). No responses were recorded in the Neutral, Disagree, or Strongly Disagree categories. Based on the usability classification scale in which a percentage of 80–100% corresponds to the "Strongly Agree" classification, the overall UAT score of 88.23% places the system within the highest usability category. This outcome confirms that the system fulfills the operational expectations and practical requirements of the end-user at the Pontianak City Health Office. The principal findings of this study collectively demonstrate that a web-based GIS incorporating a real-time multi-parameter scoring method, Choropleth Map visualization, and Point Mapping is technically feasible and operationally acceptable for DHF surveillance in Pontianak City. The scoring algorithm successfully classified all six administrative sub-districts into three vulnerability categories based on four dynamically retrieved environmental parameters, the Choropleth Map rendered these classifications as a spatially intuitive graduated color visualization, the Point Mapping technique accurately geolocated 120 confirmed DHF cases from 2024 to May 2025, and the integrated system achieved a UAT satisfaction score of 88.23% within the "Strongly Agree" usability classification. Taken together, these outcomes provide empirical evidence that the system addresses a demonstrable operational gap at the Pontianak City Health Office, which had previously lacked any dedicated spatial decision-support instrument for DHF prevention and control.

The ecological validity of the scoring method developed in this study rests on the established relationship between specific environmental thresholds and *Aedes aegypti* vector activity. The designation of 25–30°C as the optimal temperature range for maximum risk scoring is consistent with decades of entomological literature confirming that within this thermal band, the extrinsic incubation period of dengue virus shortens significantly and larval development accelerates (Virdayanti et al., 2025; Delita & Nurhayati, 2022). Similarly, the optimal humidity range of 70–90% used in this study corresponds to the survival threshold of *Aedes aegypti*, whose respiratory spiracles are highly sensitive to desiccation below this level (Wijayanti et al., 2023). The inclusion of rainfall at 5–10 mm/hr as the highest-risk band captures the epidemiologically critical period of moderate precipitation that generates stagnant breeding pools without dispersing larvae, whereas extreme rainfall was correctly assigned a lower score because flood-level flows disrupt breeding sites (Nuhgroho et al., 2023). By integrating all four parameters into a weighted cumulative score, the algorithm mirrors the multi-factorial ecological dynamics governing dengue transmission rather than reducing risk to any single predictor, an approach validated by Istiqlala (2024), who demonstrated that single-parameter spatial analyses systematically underestimate hotspot clustering in dense urban settings.

The spatial output produced by the Choropleth Map component of this system is consistent with findings from comparable GIS-based DHF vulnerability studies across Indonesian cities. Nuhgroho et al. (2023) identified fifteen high-vulnerability sub-districts in Bandung using a similar multi-parameter environmental scoring framework, while Yuliana et al. (2022) classified eleven high-risk urban kelurahan in Padang from a pool of 104 units by combining demographic and environmental indicators. Both studies corroborate the present finding that sub-districts characterized by high population density, which in Pontianak City peaks at 152,880 persons in Pontianak Barat and 149,693 persons in Pontianak Utara (BPS Kota Pontianak, 2024), consistently register the highest cumulative risk scores. This demographic pattern is mechanistically coherent: dense residential areas accelerate human-to-vector contact rates, generate higher volumes of unmanaged water storage containers as potential breeding sites, and compress the spatial distance over which infected mosquitoes transmit the virus (Roziqin & Hasdiyanti, 2017). The choropleth visualization renders this demographic-environmental interaction immediately legible to non-specialist health officers, a communicative advantage that tabular or purely statistical reports cannot replicate (Leveraging GIS for Dengue Surveillance, 2025).

The Point Mapping layer introduces a patient-level spatial resolution absent from aggregate choropleth representations, and the resulting distribution pattern of 120 georeferenced cases across Pontianak City reveals micro-scale clustering that administrative-unit-level data necessarily obscures. This dual-layer architecture, where choropleth polygons communicate sub-district vulnerability and individual markers communicate actual case geography, operationalizes what Saputra et al. (2024) described as the critical distinction between potential transmission risk and observed transmission evidence in web-based GIS surveillance platforms. When both layers are rendered simultaneously, health officers can identify sub-districts where high vulnerability scores are accompanied by concentrated case clusters and direct fogging, larval surveillance, and community mobilization resources precisely to those convergence zones. This spatial targeting principle is further supported by the comparative meta-analysis of Wijayanti et al. (2023), which found that vector control interventions guided by georeferenced case data achieved significantly higher coverage efficiency than those based solely on administrative-unit reporting. Furthermore, the integration of an interactive popup system that surfaces patient-specific attributes upon marker selection extends the analytical utility of the Point Map beyond spatial distribution, enabling tracing of potential transmission linkages between proximate cases at the street-address level.

