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Redesigning the Future of Farmland Management: The Precision FarmTrac Framework

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Abstract – Farmland management in the agricultural sector involves a number of planning and decision-making responsibilities, such as providing farmers with information, selecting crops, and maintaining farmers' land. Agriculture holds significant importance in the development and progress of a country. Challenges in the agriculture sector constantly limit a country's progress. The answer to addressing these difficulties is to improve traditional farmland management and adopt precision agriculture approaches. To address this challenge, a precision agriculture framework for farmland management is proposed. The Precision FarmTrac framework was designed based on interviews with the Department of Agriculture office, as well as data provided from document analysis and observations. The proposed framework shall assist the Department of Agriculture in monitoring farmers' farmland management. The proposed framework shall be well-suited to effectively oversee and monitor farmers' farmland, enhancing traditional land management practices, monitoring crop growth, and ensuring equitable distribution of benefits among farmers and stakeholders. As a result, the Precision FarmTrac framework becomes an essential tool for transforming the future of agriculture by increasing productivity, and maintaining the sustainable development of farmland resources. This framework can be used by the department of agriculture to facilitate the dissemination of information to various agricultural sectors and farmers, allowing for more efficient and effective farmer's and farmland monitoring.

Keywords *– Farmer Management, Farmland Mapping, Framework, Precision Agriculture, Image Processing, Rice Crop*

I. Introduction

Access to up-to-date and reliable data on farm activities is critical in modern agricultural production. To fulfill this demand, farms are increasingly using digital technologies such as sensors, monitoring devices, and advanced analytics, as well as smart equipment [1]. The agricultural landscape is rapidly shifting toward intelligent farming systems, fueled by the rapid expansion of technologies such as Internet of Things (IoT), robotics, big data analytics, machine learning, and augmented reality [2], [3]. In the Philippines, the department of agriculture in Nueva Ecija is still adjusting to technological trends and persistently adopting the growing modernization of agriculture. This technological advancement enables farmers, stakeholders, including the government, to engage in effective and sustainable agriculture. The Department of Agriculture (DA) and other agricultural agencies in the Philippines continue to rely on traditional methods for farmer and farmland management monitoring and control. Employing manual labor for farmer registration and monitoring of their farmland is essential for accessing benefits provided by the Department of Agriculture, including additional support such as crops, fertilizers, and government cash assistance.

Traditional farmland management often relies on accumulated knowledge passed down through generations and is heavily influenced by local customs, cultural practices, and environmental factors. Many traditional farming methods require significant manual labor, which can be time-consuming, labor-intensive, and costly [4]. Traditional farming methods have become inefficient and are unable to meet the growing demand for food production. The agricultural sector must modernize and adopt technology to address these challenges. The Department of Agriculture addresses this issue by combining farmland management and precision agriculture techniques. Precision agriculture, an evolving paradigm in agricultural research, leverages advanced technologies to transform farming practices [5]. By integrating cutting-edge tools such as satellite imagery, global positioning system (GPS), and sensor technology, precision agriculture aims to enhance crop productivity, minimize resource utilization, and mitigate environmental impact [6]. These tools enable the department of agriculture and farmers to collect vast amounts of data on various aspects of their operations, including soil health, crop growth, weather conditions, and equipment performance. This revolutionary method shows potential for increasing agricultural productivity while promoting sustainability in the face of changing global problems [7]. Simultaneously,

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both farmer monitoring and farmland management have emerged as valuable tools for tracking and analyzing farm activities in real time. These systems use sensors, cameras, and other monitoring equipment to collect data on important factors including crop health, water usage, and pest infestations. Department of agriculture and stakeholders can obtain important insights into their operations, detect trends, and make data-driven decisions to improve productivity and profitability by gathering and analyzing this information [8].

