CROPTIMIZE: INTEGRATED AGRI-TECH SOLUTION FOR OPTIMIZED FARM LOT UTILIZATION AND RESOURCE MANAGEMENT

Hannah Aizel C. Garcia
Jake Harold B. Roxas
Vianca Dhenise D. Vergara

College of Engineering
First Asia Institute of Technology and Humanities, Tanauan City, Batangas, Philippines
garciahannah823@gmail.com, jhsaxor@gmail.com. viancadhenisev@gmail.com

ABSTRACT

CrOptimize is an integrated agri-tech solution designed to optimize farm lot utilization and resource management by combining geo-tagging, drone surveillance, and soil nutrient monitoring. The system aims to improve agricultural efficiency and sustainability, especially in regions like the Philippines, where food security is a growing concern. Geo-tagging enables accurate measurement of farm areas, ensuring precise seed allocation and minimizing surplus or shortages. Soil nutrient sensors analyze soil composition and guide farmers in selecting suitable crops and planting strategies, enhancing yield potential. Drone surveillance validates seed distribution and continuously monitors crop growth, promoting transparency and accountability in farming practices. This data-driven approach reduces inefficiencies and resource wastage while supporting informed decision-making among farmers and agricultural suppliers. Suppliers also benefit from enhanced supply chain accuracy, enabling better distribution planning and inventory management. Although challenges such as GPS signal limitations, sensor calibration, and drone maintenance may impact deployment, CrOptimize offers a scalable and adaptable framework for modernizing agriculture. By integrating advanced technologies, the system empowers stakeholders to improve productivity and align with global efforts toward sustainable and resilient food systems.

1.0 INTRODUCTION

The issues of food security and food accessibility are the challenges for the global food supply system today, not to mention such factors as conflicts or climate change. Solving these issues demands a collaborative, open, and responsible approach from governments, international organizations, and other relevant partners. There are 222 million populations in 53 nations in acute food insecurity, which means their lives or their means of living are at risk because of a lack of food (Pangetsu, 2022).

The Philippines, as a Southeast Asian, archipelagic country, cannot be exempted from the existing global issues on food security. Agriculture is the backbone of the country, and yet the country cannot feed itself sufficiently in staple foods such as rice, coffee, and animals. Genota (2022) stated that poverty, unfavorable environmental conditions, and inadequate distribution networks have been some of the obstacles that have slowed down the process of achieving food security for its expanding populace. Reflecting these challenges, 44. The FAO's State of Food Security and Nutrition in the World 2023 report, 7% of Filipinos face moderate to severe food insecurity, while the FAO reports 29% of children suffer from stunted growth (Payne, 2024). Poverty is a major factor, with 30% of the population living below the poverty line and 10% eating only once a day (Genota, 2022). Indigenous groups like the Suludnon tribe in Iloilo struggle to cope with climate change, especially those relying on agriculture, often depending on local government aid. Nelson et al. (2019) suggest supporting these communities by preserving traditional, sustainable farming. The Department of Agriculture provides assistance through funding and resources, yet many farmers still face challenges due to soil degradation and nutrient loss. Upland soils often lack nitrogen and phosphorus, and studies show low corn yields when soil pH is around 5.3 with high aluminum toxicity (Rondal, 2004).

The current method of determining the appropriate quantity of seeds for farmers is often inaccurate. Because farmers' field sizes are not adequately measured, suppliers frequently provide incorrect amounts of seeds. This mismatch leads to either a surplus or a deficiency in the seed supply, exacerbating the country's food security and availability issues. Farmers or distributors often sell surplus seeds without approval from relevant government bodies or suppliers, such as the Department of Agriculture of Tanauan City.

Lack of transparency and accountability in the distribution of agricultural inputs worsens supply constraints, impacting food security. Geotagging can assist regional Departments of Agriculture by using satellite imagery, AI, and big data to generate actionable insights (Sahoo, 2022). It embeds geographic metadata—like latitude and longitude into digital media, especially photos taken by GPS-enabled devices, via EXIF data (GIS Geography, 2024). GPS modules with built-in geotagging help identify precise user coordinates, aiding in location-based monitoring and decision-making.

Drones play a vital role in crop monitoring by capturing aerial imagery and real-time data. Equipped with image processing technology, they can identify crop types, assess plant health, and detect issues like pests or water stress. High-resolution images and videos support accurate crop counts and efficient monitoring, helping optimize yields and resource use. Integrating drones offers a comprehensive field view and supports data-driven decisions for farmers and agricultural agencies.

