



Development of Inventory and Environmental Resource Monitoring System

Abstract: Environmental monitoring is a crucial role in informing evidence-based policy development and governance systems for policymakers, governments, and stakeholders to make informed decisions and track progress towards sustainable development. CENRO is tasked with the implementation of environmental laws and policies at the local level, however, despite its mandate, CENRO currently faces a significant problem which is the need for a centralized inventory system for efficient data management. To address this, the researchers propose an Inventory and Environmental Resource Monitoring System that centralizes data and integrates GIS with inventory analytics using the Iterative System Development Model which enables continuous monitoring of resource quantity, quality, and spatial distribution, supporting more accurate analysis and visualization. Results revealed the overall functionality of the developed system received a score of 4.30, classified as “strongly agree,” with standard deviation of 0.17. which means the functional correctness received the highest score, indicating that the developed system is accurate in terms of the expected outputs and its performance. This result supports the comprehensive solution to enhance CENRO's capacity to handle diverse environmental datasets efficiently, improve data connectivity, and provide actionable insights for better decision-making contributing to the achievement of sustainable development and preservation of natural resources.

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1. Introduction

Environmental monitoring is a crucial role in informing evidence-based policy development and governance systems aimed to achieve the Sustainable Development Goal (SDG). By providing essential data on environmental trends and pressures, monitoring efforts are a foundational tool for policymakers, governments, and stakeholders to make informed decisions and track progress towards sustainable development. Additionally, monitoring technology has advanced in recent years, environmental monitoring systems have evolved from essential remote monitoring to an advanced environment monitoring system. The Community Environment and Natural Resources Office (CENRO) is a vital agency in the Philippines operating under the Department of Environment and Natural Resources (DENR). CENRO is tasked with the implementation of environmental laws and policies at the local level, focusing on the management and protection of natural resources while promoting sustainable development initiatives within its designated jurisdictions. The primary functions of CENRO



include enforcing environmental regulations, conserving biodiversity, managing forest resources, overseeing land use, and facilitating community-based natural resource management. CENRO offices are instrumental in fostering environmental awareness, advocating for sustainable resource utilization, and encouraging community participation in efforts to protect and preserve the environment. In recent years, CENRO has also adapted to emerging challenges such as climate change, urbanization, and the need for integrated approaches to environmental management. This includes collaboration with local government units, non-governmental organizations, and community stakeholders to enhance the effectiveness of conservation efforts and promote resilience in local ecosystems. Through these initiatives, CENRO aims to empower communities and ensure the sustainable use of the Philippines' rich natural resources for future generations. Inventory analytics is the process of measuring and analyzing inventory data to optimize inventory performance and customer satisfaction. Inventory analytics serves as a critical strategic framework for modern resource management, transforming raw data into actionable intelligence by systematically measuring, summarizing, and forecasting inventory performance to optimize both operational efficiency and stakeholder satisfaction. To implement this effectively, organizations must navigate four analytical layers, descriptive (what happened), diagnostic (why it happened), predictive (what will happen), and prescriptive (how to respond) while adhering to best practices such as defining rigorous Key Performance Indicators (KPIs), deploying specialized inventory management software, and utilizing predictive modeling to anticipate fluctuations. For environmental managers and agency leaders, mastering these tools is essential for transitioning from reactive, manual tracking to a proactive, data-driven decision-making model that ensures the long-

term sustainability and optimal distribution of vital natural resources. CENRO, particularly in Tayabas City, is responsible for supervising the management and conservation of environmental and natural resources in its area of authority. However, despite its mandate, CENRO currently faces a significant problem: the need for a centralized inventory system for efficient data management. Instead, the office relies primarily on shattered and outdated systems, such as Microsoft Excel spreadsheets, to handle critical environmental data. This scattered approach hampers CENRO's ability to effectively monitor, analyze, and manage environmental data, leading to inefficiencies in decision-making and policy formulation.

