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DEVELOPMENT OF A WEB-BASED GIS SIMULATOR FOR REAL-TIME MODELING OF AFRICAN SWINE FEVER SPREAD

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Abstract – *African swine fever poses a tough challenge to the swine industry, particularly in regions such as the Philippines, where its impact has been devastating. This paper introduces the development of a web-based GIS simulator tailored to model real-time African swine fever spread dynamics. Through iterative processes within the system development life cycle, the system was meticulously designed to address the specific needs of small-scale backyard farmers and government agencies. A thorough requirement analysis and stakeholder engagement defined the system's core functionalities, including real-time disease monitoring, interactive mapping, and customized best practices dissemination. Implementation involved integrating these features into a user-friendly platform, ensuring usability and effectiveness. Rigorous testing confirmed the reliability and functionality of the system, with high system usability scale scores reflecting positive user perception. Deployment in a pilot municipality showcased the system's potential to empower stakeholders with timely information and proactive measures against African swine fever outbreaks. The newly developed system for simulating African swine fever spread dynamics and mapping confirmed cases has received positive feedback and a high system usability scale score. It is recommended to further explore and integrate the newly developed system for simulating African swine fever spread dynamics and mapping confirmed cases. To build on this success, stakeholders are encouraged to consider gradually expanding the use of the system, gathering ongoing feedback for improvement, offering user support and training, nurturing partnerships with research institutions and system usability scale control agencies, and raising awareness of the system's benefits.*

Keywords: African swine fever, disease spread dynamics, stakeholder engagement, swine industry management, web-based GIS simulator.

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I. INTRODUCTION

African swine fever (ASF) is a highly contagious and deadly disease affecting pigs, with no cure or limited vaccine available, posing a significant global challenge [1]. Since its arrival in the Philippines in 2019, ASF has devastated small-scale farms across 12 regions, leading to financial ruin for farmers due to pig culling and lost income [2]. This economic hardship threatens the broader agricultural industry and food security in the Philippines, prompting the government to declare a state of calamity and implement temporary pork importation measures [3].

Research by Hsu et al. [4] reveals spatial and temporal clustering of ASF outbreaks in the Philippines, influenced by environmental and human factors. Swill feeding, inadequate biosecurity protocols, and personnel movement between farms are key contributors to the disease's spread, highlighting the need for timely reporting, improved biosecurity measures, and targeted interventions for effective outbreak management. Additionally, Hsu et al. [5] emphasize the necessity of a coordinated international approach for managing transboundary swine diseases like ASF in Asian islands. Collaborative efforts are vital to protect the regional swine industry and ensure food security. Luskin et al. [6] underscore the urgent need for research, surveillance, stricter biosecurity measures, and international collaboration to mitigate the impacts of ASF on Southeast Asia's endemic wild pig species.

Movement restrictions on pigs and pork products are a common thread, particularly in outbreak zones [7]. Biosecurity measures, from farm-level practices to public awareness campaigns, are crucial for preventing further transmission [8]. Surveillance programs and designated control zones aim to monitor outbreaks and limit their spread [9]. Notably, Vietnam stands out as the only country deploying ASF vaccines nationwide. Financial assistance also provides a lifeline to affected farmers in some areas [7].

China, with its centralized government, offers a unique case study. They've adopted a 'big government' approach, coordinating efforts across ministries to implement systematic prevention measures and recovery policies. This top-down approach has shown effectiveness despite challenges like delayed responses and differing priorities between central and local authorities [10]. The Philippines, however, faces a critical challenge: a gap in effective surveillance and mapping systems specifically designed for backyard farms. While the Department of Agriculture (DA) has implemented monitoring processes, these systems often lack the granularity and real-time data needed for early detection and rapid response in these smaller-scale operations. This gap hinders the success of national control efforts, jeopardizes farmers' livelihoods, and limits the DA's ability to manage the disease effectively.

