Developing Smart Precision Farming Using Big Data and Cloud-Based Intelligent Decision Support System

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Abstract* - *This study discusses the development of smart precision farming systems using big data and cloud-based intelligent decision support systems. Big data plays an important role in collecting, storing, and analyzing large amounts of data from various sources related to agriculture, including data from weather stations, soil sensors, satellite imagery, crop yield records, pest and disease reports, and other sources. This study highlights the differences between smart farming and precision farming. This study describes key techniques and system architecture, including data collection, processing, analysis, and decision support components. Utilizing a cloud platform enables scalability and optimized performance, which lowers costs and makes it safer and easier to manage. The integration of big data and Alibaba cloud computing in smart precision farming can improve farming productivity by providing timely information and recommendations to farmers for better decision-making. Finally, the system produces smart precision farming, which provides cost-effective real-time monitoring and predictive analytics to increase agricultural production and sustainability.

Keywords—smart farming, precision farming, intelligent agent, decision support system, big data, cloud computing

I. INTRODUCTION

Indonesia, as a rapidly developing agricultural country, must have efficient agricultural practices so that it can achieve sustainable industrial growth. The agricultural sector is a key aspect of the Indonesian economy, absorbing the majority of the workforce and contributing significantly to the country's GDP [1]. With a rapidly growing population, Indonesia's land resources are under significant threat, such as land conversion for housing, industry, and mining. In addition, smallholders have tenure problems as they often do not have legal rights to their land. The other issue is that climate change affects Indonesia as well. Inadequate district and village roads, irrigation systems, and storage facilities, for example, might limit farmers' ability to access markets and improve the value of their produce.

Farmers in Indonesia often face challenges in accessing markets due to a lack of market information, limited transportation options, and weak value chain linkages. These factors encourage the Indonesian government to develop sustainable agriculture to be more resilient and inclusive in the near future [2]. The concept envisions a new era of human society that integrates advanced technologies, giving rise to the terms agriculture 4.0, digital farming, smart farming and precision farming, which offer important tools to address agricultural productivity and sustainability [3][4]. By developing and implementing smart precision farming in Indonesia it can contribute to the country's food security and reducing dependence on imported agricultural products. Moreover, smart precision farming can provide new job opportunities and enhance the livelihoods of farmers and agricultural communities.

However, implementing smart precision farming in Indonesia faces challenges such as low adoption rate, high investment costs, limited internet access, and complexity of technology [5]. Collaboration among government agencies, private sector companies, and academic institutions is necessary for successful implementation of smart precision farming in Indonesia, which has been facilitated by the emergence of big data and analytics [6]. We proposed a smart precision farming model that integrates technologies such as drones, sensors, big data analytics, cloud computing, and artificial intelligence (AI). This model aims to optimize farming operations, enhance agricultural productivity, promote sustainability, and minimize environmental impact.

Our objectives are to develop an intelligent decision support system for smart precision farming by empowering big data and cloud computing. This allows for a comprehensive understanding of the farming ecosystem and facilitates data-driven decision-making. This work advances agriculture by proposing and demonstrating a cutting-edge way to combine big data and cloud-based intelligent decision support systems in smart precision farming. The novel big data cloud-based system architecture makes a significant contribution to the field by introducing an innovative approach to handling and analyzing large volumes of agricultural data.

We create system architecture and describe key techniques for Intelligent Agents (IA) using big data in the cloud computing platform as well as the machine learning (ML) platform. By utilizing Alibaba's cloud platform, we can achieve scalability of cloud capacity, optimize performance, enable high-speed data downloading, facilitate parallel data processing, and provide cloud computing analytics and insights. This integrated approach empowers farmers to optimize resource utilization, make better decisions, and ultimately enhance farming production systems regarding soil management, crop management, and water management.

II. RELATED WORK

We do review journal and papers related to our research. We primarily targeted the papers that related to big data and cloud-based platform in the agriculture domain The integration of big data techniques and strategies into agriculture has emerged as a crucial avenue for leveraging data driven decision making tools, securing funding, and enhancing the value proposition of the agricultural sector [7][8]. Additionally, a big data smart agricultural system can recommend optimum fertilizers for crops [9]. This study suggests that digital agriculture utilizing big data analytics can focus on predictive irrigation techniques for smart farming applications in Morocco [10]. The multi-level perspective on socio-technical transitions can provide insights into understanding the complexities of smart farming and big Data in agriculture [11].

