

SoilScope: Integrating Artificial Intelligence into Mobile Diagnostics for Soil Health

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Abstract

Soil degradation, unpredictable climate patterns, and limited access to agricultural diagnostics continue to challenge small-scale farmers and home gardeners, particularly in developing regions such as the Philippines. This study presents SoilScope, an AI-powered mobile application designed to provide real-time soil analysis, early disease detection, and sustainability-focused recommendations through accessible smartphone technology. Developed using React Native, Firebase, and lightweight Convolutional Neural Network (CNN) models, the system classifies soil types and detects visible soil-related plant diseases using in-app image capture. The application incorporates offline functionality, gamification, and an AI chatbot to enhance usability and agricultural literacy among users with varying technical backgrounds. A mixed-methods evaluation involving end-users and information technology experts was conducted using the System Usability Scale (SUS) and the ISO/IEC 25010 quality framework. Results indicated high perceived usability, responsiveness, reliability, and overall effectiveness in supporting precision soil care practices. SoilScope demonstrates strong potential as a cost-efficient digital agriculture tool that empowers farmers to make timely, science-based decisions, contributing to sustainable farming and food security initiatives aligned with national and global development goals.

Keywords: Artificial Intelligence, CNN, Digital Agritech, Mobile Application, Precision Agriculture, Soil Disease Detection, Soil Analysis, Sustainable Farming, Usability Evaluation

Introduction

Background of the Study

Environmental challenges such as climate change, soil degradation, and food insecurity have intensified globally, directly affecting soil composition, moisture retention, and plant health. Rising temperatures and shifting rainfall patterns accelerate organic matter loss, disrupt microbial communities, and reduce soil productivity [1, 2]. Recent reports indicate a global decline of over 2,000 gigatons in soil moisture within two decades, annual land degradation exceeding one million square kilometers, and increasing soil erosion risks without conservation measures [3, 4, 5]. These trends threaten agricultural sustainability and underscore the urgent need for accessible, data-driven soil management solutions.

It is particularly relevant to note that these challenges most acutely impact home gardeners, agriculture students, and smallholder farmers, many of whom rely on intuition or costly and inaccessible laboratory testing. Botanist Levi Antonio D. Zabala highlights the relevance of AI-based mobile tools like SoilScope in addressing these limitations through affordable, user-friendly soil assessment. Guided by precision agriculture and smart farming principles, SoilScope integrates AI-powered image analysis, personalized recommendations, and an interactive chatbot to support early disease detection, efficient resource use, and sustainable practices. Designed as a mobile application to maximize accessibility amid growing smartphone adoption in the Philippines [6], SoilScope contributes to improved crop management while aligning with the United Nations Sustainable Development Goals and the Philippine Development Plan 2023–2028.

Objectives of the Study

The primary objective of this study is to design, develop, and evaluate SoilScope, an AI-powered mobile application aimed at enhancing soil analysis, disease detection, and the promotion of sustainable agricultural practices among small-scale farmers and home gardeners. Specifically, it aims to design and develop the SoilScope mobile application that integrates artificial intelligence to perform real-time soil quality analysis and disease detection, assess user adoption and improve the delivery of context-based, actionable sustainable farming recommendations particularly in rural and semi-urban communities, and evaluate the system using the System Usability Scale (SUS) and ISO/IEC 25010 quality framework.

Conceptual Framework or Theoretical Framework

This study is anchored on the Input–Process–Output (IPO) model, which provides a structured framework for the conceptualization, development, and evaluation of the SoilScope mobile application. The Input phase includes human resources such as a team of student developers and designers and expert consultation from Mr. Levi Antonio D. Zabala, a retired OFW and botanist, as well as technological resources including React Native, TensorFlowJS, Google Firebase, smartphones for testing, open-source image datasets, and a usability questionnaire adapted from the System Usability Scale (SUS), all guided by a review of relevant literature. The Process phase was implemented through iterative development sprints involving UI/UX design for non-technical users, AI model training and integration for on-device soil and disease diagnostics with offline functionality, and usability testing using structured surveys analyzed through descriptive statistics. The Output of this framework is the SoilScope mobile application, which provides real-time AI-powered soil analysis, actionable recommendations for sustainable agriculture, an interactive AI chatbot, and quantified usability feedback, supporting the project's goal of delivering an accessible, intelligent, and environmentally responsible tool for small-scale growers.