Existing literature emphasizes the importance of data-driven approaches, biodiversity documentation, and systematic environmental monitoring in conservation and resource management. Environmental monitoring can be defined as the systematic sampling of air, water, soil, and biota in order to observe and study the environment, as well as to derive knowledge from this process [1]. Monitoring can be conducted for a number of purposes, including to establish environmental "baselines, trends, and cumulative effects" [2], to test environmental modeling processes, to educate the public about environmental conditions, to inform policy design and decision-making, to ensure compliance with environmental regulations, to assess the effects of anthropogenic influences, or to conduct an inventory of natural resources [3]. Environmental monitoring programs can vary significantly in the scale of their spatial and temporal boundaries. For example, an endangered fish in a small stream and the viability of its short-term fate will require monitoring on short and localized temporal and spatial scales, while the management of natural resources that span a nation will require monitoring programs that are much broader in scale [4]. Monitoring programs can



vary significantly in scope, ranging from community-based monitoring on a local scale, to large-scale collaborative global monitoring programs such as those focused on climate change [5,6]. Studies by [7] demonstrate the value of analytics in forest management, while works by [8,9,10,11] contribute extensive biodiversity and ethnobotanical data. However, these studies largely focus on assessment and documentation rather than on the development of integrated digital inventory systems for operational use by local environmental offices. Similarly, research on forest protection programs and biomonitoring frameworks by [12,13] highlights the need for reliable environmental data but lacks practical, analytics-enabled information systems to support local decision-making. At broader scales, [14,15] underscore the importance of robust environmental inventories while revealing the absence of localized, centralized inventory platforms tailored for city-level agencies such as CENRO. These gaps justify the need for a data analytics-based inventory management system to enhance environmental monitoring and decision-making at the local level. Several technological and institutional solutions have been developed to support natural resource inventory and monitoring, combining geospatial tools, sensor networks, and real-time data systems to improve environmental assessment and management. Remote sensing and Geographic Information Systems (GIS) are widely used for large-scale mapping and monitoring of forests, water bodies, land cover change, and other natural resources. These tools allow for periodic inventories and analysis, providing critical information for planning and policy-making [16]. Advanced analytics, including machine learning and big-data processing, are increasingly applied to remote sensing and IoT data, allowing detection of patterns, anomalies, and trends in natural resource conditions, such as deforestation, land degradation, and water quality changes [17]. Additionally, community-

based monitoring initiatives and citizen science programs contribute to natural resource inventories by engaging local populations in data collection, validation, and reporting, thereby supplementing formal monitoring systems and improving spatial coverage [18]. Also, cloud-based analytics and spatial statistics, improve the predictive accuracy and scalability of monitoring systems [19]. Overall, the application of data analytics in natural resource monitoring strengthens the ability to detect environmental changes, optimize resource management, and support policy implementation. However, most of these studies focus primarily on assessment and documentation, with limited emphasis on the development of integrated, analytics-enabled digital inventory systems designed for operational use by local environmental offices. Similarly, research on biomonitoring frameworks and forest protection programs highlights the importance of reliable environmental data but often lacks practical information systems that directly support local-level decision-making.

Despite existing environmental monitoring studies in the Philippines, there remains a significant gap in developing a long-term, GIS-integrated, and analytics-driven system capable of comprehensively tracking forest dynamics, plants, and biodiversity. Current practices, particularly in local offices such as CENRO, remain fragmented and largely manual.

To address this, the project proposes an Inventory and Environmental Resource Monitoring System that centralizes data and integrates GIS with inventory analytics. The system enables continuous monitoring of resource quantity, quality, and spatial distribution, supporting more accurate analysis and visualization.

This project endeavors to contribute significantly to the field of environmental management and computing through the integration of innovative technologies and robust software solutions that enforces digital documentation into a scalable system designed for long-term conservation planning and stronger environmental governance. Moreover, the project also supports the Sustainable Development Goals (SDGs) of the United Nations, particularly SDG 12 (Responsible Consumption and Production) by improving resource tracking and reducing data inefficiencies, SDG 13 (Climate Action) by enabling timely monitoring of environmental conditions, and SDG 15 (Life on Land) by strengthening digital documentation of biodiversity and forest resources.