This research [12], provided a thorough examination of the possibilities of big data analysis in agriculture to boost production by monitoring the physical environment and extracting value from data. The number of agricultural domain applications that use the combination of Cloud, Fog, and Edge is increasing in the last few decades [13]. This paper [14], assesses the current status of big data solutions in agriculture and identifies the need for additional technology development to address the idiosyncrasies of agricultural application. This study focuses on recommending strategic utilization of agricultural big data like rainfall, temperature, and winds using cloud computing analytics [15]. The paper proposes a design for implementing IoT in agriculture based on cloud computing and a two-tier storage structure of HBase, which provides scalable storage, efficient data access, and eases other processing of sensor data [16].

A multidisciplinary model for smart agriculture with the used of technologies such as IoT, sensors, cloud computing, mobile computing, and big data analysis are purposed in this study [17]. This study [18], employs IoT devices for data sensing, cloud storage for analysis, and a mobile app for farmer communication. This paper [19] proposes a cloud-based system for delivering Agriculture-as-a-Service (AaaS) using cloud and big data technologies. The system uses K-NN (k-Nearest Neighbor) classification mechanism to classify the agriculture data. This study [20], present their design and implementation of an IoT system to tackle limited farmland resources in a growing population. covers cloud platform development, farm-to-cloud connection procedures, and system interaction interfaces. Experimental results and simulations demonstrate the feasibility of the IoT-based monitoring system, cloud computing, data mining, and other technologies for agriculture [21].

This study discusses the development of a cloud-based decision Support and automation system for precision agriculture in orchards [22]. The system can acquire data from various sources, synthesize application-specific decisions, and control field devices from the cloud. This paper [23], suggests using Cloud Service Oriented Architecture (CSoA) for IoT and Big Data in agriculture to enable smart and user-friendly farming. This study [24], presents an automated crop classification workflow based on machine learning techniques to overcome the challenges of big data downloading and processing. Amazon web services (AWS) are used for image processing and advanced classifiers, offering fast access to imagery and powerful computational resources.

This study [25], proposes a cloud computing framework based on Dempster-Shafer theory for determining the optimal location for cultivating orange trees. It enables the mapping of different risk levels at the request of the user who can use different data following environmental conditions. This study [26], introduces big data and cloud computing technologies, including their definitions, characteristics, related technologies, challenges, and development prospects. It also considers knowledge discovery in database (KDD) model rom data to knowledge. The paper [27], presents a cloud platform system for video monitoring function based on motion detection and big data processing using machine learning technology. It includes a RESTful interface service system and utilizes ExtJs and WeChat technologies. The system incorporates a big data processing module using Hadoop and machine learning for crop management solutions.

This paper [28], explores the application of Big Data technologies and algorithms in Smart Farming to manage and monitor data related to Precision Agriculture (PA) and Precision Livestock Farming (PLF). The purpose pipeline for streaming, processing and storage using Apache and visualization with NodeJS and Python. This study [29], proposed system architecture comprises three components: a data pipeline, an advisory system for data analytics, and a data repository, providing significant value for the agricultural sector. The data processing using Apache Casandra and Sparks, while the data analysis and visualization using R.

The paper [30], suggests an environment safety monitoring system for agriculture, utilizing cloud computing, artificial intelligence, and big data networks. It examines data transmission between WSN and cloud nodes, evaluating various algorithms for system performance. This paper conducted a systematic literature review that summarizes the challenges involved in implementing machine learning in agricultural Big Data [31]. A framework is developed that summarizes the main challenges encountered, machine learning techniques, and the leading technologies used.

III. METHODOLOGY

A. Research Method

Our research method has a four-phase approach that is structured and systematic. Phase 1 is doing a literature review for big data analytics in smart precision farming and decision support systems for big data analysis. This phase is critical for gaining a thorough understanding of existing research or related work and identifying any gaps in the literature. Phase 2 is reviewing and identifying the differences between precision farming and smart farming. This step is critical for ensuring that the study is focused on the right topic and identifying any potential problems or constraints.

Phase 3 is identifying the big data pipeline for smart precision farming. This phase is important to understand the flow of data in the system and to identify any potential bottlenecks or areas for improvement. Phase 4 is building system architecture and describing key techniques. This phase is important to develop a practical solution that can be implemented in the real world and to identify any potential challenges or limitations in the implementation process. The research methods are shown in Figure 1.