Figure 1. Conceptual Framework

Input	Process	Output
Small-scale farmers, gardeners, and agriculture students needing accessible diagnostics	Development guided by the Scrum Agile Framework System design and development (UI/UX, features)	SoilScope: An AI-Powered Mobile Application for Soil Analysis and Disease Detection

Expert consultation from Mr. Levi Antonio D. Zabala	AI model training and integration	
Image datasets (Red Soil, Black Soil, Alluvial Soil, Cinder Soil)	App deployment	
Ethical clearance from the University Research Ethics Board (REB)	Usability testing and feedback collection	
	Data analysis	
	Third-party API (Google Gemini) for the AI Chatbot	

Methods

Research Design

This study employs a developmental research design focused on developing and evaluating SoilScope, an AI-powered mobile application for soil analysis and disease detection. It emphasizes iterative prototyping, user-centered development, and real-world validation to deliver real-time diagnostics and actionable recommendations for small-scale farmers and home gardeners. System evaluation integrates technical performance metrics, such as model accuracy and responsiveness, with usability, accessibility, and engagement measures using the System Usability Scale (SUS), ISO/IEC 25010 assessments, and expert feedback. Descriptive statistics, including mean and standard deviation, were used to analyze response consistency. A 4-point Likert scale (Strongly Disagree to Strongly Agree) was selected to eliminate neutral responses and produce clearer, more actionable evaluation data.

System Development Methodology

This study adopted the Scrum Agile Framework to guide the development of SoilScope using iterative sprints that emphasized adaptability, feedback, and user-centered design. The project was completed in four two-week sprints covering system architecture, UI prototypes, authentication, and Firebase integration, followed by the CNN-based soil analysis model and final features such as gamification, an AI chatbot, and usability testing. Development with React Native and TensorFlowJS, tested on mid-range Android devices, ensured performance and compatibility. Consistent with Scrum principles of incremental delivery and continuous improvement [7], this approach supports findings by Nabilla et al. (2024) [8] that iterative development enhances responsiveness and user satisfaction.

Figure 2. Agile Development Model



Participants and Setting

Respondents and participants were selected through snowball sampling to ensure relevance to the SoilScope application. An initial user downloaded the application and referred to other qualified individuals within their networks, including small-scale farmers, home and urban gardeners, and agriculture or plant science students. Agricultural experts such as agronomists, botanists, and extension workers were also interviewed for expert insights. No fixed limit was set on participant numbers, allowing inclusion of all eligible and interested individuals within San Agustin Norte, Arayat, Pampanga, and similar rural or semi-urban areas.

Research Instrument

Data were gathered using a structured survey questionnaire adapted from the System Usability Scale (SUS), a validated tool widely employed for evaluating software interfaces and user experiences. The instrument was administered through Google Forms and consisted of usability-related statements measured on a 4-point Likert scale, ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). The questionnaire is intended to assess respondents' perceptions of the SoilScope mobile application, particularly its usability and effectiveness in supporting soil analysis, disease detection, sustainability recommendations, and chatbot interaction. The use of SUS is supported by prior studies in mobile agriculture and diagnostic tools, such as Wang et al. (2023) [9], who evaluated a mobile irrigation application and reported high usability scores, Yoo et al. (2022) [10], who assessed plant disease diagnosis applications, and Sharma and Singh (2021) [11], who examined soil fertility tools among smallholder farmers.