1.1 Objective of the Project

This project aims to design an integrated agricultural management system that utilizes technologies to optimize farming practices, monitor crop yields, and ensure data-driven transparency and accountability in the agricultural supply chain.

- Utilize geo-tagging to measure the size of the farm and determine the optimal amount of seeds needed.
- Incorporate soil sensing to determine soil nutrients for specific farm conditions.
- To validate the planting of seeds using drone cameras, ensuring that the seeds planted match the quantity of seeds distributed and confirming proper utilization and planting.
- Develop a framework for testing and evaluating the system's effectiveness through measurable metrics, ensuring the success and reliability of agricultural processes.

1.1.1 Scope and Limitation of the Project

The research project has created an agricultural management system designed to enhance seed distribution and crop monitoring efficiency and transparency. This system integrates geo-tagging, drone technology, and soil nutrient analysis to address critical issues in agriculture, such as seed allocation, effective crop monitoring, and soil health assessment. The following considerations and limitations have been identified and are detailed as they emerged throughout the development process:

Machine Learning. It is a field of artificial intelligence that focuses on making it possible for computer systems to learn from data and develop without explicit programming. Various domains, including image identification and predictive analytics, also use it.

GPS Device Limitations. GPS modules typically do not work indoors since they cannot receive satellite signals. When powered on, GPS modules can take some time (seconds to minutes) to acquire satellite signals and determine the initial position, known as Time to First Fix (TTFF).

ESP 32 Limitations. The ESP32 needs cellular data to transfer data directly to Google Sheets. It cannot transfer data to the database in farm areas without cellular signals.

Drone Camera Limitations. While effective for capturing aerial imagery and monitoring crops, drone cameras can encounter difficulties in adverse weather conditions, such as rain or low clouds, which may obscure views and affect image quality. Regular maintenance and calibration of drones are also required to ensure data collection.

Soil Nutrient Sensor Limitations. Soil nutrient sensors, including NPK sensors, need frequent maintenance and calibration to provide readings. These sensors typically measure only the top few centimeters of soil, potentially missing nutrient variations at deeper soil levels.

Implementation Constraints. The system's successful implementation may depend on factors such as resource availability, technical expertise, and organizational support. Time constraints, budget limitations, and farmer cooperation could also affect the feasibility and scope of the project.

2.0 REVIEW OF RELATED WORK

Soil Nutrients Monitoring

Advancements in precision agriculture, especially real-time soil nutrient sensing are improving farming practices. Optical and electrochemical sensors provide accurate, real-time nutrient data, helping farmers optimize productivity and reduce environmental impact. While some technologies are already commercially available, challenges like soil variability and high costs remain barriers to widespread adoption (Burton et al., 2020).

Monitoring soil nutrients is essential for the progress of modern agriculture. Assessing soil nutrient levels is crucial for developing systematic and informed fertilization plans. These plans enhance crop growth and yield while maintaining soil health. This review offers a thorough overview of current soil nutrient analysis techniques, focusing mainly on laboratory methods, spectroscopy approaches, and electrochemical techniques (Yuan et al., 2023).

IoT-based soil monitoring systems have become quite popular in recent years. These systems use moisture, pH, and nutrient sensors to gather real-time information about soil conditions. The collected data is then utilized to optimize irrigation and fertilizer, leading to better crop yields and more efficient water usage (Islam et al., 2023).

Geo-Tagging

Geo-tagging can significantly improve food security and agricultural resource distribution in the Philippines. Farmers can use GPS devices to map farmland, including soil type, crop population, and nutrient levels (Techurate, 2023). It also enhances accountability by tracking seed distribution and estimating optimal seed quantity per hectare using systems like Google Earth. This ensures accurate seed allocation, preventing shortages or excess and boosting productivity.

GPS Module

GPS Modules offer a reliable solution for geo-tagging in agricultural applications. Unlike smartphones, which rely on cellular networks for location data and can be less reliable in remote areas, the GPS Module provides robust and consistent satellite-based positioning, as RewireSecurity (2019) stated in their article. According to research by Singh S. (2024), GPS is crucial for achieving precision farming, enabling various applications such as farm planning, field mapping, soil sampling, crop scouting, and yield mapping.

Drone

Drones have been quite essential in the agriculture sector. As stated by Travelers in their article (2020), drones have become a valuable asset in agriculture, offering extensive and high-resolution imagery for comprehensive crop and livestock monitoring, thereby facilitating more detailed data collection. In another article by Crop tracker (2024), they stated that the data gathered from drones surveying fields assists farmers in planning their planting and treatment strategies to maximize yields. Some studies suggest that implementing precision farming systems can boost yields by up to 5%, a significant improvement in an industry known for its narrow profit margins.

