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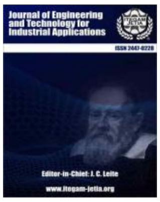

RESEARCH ARTICLE OPEN ACCESS

# A GIS-BASED SITE SUITABILITY ASSESSMENT SYSTEM FOR SUSTAINABLE AND PRODUCTIVE FISH REARING

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## ABSTRACT

The study focused on the development of a web-based fishpond planner and recommender for Ilocos Norte that fills the gap in sustainable aquaculture site selection. Adopting a descriptive-development approach, the system combined the Analytic Hierarchy Process with Geographic Information System (GIS) for evaluating major environmental factors; water availability, soil type, flood susceptibility and water quality in terms of their weighted contributions to site suitability for fishpond. The system provided user- friendly visualization and decision supporting the built-in capabilities of Geographic Information System (GIS), remote sensing, and interactive web mapping. Major findings indicate that the tool ranks fish species well for appropriate locations and generates trust-worthy, simple, implementable recommendations. Acceptance testing responses were overall positive in usability and reliability, with recommendations on slight improvement regarding interface responsiveness/guidance amenities. The study concludes that the GIS-based, AHP-driven platform created is potentially useful as a decision-support tool for sustainable fish farming in Ilocos Norte. The study provides a step toward promoting efficient, environmentally friendly and technology-based planning in the aquaculture sector.

## I. INTRODUCTION

Many fishpond projects fail not because of poor management but due to selecting unsuitable sites [1-,3]. Fish farmers risk high losses if ponds are in areas prone to environmental stress, flooding, water shortage, or poor soil quality [4-9]. Optimal conditions include reliable water flow, good water quality, abundant natural food, and minimal threats from predators or competitors [10-14]. Natural disasters such as typhoons and droughts further threaten these fragile systems [15], [16]. Effective site planning and mapping are thus essential for modern fish farmers [17-22]. Aquaculture remains vital for the Ilocos Region's fisheries, with production rising 12.7% in early 2025 [23]. However, growth is uneven: Pangasinan dominates, while Ilocos Norte and Ilocos Sur show production declines due to environmental and economic challenges.

Ilocos Norte's total output dropped 15.35%, despite localized gains in specific pond types. The region faces risks from environmental variability and resource scarcity, impacting fishpond resilience. To address these challenges, initiatives like the FishCoRe Project promote resilience through resource management, infrastructure improvements, and livelihood diversification [24]. Future efforts must focus on site-specific planning, data-driven management, and climate adaptation to sustain and rebuild the aquaculture sector [25] in Ilocos Norte and the surrounding region. This study aims to develop site-specific fishpond mapping and planning for Ilocos Norte by assessing sites, best practices, and relevant data from local fishpond owners.

## II. THEORETICAL REFERENCE

### II.1 GIS AND AHP PROVIDE A ROBUST, SYSTEMATIC METHODOLOGY FOR RECOMMENDING OPTIMAL FISHPOND LOCATIONS BY INTEGRATING MULTIPLE ENVIRONMENT AND SOCIOECONOMIC CRITERIA.

Studies across different regions demonstrate the method's effectiveness. It was found that 18.71% of analyzed land was highly suitable for fish farming, while identified that 27.29% of territory was very moderately suitable for aquaculture. The approach involves: collecting spatial data using GIS, applying Analytical Hierarchy Process to weigh selection criteria, creating suitability maps with graduated classifications specially highlighted that this combined method provides a better database for planners, enabling more informed decision-making in aquaculture site selection [26-30].

## III. MATERIALS AND METHODS

This study used a descriptive-developmental design to create and validate a web application integrating the Analytic Hierarchy Process (AHP) [26], [27] with geospatial data visualization for recommending suitable domesticated fish species for cultivation. The methodology encompassed phases from data collection to application deployment. Phase 1 involved gathering primary field data and secondary environmental datasets from official agencies. In Phase 2, key site suitability parameters were identified, standardized into GeoJSON format, and organized for system use. Phase 3 prepared fish species data in JSON format, distinguishing domesticated from non-domesticated species.

The AHP decision model was developed in Phase 4 to weigh environmental parameters, ensuring consistency [28-30]. Phase 5 covered application setup using Laravel, Bootstrap, and Leaflet for interactive mapping. User interactions, data processing, and suitability calculations using AHP were implemented in Phase 6. Phase 7 involved filtering fish species based on suitability scores. Phase 8 enhanced user experience with results display, adjustable parameters, filtering options, and report export features. Finally, Phase 9 deployed the application on a web server and provided documentation and training materials.