In [9], the authors emphasized the growing interest in precision agriculture techniques and technologies, highlighting their potential to transform conventional farming methods. The study focuses into several techniques designed to improve the efficiency and sustainability of farming activities. Wireless sensors and unmanned aerial vehicles (UAVs) play integral roles in precision agriculture, enabling the monitoring, control, and data collection necessary for analyzing various activities within farmland. Nandurkar et al. [10], the authors proposed a cost-effective and efficient wireless sensor network technique designed to acquire soil moisture and temperature data from multiple locations within a farm. Based on this data, the crop controller can determine when to activate or deactivate irrigation as needed. In [11], the authors examine and explore the current trends in employing drones within agribusiness and precision farming. It highlights the growing necessity for data derived from unmanned aerial systems, particularly for aerial photography, due to satellite observations often failing to meet the diverse needs of users across various regions. IoT-enabled devices can also contribute to irrigation, an essential component of agriculture known as precision irrigation, aiding farmers in efficiently watering their crops as outlined in [12]. The application of remote sensing with satellite images to monitor agricultural land, including paddy fields, can be an essential part of sustainable agricultural development aimed at increasing farmer and stakeholder productivity. Nguyen et al. [13], authors proposed an innovative approach to multi-temporal high-spatial resolution classification using an advanced spatio - temporal-spectral deep neural network. The method aims to identify paddy fields at the pixel level throughout the entire year and at each temporal instance.

In the field of remote sensing and wireless network sensors the application of deep learning algorithm model increases the accuracy results of the datasets [14]. Some research suggests that deep learning has surpassed traditional methods in remote sensing performance [15]. The most commonly used deep learning model for image processing is the Convolutional Neural Network (CNN) it provides high accuracy rate in terms of image classification [16]. In [17], the author develop an automated method for the recognition of agricultural land boundaries with the use of CNN, using the method improves the speed and ability to detect patterns outside the study area. Nowakowski et al. [13] introduced a method employing CNN as the image classifier for farm mapping, incorporating transfer learning. The outcomes demonstrate significant accuracy in image classification.

The paper presents a framework designed for the Department of Agriculture to enhance the management of farmers' farmland, that includes control, monitoring, supervision, and decision-making. This proposed framework enables efficient monitoring of all registered farmers within the system and facilitates the controlled distribution of seeds and benefits such as fertilizers and cash allowances. The Precision Farmtrac framework also integrates satellite imagery of farmers' farmland, enabling the Department of Agriculture to monitor agricultural land and crops of every farmer. This contributed to the sustainable agricultural development of the Philippines.

II. METHODOLOGY

This section discusses the creation of the proposed framework for farm management, which incorporates farm mapping in aerial images. It also outlines the steps involved in data collecting and processing, as well as the accuracy assessment of farm mapping. The proposed framework was developed using a qualitative research design, with the objective of investigating the present issues and challenges related to farm management in Nueva Ecija province, specifically under the Local Government Unit of Science City of Muñoz and the Department of Agriculture. Moreover, relevant articles pertaining to the study were examined to broaden the understanding of precision agriculture in farm management.

A. Study area and data acquisition

As shown in figure 1, this study was conducted in Science City of Muñoz, located in Nueva Ecija, Central Luzon Philippines. Known as the “Rice granary of the Philippines” because of its agricultural area. Nueva Ecija is the largest province and rice producer in Central Luzon, with a total land area of 318,284 hectares, predominantly dedicated to rice production [18].

The initial step of data collection relies on interviews conducted with officials from the Department of Agriculture and selected farmers with their relevant functions that covers the scope of the study. Additionally, data are sourced from document analysis and observations made within the office. The next step involves gathering data from remote sensing, which uses satellite imagery of the farmland belonging to registered farmers within the designated study area.

Fig 1. An overview of the study area using satellite imagery from Google Maps.

B. *Data processing*

1) *Satellite data and pre-processing*

First the images of the farmers' farmland were obtained using drones, which are unmanned aerial vehicles (UAVs) designed to capture image data from each farmer's land [19], [20]. Second, image processing of the collected images is conducted, employing Convolutional Neural Network (CNN), a deep learning algorithm utilized for image classification [21]. The pre-processing of the datasets includes training and testing data. This technique tries to determine the area of the farmer's farmland. Mapping the farmland will enable the DA officer to pinpoint the precise location of each farmer's land, facilitating effective management of the system.