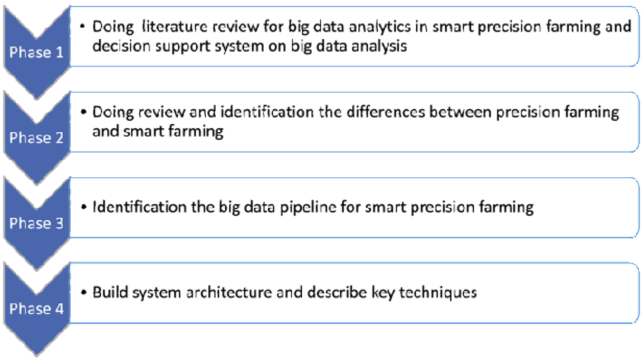

Fig. 1. Research Methodology

B. Smart Precision Farming

We conduct research regarding smart farming and precision farming. This article focuses on a platform strategy for creating smart farming systems that incorporate features like end-to-end security and privacy, interoperability, stability, scalability, real-time data processing, and standard rules and regulations [32]. The Indonesian Ministry of Agriculture has devised a plan to advance Smart Farming, with the aim of enlisting the youth as key proponents of the initiative to popularize smart agriculture practices in Indonesia [33].

This article proposes a distributed IoT architecture that leverages edge and fog computing to assist farmers in developing smart systems, both in existing and new facilities, enabling them to harness the power of advanced analytics and IoT technologies to optimize their agricultural practices [34]. This paper introduces an IoT-based system that employs data analytics and ML techniques to develop a prediction model for detecting Apple disease in the apple orchards of Kashmir valley, providing farmers with an effective tool to predict and mitigate the risk of disease outbreaks and take timely action to prevent crop loss [35]. Here's our summary of the differences between smart farming and precision farming in Table 1.

TABLE I. SMART FARMING VS PRECISION FARMING

Smart Farming	Precision Farming
The use of information and data technology to enhance complicated agricultural systems	Highly controlled, accurate, and optimized agricultural production.
Access to data and how farmers might make smart or intelligent decisions using the information gathered	A contemporary approach to farming management that leverages digital techniques for monitoring and optimizing agricultural production processes
Increase the quality and quantity of the products with optimize human effort in the same amount of land	Simultaneous achievement of improved resource utilization efficiency, increased yield, and decreased environmental impact.
Access to real-time data about weather patterns, climate change, soil conditions, crops, human labor, finance, etc.	An assemblage of devices and machinery designed to capture essential field data.

C. Research Positioning

After doing literature review from previous research, we can gain a comprehensive understanding of the existing research and identify several limitations from previous research that related to big data and cloud-based platform in the agriculture domain. The previous research to big data and cloud-based platform in the agriculture domain has limitations related to cloud storage, capacity, and performance issues, focus on crop production, framework specificity, and accuracy of classification result.

This study proposes an original system architecture integrating big data and cloud-based intelligent decision support systems in precision farming, utilizing the Alibaba cloud platform to optimize performance and empower farmers to make better decisions regarding soil, crop, and water management. The data visualization and insight are explainable and interpretable as making it easier for users to understand, correctly trust, and efficiently manage this new robust AI in Smart Precision Farming. The goal is for users and farmers to understand and believe in the results provided by AI. To handle smart precision farming systems, several big data solutions are supplied, such as recommendation systems, graph analysis, BI tools, and so on. Research conducted by Fajar and Nurcahyo has created an architecture big data and cloud computing on online travel agent for tourism system using Alibaba Cloud Platform [36].

IV. RESULT AND DISCUSSION

The big data pipeline for smart precision farming are shown in Figure 2, that involves the following process:

- Raw Data: In smart precision farming, there are several types of raw data that are important. First, environmental data includes weather, temperature, rainfall, humidity, wind speed, and solar radiation. Second, soil data provides information about soil moisture, nutrients, and pH. Third, plant data includes plant growth, development stage, yield potential, and quality parameters. Fourth, data on crops include water requirements, irrigation system data, and water quality data. These data can be formed of various types, numerical, scale, image, time, and textual.
- Data Acquisition: The data acquisition involves placing sensors at various locations on the farm to collect data in real time. This sensor can be placed on

agricultural land. The sensor measures various parameters such as soil moisture, temperature, air humidity and light intensity. The data collected by these sensors is carried out regularly or continuously. The data collected includes readings from the installed sensors, which can be numeric values, images, or other types of data. The data from image search and image recognition are collected in the automatic identification of agricultural land. Meanwhile, messaging service data is collected from real-time communication channels between farmers, agronomists, and agricultural experts. The collected data is then transmitted wirelessly to the cloud storage.

