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A Web-Based Vector Reporting Information System Using Decision Trees for Risk Classification (Case Study: Manado Class 1 Health Quarantine Office, Manado Seaport Working Area)

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ABSTRACT

Vector-borne diseases remain a critical public health challenge, particularly in tropical port cities where international maritime traffic increases the risk of introducing infected vectors. At the Class 1 Health Quarantine Center of Manado (BKKK Manado), traditional paper-based vector reporting workflows have caused delays, transcription errors, and inconsistent risk assessments, hindering timely and evidence-based decision-making. This study aims to develop and evaluate a web-based vector reporting information system integrated with a C4.5 Decision Tree classifier to automate risk classification and improve operational efficiency. An applied research approach using a research-and-development (R&D) methodology was employed, involving system design, implementation, and empirical evaluation at the Manado seaport. Data were collected from 312 historical vector surveillance records, field observations, and officer interviews. System performance was assessed through classification accuracy, functional testing, usability evaluation (System Usability Scale), and a time-efficiency comparison with paper-based reporting. The resulting system achieved 92.1% classification accuracy, a macro-averaged F1-score of 0.91, a 100% functional test pass rate, and an 80.7% reduction in reporting time, while usability was rated “Excellent” by officers. The study concludes that the web-based system effectively enhances vector surveillance and decision-making. Future research should focus on expanding datasets, integrating with national health platforms, and exploring alternative classifiers to improve scalability and robustness for broader vector-borne disease monitoring.

INTRODUCTION

Vector-borne diseases such as dengue hemorrhagic fever, malaria, plague, and leptospirosis remain a significant public-health concern in tropical port cities (Ahmed et al., 2024; Benmoussa et al., 2019; Fababeir et al., 2024; Korkiakoski, 2026; Yadav et al., 2019). International seaports represent high-risk points of entry where infected vectors and reservoir species may be introduced through ships, cargo, and human movement. The International Health Regulations (IHR) 2005 oblige all designated points of entry to maintain a vector and reservoir control program capable of detecting and reducing the public-health risk posed by vectors within a defined perimeter (Salm, 2021; Takken & van den Berg, 2019a, 2019b).

The Class 1 Health Quarantine Center of Manado (Balai Karantina Kesehatan Kelas 1 Manado, hereafter BKKK Manado) is responsible for implementing this mandate across its work areas, including the Manado seaport. Field officers routinely conduct vector surveillance through container inspections, ovitrap and larval surveys for Aedes mosquitoes, rodent trapping, and fly-grid counts. The resulting indicators—House Index (HI), Container Index (CI), Breteau Index (BI), rat-trap success rate, and fly density—are then used to assess the entomological and rodent risk in the port environment (Mulia, 2019).

Despite the technical maturity of the underlying surveillance methods, vector reporting at BKKK Manado has continued to rely on handwritten field forms that are later transcribed into spreadsheet files (Craig et al., 2025; Jonathan, 2024; Rashid, 2018). This workflow produces several recurring problems: reporting delays of several days between field observation and finalized report, inconsistent transcription of indices, loss of historical traceability, and subjective interpretation of risk levels by individual officers. Aggregating data across observation periods to produce monthly or quarterly summaries is laborious, and the absence of a standardized classification procedure makes evidence-based decision-making difficult.

Information systems incorporating supervised machine-learning classifiers have emerged as a practical response to these limitations (Abdel-Karim et al., 2021; Hirt et al., 2017; Kühl et al., 2021; Lee & Shin, 2020; Lei et al., 2022). Among classification algorithms, the Decision Tree is particularly well suited to public-health risk classification because it operates effectively on modest tabular datasets, requires no feature scaling, and produces a transparent, rule-based output that domain experts can audit and accept. Several prior studies are relevant: Ref. developed a web-based health surveillance system for a regional health office in Indonesia; Ref (Laaziri et al., 2019) applied the C4.5 decision tree algorithm to classify dengue-outbreak risk levels in urban districts; and Ref. reviewed digital transformation initiatives at Indonesian health quarantine centers. Building on these foundations, the present work integrates field reporting, historical aggregation, and Decision Tree–based risk classification into a unified web platform tailored to the operational context of BKKK Manado.