To bridge this gap, a web-based GIS simulator for modeling ASF transmission is proposed. This system aims to empower backyard farmers and government agencies, particularly the DA and local government units (LGUs), by providing real-time disease information and best practices tailored to their needs. The simulator offers a visual representation of potential ASF spread, pinpointing areas at risk and enabling proactive prevention and targeted interventions.

The user-friendly platform facilitates real-time disease monitoring and mapping, allowing rapid response by farmers and government agencies. Automated data collection and analysis improve reporting accuracy, providing crucial insights for developing and refining national control strategies. By fostering collaboration between farmers and government agencies, the system enhances information sharing and collaborative decision-making, significantly mitigating the impact of ASF outbreaks.

This integrated surveillance and mapping system addresses the knowledge gap in backyard farm management. By empowering both farmers and government agencies, it aims to minimize economic losses, promote sustainable practices, and significantly contribute to mitigating the impact of ASF outbreaks in the Philippines.

II. METHODS

The development of a web-based GIS simulator for modeling ASF transmission follows the iterative waterfall model within the system development life cycle (SDLC). This model's systematic, well-defined phases were chosen for their accuracy in requirements gathering, clarity in documentation, and focused exploration of each aspect. The structured progression of the iterative waterfall model aligns well with the predictable characteristics of this project, making it an ideal framework for GIS simulator development. Its iterative nature allows for continuous refinement, promoting adaptability and responsiveness throughout the development process [11]. As illustrated in Figure 1, this approach ensures that stages can be revisited and revised as necessary, enhancing the reliability and effectiveness of the final product.

A. Requirement analysis

In an iterative preliminary phase, the ASF surveillance and mapping system meticulously acquired and documented precise requirements through active participation from LGU personnel, backyard farm owners, and municipal DA personnel. On-site interviews and consultations focused on understanding their specific needs and challenges during ASF outbreaks. For instance, LGU personnel discussed data sharing protocols and resource allocation workflows, while farmers

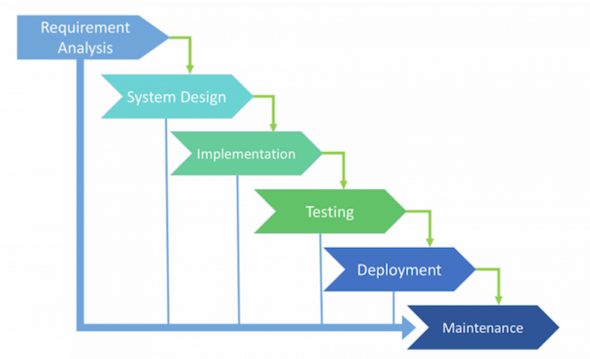

Fig. 1: Iterative waterfall model

emphasized the need for clear, localized information on biosecurity measures. This understanding informed the development of foundational elements, such as real-time disease information displayed through interactive maps, alongside customized best practices tailored to local farming practices. This iterative process ensured the system effectively addressed core challenges by prioritizing the needs of those most impacted by ASF outbreaks.

B. System design

The ASF surveillance and mapping system is a web-based platform designed with user needs at its core. Through an iterative design process that incorporates feedback from local stakeholders, the system addresses specific challenges faced during ASF outbreaks. LGU personnel will benefit from streamlined data-sharing protocols and efficient resource allocation workflows. Backyard farm owners will gain access to real-time information on ASF cases and interactive maps depicting spread patterns. Additionally, the system will provide customized best practices for biosecurity measures and farm management tailored to local contexts. Municipal DA personnel will experience enhanced communication and collaboration with both LGUs and farmers. Data visualization tools will further support informed decision-making.