## IV. RESULTS AND DISCUSSIONS

Table 1: Key factors determining the suitability of sites for sustainable fish farming in the region.

| **Key Suitability Factor** | **Description** | **Weight (w)** |
|---|---|---|
| Inland Water | Distance to freshwater sources (rivers/lakes). i.e., 5 = near, 1 = far | 0.46 |
| Underground Water | Depth to water table. i.e., 5 = shallow, 1 = deep | 0.28 |
| Flood Zones | Flood susceptibility. i.e., 5 = low flood risk, 1 = high flood risk | 0.17 |
| Soil Type | Soil permeability / water retention. i.e., 5 = clay loam (good), 1 = sandy (poor) | 0.09 |

Source: Authors, (2026).

Table 1 presents the key factors that determine the suitability of a fishpond site and assigns a weight to each based on its importance. Inland water has the highest weight because the distance to freshwater sources like rivers or lakes is critical. Sites closer to these sources are much more suitable for fishponds. Underground water is also important, with the depth to the water table indicating how easy it is to access groundwater. Shallower water tables lead to higher suitability. Flood zones receive a smaller weight but are still significant because flood susceptibility affects the safety and stability of the pond. Sites with low flood risk are preferred. Lastly, soil type has the lowest weight among these factors but remains important.

Soils with good water retention, like clay loam, enhance pond water dynamics, whereas sandy soils are less suitable. The weights show the relative importance, with inland water availability being nearly half the decision weight, emphasizing water supply as the key suitability driver. Meanwhile, flood risk and soil properties contribute to the pond's resilience and management potential. The scoring scale of 1 to 5 for each factor allows evaluators to quantify site conditions in a consistent way, which supports multi-criteria analysis techniques such as the Analytic Hierarchy Process (AHP) to identify optimal fishpond locations. This approach aligns well with standard fishpond site selection guidelines and best practices from aquaculture literature.

Table 2: Appropriate Geospatial and Information Technologies for Optimizing Aquaculture Site Recommendation.

| Technology | Role |
|---|---|
| Geographic Information System (GIS) | Spatial Data Platform |
| Remote Sensing (RS) | Environmental Data Source |
| Global Navigation Satellite System (GNSS) | Precise Geolocation |
| Multi-Criteria Decision Analysis (MCDA) / Analytic Hierarchy Process (AHP) | Decision Support Framework |
| Web-based Mapping Tools (Leaflet, OpenLayers) | Interactive Mapping Interface |
| Standardized Spatial Data Formats (GeoJSON) | Data Interoperability and Visualization |
| Backend Framework (Laravel 10) | Server-side Web Application Development |
| Frontend Framework (Bootstrap) | Responsive UI Design |
| JavaScript | Client-side Interactivity and Data Handling |
| Leaflet.js and Plugins (Leaflet-PIP) | Web Mapping and Spatial Querying |
| Decision Analysis Algorithms (AHP) | Analytical Modeling |

Source: Authors, (2026).

GIS is the core platform for site suitability assessment, enabling storage, analysis, and visualization of environmental and spatial data such as soil, water bodies, elevation, and flood zones. Remote Sensing complements GIS by providing updated satellite or drone data, ensuring current site conditions. Accurate location referencing is achieved via GNSS for geospatial validation. AHP within GIS serves as a decision-support tool, weighting multiple environmental and socioeconomic criteria to rank site suitability and recommend fish species. Web tools like Leaflet provide user-friendly access, while standardized data formats like GeoJSON ensure interoperability. Backend systems built with Laravel and frontend frameworks like Bootstrap and JavaScript enable efficient data processing and interactive user experiences. Together, these technologies form an integrated, data-driven platform that facilitates informed, sustainable fishpond site selection through advanced spatial analysis and accessible web interfaces.

**Fishpond site suitability evaluation using weighted environmental criteria.**

The study applied the Analytic Hierarchy Process (AHP) with spatial data to evaluate fishpond sites based on four key environmental criteria: inland water proximity, underground water depth, flood risk, and soil type.