3.0 METHODOLOGY

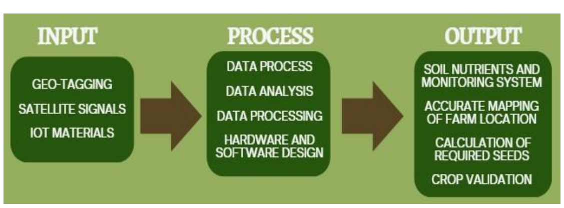


Fig. 1. Conceptual Framework

This conceptual framework applies technology to improve agricultural accountability through three components: Input, Process, and Output. In the Input stage, geo-tagging identifies specific field areas and distinguishes soil conditions. NPK sensors measure soil nutrient levels such as nitrogen (N), phosphorus (P), and potassium (K) while drones provide imagery of crop placement and condition. The Process stage involves collecting, analyzing, and refining this data: geo-tagged data supports field mapping, drone images help validate crop counts, and sensor data assesses soil health. In the Output stage, results include a Soil Nutrients Monitoring System to guide fertilization, Farm Mapping for better planning, and Crop Count Validation through drone imagery. Together, these support smarter and more transparent agricultural decision-making.

In summary, the CrOptimize framework integrates geo-tagging, drone camera, and soil nutrient monitoring to collect and process data, resulting in outputs that optimize seed requirements and validate crop counts. This comprehensive approach enhances farm management, ensuring better productivity and efficient resource utilization.

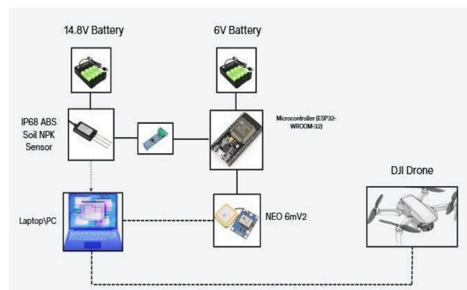


Fig. 2. Block Diagram

Fig. 2 illustrates the hardware system of the project, developed to monitor soil health and provide comprehensive mapping for agricultural management. The system is powered by a 14.8V battery for the IP68 ABS Soil NPK Sensor and a 6V battery for the ESP32-WROOM-32 microcontroller and supporting components. The soil sensor measures key nutrients—nitrogen (N), phosphorus (P), and potassium (K) with data transferred via an RS485-to-TTL converter, which ensures compatibility between the sensor's RS485 output and the microcontroller's TTL input. The ESP32 processes this data and communicates it wirelessly to a laptop or PC, where it is visualized and analyzed. A NEO 6mV2 GPS module records the geographic coordinates of each soil sample, while a DJI Drone is utilized to determine the number of crops in the area. This integrated system supports efficient soil monitoring and crop management.

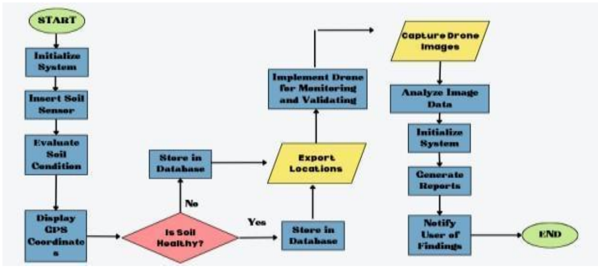


Fig. 3. Flow Chart

Figure 3 shows the CrOptimize system's workflow, combining soil health evaluation and crop monitoring to improve agricultural decisions. After system initialization, the soil sensor measures nutrient levels to assess soil health. If the soil is healthy, GPS coordinates are displayed and saved; if not, the data is logged for further analysis. Simultaneously, a drone captures aerial images to count crops and validate conditions. The system analyzes this data and generates a combined report, notifying the user with actionable insights for better farm management. This process enables efficient data collection, analysis, and reporting to optimize agriculture.

4.0 DATA AND RESULTS

Fig. 4. Prototype Setup (*Hardware*)

The prototype follows a systematic process for soil data collection and location mapping. The GPS module is activated 15 minutes prior to stabilize and acquire accurate coordinates. Once stable, the soil sensor is powered on and inserted into the soil. Nutrient data appears on the LCD screen within seconds. The user then presses one button to upload GPS data and another to send soil sensor data to the database. This ensures both soil conditions and precise locations are logged for future analysis.

