Digging Deeper: Soil Quality Monitoring System for Alaminos City Farmers

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ABSTRACT

Soil quality plays a critical role in determining soil suitability for crop production. Despite its importance in plant growth, the concept of soil quality remains largely unfamiliar to many in the Philippines. In Alaminos City, while technological advancements in agriculture, particularly in soil quality testing—are embraced, farmers often lack access to real-time and user-friendly monitoring systems. The proponents developed a system that can display the soil parameters that make the soil fertile. The proponents used Purposive sampling to identify the number of respondents. An interview with the Agriculturist from the Office of City Agriculture in Alaminos City is conducted to understand the proposed system's underlying concepts. The proponents used the Agile Model for software development. Findings show that the overall weighted mean of the proposed application in its assessment of acceptability is 3.77 which is interpreted as excellent in terms of system evaluation adapted from ISO 25010. The procedure of implementation sought in this study will serve as a guide in crafting detailed suggestions in monitoring the soil quality here in Alaminos City. The developed features of the application provided necessary data that could help the City of Agriculturist to monitor the soil parameters and interpret the result. The application is intended to run on smartphones, only suitable for Android platforms. Further study is recommended for various processes, measures, and certain other features not included in the developed application functionality.

Keywords: soil, NPK, soil moisture, soil pH, soil quality

INTRODUCTION

Agriculture has been a fundamental contributor to the nourishment and economic stability of countries worldwide [1]. Plants, crops, and agricultural machinery often come to mind when we think about agriculture. However, there is often a lack of attention paid to the soil which gives rise to plant and crop growth.

Technological developments have led to a rapid expansion of the agricultural sector, which is now bringing information and communication technologies to agriculture as part of Farming 4.0 [2]. The global agricultural sector is estimated to employ more than 856 million people [3]. In the third quarter, GDP grew by 5.9 % compared to 4.3 % in the second [4] and agriculture contributed 0.08 percentage points as it expanded by 0.9 percent during that period [5]. Despite this growth, the agriculture industry faces significant challenges in soil quality monitoring.

Traditional soil monitoring methods, which rely on laboratory analysis of isolated samples, are often slow and costly and do not account for climate, temperature, materials, vegetation, and soil characteristics [6]. Budgets, in particular small farms, may be strained by this. In addition, to interpret complex data and act based on them, which some farmers may not have the means of doing, there is a need for specialized knowledge in soil observation. The lack of standardized metrics across different regions makes it challenging to compare data and establish benchmarks for improvement [7].

Innovative technologies such as remote sensing and ground-based sensors offer promising solutions, but some farmers are reluctant to adopt these technologies due to unfamiliarity, perceived complexity, or high initial

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costs [8]-[9]. Interoperability of platforms and fragmentation of data formats also hinders the integration of soil data with other farm management data, e.g. weather and yield information to provide a holistic view [10].

A key role in promoting soil health monitoring and sustainability agriculture can be played by supporting government policies and incentives [11]-[12]. Training programs for farmers on soil quality monitoring techniques, data interpretation and best management practices are essential for successful implementation [13]. Collaboration between farmers, researchers, extension services, and technology firms can drive innovation, knowledge sharing, and the development of cost-effective soil quality monitoring solutions [14].

The authors conducted this study to address these challenges by developing a mobile application that tests soil moisture, soil pH, and NPK levels using Arduino-based sensors. This technology is intended to improve the ability of farmers in Alaminos City to monitor and manage soil health effectively by making it easier for them to carry out quality tests on their land.

METHODOLOGY

To have a clear view of the underlying problems that need to be solved, Agile Methodology was used as the Software Development Life Cycle in this study. Agile Methodology is the ability to create and respond to change. It is a way of dealing with, and ultimately succeeding in, an uncertain and turbulent environment [6]. Involving six phases - Requirements, Design, Development, Testing, Deployment, and Review – it is most useful to tackle problems that are ill-defined or unknown. Figure 1 shows the Agile Methodology.