Table 3: Pairwise comparison matrix showing the relative influence of environmental factors on aquaculture site suitability.

| Criteria | Inland Water | Underground Water | Flood-Prone | Soil Type |
|---|---|---|---|---|
| **Inland Water** | 1 | 2 | 3 | 4 |
| **Underground Water** | 1/2 | 1 | 2 | 3 |
| **Flood-Prone** | 1/3 | 1/2 | 1 | 2 |
| **Soil Type** | 1/4 | 1/3 | 1/2 | 1 |

Source: Authors, (2026).

Expert judgment assigned the highest weight to inland water availability (0.46), followed by underground water (0.28), flood risk (0.17), and soil type (0.09). The consistency ratio of 0.044 confirmed reliable weighting.

Table 4: Inputs extracted from a sample site used in AHP computation for fishpond suitability assessment, showing scaled environmental criteria values.

| Criterion | Value | Scaled (1–5) |
|---|---|---|
| Inland Water | 1.2 km | 4 |
| Groundwater Depth | 6 m | 5 |
| Flood Risk | Moderate | 3 |
| Soil Type | Clay loam | 5 |

Source: Authors, (2026).

At a sample site in Batac, Ilocos Norte, scaled scores were inland water 4, groundwater 5, flood risk 3, and soil type 5, resulting in a high overall suitability score.

Table 5: Consistency ratio check for AHP: calculation of λmax, consistency index (CI), and consistency ratio (CR) demonstrating matrix consistency (CR < 0.10).

| Criterion | (A×W)_i | λ_i = (A×W)_i / W_i |
|---|---|---|
| Inland Water | 1×0.465 + 2×0.277 + 3×0.160 + 4×0.098 = 1.982 | 1.982 / 0.465 = 4.26 |
| Underground Water | 0.5×0.465 + 1×0.277 + 2×0.160 + 3×0.098 = 0.986 | 0.986 / 0.277 = 3.56 |
| Flood-Prone | 0.333×0.465 + 0.5×0.277 + 1×0.160 + 2×0.098 = 0.574 | 0.574 / 0.160 = 3.59 |
| Soil Type | 0.25×0.465 + 0.333×0.277 + 0.5×0.160 + 1×0.098 = 0.341 | 0.341 / 0.098 = 3.48 |

Source: Authors, (2026).

Compute λmax, CI, CR:

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI}$$

Assume λmax ≈ 4.12, then
CI = (4.12−4)/3 = 0.04,
CR = 0.04 / 0.90 = 0.044 < 0.10 ✅ Consistent.

The weighted sum calculations for each criterion demonstrate the relative influence of environmental factors in the AHP analysis. Inland Water, with the highest weight, yields a principal eigenvalue estimate of 4.26. Underground Water, Flood-Prone areas, and Soil Type follow with eigenvalues of 3.56, 3.59, and 3.48, respectively. These values reflect each criterion's contribution to the overall decision hierarchy and help assess the consistency and reliability of the weighting scheme before final suitability ranking.

Table 6: Species environmental preference ratings used for suitability assessment of Tilapia, Bangus, and Catfish common in the Philippines.

| **Fish** | **Inland Water** | **Groundwater** | **Flood-Prone** | **Soil Type** |
|---|---|---|---|---|
| Tilapia | 5 | 4 | 4 | 5 |
| Bangus | 4 | 3 | 3 | 4 |
| Catfish | 3 | 4 | 5 | 3 |

Source: Authors, (2026).

Table 7: Calculation of weighted suitability scores per location by combining criterion weights with scaled environmental ratings.

| **Fish** | **(0.46×IW)** | **(0.28×GW)** | **(0.17×Flood)** | **(0.09×Soil)** | **Total (S)** |
|---|---|---|---|---|---|
| Tilapia | 0.46×5=2.30 | 0.28×4=1.12 | 0.17×4=0.68 | 0.09×5=0.45 | **4.55** |
| Bangus | 0.46×4=1.84 | 0.28×3=0.84 | 0.17×3=0.51 | 0.09×4=0.36 | **3.55** |
| Catfish | 0.46×3=1.38 | 0.28×4=1.12 | 0.17×5=0.85 | 0.09×3=0.27 | **3.62** |

Source: Authors, (2026).