- Data Processing: Before analysis, raw agricultural data needs to undergo preprocessing. This involves cleaning, filtering, and transforming the data to remove noise, inconsistencies, and outliers. Cloud-based data preprocessing tools can handle large volumes of data efficiently, ensuring data quality and readiness for analysis. Integration platforms or middleware are employed to aggregate and integrate data from various sources. These platforms enable seamless connectivity between different systems, devices, and data formats. By integrating data, farmers can gain a comprehensive view of their farm operations and make data-driven decisions.

- Data Analysis: To find patterns and abnormalities, the data is analyzed using AI and ML algorithms. These algorithms, which are trained on past data, can provide real-time insights into crop growth, soil quality, and weather patterns. Farmers may forecast optimal planting and harvesting dates by examining historical data on weather patterns and crop yields, which can boost yields and save waste. Furthermore, by using ML to analyze data from farm devices and sensors, farmers can discover early indicators of plant diseases or pests, allowing them to take preventive steps before the crops are harmed.

- Data Insight: Cloud-based analytics tools offer advanced visualization capabilities that simplify the interpretation and communication of complex agricultural data. Interactive dashboards, charts, and maps enable farmers to understand data trends immediately. Visualization tools also support geospatial analysis, helping farmers identify spatial patterns and optimize resource allocation across their farms. In smart precision farming, the important data is to make decisions regarding irrigation, crop protection, and planting schedules. The data also helps in monitoring crop health, detecting diseases or pests, and making decisions regarding harvesting, crop rotation, irrigation, and maintaining the quality of water used in agriculture.

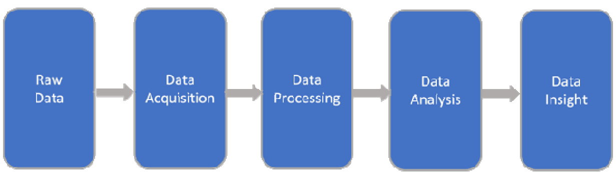

Fig. 2. Big Data Analytic Pipeline

Our system architecture using Alibaba Cloud Platform environment are shown in the figure 3, that consisting of:

- Data Acquisition: All data from the remote sensing, UAV, weather station, and soil sensors is passed through DataHub in real time to the IoT Suite, which builds stable communication between devices and the IoT Platform. Data processing will never stop when connections are broken, and it will also process the data between the devices, cache the data, and enable communication between the edge node and the cloud. Data from image search, image recognition, and message services is passed through DataWorks, which makes it possible to integrate data from various sources, both internal and external. Drones capture any affected crops, and AI image search can uncover crop remedies by studying historical data. Furthermore, if a farmer discovers a cure for a certain condition, they can publish the information with associated tags and photographs. Drone monitoring reduces monitoring costs for large farms since the data collected by these drones is delivered back to the server for analysis and decision-making on the edge node. Temperature, humidity, and light intensity can all be monitored from the weather station, and soil moisture can be monitored from the soil sensor.

- Data Processing: Stream Compute and Max Compute are used to build a data streaming pipeline and extract more data value. StreamCompute can be used to manage and analyze farm sensor data in real time. This service allows users to process, analyze, and take real-time action on incoming streaming data. MaxCompute can be used to manage and analyze large farm data sets. After completing this, the data is forwarded to the Polar DB with data forwarding rules for SQL Data storage involves storing the data collected from various sources in smart precision farming. The data may be stored in various formats, such as structured, semi-structured, and unstructured data. Cloud storage solutions are ideal for storing large volumes of data, as they are scalable and can be accessed from anywhere. We stored three types of data in Polar DB, consisting of soil data, crop data, and irrigation data. We have used three sets of APIs in our project: image search message service and translation for image search. DataWorks provides easy-to-use tools to perform ETL (extract, transform, and load) processes on-farm data. We can clean, transform, and load data into the system easily, preparing it for further analysis. Polar DB for SQL is a database service that is highly characterized by high performance and availability. We have deployed our application in CI/CD deployment, this is a real-time, broad architecture, but in prototype, we have deployed a simple application server.