A. Conceptual Framework

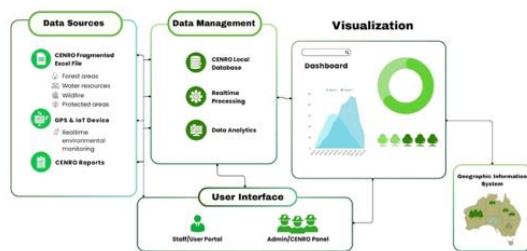


Figure 1. Conceptual framework of the project

Figure 1 shows the conceptual framework of the project. This model outlines the flow of resources and information through a system, starting with data source, undergoing processing or transformation, and culminating in visualization. It serves as a framework for understanding how systems function and how changes in inputs or processes influence the outcomes. Fragmented excel files and feedback from the CENRO will be the data source. Database and software tools will be used for the data management. A centralized inventory system and environmental resource monitoring will be the output. Addressing CENRO's data management challenges requires a systematic approach that considers

technological resources, organizational readiness, and a well-structured process for system development. The CENRO emphasized the importance of incorporating the following features based on the agreed requirements: a) A centralized digital inventory system for tracking natural resources such as forest areas, water resources, wildlife, and protected zones; b) Real-time environmental monitoring; c) Automated report generation to streamline compliance and regulatory submissions; and d) A detailed analytics report.

2. Methods

B. Research Design

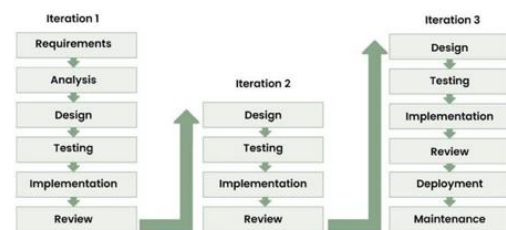


Figure 2. Iterative methodology paradigm

In this research design, the iterative methodology functions as a continuous feedback loop—moving through Requirements, Analysis, Design, Testing, Implementation, and Review—as illustrated in figure 2, to progressively refine the integration of static and dynamic data. In the initial iterations, the focus is on the centralized digital inventory system, where the research establishes the structural metadata required to categorize forest areas, water resources, wildlife, and protected zones, ensuring the database schema is flexible enough to handle diverse natural resource attributes. As the design evolves, the methodology shifts to real-time environmental monitoring, where IoT sensor integration is prototyped and tested in small-scale "sprint" cycles to resolve data latency or hardware reliability issues in remote terrains. This stabilized data stream then feeds into the automated report generation phase, where compliance logic is iteratively mapped



against specific regulatory standards to ensure that digital submissions for environmental agencies are both accurate and legally valid. Finally, the research concludes with detailed analytics reports, using historical data gathered in previous cycles to build and evaluate predictive models—such as deforestation trends or water scarcity forecasts—which are refined through stakeholder feedback to ensure the visualizations provide actionable intelligence for resource management.

C. Requirement Phase

The requirements phase serves as the critical elicitation period where the specific operational needs of the Community Environment and Natural Resources Office (CENRO) are translated into technical specifications. This phase, which initiates the first cycle of the iterative process, involves intensive consultation with CENRO officers to define the parameters for the centralized digital inventory, specifically identifying which attributes are vital for tracking forest areas, water resources, and wildlife within their local jurisdiction. Essential data from the CENRO were gathered to identify the functional and non-functional requirements needed in the project. This serves as a crucial step in understanding the expectations, processes and challenges associated with the project's development. Also, through focus group discussion, document analysis and interviews, problems and the desired system feature were identified.

D. Analysis Phase

During this phase, a comprehensive analysis of several critical system components was conducted, following a structured data analysis approach. Then, examining the data requirements, carefully reviewing the forms, policies, and operational constraints implemented by the CENRO to ensure data accuracy and compliance with existing standards. This step helped define the

necessary data elements, data relationships, and validation rules that would guide the system's database design. The data management analysis focused on reviewing the existing network architecture to confirm that the proposed solution would remain accessible, reliable, and scalable within the current infrastructure. For data reporting, the project team collaborated closely with the beneficiary to identify the most relevant and actionable reports to be displayed on the main dashboard, ensuring that decision-makers would have timely and meaningful insights. Finally, the team reviewed the system documentation format to ensure clarity, completeness, and ease of understanding, thereby supporting maintainability and future system enhancements. The data management analysis focused on reviewing the existing network architecture to confirm that the proposed solution would remain accessible, reliable, and scalable within the current infrastructure. For data reporting, the project team collaborated closely with the beneficiary to identify the most relevant and actionable reports to be displayed on the main dashboard, ensuring that decision-makers would have timely and meaningful insights. Finally, the team reviewed the system documentation format to ensure clarity, completeness, and ease of understanding, thereby supporting maintainability and future system enhancements.