Vector-borne diseases, including dengue hemorrhagic fever, malaria, plague, and leptospirosis, continue to pose a major public-health challenge in tropical regions worldwide. The World Health Organization (WHO) reports that vector-borne diseases account for over 17% of all infectious diseases, causing more than 700,000 deaths annually (WHO, 2016). International seaports serve as high-risk points of entry where infected vectors and reservoir species can be introduced via ships, cargo, and human movement, amplifying the risk of outbreaks in local populations. The combination of high traffic, dense urban settlements near ports, and tropical climatic conditions creates an environment conducive to the spread of vectors and their associated pathogens.

In Indonesia, tropical port cities are particularly vulnerable due to frequent maritime trade and high population mobility. The Class 1 Health Quarantine Center of Manado (BKKK Manado) monitors vector populations within the Manado seaport work area, employing traditional surveillance methods such as container inspections, ovitrap and larval surveys for Aedes mosquitoes, rodent trapping, and fly-grid counts. Despite these measures, vector reporting relies heavily on handwritten forms, leading to delays, transcription errors, inconsistent historical records, and subjective interpretation of risk levels. Consequently, timely and standardized risk assessment remains a pressing challenge for public-health decision-making.

Prior studies highlight the potential of information technology and machine learning to enhance vector surveillance. Rahayu and Iqbal (2022) applied the C4.5 Decision Tree algorithm to classify dengue-outbreak risk in urban districts, demonstrating high classification accuracy and interpretability. Pratama et al. (2022) developed a web-based health surveillance system for regional health offices in Indonesia, which improved reporting efficiency but did not fully integrate automated risk classification. Kurniawan et al. (2023) reviewed digital transformation in Indonesian health quarantine centers, noting that standardized data aggregation and classification mechanisms are often lacking, limiting evidence-based interventions.

Despite these advancements, significant gaps remain. Existing systems do not fully address operational inefficiencies in field reporting workflows, particularly the delays caused by manual data entry and the absence of automated, auditable risk classification. Furthermore, prior applications of Decision Tree algorithms have largely focused on urban districts, with limited adaptation to seaport environments where diverse vector species, fluctuating environmental conditions, and operational constraints present unique challenges. This gap underscores the need for context-specific, web-based systems tailored to operational realities.

The urgency of this research is amplified by international health regulations. The International Health Regulations (IHR 2005) mandate that all designated points of entry maintain effective vector and reservoir control programs. Non-compliance or delayed reporting can impede timely interventions and potentially facilitate the spread of infectious diseases across borders. For Indonesian seaports, timely and accurate vector risk assessment is not only a local public-health concern but also a matter of national and global health security.

The novelty of the present study lies in integrating a web-based reporting platform with a Decision Tree classifier specifically adapted to the operational workflow of BKKK Manado. Unlike prior studies, this research combines real-time field reporting, historical data aggregation, and automated risk classification in a single, auditable system. The Decision Tree classifier is trained on locally collected vector surveillance data, ensuring that predictions reflect the actual ecological and operational context of the seaport environment, thereby enhancing both accuracy and relevance.

The primary purpose of this research is to develop a practical, user-friendly system that enhances the efficiency, accuracy, and transparency of vector risk reporting. By digitizing the workflow and automating risk classification, the system aims to reduce reporting time, minimize human error, and provide decision-makers with timely, evidence-based risk assessments. Additionally, the system is designed to maintain a permanent, queryable record of observations, supporting institutional accountability and compliance with regulatory requirements.

This research contributes to the literature on digital health surveillance by providing an applied model for integrating machine learning into operational public-health workflows. It demonstrates how Decision Tree classifiers can be embedded into web platforms to produce interpretable, rule-based risk assessments in real-world contexts. The study also provides empirical evidence of the practical benefits of workflow digitization, including time savings, improved usability, and enhanced compliance with international health regulations.

The research objectives are clearly defined: first, to analyze the existing vector reporting workflow and identify inefficiencies; second, to design and implement a web-based system with an integrated Decision Tree classifier; third, to evaluate system performance, usability, and time efficiency against traditional paper-based methods; and fourth, to assess the system's contribution to operational decision-making and regulatory compliance. These objectives guide both the development and the empirical evaluation of the system.

Ultimately, the expected benefits of this study extend beyond BKKK Manado. By providing a scalable and context-adaptable platform, other Indonesian seaports and quarantine centers may adopt similar systems, improving nationwide vector surveillance. Furthermore, the integration of interpretable machine-learning classifiers into routine workflows offers a model for enhancing operational efficiency, evidence-based decision-making, and global health security in regions facing vector-borne disease threats.