The system design aligns closely with the goals outlined in the statement, both emphasizing a user-centered approach to address the needs of LGU personnel, backyard farmers, and agricultural department staff during ASF outbreaks. The design details specific benefits for each group: streamlined data sharing and resource allocation for LGU personnel, real-time data and localized best practices for farmers, and improved communication and data visualization for agricultural staff. Figure 2 illustrates the system architecture, showing user groups, an interactive interface, and a server-database component for managing data. These functionalities directly support the user-centered design and goals mentioned in the statement.

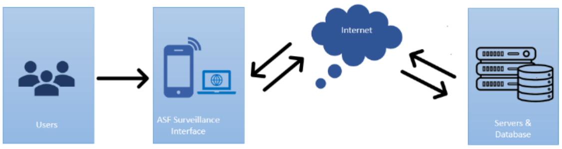

Fig. 2: Architectural layout of the system

In this phase, a context diagram for the system was introduced and crafted to delineate the system's scope, as depicted in Figure 3. The diagram illustrates that the web-based GIS simulator serves as the central hub in the collaborative effort against ASF. This online platform functions as the core of the operation, simulating and modeling ASF spread in real-time.

Farmers play a crucial role by providing valuable data on animal movement, suspected cases, and feedback on the system's effectiveness. In return, they receive visualizations of ASF spread and timely alerts about potential outbreaks.

Government agencies collaborate with farmers through the simulator, sharing animal disease data and details of their interventions while receiving reports on ASF spread, suggested intervention strategies, and visualizations of potential impact. This collaborative approach fosters knowledge sharing and informed decision-making, enhancing the overall response to ASF threats.

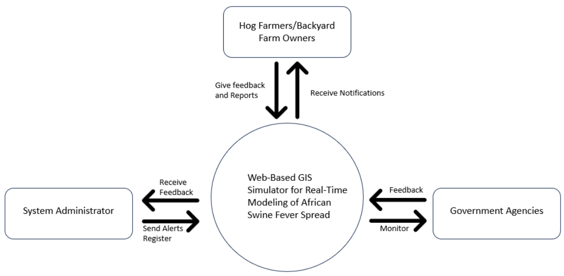

Fig. 3: Context diagram of the system

C. Implementation

During the implementation stage, the web-based GIS simulator for ASF was developed and fine-tuned according to the context diagram outlined in Figure 3. The system's core functionalities, including real-time data processing, ASF spread simulation, and interactive mapping, were meticulously integrated. A secure server-database component was established to manage large data volumes from various sources, ensuring data integrity. An intuitive user interface was designed for farmers, LGU personnel, and agricultural department staff, featuring visualization tools for ASF spread patterns and intervention impact assessments. Consultation and feedback sessions were conducted with target respondents to ensure the system's full functionality, with users given options regarding the process flow of the entire system.

This implementation process prioritized user engagement and satisfaction, ensuring that the system's features and interface met the diverse needs of stakeholders involved in ASF management. Through iterative refinement and close collaboration with end-users, the web-based GIS simulator was successfully developed to empower stakeholders with effective tools for ASF surveillance, decision-making, and collaboration.

D. Testing

During the testing phase of the web-based GIS simulator for ASF transmission, a series of tests were conducted to ensure the system's reliability, functionality, and usability. In unit testing, each component of the ASF case reporting module was validated to ensure proper functionality. Data input forms were tested to accept valid input and reject invalid data, mandatory fields were checked for correct validation and data formats, and the submission process was verified to ensure data was correctly stored in the database with appropriate success messages. Error handling mechanisms were also tested by introducing intentional errors to confirm appropriate error message display and logging.