NPK SOIL SENSOR

12	12/14/2024 12:53:	NPK_Device_001	50	20	112	Healthy
13	12/14/2024 12:53:	NPK_Device_001	35	15	105	Healthy
14	12/14/2024 12:53:	NPK_Device_001	35	17	125	Healthy
15	12/14/2024 12:53:	NPK_Device_001	40	13	107	Healthy
16	12/14/2024 12:53:	NPK_Device_001	45	18	102	Healthy

Fig. 5. Compact Soil

In figure 5, the sensor has consistent readings for nutrient levels. Compact soil retained higher moisture and nutrient readings, which aligns with expected outcomes in farm conditions.

1	Time Stamp	Nitrogen	Phosphorus	Potassium	Soil Status	Column 1
2	12/14/2024 12:52:	NPK_Device_001	39	39	55	Unhealthy
3	12/14/2024 12:52:	NPK_Device_001	111	39	55	Healthy
4	12/14/2024 12:52:	NPK_Device_001	111	39	55	Healthy
5	12/14/2024 12:52:	NPK_Device_001	111	39	55	Healthy
6	12/14/2024 12:53:	NPK_Device_001	40	40	56	Unhealthy

Fig. 6. Dry Soil

In figure 6, the sensor effectively identified nutrient deficiencies due to the lack of moisture. Readings were slightly inconsistent, highlighting the need for calibration to address lower conductivity.

7	12/14/2024 12:53:	NPK_Device_001	0	0	0	Unhealthy
8	12/14/2024 12:53:	NPK_Device_001	0	0	0	Unhealthy
9	12/14/2024 12:53:	NPK_Device_001	0	0	0	Unhealthy
10	12/14/2024 12:53:	NPK_Device_001	0	0	0	Unhealthy
11	12/14/2024 12:53:	NPK_Device_001	0	0	0	Unhealthy

Fig. 7. Rocky Soil

In figure 7, frequent errors occurred due to uneven contact with the soil surface. Nutrient readings were inaccurate, likely caused by limited soil-to-sensor contact. This condition was flagged as unsuitable for farming due to insufficient nutrients and poor soil structure.

GPS MODULE

The GPS module was tested in various applications to evaluate its performance and reliability in different scenarios. The results are summarized below:

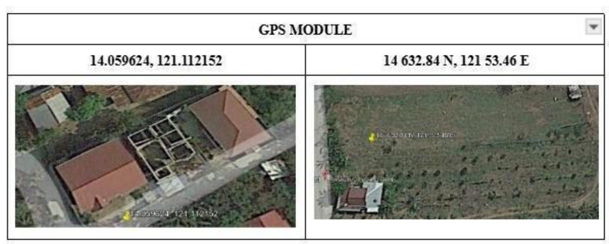
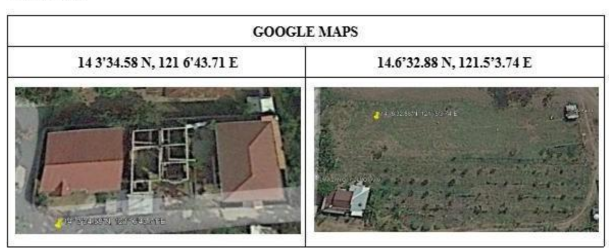


Fig. 8. GPS Module NEO6M-V2

Google Maps



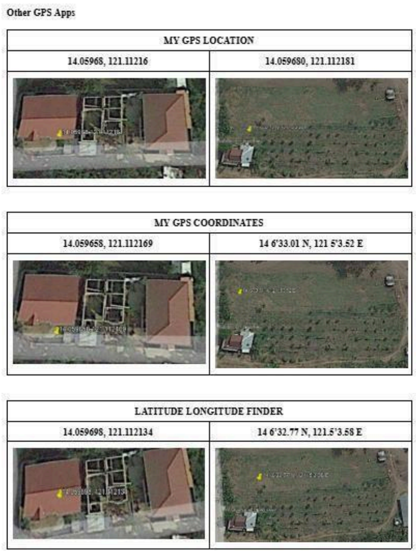


Fig. 9. Other GPS Maps

Figures 8 and 9 show the initial results of the GPS accuracy test. The GPS Module provided the most accurate coordinates after Google Maps, while tools like Latitude Longitude Finder were the least accurate. This suggests the GPS Module is reliable for geolocation tasks. The test also showed that GPS accuracy improves in clear weather and open spaces, while urban areas with tall buildings and foliage reduce precision. Variations in signal strength and satellite connectivity across devices were also noted, highlighting the need for further testing in diverse conditions to assess the module's performance fully.