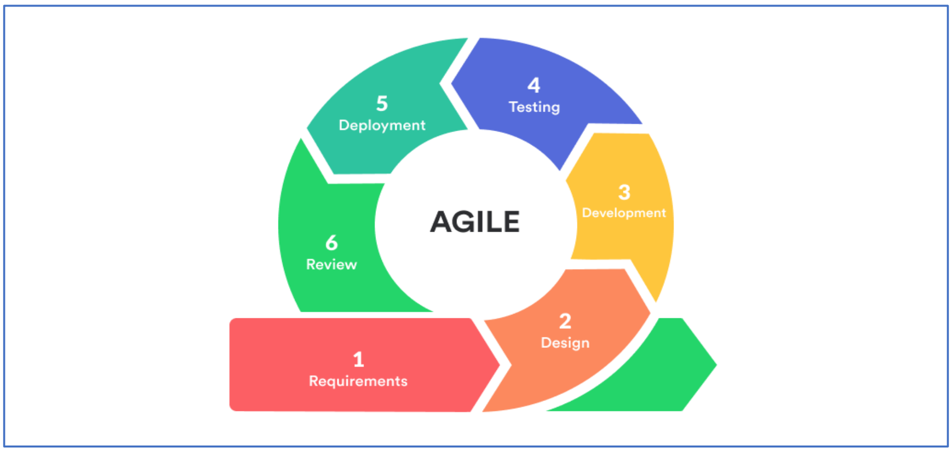

Fig. 1. Agile Methodology

(https://serenagray2451.medium.com/what-is-the-agile-methodology-in-software-development-c93023a7eb85)

In the initial phase of the agile methodology, the proponents identify first the the gaps in the traditional method of soil quality monitoring and proposed key features and functionalities to be integrated in the system by engaging with Alaminos City Farmers and gathering data from local experts and respondents. They discuss user requirements and use participatory observation to refine the app's requirements.

Next, the design phase is essential for crafting a user-friendly interface by understanding the project requirements, platform, and processes. It involves gathering requirements, exploring solutions, suggesting improvements, and using prototypes to refine designs through feedback and testing, ensuring an interactive and user-centric development approach. The proponents also considered building prototypes for the sensor, as well as the interface of the system.

Implementing algorithms; integrating of soil parameters such as NPK (nutrients), pH, moisture, and temperature of soil; and ensuring the system meets the performance standards through rigorous testing were proposed by the authors in the development phase of agile methodology. Using tools like Android Studio for development of the mobile app (farmers and soil specialists' side), Visual Studio Code for the development of the web app (admin side), and Figma for UI/UX design, the authors construct the system architecture and core functionalities, focusing on accurate soil fertility assessment and nutrient level monitoring as foundational steps in transforming concepts into tangible components. The system utilized Firebase Realtime Database, a cloud-based NoSQL database that allowed for real-time synchronization of soil parameters and the tips suggested based on the results of soil testing, ensuring that data was instantly reflected across all user roles

In the next phase, coding is finalized, and rigorous testing commences to ensure the system meets all specified requirements and quality standards. Developers conduct thorough assessments, fix any issues, and involve soil specialists and farmers for validation and feedback. Demonstrations are conducted iteratively to confirm error-free operation and ensure the system's security and alignment with business needs.

After rigorous testing, the software is now in its final deployment stage, awaiting approval. The deployment closely observed that all the nodes in the system is configured correctly.

Lastly, during the review phase, the development team will evaluate whether the requirements have been met and will propose solutions for any emerging challenges. They will ensure the system aligns with user expectations by addressing issues promptly and enhancing features to exceed user requirements. This thorough assessment will aim to deliver a robust, functional system with high user satisfaction and usability.

By implementing the Agile Methodology, the project was able to establish a structured and reliable system that met the defined objectives and stakeholder requirements. This approach encouraged systematic progress and effective risk management, significantly contributing to the project's overall success. Throughout the development process, a range of tools was employed to enhance clarity and organization, promoting efficient communication and a smooth workflow during the project.

Flowchart. It was a diagram that visually showed the stages of a process, using shapes and arrows to indicate the flow. A flowchart helped the proponents identify key steps in a system and arrange tasks in the order they occurred.

ERD (Entity Relationship Diagram). This displayed the different entities (like tables) within a database along with their relationships. The ERD helped the proponents get a clear representation of the data and assisted them in creating and modifying the system’s database.

Database Schema. In addition to the ERD, the database schema outlined the framework of the database by specifying tables, fields, and data types. This enabled the team to verify that the system was capable of efficiently storing and retrieving data while upholding security and integrity, particularly important for handling sensitive case details.

Weighted Mean. To assess the effectiveness of the system, the proponents utilized the weighted mean to determine the average responses from the survey about the conventional approach to soil quality monitoring. This statistical method provided valuable insights into respondents' perceptions of the system and influenced decisions on essential enhancements.

Scale of Measurement. The scale of measurement was employed to evaluate the acceptance level of the suggested system. It offered a numerical insight into how effectively the system fulfilled user expectations, enabling modifications to improve user satisfaction. The rating is shown in the Table 1:

Table I. Scale of Measurement

Scale	Statistical Limits	Rating
1	1.00 – 1.75	Poor
2	1.76 – 2.50	Fair
3	2.51 – 3.25	Very Good
4	3.26 – 4.00	Excellent

This scale was specifically created to assess how well the system is accepted, allowing for necessary adjustments to be made based on user feedback.