Legend:

IW – Inland Water
GW – Ground Water

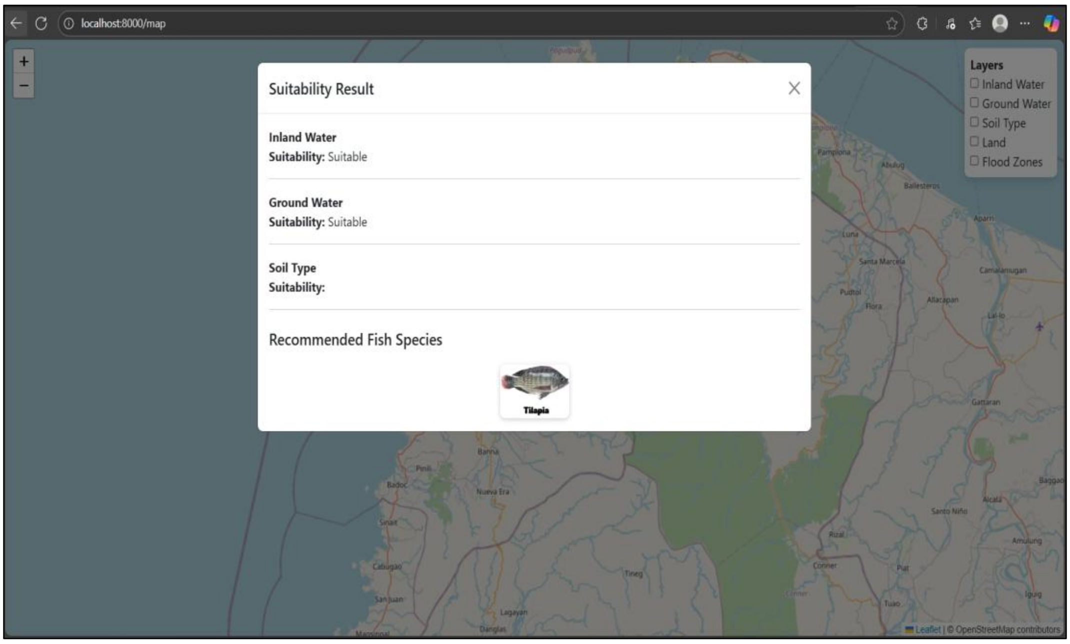
Using the formula (Compute Weighted Suitability Score per location):

$$S_i = \sum(w_j \times r_{ij})$$

Species-specific suitability showed tilapia with the highest score of 4.55, highlighting the site's potential for tilapia farming. A suitability map integrating these weighted criteria identified optimal pond zones, demonstrating that the spatial AHP method effectively distinguishes suitable sites based on critical environmental factors.

**Sample outputs demonstrating the application of Multi-Criteria Decision Analysis and AHP for fish farming site suitability.**

Figures 1 to 4 show the effectiveness of Multi-Criteria Decision Analysis (MCDA) using the Analytic Hierarchy Process (AHP) to identify suitable fish farming sites based on critical environmental factors. AHP integrates inputs like soil type, nutrient levels, water availability, and flood risk by assigning weights to each, creating a reliable suitability index. The results rank fish species such as tilapia and catfish by environmental suitability, with maps confirming zones favorable to each species' requirements. The system also highlights which environmental factors positively or negatively influence suitability, aiding understanding.