CROP VALIDATION

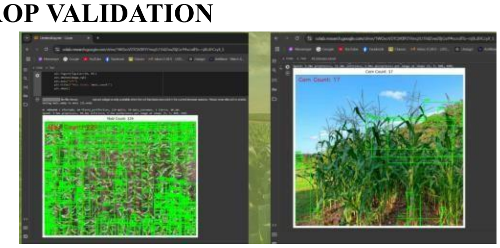


Fig. 10. Corn Count

Fig. 11. Rice and Papaya Count

Figures 10 and 11 showcase the result of our object detection model, specifically designed for crop counting. The visual output highlights the detection of crops within the input image, with bounding boxes marking each detected object.

5.0 CONCLUSION

CrOptimize introduces an integrated agri-tech solution to enhance farm lot utilization and resource management in the Philippines. It addresses critical challenges such as food security, inefficient resource allocation, and a lack of transparency in agricultural practices. Leveraging technologies like geo-tagging, drone imagery, soil nutrient sensors, and IoT frameworks, CrOptimize seeks to modernize agriculture through precision farming. Geo-tagging aids in determining accurate farm sizes and optimizing seed distribution, while soil sensors assess soil health to guide fertilization strategies. Drone technology and high-resolution imagery validate crop counts and monitor field conditions. These components are integrated using the ESP32 microcontroller, which processes and transmits real-time data to enable data-driven decisions. The prototype demonstrated the system's capacity to streamline farming practices, improve transparency, and enhance crop yields.

6.0 RECOMMENDATIONS

The study recommends piloting CrOptimize in diverse agricultural settings to evaluate scalability and adaptability. Collaboration with government and farming groups is vital for wider adoption. Improving drone resilience in bad weather and integrating advanced AI like YOLOv8 can boost crop monitoring accuracy. Farmer education through workshops and ongoing support will enhance system use and understanding. Incorporating blockchain could improve supply chain traceability, while renewable energy may power IoT devices in remote areas. Cost reduction of hardware is key to accessibility for small-scale farmers. Additionally, designing CrOptimize as an unmanned, wheeled prototype will enable efficient, low-intervention operation. These steps will strengthen CrOptimize's impact on modern agricultural challenges.

7.0 ACKNOWLEDGMENT

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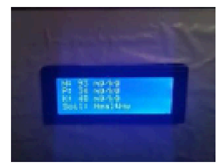
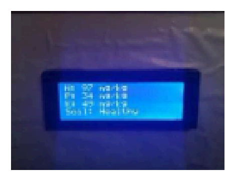
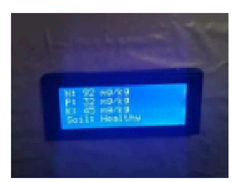
9.0 ABOUT THE AUTHORS

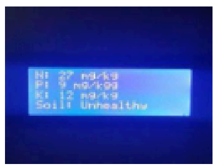
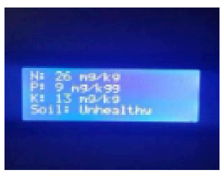
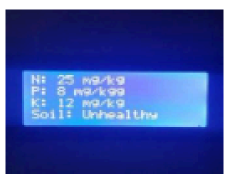
Studying at FAITH Colleges in Tanauan City, Batangas, Philippines, the authors are in their final year of Electronics Engineering and Computer Engineering programs. Their academic path has strengthened their expertise in engineering fundamentals, research methodologies, and applied technologies, preparing them to contribute to technological advancements in the future.

10.0 APPENDIX

Appendix A - Dry Soil NPK Parameters

Dry Soil	
Trials	**Values**
1st	
2nd	
3rd	
4th	
5th	

Appendix B - Compact Soil NPK Parameters

Compact Soil	
Trials	**Values**
1st	
2nd	
3rd	
4th	
5th	

Appendix C - Rocky Soil NPK Parameters

Rocky Soil	
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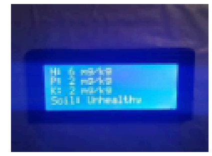
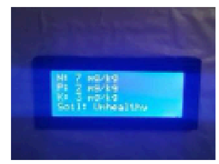
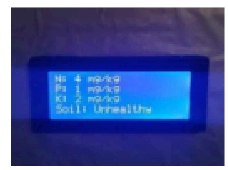
1st	
2nd	
3rd	
4th	
5th