C. *Farm Map*

The Farm Map's accuracy assessment is based on the deep learning CNN algorithm model's overall classification accuracy [22]. Following image processing, the image shall identify as farmland. This map shall assist the Department of Agriculture in monitoring and tracking the farmland of all registered farmers.

III. Result and Discussion

In this section, we examine the key components of the FarmTrac farmland management framework and discuss their implications for sustainable agriculture. Our approach is designed to address the challenges facing modern agriculture in the Philippines. The framework optimizes farmland management techniques in the Department of Agriculture, Science City of Muñoz, Nueva Ecija.

A. *Proposed FarmTrac Framework*

The architectural framework depicted in Figure 2 outlines the phases of the farm management system, managing both the farm mapping process and the execution of other components. The framework comprises four major components which shall aid the Department Agriculture in effectively managing all the farmers and their farmland within the study area. This framework aims to offer improved guidance for both the Department of Agriculture and farmers.

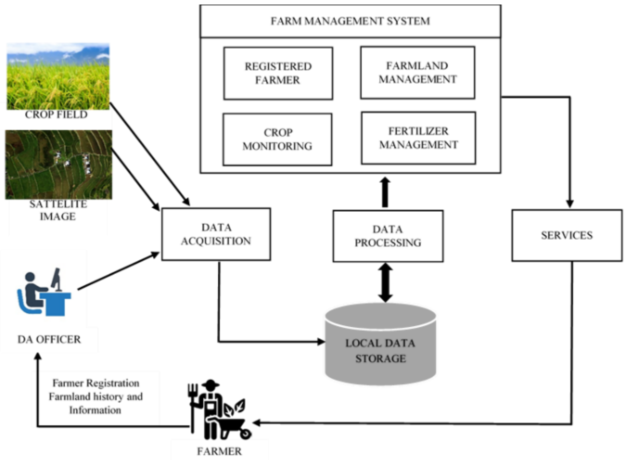

Fig 2. The Proposed Architectural Framework of the FarmTrac Management System

The proposed framework is designed for use by DA officers as system users. The traditional farmer registration method takes too long since DA officers must perform manual tasks after conducting interviews with farmers. Farmers shall provide information including the area and size of their farm with other requirements upon registration. The process of gathering all the information about the farmers is conducted manually using pen and paper. The proposed framework should deliver outstanding services to farmers. Digitizing the process is expected to significantly impact the services received by farmers from the Department of Agriculture. The farmtrac farm management system has four components: registered farmer, farmland management, crop monitoring, and fertilizer management.

1) Registered farmer. This module encompasses all farmers to be registered in the system. It shall include all the information of the farmer and their farmland and shall be stored in the database. The objective of this module is to enable the assigned DA officers to monitor and track all farmers within the study area. Based on the interview, this should significantly aid the DA officers, especially considering they currently rely solely on manual forms for monitoring their farmers. The digitization of agriculture supports real-time decision-making and agricultural advancement [23].

2) Farmland Management. According to the interview, once farmers are registered, they are entitled to benefits provided by the Department of Agriculture. All forms related to the distribution of benefits to farmers are manually distributed to all DA officers, who then facilitate distribution to the farmers. The module shall include monitoring and tracking farmers who are registered and have received assistance from the Department of Agriculture. This module grants access to various benefits, including cash assistance and the historical records of farmers' farmland. Management should increase agricultural production [24].

3) Crop Monitoring. Based on the interview, crops that are given to the farmers are based on the farming season (dry and wet season) in the province. Crop distribution to farmers is carried out via manual forms, which include the farmer's name and the size of their farmland. This module shall enable DA officers to access information regarding the distribution of crops to registered farmers within the system. It generated reports detailing the types of crops allocated to farmers, with the quantity of crops determined according to the size of their farmland. Using new agricultural technology for crop monitoring improves farm operations [25].

4) Fertilizer Management. According to the interview, every registered farmer is eligible to receive fertilizers from the DA, with the allocation determined by the size of their farmland. Fertilizer distribution to farmers is conducted by reviewing manual forms containing the list of registered farmers. This module can be used by the DA officers to monitor and track the distribution of fertilizers to farmers. The module shall cover fertilizer types, allocated amounts, and the most suitable option for the current season. Adoption of this technique has had positive results, with some studies indicating cost efficiency and greater agricultural yields [24].