Data Collection Procedure and Analysis

Participants were recruited through snowball sampling, beginning with an initial respondent who tested the SoilScope mobile application and referred other qualified individuals such as farmers, gardeners, agriculture students, and agricultural experts. After using the application on Android smartphones and exploring its features including soil image analysis, disease detection, sustainability recommendations, and the AI-powered chatbot, respondents completed a structured usability questionnaire via Google Forms. The questionnaire, adapted from the System Usability Scale (SUS), used a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree) with descriptive ratings and mean ranges for interpretation. End-users were evaluated using SUS, while information technology experts assessed the application based on the ISO 25010 quality model. Quantitative data were analyzed through mean scores and descriptive ranges, providing a comprehensive assessment of SoilScope's usability and quality.

Ethical Considerations

The researchers ensured that all participants voluntarily participated in the study and were fully informed regarding the purpose of the research before data collection commenced. Confidentiality and privacy of all participant information were strictly maintained throughout the conduct of the study. Ethical clearance was obtained from the University Research Ethics Board (REB) of the University of the Assumption prior to data gathering. All data collected were used exclusively for academic and research purposes.

Results and Discussions

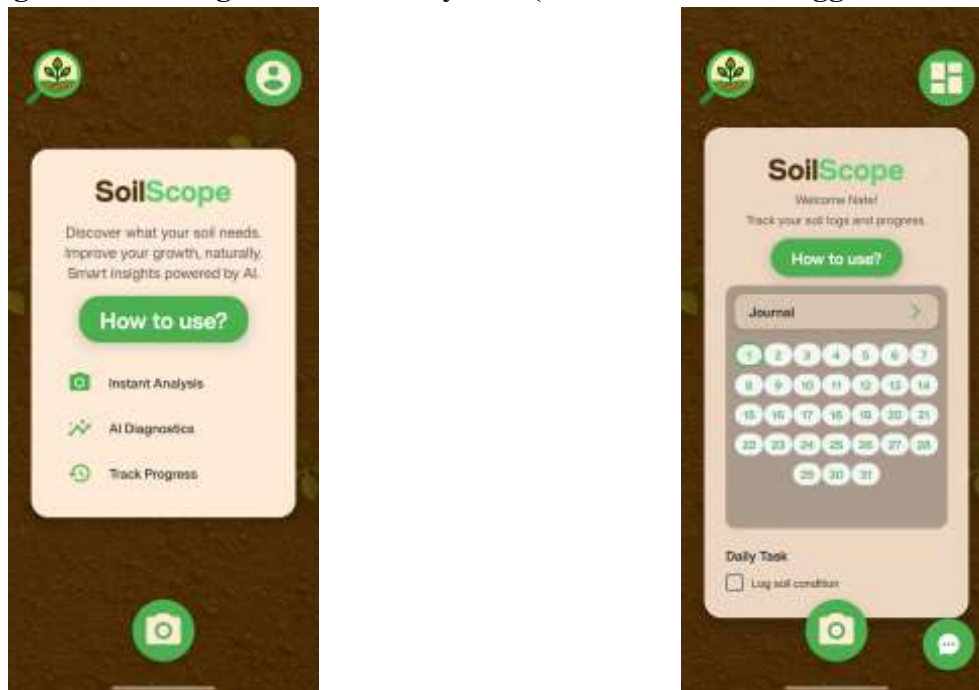
Design of the Mobile Application

During the design and development of SoilScope, the team prioritized accessibility and ease of use to support users with varying levels of technical proficiency, incorporating a built-in guide, responsive layouts for diverse screen sizes, and compatibility with legacy Android versions such as Android 7. Developed using React Native and Expo, the application features a flexible front end, secure Firebase-backed data storage, and real-time image capture via Expo Camera with user permission.