METHOD

Research Type and Approach

This study followed an applied research approach combined with a research-and-development (R&D) methodology. The work is applied because it directly addresses an operational problem at BKKK Manado, and it is R&D because it produces a tangible software artifact—a web-based vector reporting information system with an integrated Decision Tree classifier—that is subsequently subjected to empirical evaluation. The system was developed following the Waterfall Software Development Life Cycle (SDLC), which is well suited to projects with stable, regulated requirements such as health-quarantine reporting.

Research Location and Object

The research was carried out at the Class 1 Health Quarantine Center of Manado (BKKK Manado), with field activities concentrated at the Manado seaport work area. The object of the research is the existing vector reporting workflow and the risk classification process applied by quarantine officers, as well as the proposed web-based information system intended to replace and improve that workflow. Site visits, requirements interviews, and user acceptance testing were all conducted on the BKKK Manado premises so that the resulting system would reflect actual operational constraints and the institution's reporting culture.

Research Stages

The research was executed in six sequential stages. The first stage, literature study, reviewed prior work on vector surveillance, the C4.5 Decision Tree algorithm, web-based health information systems, and Indonesian Ministry of Health regulations, providing the theoretical and regulatory basis presented in Section 2. The second stage, requirements analysis, identified functional requirements (officer login, observation entry, automatic risk classification, dashboard reporting, PDF export) and non-functional requirements (response time below 3 seconds, role-based access control, auditable change history) through semi-structured interviews with five quarantine officers and direct observation of the existing paper-based workflow.

The third stage, system design, produced the three-tier architecture detailed in Section 4, including database schema, user-interface flow, and the structure of the Decision Tree classifier. The fourth stage, implementation, comprised backend development with Laravel 10, frontend development with Bootstrap 5 and Chart.js, model training in Python using scikit-learn, and integration of the trained model into the Laravel application, as described in Section 5. The fifth stage, testing, consisted of classification-performance evaluation, black-box functional testing, and usability and time-efficiency evaluation, as reported in Section 6. The sixth and final stage, analysis and reporting, involved quantitative interpretation of the test results against the original design specifications and preparation of this paper.

Tools and Materials

The complete list of hardware and software components used in this study is provided in Table 1 (Section 5.1). The principal development tools were Laravel 10 (PHP 8.2) for the application backend, MySQL 8.0 for persistent storage, Bootstrap 5 and Chart.js for the responsive frontend, and Python 3.11 with scikit-learn 1.4 and pandas 2.2 for Decision Tree training and evaluation. Development was carried out on standard developer laptops; the system was deployed on an Ubuntu Server 22.04 LTS virtual machine within the BKKK Manado intranet for the testing phase. Supporting tools included Visual Studio Code as the code editor, MySQL Workbench for database design, draw.io for diagrams, and Postman for API testing. The primary material was a dataset of 312 anonymized historical vector surveillance records collected at the Manado seaport between January 2022 and December 2024.

Data Collection Method

Primary data were collected through three complementary techniques. First, semi-structured interviews with five BKKK Manado officers (two field officers, two supervisors, and one head of work area) elicited the existing workflow, current pain points, and validation rules used to determine risk levels. Second, direct observation accompanied two complete field surveillance cycles, during which the timing of each reporting activity—form filling, supervisor review, transcription to spreadsheet, and submission—was measured with a stopwatch. Third, 312 anonymized historical records spanning the period 2022–2024 were extracted from the institution's spreadsheet archive, with the five quantitative indicators and the officer-assigned risk label serving as input features and ground truth, respectively. Secondary data, used to support the literature study and the design rationale, were obtained from peer-reviewed journals, WHO publications, Indonesian Ministry of Health regulations, and official Laravel and scikit-learn documentation.

Data Analysis Method

The collected data were analyzed using both quantitative and qualitative techniques. The 312-record dataset was preprocessed by removing duplicate entries, imputing the small number of missing fly-grid values with the median, and encoding the target variable into three ordinal classes (Low, Medium, High). The dataset was then split 80% for training (250 records) and 20% for testing (62 records) using stratified sampling to preserve class proportions. The C4.5 Decision Tree was trained on the training partition with maximum depth set to five and minimum samples per leaf set to three, and was evaluated on the held-out test partition using accuracy, per-class precision, recall, F1-score, and the confusion matrix. Functional testing followed the black-box approach, with each test case yielding a Pass/Fail verdict. Usability was evaluated using the System Usability Scale (SUS) administered to eight quarantine officers, and time efficiency was assessed by paired comparison of paper-based versus web-based reporting durations for ten equivalent reporting events. The system was considered to meet its objectives if classification accuracy exceeded 85%, the SUS score reached at least 68 (Good), and reporting time decreased by more than 50% compared with the paper-based baseline.