Suitability Result

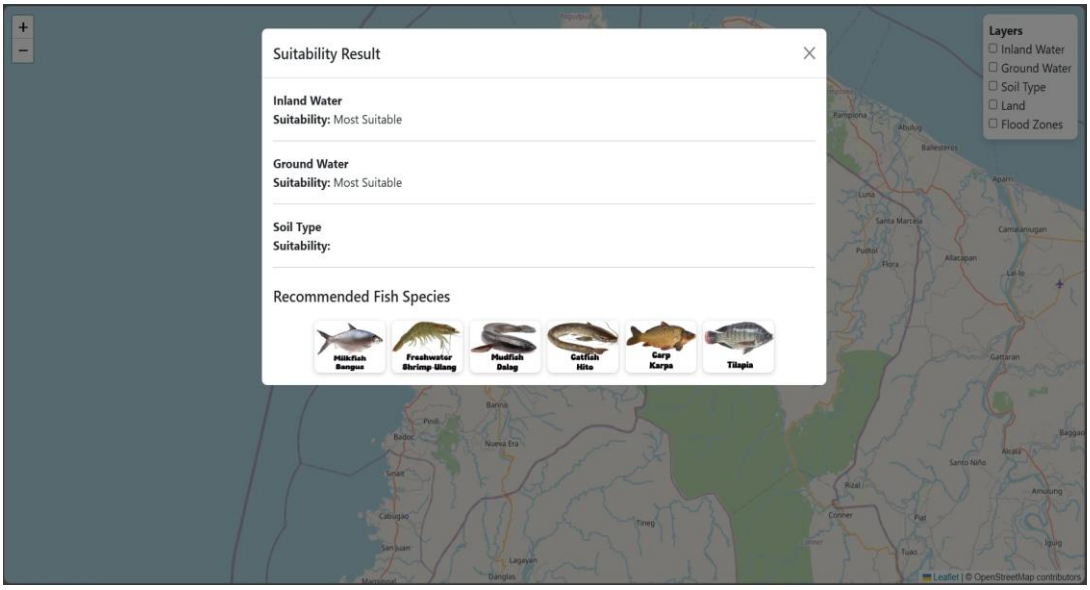
Inland Water
**Suitability:** Suitable

Ground Water
**Suitability:** Suitable

Soil Type
**Suitability:**

Recommended Fish Species

Figure 1: Map Interface Showing Suitability Results for Fish Farming Including Environmental Factor Suitability and Recommended Fish Species.
Source: Authors, (2026).



Suitability Result

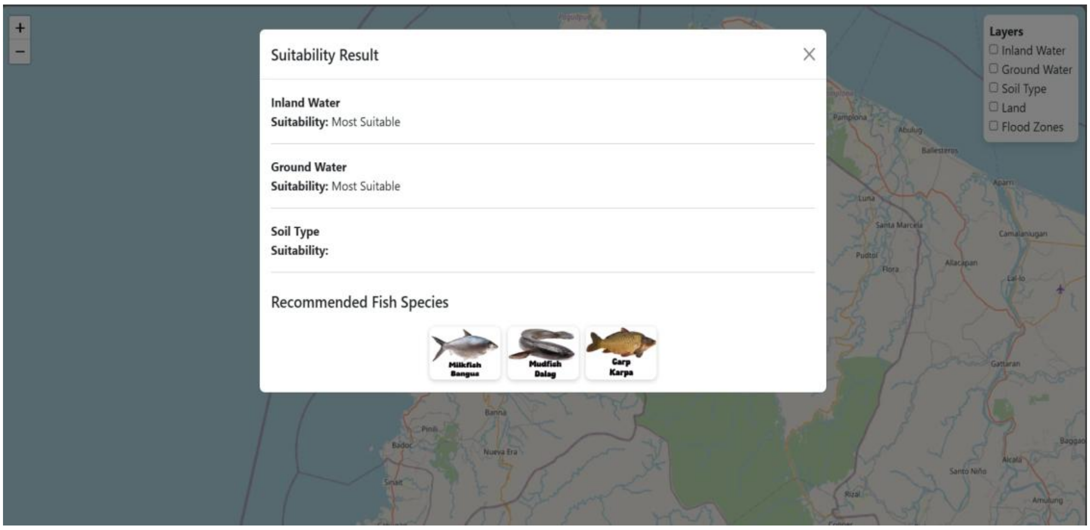
**Inland Water**
**Suitability:** Most Suitable

**Ground Water**
**Suitability:** Most Suitable

**Soil Type**
**Suitability:**

Recommended Fish Species

Figure 2: Map Interface Showing Suitability Results for Fish Farming Including Environmental Factor Suitability and Recommended Fish Species.
Source: Authors, (2026).



Suitability Result

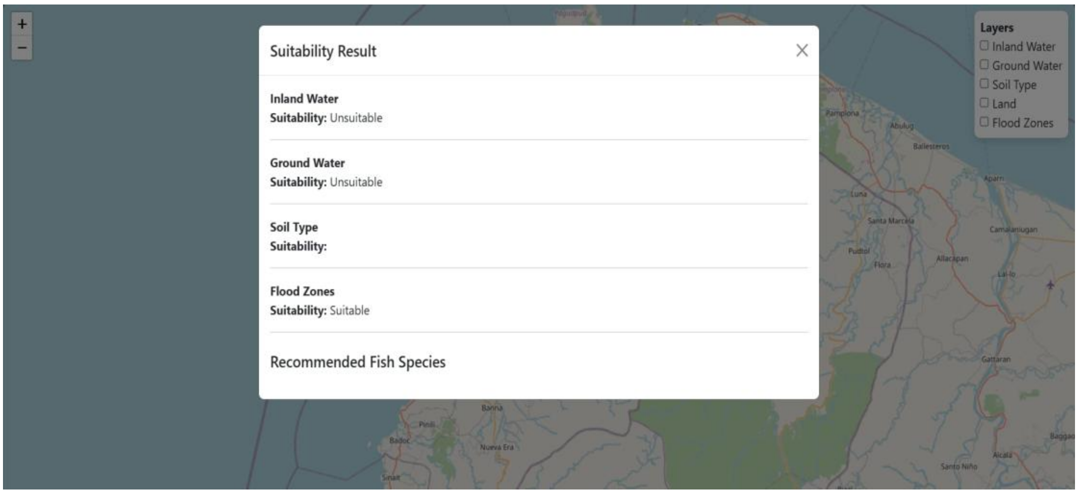
**Inland Water**
**Suitability:** Most Suitable