SoilScope integrates artificial intelligence for image-based soil and disease analysis, evaluating multiple models—including Random Forest (RF), Support Vector Machines (SVM), and Convolutional Neural Networks (CNN)—and ultimately selecting CNNs for their superior performance in visual pattern recognition. Trained on publicly available datasets, the CNN models achieved an average accuracy of 94% by automatically learning spatial features directly from raw images, outperforming RF and SVM approaches that rely on manual feature extraction and struggle with high-dimensional image data.

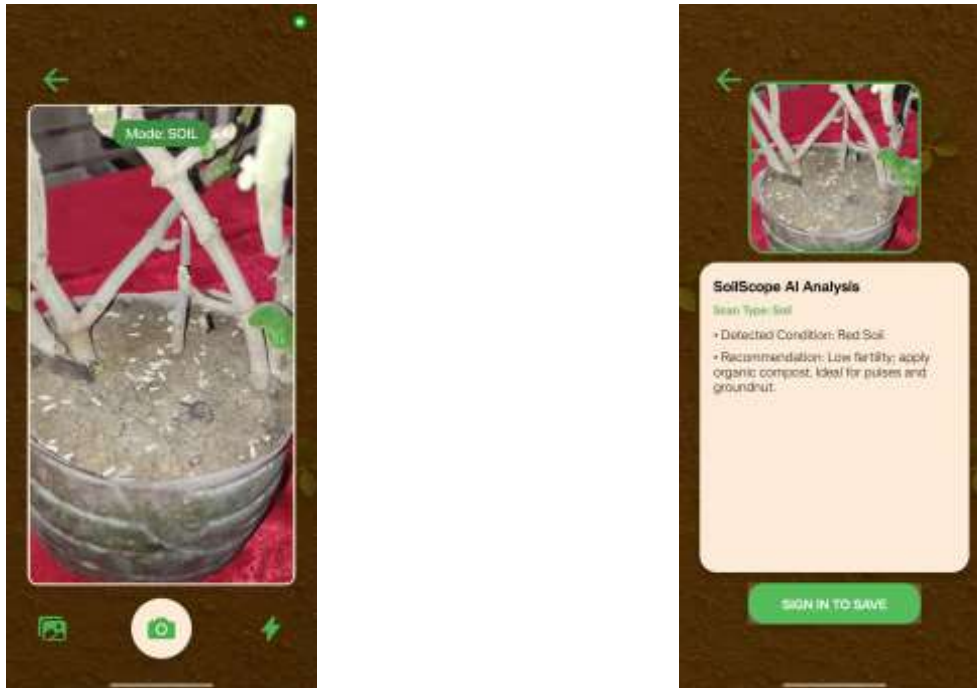
Additionally, the application includes an AI-powered chatbot accessible from the main navigation, powered by the Google Gemini large language model API, which provides users with conversational support, explanations of analysis results, plant care guidance, and sustainable farming recommendations, enhancing both the educational value and practical usability of the system.

Figure 3. Landing Screen of the System (Guest Mode and Logged-In Mode)



The landing screen of the SoilScope mobile application features a clean and intuitive interface designed for immediate use, allowing users to access core functionalities without requiring authentication. Upon launch, users are presented with key features such as Instant Analysis, AI Diagnostics, and Track Progress, along with a prominently displayed “How to use?” button that provides a built-in tutorial for first-time users. The central camera button directs users to a specialized camera mode based on their selected analysis.

Figure 4. Camera Capture and Analysis Result Workflow



The camera capture and analysis feature in SoilScope allows users to take or upload soil images through a dedicated screen accessed from the landing page. A live camera preview with upload and flashlight options supports accurate image capture, followed by a confirmation step before analysis. The result screen displays the captured image with AI-generated soil diagnostics and care recommendations, while saving options adapt to user status by prompting guests to sign in and allowing logged-in users to store results in their dashboard.