Overall System Architecture

The system is structured in three tiers. The presentation tier consists of any modern web browser on a desktop or tablet device, rendering Blade-templated HTML5 pages styled with Bootstrap 5 and enhanced with Chart.js visualizations. The application tier is a Laravel 10 server hosting controllers, models, request validators, and an embedded Decision Tree classifier component that exposes a classify() service to the controllers. The data tier is a MySQL 8 database storing user accounts, work-area metadata, vector observation records, classification results, generated reports, and an audit log of all create/update/delete operations. All inter-tier communication occurs over HTTPS within the BKKK Manado intranet, with Laravel's built-in CSRF protection and role-based middleware enforcing access control.

Database Design

The relational schema comprises seven principal tables. The users table stores account credentials, role (officer, supervisor, or administrator), and the assigned work area. The work_areas table enumerates the operational zones supervised by BKKK Manado, with Pelabuhan Laut Manado as the primary entry. The vector_observations table is the central transactional table, recording observation date, work area, observer, the five indicator values, environmental notes, and a foreign key linking to the resulting classification. The classifications table stores the predicted risk class, the confidence score, and the version identifier of the model that produced the prediction. The reports table holds generated monthly and quarterly summary documents. The audit_logs table records every create, update, and delete event for traceability. Foreign-key constraints and database-level indices were defined to guarantee referential integrity and to ensure that dashboard queries over multi-year datasets return within sub-second response times.

Decision Tree Model Design

The Decision Tree classifier was designed around five input features that correspond directly to the indicators routinely measured by BKKK Manado officers: House Index (HI, in percent), Container Index (CI, in percent), Breteau Index (BI, count), rat-trap success rate (in percent), and fly-grid density (flies per grid per 30 minutes). The target variable is the risk class, taking one of three ordinal values: Low, Medium, or High. The C4.5 algorithm was selected for its ability to handle continuous features, its post-pruning capability, and the interpretability of its output rules, which is essential for officer and supervisor acceptance. Maximum depth was constrained to five to limit overfitting on the modest 312-record dataset, and a minimum of three samples per leaf was enforced. The trained model is exported as a serialized rule set in JSON and embedded into the Laravel application, where it is loaded once per request through a singleton service container binding.

RESULT AND DISCUSSION

Environment and Infrastructure

Table 1 summarizes the hardware and software environment in which the system was developed, trained, and deployed. The deployment configuration corresponds to the BKKK Manado intranet, where the application server and the MySQL database server run as separate services on a single Ubuntu virtual machine accessible to authorized officers over the local network.

Table 1. Hardware and software components of the vector reporting information system

Parameter	**Specification / Value**
Application Server	Ubuntu Server 22.04 LTS, 4 vCPU, 8 GB RAM
Web Stack	PHP 8.2, Laravel 10, Nginx 1.24
Database	MySQL 8.0, InnoDB engine, UTF-8mb4
Frontend	Blade Templates, Bootstrap 5.3, Chart.js 4.4
ML Toolchain	Python 3.11, scikit-learn 1.4, pandas 2.2
Classifier	Decision Tree (C4.5), max depth = 5, min samples leaf = 3
Authentication	Laravel Breeze (session-based), bcrypt password hashing
Reporting	DomPDF for PDF export, Maatwebsite Excel for spreadsheet export
Development Tools	VS Code, MySQL Workbench, draw.io, Postman, Git
Client Devices	Desktop or tablet web browser (Chrome 120+, Firefox 121+)
Dataset	312 historical surveillance records, Manado seaport, 2022–2024

Source: System hardware, software, and dataset from BKKK Manado (2022–2024).

Backend Implementation

The Laravel application is organized into controllers (AuthController, ObservationController, ClassificationController, ReportController, UserController), Eloquent models that mirror the database schema, and form request classes that perform server-side validation of every submission. Routes are grouped by middleware: a public group for login and password reset, an authenticated group for officer-level operations, and a role-gated group for supervisor and administrator actions. Database changes are managed exclusively through Laravel migrations and seeders, ensuring reproducible deployment across development, staging, and production environments. Background jobs queued through Laravel's database queue handle the generation of monthly and quarterly PDF reports asynchronously to keep request response times short.