E. Design Phase

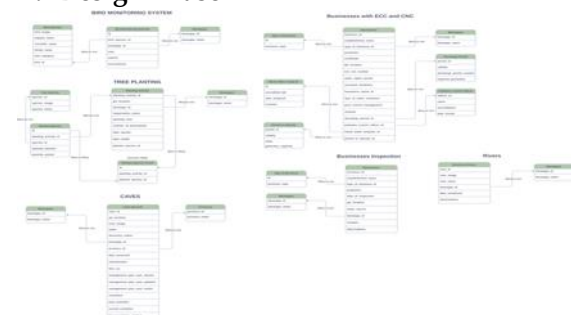


Figure 3. Crow's foot notation ER diagram of the project

In an inventory and environmental resource monitoring system, the Crow's Foot notation

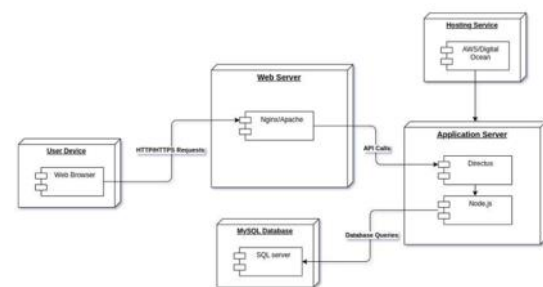


ER diagram serves as the structural blueprint that bridges physical asset management with dynamic telemetry data. Thus, figure 3 illustrates the ER diagram that is divided into six interconnected modules, each focusing on a specific area of inventory of environmental resource and regulation. The diagram is anchored by the Location entity, which maintains a "one-to-many" (1:N) relationship with both Assets and Sensors; this signifies that while a specific forest sector or water body can house multiple resources and monitoring devices, each asset and sensor is logically tied to one primary geographical coordinate. The Asset entity functions as the centralized digital inventory, capturing metadata for forest areas, wildlife, and protected zones, while the Sensor entity acts as the gateway to Real-time Monitoring. This is represented by a mandatory "one-to-many" relationship between Sensors and Readings, where a single hardware device generates a continuous stream of environmental data points. Furthermore, the architecture integrates Automated Report Generation and Detailed Analytics through a relationship between the Readings and a Compliance Report entity. In this notation, the Reading entity may have an optional "one-to-many" link to an Alert table, ensuring that when a threshold is breached (e.g., high turbidity or illegal logging sounds), a record is generated for immediate intervention. The Compliance Report entity often maintains a many-to-many relationship with Resources, typically resolved through a join table, allowing for the aggregation of time-series data into the structured formats required for regulatory submissions. This relational flow ensures that every data point, from a simple temperature reading to a complex wildlife population count, is traceable back to its physical origin and forward to its finalized regulatory output.

F. Testing Phase

The testing phase was conducted using a controlled prototype-based evaluation. A survey questionnaire based on ISO 25010 validated by experts to ensure that all items are accurate and complete based on the requirements such as functionality, usability, reliability, portability, and maintainability. The prototype of the system was prepared and demonstrated in CENRO to simulate the actual system operation. Necessary materials such as test scenarios, sample data, user guides, and evaluation forms were organized to ensure a smooth testing activity. The system evaluators were composed of technical experts, CENRO's head, and selected staff of the management team. They were formally invited to participate. An orientation session was conducted to explain the objectives of the evaluation, the scope and limitations of the prototype, and the proper procedure for interacting with the system and completing the questionnaire. During the session, evaluators were guided through the key features of the prototype and allowed to perform representative tasks based on prepared use-case scenarios.

G. Implementation



Deployment diagram of the project

All the requirements for the developed system were prepared and identified, particularly the hardware device and software components for the deployment of the application into the user's machine, as shown in figure 4. The frontend is developed using Vue.js (3.x) with Vuetify for UI components, while the backend utilizes Directus as the CMS and SQL Server for database management. Development tools

include Docker for containerized development and deployment, Node.js and npm for managing JavaScript dependencies, and Axios for API integration. Version control is managed using Git, with repositories hosted on GitHub for collaboration and tracking changes. Additionally, design tools such as Figma or Adobe XD assist in prototyping and UI/UX design. Testing tools like Postman facilitate API testing, while Selenium is used for browser automation testing, ensuring the reliability and efficiency of the developed system. Version Control was used with Git and repositories hosted on Github for simultaneous and collaborative development. It was used to effectively monitor the version history of the system. Proper database schema design, indexing, and optimized queries were implemented to minimize system latency and enhance responsiveness. Users access the system through client devices like computers or laptops, which connect to an application server hosting the main software and handling data processing and analytics. The application server communicates with a database server that securely stores all environmental data, including user inputs, and analysis results. All components interact over a network, ensuring seamless data flow and system functionality to support environmental monitoring and management.