Integration testing focused on verifying the seamless interaction between the ASF case reporting module and other system components, such as the mapping and notification systems. Data flow from the case reporting module to the GIS map was tested to ensure accurate plotting of reported cases and accessibility of case details through map markers. It was also confirmed that reporting an ASF case triggered the notification system to send timely alerts to relevant stakeholders via email or SMS. The system was evaluated using the system usability scale (SUS), a 10-item questionnaire developed by John Brooke in 1986 to quantitatively measure user perception of system usability. Participants rated responses on a five-point Likert scale (1 to 5). Odd-numbered questions were positive, while even-numbered ones were negative. SUS score calculation involves summing responses for odd (X) and even (Y) questions, then computing X0 (X - 5) and Y0 (25 - Y). The SUS score, reflecting system usability in effectiveness, efficiency, and overall ease of use, is obtained by adding X0 and Y0, multiplied by 2.5 (SUS Score = (X0 + Y0) * 2.5). SUS insights help identify areas for improvement in the backyard management system's user experience (see Table 1 for SUS interpretation).

The system's initial implementation took place in the DA office in the Municipality of Sogod, Southern Leyte. All DA personnel participated in usability testing, where the team provided training and orientation on system usage and functionality. After two weeks of testing, all personnel evaluated the system using the SUS standard questionnaire. Beyond the DA personnel, the system was introduced to backyard farmers in one pilot barangay that had previously experienced ASF outbreaks. In collaboration with barangay officials, a training session was conducted for all backyard farm owners. Following two weeks of pilot testing, farmers assessed the system using the SUS standard questionnaire (see Table 2 for interpretation).

Table 1: SUS standard questionnaire

Particular
1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need assistance to be able to use this system.
5. I found the various functions in the system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that user would learn to use this system very quickly.
8. I found the system very awkward to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Table 2: SUS standard rating

SUS Average Score	Grade Adjectival	Rating
> 80.3	A	Excellent
68-80.3	B	Good
68	C	Okay
51-68	D	Awful
< 51	F	Poor

E. *Deployment*

The system was deployed online using dedicated web servers and an online database. Initially, the web-based GIS simulator was uploaded and tested at the DA office in the Municipality of Sogod, Southern Leyte, Philippines. The testing and implementation phase lasted for two weeks through dedicated online web portals, with DA personnel and backyard farm owners from the pilot barangay actively testing the system. The system was fully accessible online for testing and deployment purposes only.

During the deployment phase, the DA office took on the role of system administrator, responsible for monitoring and registering interested backyard farm owners in the pilot barangay. Ensuring internet connectivity was a priority to enable target users to access the system. The team conducted user assessments and organized a committee, comprising the research team, to facilitate the smooth implementation and deployment of the system. Valuable feedback from users was gathered and meticulously analyzed to enhance the performance and functionality of the system.

F. *Maintenance*

The system maintenance plan is strategically designed to address future updates, improvements, and emerging needs in the surveillance and mapping system. A continuous feedback loop will be established with users to refine the system's capabilities and tackle evolving challenges in swine fever management. Priority will be given to ongoing collaboration with stakeholders to foster improvements and adapt the system to changing circumstances. A memorandum of agreement will be utilized to help the partner municipality address the technicality of the system. Interested municipalities and provinces will be accommodated through partnerships with government agencies and local government units. Possible funding is required to help optimize the system and sustain its functionality in online platforms. Security remains one of the most important aspects of the system.

III. RESULTS AND DISCUSSIONS

A. *System implementation and design*

The swine fever surveillance and mapping system, tailored for small-scale farmers in Sogod Southern Leyte, Philippines, is a web application seamlessly integrating real-time surveillance, geospatial mapping, and centralized data management. Its core objective is to empower local farmers and local government agencies with accessible tools for increased productivity, proactive swine fever prevention, and sustainable backyard farming. The system features an intuitive web interface for easy reporting and monitoring of potential outbreaks, utilizing open-source mapping technology (e.g., OpenStreetMap and Leaflet), Bootstrap, JavaScript Frameworks, and MySQL for front-end and back-end functionalities. A centralized database efficiently collects and stores surveillance data from various sources, fostering robust data analysis. While initially focused on swine fever in Sogod, its web-based nature allows for scalability, serving as a model for similar initiatives in agriculture and contributing to disease monitoring advancements across the broader agricultural landscape.