- Data Analysis: Data are being extracted and prepared for transformation. Standardization, normalization, feature selection and extraction, and data reduction are transformation processes used in the machine learning pipeline. We used the Machine Learning Platform for AI (PAI) and we trained our machine learning models with sci-kit-learn-lib's Python. The models were then incorporated into our framework. We employed Random Forest, Logistic Regression, Decision Tree, Nave Bayes, SVM (Support Vector Machine), and other techniques. As a result, we gain predictions and recommendations for soil management, crop management, and water management are provided

- Data Insight: We make data visualization tools by using Quick BI and Graph Analysis, which can be used to create interactive dashboards and reports that provide real-time insights into key metrics such as soil moisture levels, weather patterns, and crop yields. Whenever the data is injected into the Polar DB, it will update the Quick BI in real-time. These tools enable farmers to easily understand and interpret the data collected and analyzed in smart precision farming. With the use of predictive analytics and machine learning, farmers can optimize crop management and improve yields.

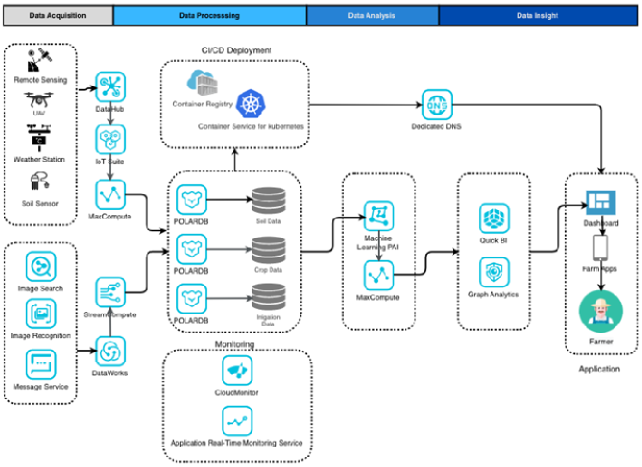

Fig. 3. Big Data Cloud-Based System Architecture

The results to an intelligent decision support system for smart precision farming that we develop are:

- Improved Data Collection: IA can be equipped with advanced data collection capabilities using a variety of sensors, IoT devices, and remote detection technologies. These improvements ensure a comprehensive and real-time data acquisition process, enabling better monitoring and analysis of factors such as soil conditions, weather patterns, plant health, and resource use.

- Intelligent Data Processing: By combining machine learning algorithms and artificial intelligence techniques, IA can intelligently process the collected data. This includes data cleansing, normalization, integration, and transformation to generate meaningful insights. Agents can identify patterns, correlations, and anomalies in data, facilitating better decision-making for precision farming practices.

- Adaptive Decision Making: IA can be designed to adapt and optimize decision-making processes based on changing conditions and the needs of evolving agriculture. They can adjust crop management strategies, irrigation schedules, and resource allocation dynamically based on real-time data input, weather forecasts, market trends, and specific agricultural goals.

- Collaborative Knowledge Sharing: IA can facilitate knowledge sharing and collaboration between farmers, agricultural experts, and researchers through a cloud-based platform. They can enable the exchange of best practices, data-driven recommendations, and insights gleaned from collective experience, ultimately driving continuous improvement and innovation in smart precision agriculture.

- Integration with Cloud-Based Decision Support Systems: IA can be integrated with cloud-based decision support systems, taking advantage of the scalability and computing power of cloud infrastructure. This integration enables efficient storage, processing, and analysis of agricultural data at scale, enabling faster and more accurate decision-making.

V. CONCLUSION

It is critical to monitor the agricultural production environment to achieve optimal agricultural growth and resource efficiency. Our system design leverages cutting-edge devices and advanced sensors to efficiently gather, securely store, seamlessly process, meticulously analyze, and visually present vast quantities of data. This invaluable data is then used to generate actionable insights for optimizing crop yield, soil health, and irrigation practices, ultimately fostering sustainable and efficient farming methodologies. The proposed system architecture is original and contributes significantly to the field of agriculture by proposing a fresh technique for handling and analyzing massive volumes of agricultural data.

The integration of big data and Alibaba cloud computing in smart precision farming is far cheaper and has the potential to transform farming practices into smart precision farming models that can improve farming productivity. Our system architecture allows batch, interactive, stream, and graph computation, as well as a machine learning platform for AI on heterogeneous cloud-scale data collection. The improvement in intelligent agents is the outcome of developing smart precision farming employing big data and cloud-based decision support systems. This system offers farmers timely information and advice to help them make better decisions about resource optimization, soil management, crop management, and water management. Overall, in future studies, we will do experiments in data mining, software-defined control, and deployment of machine learning-based decision support systems for our smart precision farming platform.

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