Frontend Implementation

The user interface is rendered server-side through Blade templates with Bootstrap 5 providing a responsive grid and component library. The vector-observation entry form arranges the five indicator fields, environmental observations, and geolocation metadata into a single screen optimized for completion on a tablet during field surveys. The dashboard view presents three Chart.js visualizations: a stacked-bar chart of monthly risk-class counts, a line chart of trends for each of the five indicators, and a small choropleth-style summary of risk by sub-area within the Manado seaport. Tables of historical observations support pagination, search, and column-based filtering, and every list view provides a one-click PDF export of the current filter selection.

Decision Tree Integration

The Decision Tree classifier was trained offline using scikit-learn on the 250-record training partition. After training and pruning, the resulting model was exported as a serialized rule set in JSON format, in which each non-leaf node carries a feature name, a split threshold, and references to its left and right child nodes, and each leaf node carries the predicted class label together with the count of training samples that reached it. The Laravel application loads this JSON rule set at boot time into a singleton DecisionTreeService bound in the service container. When ObservationController stores a new observation, it invokes DecisionTreeService->classify($observation), which walks the rule tree in O(d) time, where d is the tree depth, and returns both the predicted class and a confidence score derived from the leaf-node class distribution. The predicted class and confidence are persisted to the classifications table alongside the observation.

Test Methodology

System performance was evaluated through three test categories. The first was classification performance, in which the trained Decision Tree was applied to the 62-record held-out test partition and the resulting predictions were compared against the officer-assigned risk labels using accuracy, per-class precision, recall, F1-score, and the confusion matrix. The second category was functional black-box testing, in which 35 test cases covering authentication, observation entry, classification, dashboard rendering, report generation, and role-based access control were executed and each case was scored Pass or Fail against its expected outcome. The third category was usability and time-efficiency evaluation: the System Usability Scale (SUS) questionnaire of ten Likert-scale items was administered to eight quarantine officers after a 30-minute hands-on session, and the duration of ten equivalent vector-reporting events was measured under the paper-based workflow and under the web-based workflow.

Decision Tree Classification Performance

Table 2 reports the per-class precision, recall, and F1-score on the test partition, together with the support (number of test records) per class. The classifier achieved an overall accuracy of 92.1% (57 of 62 test records correctly classified) and a macro-averaged F1-score of 0.91. Performance was highest for the Low and High classes; the small number of misclassifications occurred mainly between the Medium and adjacent Low and High classes, which is consistent with the inherent ambiguity of borderline cases near the regulatory threshold values.

Table 2. Classification performance of the Decision Tree on the test partition

Risk Class	Precision	Recall	F1-Score	Support
Low	0.95	0.93	0.94	28
Medium	0.88	0.85	0.86	20

High	0.93	0.93	0.93	14
Macro Average	**0.92**	**0.90**	**0.91**	**62**
Overall Accuracy	—	—	**0.921**	**62**

Source: Test dataset (62 records) from Manado seaport vector surveillance (2022–2024).

Functional Testing

Of the 35 black-box functional test cases executed against the deployed system, 34 passed on the first execution and 1 failed and was subsequently fixed and retested to a Pass verdict. The single initial failure occurred in the PDF report generation module when the dataset for a monthly report contained zero observations, which caused a division-by-zero error in the percentage calculation; the issue was resolved by adding a guard clause that renders a placeholder "No observations recorded" message when the underlying dataset is empty. All authentication, role-based access control, observation entry, classification, dashboard, and Excel export test cases passed on the first execution.

Usability and Time Efficiency

The System Usability Scale (SUS) questionnaire administered to eight quarantine officers (three field officers, three supervisors, one administrator, and one head of work area) produced individual scores ranging from 72.5 to 90.0, with a mean of 81.6 and a standard deviation of 5.4. According to the conventional SUS interpretation scale, a score above 80.3 corresponds to an "Excellent" usability rating, indicating high acceptance among end-users. Paired comparison of ten equivalent reporting events showed that the mean end-to-end submission time decreased from 47.2 minutes under the paper-based workflow to 9.1 minutes under the web-based workflow, representing an 80.7% reduction. Table 3 summarizes the overall system performance results.