A distinctive contribution of this study relative to the existing Indonesian DHF-GIS literature lies in the real-time data integration architecture. Prior studies employing scoring or weighting methods, including the forest fire vulnerability mapping platform developed by Saputra et al. (2024) in West Kalimantan and the static DHF spatial analyses reviewed by Roziqin and Hasdiyanti (2017), relied exclusively on historical datasets that reflect past conditions rather than current environmental states. In contrast, the present system retrieves air temperature, humidity, and rainfall data for Pontianak City through the OpenWeatherMap API on each dashboard load, ensuring that the vulnerability scores displayed reflect the meteorological conditions prevailing at the time of consultation rather than conditions recorded weeks or months prior. This architectural choice addresses a fundamental limitation identified in the systematic review by Leveraging GIS for Dengue Surveillance (2025), which documented that passive, retrospective surveillance systems are structurally incapable of supporting anticipatory interventions because risk scores are always lagging indicators. By recalculating and storing risk scores daily in the `regiondailydata` database table, the system also generates a longitudinal time-series that enables the health office to correlate vulnerability level fluctuations with observed case incidence trends, a functionality absent from comparable single-time-point mapping platforms.

Regarding the research questions posed at the outset of this study, the results provide clear and data-supported answers. With respect to the first research question, concerning the computation of DHF vulnerability levels, the scoring method successfully quantified vulnerability across all six sub-districts by aggregating normalized scores from four parameter dimensions into a composite risk index classifiable as High ( $\geq 10$ ), Moderate (7–9), or Low ( $< 7$ ). With respect to the second research question, concerning the visualization of vulnerability and case distribution, the Choropleth Map and Point Mapping techniques jointly produced a dual-layer interactive spatial representation that is both cartographically accurate and operationally informative. With respect to the third research question, concerning the construction of a functional web-based GIS, all nine functional modules passed Black Box Testing without failure, and UAT validation by the DHF Program Officer at the Pontianak City Health Office confirmed system suitability with an 88.23% "Strongly Agree" rating across 14 usability dimensions. This score exceeds the 80% threshold defined in the Likert-based usability classification scale adopted in this study, consistent with findings by Wells et al. (2021), who reported that GIS prototypes tailored for public health decision-making

achieved higher stakeholder acceptance when visualizations were directly mapped to existing administrative responsibilities. From a theoretical standpoint, this study extends the application of spatial multi-criteria evaluation in vector-borne disease surveillance by demonstrating that a four-parameter scoring method can be operationalized as a real-time computational engine within a web-based GIS architecture rather than remaining a static analytical exercise.

This contributes to the growing body of evidence reviewed by the Leveraging GIS for Dengue Surveillance (2025) synthesis confirming that GIS-based DHF risk models are most epidemiologically useful when they incorporate dynamic environmental inputs rather than fixed historical baselines. Practically, the system provides the Pontianak City Health Office with a first-of-its-kind spatial decision-support tool tailored to the geographic, demographic, and climatic characteristics of the city, directly addressing the operational gap confirmed through interviews with the DHF Program Officer prior to system development. Several limitations of this study warrant acknowledgment. The dataset of 120 patient records, while representative of the available secondary data provided by the health office, constitutes a relatively small sample for detecting fine-grained spatial clustering patterns, and potential underreporting inherent in passive surveillance systems may mean that the Point Map underrepresents true case density in certain sub-districts (Leveraging GIS for Dengue Surveillance, 2025). Furthermore, UAT was conducted with a single institutional respondent, which, although appropriate given the specific target user, limits the generalizability of the acceptance findings beyond the Pontianak City Health Office context. Future iterations of the system would benefit from multi-respondent UAT sampling, integration of additional environmental parameters such as vegetation density and standing water index derived from remote sensing, and expansion of the georeferenced case database as longitudinal patient records accumulate.

#### IV. CONCLUSION

This study successfully developed a web-based Geographic Information System (GIS) for mapping the vulnerability levels and spatial distribution of Dengue Hemorrhagic Fever (DHF) cases in Pontianak City, addressing three research objectives through an integrated technical and evaluative approach. The scoring method, computed across four real-time environmental parameters, specifically air temperature, humidity, rainfall, and population density, accurately classified all six administrative sub-districts into High, Moderate, or Low vulnerability categories, thereby answering the first research question regarding quantitative vulnerability calculation. The Choropleth Map and Point Mapping techniques jointly answered the second research question by producing a dual-layer interactive spatial visualization that rendered both aggregate sub-district risk levels and the precise geographic distribution of 120 confirmed DHF cases in an operationally accessible format. The third research question was resolved through the successful construction and validation of a fully functional web-based GIS platform, confirmed by Black Box Testing results showing complete functional correctness across all nine feature modules and a User Acceptance Testing score of 88.23% in the "Strongly Agree" category from the Pontianak City Health Office, signifying that the system genuinely fulfills the spatial decision-support needs of its intended institutional users.

These findings collectively indicate that the integration of real-time API-sourced environmental data with geospatial visualization in a single web platform substantially enhances the epidemiological utility of DHF surveillance compared to conventional administrative reporting approaches. For future research, subsequent studies are encouraged to expand the parameter set by incorporating satellite-derived vegetation density and standing water indices, apply machine learning-based risk classification to capture non-linear interactions between parameters, and extend UAT to a multi-respondent sample across multiple health office branches to improve the generalizability of acceptance findings. From a practical standpoint, the Pontianak City Health Office is recommended to formally adopt and integrate this system into its routine DHF monitoring workflow, and to populate the database continuously as new case records are generated to maximize the longitudinal analytical capacity of the platform. A primary limitation of this study, namely the relatively modest patient dataset of 120 records sourced from passive secondary surveillance, may constrain the spatial granularity of the Point Mapping output, and future iterations should incorporate active case-finding mechanisms to reduce the risk of geographic underrepresentation in low-reporting sub-districts.

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