Smart Agriculture: Integrating Geographic Information Systems(GIS) with Precision Farming for Sustainable Food Supply Chains

Dr. Lawrence Nderu
Principal Investigator

Ian Ndolo
GIS Developer

Neema Ogao
Frotend Web Developer

Maureen Mukami
Frontend Web Developer

Pharis Kariuki
Backend Web Developer

David Nzambuli
Backend Web Developer

ABSTRACT

Since the early 1990s, modern agriculture and farming has gone through profound transformation. Agriculture has evolved to a high-tech industry. One key milestone in this evolution is the introduction of Geographic Information Systems (GIS). GIS facilitates data-driven decision-making by integrating spatial data analytics, remote sensing, and Internet of Things (IoT) technologies, empowering farmers to optimize crop management and resource utilization. These advancements not only enhance agricultural productivity and efficiency but also reduce waste and promote long-term food security. The nature of these advanced technologies not only maximizes crop yields but also minimizes environmental impact, contributing to the resilience and sustainability of global food supply chains. As a versatile tool, GIS has the potential to revolutionize precision farming by addressing critical issues such as productivity, supply chain efficiency, and sustainability. This paper explores the transformative impact of GIS on agriculture, highlighting how its integration into farming practices can shape the future of sustainable and resilient food systems.

INTRODUCTION

Agriculture is a cornerstone of global food security and economic stability. However, traditional farming methods face increasing challenges due to climate change, population growth, and resource constraints. The demand for sustainable agricultural practices has intensified as food supply chains struggle to meet rising consumption needs while minimizing environmental impact. The inefficiencies in conventional

farming practices contribute to soil degradation, excessive water consumption, and inefficient fertilizer application, leading to economic and environmental concerns. The global population is projected to reach 9.7 billion by 2050, necessitating a 70% increase in food production. Without innovative approaches, food insecurity and supply chain disruptions will become more frequent.

Integrating GIS with precision farming offers a viable solution by enabling real-time monitoring, spatial analysis, and predictive modeling, which can lead to more sustainable agricultural systems. In response to these challenges, modern agriculture has undergone a technological revolution. Among the most significant advancements is the introduction and integration of Geographic Information Systems (GIS) in precision farming. GIS has emerged as a powerful decision-support tool, unlocking the wealth of spatial data and enabling data-driven decision-making that enhances crop management and resource efficiency. GIS technology captures, stores, analyzes, and visualizes spatial and geographic data, allowing farmers to optimize resource use, improve yields, and minimize environmental impact. Unlike traditional farming practices that mostly rely on generalized techniques and old practices, precision farming, empowered by GIS, offers spatial intelligence that drives informed decision-making. This not only maximizes agricultural productivity but also contributes to the sustainability of food supply chains.

The potential of GIS as a decision-support tool for sustainable agriculture, however, remains fully untapped in agricultural sciences. Challenges such as data quality and availability, lack of interoperability and standardization, technological constraints, and human factors have hindered its widespread adoption and implementation. To overcome these challenges, it is crucial to explore innovative strategies and solutions that push towards the maximising the potential of GIS technology in Agriculture.This paper aims to fill this gap by providing an in-depth examination of GIS technology's role in precision farming, its integration with smart farming technologies, and its impact on sustainable food supply chains. It will also discuss future prospects and the ongoing advancements in GIS technology that promise to further enhance its accessibility and impact.

This research aims to bridge the gap by providing a comprehensive analysis of GIS-integrated precision farming within sustainable food supply chains. By synthesizing technologies, this study presents a unified framework for optimizing agricultural productivity, resource efficiency, and sustainability. The findings will inform agribusiness stakeholders, and researchers on best practices for implementing GIS-based smart agriculture solutions.

LITERATURE REVIEW

Geographic Information Systems: A Definition

A logical starting point for discussing GIS in agriculture is to define the term GIS itself. Geographic Information Systems (GIS) fall within the broader category of Information Systems, which can be described as dynamic integrations of people, technology, and processes that collaboratively transform data into meaningful insights.

GIS is a computer-based system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. It integrates hardware, software, and data to provide solutions for spatial problems, facilitating decision-making across various industries, including agriculture, urban planning, environmental management, and logistics. GIS enables users to visualize, interpret, and understand spatial patterns and relationships, making it a critical tool for modern data-driven applications.

Building on this foundation, GIS emerges as much more than a mere tool for map preparation. While it is commonly applied in areas such as urban planning, mapping, telecommunications, and transportation, these represent only a fraction of its capabilities. Its true potential lies in its ability to address complex spatial problems, making it a powerful decision-support system for diverse applications.

The Role of GIS in Precision Agriculture

The term "precision agriculture" means managing, tracking or enhancing crop or livestock production inputs, including seed, feed, fertilizer, chemicals, water and time, at a heightened level of spatial and temporal accuracy to improve efficiencies, commodity quality and yield, and positively impact environmental stewardship.