H. Review

The successful implementation of the Inventory and Environmental Resource Monitoring System requires careful preparation and the identification of necessary tools. The essential hardware, including workstation and network equipment were determined, to ensure the system can operate efficiently. Software requirements, such as database management system, programming frameworks, and development tools, were also determined to support the system deployment. Proper backup mechanisms, security tools, and testing environments were also arranged to ensure

data integrity and system reliability during implementation.

3. Results and Discussion

Table 1. Inventory and Environmental Resource Monitoring System Functionality

Functionality of the system	WM	STD	VI
1. The system provides all the features needed to complete my tasks.	4.30	0.25	SA
2. The system produces accurate results and performs tasks as expected.	4.60	0.51	SA
3. The system has all the tools and features necessary for the work.	4.50	0.20	SA
4. The system is accessible whenever needed.	3.40	0.31	S
5. The system ensures data are accurate and protected from changes without permission.	4.70	0.44	SA
Total Mean	4.30	0.17	SA

Table 1 presents the overall results of the functionality of the developed system, which received a score of 4.30, classified as “strongly agree,” with standard deviation of 0.17. This suggests that the respondents were relatively consistent in their evaluation of the developed system’s appropriateness, correctness, completeness, availability, and integrity. Among these features, the functional correctness of the developed system received the highest score, indicating that the developed system is accurate in terms of the expected outputs and its performance. However, functional aspect somehow impact the overall performance of the developed system and

require improvement, particularly in the features that is accessible whenever needed. This feature scored the lowest at 3.40, with standard deviation of 0.31.



Figure 5. Admin dashboard of the project

Figure 5 shows the dashboard of the admin portal where it is the central hub designed for the staff to access, analyze, and manage critical environmental data efficiently. It provides a user-friendly interface with visual analytical tools that help Admin/CENRO filter and explore specific datasets for detailed insights. The dashboard's features include data visualization and real-time filtering for better decision-making and reporting.

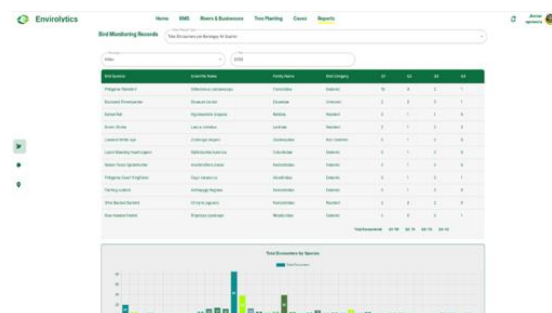


Figure 6. Bird monitoring records

Figure 6 shows the bird's monitoring records that systematically tracks the number of bird species encountered in each barangay per quarter. This data helps monitor biodiversity and provides insights into species distribution over time, supporting local conservation efforts and environmental assessments

4. Conclusion and Recommendation

The developed system is a centralized platform that addresses the challenges of fragmented and inefficient data management faced by the Community Environmental and Natural Resources Office (CENRO). By integrating various modules for monitoring, analyzing, and reporting environmental data, the system aimed to streamline data collection and management processes. Also, with the strategic integration of Geographic Information Systems (GIS), the specialized modules for monitoring and reporting were consolidated and the system transforms raw environmental data into a spatially-aware intelligence network. This comprehensive solution enhanced CENRO's capacity to handle diverse environmental datasets efficiently, improve data connectivity, and provide actionable insights for better decision-making. Ultimately, the developed system supported more effective environmental management practices and contributed to the sustainable development and preservation of natural resources.

Based on findings and conclusion, the following recommendations were drawn: a) strengthen security features that continuously updates and monitors the system's security measures to protect data integrity and confidentiality against emerging threats; b) hybrid data architecture that should be capable of local data processing and buffering, transmitting to the GIS-integrated platform only when a connection is stable or when a "Critical" alert is triggered; and c) a mobile application that allows field officers to update the inventory in real-time.

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