B. Farm Map Validation

Initial testing of the Farm Map involved the use of satellite imagery for image classification to detect the farmland area of every registered farmer in the system. Image processing was conducted using the CNN algorithm model to identify the farmland location of each farmer registered in the system. The accuracy was tested by assessing the image classification results of the farm map [22]. Figure 3 and Figure 4 depicts the outcome of testing the accuracy of image classification using the CNN algorithm model to identify farmland area. In Figure 3, the outcome showed an 80% similarity, indicating successful identification of the image as farmland, whereas in Figure 4, another image classification test yielded a 90% similarity.

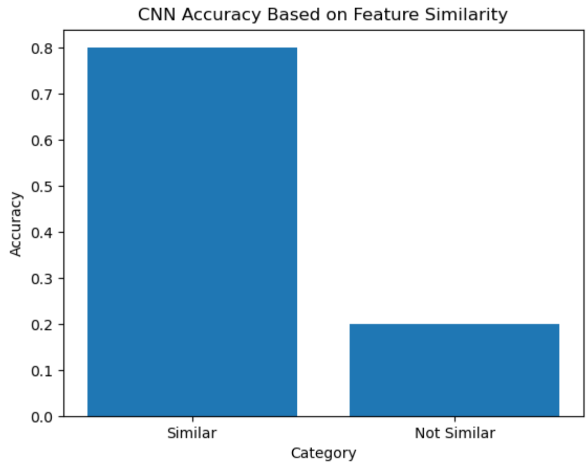

Fig 3. Test result of the image classification using CNN algorithm model with 80 percent similarity of the farmland.

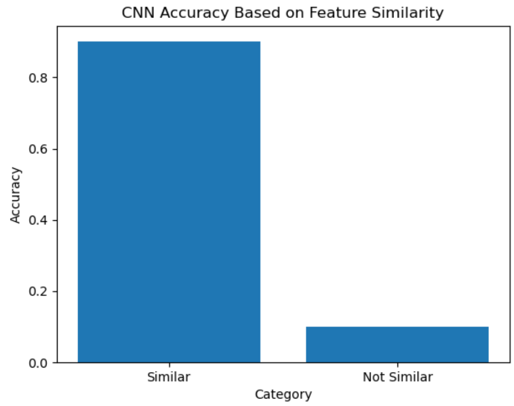

Fig 4. Test result of the image classification using CNN algorithm model with 90 percent similarity of the farmland.

The farm mapping also includes the identification of the farmland location of every registered farmer in the system. Figure 4 depicts the output of the farm map, displaying the farmland images within the study area and the testing location.

Fig 4. Result of farm mapping with farmland location of the farmer.

This study introduces a farmland management framework integrating farmland mapping through remote sensing imagery. The aim is to assist the Department of Agriculture in effectively managing the farmland of all registered farmers in Science City of Muñoz, Nueva Ecija, Philippines. Incorporating farm mapping into the farm management system simplifies agricultural monitoring and tracking, improving precision agriculture. This technique benefits the agriculture industry by increasing productivity and enhancing resource management. Based on the results of farm mapping, the Precision FarmTrac framework can assist in field monitoring and tracking. This proposed framework aims to aid DA officials in more effectively managing and administering the system, thereby providing farmers with robust support from the Department of Agriculture.

IV. Conclusion

The Precision FarmTrac Framework provides an integrated approach for effective farmland management. By combining modern technologies and specialized modules, it enables the department of agriculture to effectively monitor and optimize farm operations together with the farmers. The framework promises to increase agricultural productivity and sustainability by tracking crops, managing fertilizers, and providing vital data.

The researcher suggests forwarding the framework to the regional office of the Department of Agriculture for adaption and to facilitate the dissemination of the system to other local government units in various provinces across the Philippines. Overall, the Precision FarmTrac Framework is an important step toward precision farming and better resource utilization in modern agriculture.

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