The system encompasses key features including real-time monitoring for potential ASF outbreaks among backyard farmers in municipalities, report generation, message notifications, and backyard farmer registration. Sample functionalities of the system are outlined below. Figure 4 displays the realtime ASF outbreak monitoring interface, utilizing a map for visualizing backyard farmers potentially affected by an outbreak. The system incorporates a specialized algorithm supporting the ASF 1-7-10 protocol, a crucial measure implemented by the DA for ASF management in the Philippines. The protocol involves culling all pigs within a 1-kilometer radius, imposing restrictions on pork-related activities within a 7-kilometer radius, and continuous monitoring of hogs within a 10-kilometer radius [4]. If a backyard farm is confirmed positive, the system automatically triggers three radii groups (red for 1 km, green for 7 km, and blue for 10 km) and sends notifications to registered owners with precautionary measures and immediate actions advised by DA personnel.

Figure 4 illustrates a sample of the ASF spread pattern, showcasing the emergence of three distinct radii groups triggered by a confirmed positive ASF case in a specific location. The outcome of this study demonstrates the capability of the developed system to effectively simulate the spread dynamics of ASF by accurately mapping the origin of confirmed cases, as referenced in the study of Hsu et al. [12]. This study emphasizes that outbreaks tend to manifest in particular locations and times, often following a seasonal pattern. Furthermore, it aligns with the findings of Ghorayeb et al. [13], which advocate for the utilization of mobile applications to map the geographical distribution of ASF, enabling early outbreak detection and guiding targeted biosecurity efforts. Through continuous simulation, the developed application can generate useful patterns that aid authorities in minimizing the impact of ASF, offering valuable insights for proactive management and containment strategies.

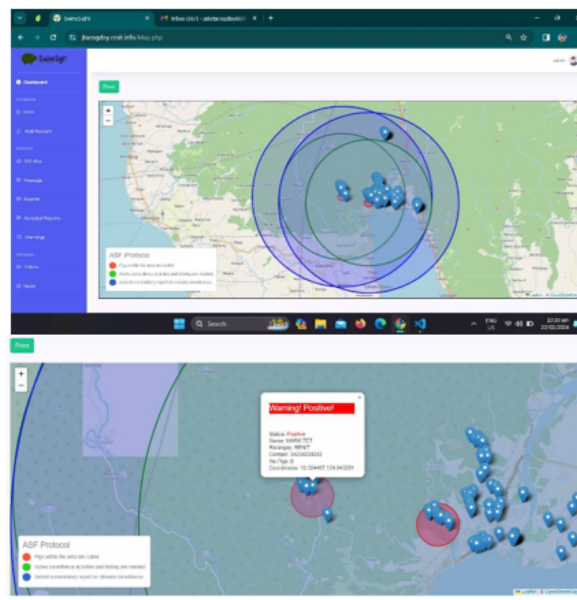

Fig. 4: Realtime ASF monitoring

B. System evaluation result

After the implementation for two weeks, the system was evaluated by all personnel of DA personnel of the pilot municipality and 20 backyard farmers from the pilot barangay. The system was evaluated using SUS. System evaluation was conducted to ensure the usability of the system as shown in Table 3 and Table 4.

Table 3 provides a breakdown of individual responses to SUS questionnaire items. The user feedback indicates strong acceptance and ease of use for the developed system, aligning with its capability to accurately simulate ASF spread dynamics and map confirmed cases. Positive ratings for usability and integration of functions suggest widespread adoption potential among stakeholders. The system's intuitive design reduces complexity, fostering confidence and rapid learning. Overall, user satisfaction implies a valuable tool for proactive ASF management, enhancing response strategies and minimizing outbreaks' impact.