System Usability Scale (SUS) Results

The evaluation of system usability revealed that end-users generally found the SoilScope mobile application intuitive, efficient, and supportive of their agricultural tasks. Key features such as image-based soil analysis, disease detection, and sustainability recommendations were rated highly for ease of use, integration, and accuracy. Respondents indicated that the system was easy to navigate (Mean = 3.84, Very High) and that most users would learn to use it quickly (Mean = 3.90, Very High). The application's ability to correctly identify soil type based on uploaded images also received strong ratings (Mean = 3.78, Very High), underscoring its functional reliability. While some participants noted minor complexity (Mean = 2.22, Low) and occasional inconsistency (Mean = 2.52, High), overall perceptions suggested that these issues did not significantly hinder usability. These findings affirm that SoilScope meets user expectations for usability and supports effective adoption in agricultural contexts.

Table 1 System Usability Scale Results

System Usability Statement	Mean	SD	Verbal Interpretation
I think that I would like to use this system frequently.	3.74	0.60	High

I found the system unnecessarily complex.	2.22	0.89	Low
I thought the system was easy to use.	3.84	0.55	Very High
I think that I would need the support of a technical person to be able to use this system.	2.62	0.95	High
I found the various functions in this system were well integrated.	3.68	0.59	High
I thought there was too much inconsistency in this system.	2.52	0.89	High
I would imagine that most people would learn to use this system very quickly.	3.90	0.36	Very High
I found the system very cumbersome to use.	2.20	0.88	Low
I needed to learn a lot of things before I could get going with this system.	2.60	0.90	High
The app correctly identified the soil type based on the image I provided.	3.78	0.51	Very High
Final Grand Mean	3.31		Very High

Table 1 shows that SoilScope achieved a final grand mean of 3.31, interpreted as Very High, indicating that end-users found the application to be intuitive, easy to navigate, and effective in supporting soil analysis and disease detection tasks. Items reflecting ease of use and learning speed obtained the highest ratings, while items on complexity and cumbersome received lower scores, suggesting that the application maintains an accessible and user-friendly experience overall.

ISO 25010 Framework Results

The ISO/IEC 25010 evaluation of SoilScope, conducted by five information technology experts, assessed nine technical attributes: functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, safety, maintainability, and flexibility, using structured checklists. Results consistently showed High to Very High ratings, confirming that SoilScope delivers accurate soil classification, supports agronomic decision-making, and performs efficiently across Android devices with minimal lag and optimized resource use. The interface was rated highly intuitive and accessible, enabling smooth navigation and minimizing user errors, though onboarding support was noted as an area for improvement. Reliability and security were strong, with stable operations and effective data protection, although recovery from crashes scored lower, suggesting enhancements in continuity features. Safety and maintainability were also rated highly, reflecting responsible design and modular architecture that supports updates and scalability. Flexibility was acceptable overall, with strong scalability and ease of installation, though evaluators indicated it should complement rather than fully replace traditional soil assessment

methods. Collectively, these findings demonstrate SoilScope's robustness, usability, and readiness for real-world agricultural deployment, while highlighting targeted areas for refinement.

Table 2 ISO 25010 Framework Results Summary

ISO 25010 Framework Criteria	Mean	Verbal Interpretation
Functional Suitability	3.07	High
Performance Efficiency	3.33	Very High
Compatibility	3.00	High
Interaction Capability	3.55	Very High
Reliability	2.93	High
Security	3.33	Very High
Maintainability	3.13	High
Flexibility	3.00	High
Safety	3.28	Very High
Final Grand Mean	3.18	High

Table 2 indicates that SoilScope achieved a final grand mean of 3.18, interpreted as High, across all ISO/IEC 25010 quality characteristics. Performance efficiency, interaction capability, security, and safety received Very High ratings, while functional suitability, compatibility, reliability, maintainability, and flexibility were rated High. The low standard deviation values across all criteria reflect strong agreement among the expert evaluators, confirming that SoilScope meets recognized software quality standards and is technically suitable for real-world agricultural deployment.