**Ground Water**
**Suitability:** Most Suitable

**Soil Type**
**Suitability:**

Recommended Fish Species

Figure 3: Map Interface Showing Suitability Results for Fish Farming Including Environmental Factor Suitability and Recommended Fish Species.
Source: Authors, (2026).



Suitability Result

**Inland Water**
**Suitability:** Unsuitable

**Ground Water**
**Suitability:** Unsuitable

**Soil Type**
**Suitability:**

**Flood Zones**
**Suitability:** Suitable

Recommended Fish Species

Figure 4: Map Interface Showing Suitability Results for Fish Farming Including Environmental Factor Suitability and Recommended Fish Species.
Source: Authors, (2026).

Table 8: Summary of User Acceptance Test Results for Fish Farming Suitability System.

| Test Aspect | Frequency | Percentage | Remarks |
|---|---|---|---|
| Map Interaction | 50 | 100% | Smooth interaction, intuitive |
| GeoJSON Data Loading | 50 | 100% | Fast loading, slight delay rare |
| Environmental Data Display | 50 | 100% | Clear and accurate display |
| AHP Calculation | 50 | 100% | Consistent and reliable results |
| Fish Recommendation Display | 50 | 100% | Clear species info, visuals good |
| User Interface Usability | 48 | 96% | Minor responsiveness issues |
| Help and Guidance | 40 | 80% | Improvement needed |

Source: Authors, (2026).

The user acceptance testing conducted with 50 respondents showed positive and very good results for the fish farming suitability system, with minor areas for improvement. Users found the map interaction intuitive, environmental data display clear, and the Automated Hierarchy Process (AHP) computations effective in recommending fish species based on multiple environmental factors. The GeoJSON spatial data loaded smoothly, and the suitability results were well visualized on the map. Some users reported minor UI responsiveness issues during data fetching and occasional slight delays when loading large spatial datasets. Additionally, respondents suggested enhancing the help and guidance features by adding more detailed explanations or tooltips for factors influencing recommendations to improve overall user experience.

## V. CONCLUSIONS

This study successfully designed and developed a web-based fishpond planning and recommendation system tailored for Ilocos Norte that integrates environmental suitability factors with geospatial technologies. The key site suitability factors—water availability, soil type, and flood zones—were accurately identified and weighted using the Analytic Hierarchy Process, supporting effective fish species recommendations. The system utilized appropriate geospatial tools such as GIS, Remote Sensing, and web mapping frameworks to provide an accessible, interactive platform for users to explore aquaculture site suitability. The deployment of the system with a user-centered interface met its intended objective of facilitating informed decision-making among stakeholders. User acceptance testing demonstrated that the system is highly usable and reliable, though minor enhancements in responsiveness and guidance would further improve user experience. The study confirms the effectiveness and utility of a GIS-based, AHP-driven platform in supporting sustainable fishpond site selection and planning in Ilocos Norte, thereby achieving the research objectives.

It is recommended to continuously enhance and promote the use of the web-based fishpond planning and recommendation system in Ilocos Norte, ensuring its accessibility and usability among fish farmers, local government units, and other stakeholders. To improve system effectiveness, it is advisable to incorporate additional environmental and socioeconomic factors—such as natural calamity risks, and market access considerations—in future system updates. Strengthening cooperative efforts with government agencies like BFAR and DA will ensure updated datasets and institutional support, fostering integrated regional aquaculture development.

## VI. AUTHOR’S CONTRIBUTION

**Conceptualization:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Methodology:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Investigation:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Discussion of results:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Writing – Original Draft:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Writing – Review and Editing:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Resources:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Supervision:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.
**Approval of the final text:** Gerry L. Contillo, Nathanies S Castro, Julius Jimenez, Ernesto del Rosario.

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