Table 3: SUS average score result

Particular	Average Score
1. I think that I would like to use this system frequently.	4.00
2. I found the system unnecessarily complex.	3.56
3. I thought the system was easy to use.	4.00
4. I think that I would need assistance to be able to use this system.	1.88
5. I found the various functions in the system were well integrated.	4.00
6. I thought there was too much inconsistency in this system.	1.32
7. I would imagine that user would learn to use this system very quickly.	4.00
8. I found the system very awkward to use.	1.00
9. I felt very confident using the system.	4.00

Note: 1.0–1.8 (Strongly disagree), 1.9–2.6 (Disagree), 2.7–3.4 (Neutral), 3.5–4.2 (Agree), 4.3–5.0 (Strongly agree)

The positive SUS score of 62.5 (Grade A, 'Good') as shown in Table 4, reflects a favorable user perception of the developed system, indicating effectiveness and alignment with expectations. This bodes well for successful implementation and impact on addressing ASF. The high SUS score underscores the well-designed nature of the system, enhancing user experience and engagement. It also highlights opportunities for targeted improvements to further enhance usability. This outcome aligns with previous research [1, 14, 15], emphasizing the importance of high SUS scores in fostering user satisfaction, adoption, efficiency, and positive brand perception. Overall, the elevated SUS score signifies the system's effectiveness in ASF management and its broader implications for user engagement and digital presence.

These findings significantly strengthen the goal of controlling the spread of ASF by enhancing the effectiveness and efficiency of management efforts. The positive SUS score, indicating a high level of user satisfaction and confidence in the system, plays a pivotal role in achieving this goal. With users perceiving the system as effective and aligned with their expectations, there is increased motivation among stakeholders involved in ASF management to actively engage with the platform. This heightened engagement, facilitated by the user-friendly design of the system, enables more efficient decision-making processes, leading to better-informed responses to ASF outbreaks.

Moreover, the positive perception of the system encourages higher adoption rates, fostering more widespread use among relevant stakeholders. This increased adoption, in turn, promotes more complete and coordinated efforts to control the spread of ASF. Additionally, the intuitive design of the system reduces the likelihood of errors in data input and analysis, further improving the efficiency of ASF control measures.

Furthermore, the feedback received provides valuable insights into targeted improvements aimed at enhancing usability and addressing user needs more effectively. By continuously refining the system based on user input, it can evolve to better support ASF control strategies over time. Overall, these findings underscore the importance of user satisfaction and usability in strengthening ASF control efforts, ultimately contributing to the successful containment of the disease and safeguarding swine populations.

Table 4: SUS result

X (sum of odd numbers)	Y (sum of even numbers)	X0	X (sum of odd numbers)	Y (sum of even numbers)	X0	X (sum of odd numbers)
20.00	9.48	15.00	10.00	62.5	A	GOOD

IV. CONCLUSION

The successful implementation of a new system for simulating ASF spread dynamics and mapping confirmed cases has received commendation from personnel and farmers, reflected in the system's high SUS core. This collective endorsement serves as a testament to the system's intuitive design, ease of use, and effectiveness in meeting user expectations. Such positive user perception not only underscores the system's potential to enhance ASF management by refining response strategies and curbing outbreak impacts but also signifies its ability to foster active user engagement in control efforts. Moreover, these findings accentuate the pivotal role of user satisfaction in achieving effective ASF control, as corroborated by studies such as Ayihou et al. [16] and Barongo et al. [17]. They stress the imperative of comprehending ASF dynamics and advocate for timely interventions, stringent biosecurity measures, and early reporting as indispensable components of ASF management strategies.

V. RECOMMENDATION

Based on the positive feedback and high SUS score, it is recommended to further explore and integrate the newly implemented system for simulating ASF spread dynamics and mapping confirmed cases. The system has shown effectiveness in meeting user needs and fostering engagement among personnel and farmers involved in ASF management. To build on this success, stakeholders are encouraged to consider gradually expanding the use of the system, gathering ongoing feedback for improvement, offering user support and training, nurturing partnerships with research institutions and ASF control agencies, and raising awareness of the system's benefits.

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