Conclusion and Recommendations

Conclusion

This study successfully designed, developed, and evaluated SoilScope, an AI-powered mobile application for soil analysis and disease detection, achieving its objectives of system development, user adoption, and performance evaluation. The application uses real-time soil image classification, an AI chatbot, and a user dashboard to provide context-based recommendations validated by experts and users. Its design effectively promotes sustainable practices and engagement. With approximately 94% accuracy, strong usability, and high ratings in functionality, performance, security, and safety, SoilScope is ready for real-world deployment as a reliable and user-friendly decision-support tool for sustainable agriculture.

Recommendations

Several enhancements are recommended to strengthen SoilScope's usability and impact. Integration of localized weather data and crop-based recommendations is suggested to support planting schedules and

farm management, while expansion of region-specific soil datasets is advised to improve AI accuracy. The addition of in-application guides on soil conditioning, composting, and organic fertilizer use is recommended to promote sustainable practices, alongside features for generating seasonal soil health reports to aid long-term management. Continuous improvement of the AI model through diverse, validated datasets and field testing is advised, as well as enhancement of dataset quality with high-resolution images to ensure diagnostic reliability. Technical refinements such as robust error handling for non-soil inputs, improved session stability, and expanded compatibility with iOS and other devices are also recommended to optimize user experience and broaden accessibility.

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References

1. Eekhout J.P.C., et al., “Global Impact of Climate Change on Soil Erosion and Potential for Adaptation”, *Earth-Science Reviews*, 2022, 230, 104107. <https://doi.org/10.1016/j.earscirev.2022.104107>
2. Food and Agriculture Organization of the United Nations, “Climate Change and Land & Water”, FAO, 2023. <https://www.fao.org/land-water/overview/climate-change/en/>
3. Watts J., “Land Degradation Expanding by 1m Sq Km a Year, Study Shows”, *The Guardian*, December 2024. <https://www.theguardian.com/environment/2024/dec/01/land-degradation-expanding-by-1m-sq-km-a-year-study-shows>
4. Walling M., “Earth's Storage of Water in Soil, Lakes and Rivers is Dwindling. And It's Especially Bad for Farming”, *AP News*, March 2025. <https://apnews.com/article/climate-change-agriculture-soils-water-overuse-09bd84d7f5f029c4519b7eca93a061bd>
5. Intergovernmental Panel on Climate Change, “Chapter 4: Land Degradation”, *Special Report on Climate Change and Land*, IPCC, 2019. <https://www.ipcc.ch/srccl/chapter/chapter-4/>
6. Statista Research Department, “Mobile Phone Users Philippines 2021–2029”, Statista, 2025. <https://www.statista.com/forecasts/558756/number-of-mobile-internet-user-in-the-philippines>
7. Schwaber K., Sutherland J., “The Scrum Guide”, 2020. <https://scrumguides.org/scrum-guide.html>
8. Nabilla R., Dian Y., Idris I., “Scrum-Based Mobile Application Development for Patient Satisfaction Assessment in Class B Hospitals in Padang”, *The Indonesian Journal of Computer Science*, 2024, 13 (6). <https://doi.org/10.33022/ijcs.v13i6.4506>
9. Wang X., Li S., Li Y., Wang H., “Usability Evaluation of a Mobile-Based Intelligent Irrigation System Using SUS”, *Computers and Electronics in Agriculture*, 2023, 209, 107882. <https://doi.org/10.1016/j.compag.2023.107882>
10. Yoo Y., Park Y., Lim J., “A System Usability Study of a Plant Disease Diagnosis App Using the System Usability Scale”, *Agricultural Systems*, 2022, 195, 103284. <https://doi.org/10.1016/j.agsy.2022.103284>
11. Sharma R., Singh V., “Evaluating Usability of a Soil Fertility Mobile Application for Farmers in India”, *Journal of Rural Studies*, 2021, 84, 90–98. <https://doi.org/10.1016/j.jrurstud.2021.02.004>