The study took place in Alaminos City, Pangasinan, where data was collected through interviews to evaluate the soil quality monitoring process, identify challenges, and determine areas for improvement. The study involves the Farmers, Soil Specialists, City Agriculturist, and IT experts, each providing important insights into the soil quality monitoring process. The distribution of the respondents is as follows:

Table II: Respondents

Respondents	Number of Respondents
Farmers	50
Soil Specialists	2
City Agriculturist	1
IT Experts	2
Total	55

RESULTS AND DISCUSSION

Digging Deeper improved the soil quality monitoring for Alaminos City farmers and soil specialists. The system allowed not just the soil specialists but also the farmers to effectively monitor the soil quality. It makes the soil quality monitoring more convenient and less hassle for the users. The system received an average weighted mean score of 3.77, which is categorized by "Excellent". This rating underscores the system's reliability, ease of use, adaptability, and security, demonstrating its effectiveness in making the soil quality monitoring more convenient to the farmers. Users reported that the system is trustworthy and meets their needs well, leading to a favorable overall assessment. The following discussion outlined the architecture of Digging Deeper: Soil Quality Monitoring System for Alaminos City Farmers.

System Architecture of Digging Deeper

Three-tier architecture is a well-established software application architecture that organizes applications into three logical and physical computing tiers: the presentation tier, or user interface; the application tier, where data is processed; and the data tier, where the data associated with the application is stored and managed [15].

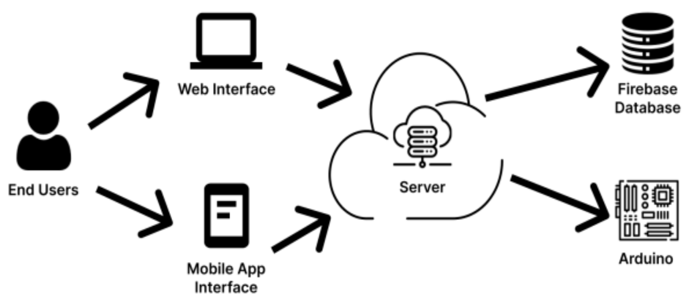

Fig. 2. Soil Quality Monitoring System Three-Tier Architecture

The Digging Deeper system was built on a three-tier architecture, providing efficient and convenient in soil quality monitoring. Accessible through web browsers and mobile applications, the user interface was located at the presentation tier. The interface enabled farmers and soil specialists test the soil, track the soil parameters in their barangay every month, and receive real-time soil results after they test their soil. The user interface was designed to be easy to navigate and interact with, utilizing flutter for the mobile interface (accessed by farmers and soil specialists), native php for the web interface (accessed by the super admin), JavaScript and CSS for optimal responsiveness. Moreover, this tier involved role-based access, which means that farmers, admins (soil specialists), and super admin (City Agriculturist) also have the privilege of carrying out their assigned duties.

Digging Deeper handled the business logic needed to handle the soil quality monitoring efficiently at the application tier. Unlike the usual user registration process, the system provided both anonymity and confidentiality by automatically creating a unique user ID for every user. This user ID empowered users to stay informed about their soil monitoring progress without revealing personal information while also maintaining their privacy and safety. It also facilitated sensor scheduling, where the city agriculturist assigned schedule for farmers to borrow the sensor used for soil testing. Farmers can't borrow the sensor if it is still being borrowed by other farmers and farmers can't borrow the sensor for more than 4 to 5 days.

At the data tier, Digging Deeper was tasked with securely storing and managing soil parameter results, users' credentials, and sensor scheduling credentials. By using Firebase Realtime Database, the system provides efficient data storage and allows for real-time synchronization across various devices. This tier was built to uphold data integrity and security, ensuring that only authorized personnel, such as super admins and admins, had access to and could manage soil testing information. Although the system did not allow farmers to retrieve data, it guaranteed that soil test result details were securely stored for monitoring and future references by authorized users. Furthermore, by employing a scalable database structure, Digging Deeper is well-equipped for future enhancements, ensuring it could adapt as new features and monitoring requirements arise.

The three-tier architecture of the system offered a structured, secure, and effective system for monitoring the soil quality of Alaminos City farmers agricultural lands. The presentation tier focused on accessibility and user-friendliness, the application tier managed intricate business logic and facilitated real-time communication, while the data tier provided well-organized and secure storage for soil test results. This setup ensured that soil testing was conducted swiftly, reducing the delays and improving the efficiency of Soil Quality Monitoring here in Alaminos City.

CONCLUSION

To help farmers with their work, improving soil quality monitoring is essential in agriculture. A well-designed system is necessary to protect farmers' information, such as the barangay where they farm. Digging Deeper: A Soil Quality Monitoring System for Alaminos City Farmers is designed to make it easier for farmers to check their soil quality by providing quick results on soil moisture, pH levels, and NPK content. The system also offers immediate tips and recommendations based on the results, unlike traditional methods that take weeks. This innovation makes soil testing faster, more accessible, and more convenient for farmers in Alaminos City.

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