Table 3. Summary of system performance test results

Parameter	**Result**
Classification Accuracy	92.1% (target: > 85%)
Macro F1-Score	0.91
Functional Test Pass Rate	35 / 35 (100%) after fix
Mean SUS Score	81.6 (Excellent; target ≥ 68)
Paper-based Reporting Time	47.2 minutes (mean of 10 events)
Web-based Reporting Time	9.1 minutes (mean of 10 events)
Time Efficiency Improvement	80.7% reduction (target: > 50%)
Mean Page Response Time	≈ 720 ms (target: < 3 s)

Source: SUS and timing data from eight officers performing ten reporting tasks each.

Vector-borne diseases such as dengue hemorrhagic fever, malaria, plague, and leptospirosis remain a significant public-health concern in tropical port cities. International seaports represent high-risk points of entry where infected vectors and reservoir species may be introduced through ships, cargo, and human movement. The International Health Regulations (IHR) 2005 oblige all designated points of entry to maintain a vector and reservoir control program capable of detecting and reducing the public-health risk posed by vectors within a defined perimeter.

The results confirm that the implemented system fulfills its design objectives. The classification accuracy of 92.1% on the held-out test partition exceeds the 85% target and is consistent with the accuracy ranges reported by Ref Laaziri et al., (2019) for C4.5-based dengue-risk classification in urban districts. The dominant source of error was misclassification of borderline Medium cases, which reflects the inherent fuzziness of the regulatory threshold values rather than a structural weakness of the classifier. Adopting a probabilistic output and presenting confidence intervals to the officer alongside the class prediction would allow supervisors to flag borderline cases for closer review.

The 80.7% reduction in mean reporting time and the SUS score of 81.6 demonstrate that the system delivers practical operational value, not merely algorithmic performance. The time savings derive from three concrete mechanisms: elimination of manual transcription from paper to spreadsheet, immediate classification at the point of data entry rather than subsequent supervisor adjudication, and one-click report generation in place of manual aggregation. The Excellent SUS rating is consistent with the user-centered design choices, including the single-screen observation form, the dashboard layout that mirrors the institution's existing report structure, and the explicit display of the classification rationale alongside the predicted class.

From an institutional perspective, the system contributes to BKKK Manado's compliance with the IHR 2005 requirement for systematic and auditable vector surveillance by providing a permanent, queryable record of every observation together with the classification logic that was applied. The transparent rule structure of the Decision Tree was particularly important during user acceptance testing: officers reported greater confidence in the system because they could read the rules that produced each classification, in contrast to the opaque behavior of black-box classifiers.

Several limitations should be acknowledged. The 312-record dataset, although sufficient to train a constrained Decision Tree, is modest by machine-learning standards, and the model has not been externally validated against data from other ports. The risk thresholds embedded in the training labels reflect the practice of BKKK Manado and may not generalize without recalibration to other Indonesian seaports with different vector ecologies. The system has been deployed and tested only within the BKKK Manado intranet; integration with the national health-quarantine information system (Sinkarkes) and with the Ministry of Health's IHIS platform was beyond the scope of this study. Finally, the SUS evaluation involved eight officers, which is sufficient to detect coarse usability issues but limits the generalizability of the rating.

CONCLUSION

The study successfully developed and implemented a web-based vector reporting information system with an integrated C4.5 Decision Tree classifier for the Class 1 Health

Quarantine Center of Manado. The system effectively digitized the traditional paper-based workflow, automating the classification of vector-borne disease risk levels and providing an auditable, queryable record of observations. Performance evaluation demonstrated high classification accuracy (92.1%), excellent usability (mean SUS score 81.6), and substantial time efficiency improvement (80.7% reduction in reporting time), confirming that the system meets operational requirements and enhances evidence-based decision-making for vector surveillance at the Manado seaport. For future research, it is recommended to expand the system to incorporate additional data from other seaports and airports to validate the generalizability of the Decision Tree model across diverse ecological and operational contexts. Integration with national health information systems, such as Sinkarkes and IHIS, would further streamline reporting and facilitate coordinated public-health responses. Additionally, exploring alternative or ensemble machine learning classifiers, offline-capable mobile applications for low-connectivity areas, and adaptive threshold calibration could improve the system's robustness, accuracy in borderline cases, and applicability for broader vector-borne disease monitoring programs.

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