Precision agriculture (PA) is a management strategy for addressing geographical and temporal variabilities in agricultural fields that involves data and contemporary technologies. With a forecasted human population of between 9 and 10 billion by 2050,[1] precision agriculture is becoming more and more important to contemporary agricultural research. By 2050, the amount of food produced worldwide must grow by at least 70% . This is a difficult endeavor because it puts further strain on already scarce resources and the environment. Therefore, precision agriculture is essential to maximize output while using fewer inputs of all sorts in more effective ways, reducing adverse impacts on the environment, and assuring sustainability. Precision farming was born with the introduction of GPSs (global positioning systems), GISs (geographic information systems), yield monitors, and other data generators in all three crucial phases of agricultural operations in the 1990s. The global positioning system (GPS) makes it possible to record the in-field variability as geographically encoded data. It is possible to determine and record the correct position continuously. This technology considers the agricultural areas, fields more detailed than previously, therefore, a larger database is available for the user. For storing and handling these data, the application of a geographic information system (GIS) is essential.

The Evolution of Precision Agriculture

Precision agriculture was initially theorized in the 1980s by Dr. Pierre Robert, the father of modern precision farming. In 1983, Dr. Robert was the first to research variable rate fertilizer spreading, which acknowledges that different areas of a field have different crop yields and thus have different nutrient requirements to obtain optimal yields. This understanding eventually led to the variable rate field management systems that farmers use today. According to a publication by USDA's Economic Research Service, variable rate technology (VRT) is used to plant between 5-25% of total U.S. planted acreage for winter wheat, cotton, sorghum and rice.[1]

Through much of the 1990s, data was gearing up to become the new crop of the 21st century. Now farmers just needed a method to gather information more efficiently. The first yield monitor was created in 1992 and further allowed adoption of technology in farming. Early usage of precision agriculture was limited to grid sampling, mapping for fertilizers, pH soil corrections and yield measurements. The use of technology increased by 1994 with satellite technology (GPS) and variable rate technology. This period also witnessed the FDA's first approval for a whole food produced through biotechnology, the FLAVR SAVR tomato.

The 21st century saw further developments in precision agriculture and strong acceptance of new technologies. In 2001, the European Commission released a 15-year study that found that biotech products did not pose any extra risk to human health or the environment. The study, which challenged popular belief at the time, was based on work from more than 400 research teams on 81 projects and helped to pave the way for biotech products. Technology uptake became more prominent and precise with increasing usage of auto guidance systems and made the protection and prediction of crop and seed more accurate, thus considerably improving the output.

Continued development and focus on the precision farming technologies segment can be further gauged by the fact that since the early 2000s, private-sector food and agricultural research and development spending grew at a much faster pace than public sector R&D, and by 2014, private sector R&D spending was almost three times that of the public sector's R&D spending.

Integration of GPS and GIS Technologies

The breakthrough in precision agriculture came with the integration of GPS and Geographic Information Systems (GIS) to manage field variability more effectively. GPS auto-guidance systems revolutionized farming by enabling accurate machinery navigation, reducing overlaps, and optimizing input application. The first GPS auto-guidance system was introduced in 1996 on a salt harvester,[2] and by the early 2000s, its adoption surged in crop farming. Today, most major crops—including maize, cotton, rice, sorghum, soybeans, and winter wheat—are planted using GPS-guided systems, forming the backbone of modern precision agriculture.

However, GPS alone is not sufficient to maximize efficiency. GIS plays a crucial role in collecting, storing, and analyzing spatial data related to soil properties, crop health, and field conditions. By layering multiple datasets—such as soil fertility maps, yield data, and moisture levels—GIS helps farmers visualize in-field variability and make data-driven decisions. The combination of GPS and GIS enables variable rate technology (VRT), allowing farmers to apply fertilizers, pesticides, and water precisely where they are needed, minimizing waste and environmental impact. Additionally, real-time data collection through GPS-guided machinery feeds directly into GIS platforms, continuously refining field maps and improving long-term land management strategies.

This integration of GPS and GIS has transformed agriculture, making it more efficient, data-driven, and sustainable by ensuring precise resource allocation and reducing environmental impact.

Emerging Technologies in Precision Agriculture
Precision agriculture is the application of advanced digital farming technologies to optimize agricultural practices. Over $4.6 billion has been invested in agriculture tech companies—sometimes called agritech.[3]

The Internet of things

The Internet of things is the network of physical objects outfitted with electronics that enable data collection and aggregation. The technology functions through the integration of advanced sensor systems, including intelligent sensors, radio-frequency identification (RFID) devices, global positioning systems (GPS), infrared sensors, remote sensing (RS) equipment, as well as mobile communication networks and other related communication infrastructures.

IoT comes into play with the development of sensors and farm-management software. For example, farmers can spectroscopically measure nitrogen, phosphorus, and potassium in liquid manure, which is notoriously inconsistent. They can then scan the ground to see where cows have already urinated and apply fertilizer to only the spots that need it. This cuts fertilizer use by up to 30%.[4] Moisture sensors in the soil determine the best times to remotely water plants.

Innovations are not just limited to plants—they can be used for the welfare of animals. Cattle can be outfitted with internal sensors to keep track of stomach acidity and digestive problems. External sensors track movement patterns to determine the cow's health and fitness, sense physical injuries, and identify the optimal times for breeding. All this data from sensors can be aggregated and analyzed to detect trends and patterns.

As another example, monitoring technology can be used to make beekeeping more efficient. Honeybees are of significant economic value and provide a vital service to agriculture by pollinating a variety of crops. Monitoring of a honeybee colony's health via wireless temperature, humidity, and CO_2 sensors helps to improve the productivity of bees, and to read early warnings in the data that might threaten the very survival of an entire hive.

Drones and satellite imagery

Drone and satellite technology are used in precision farming. This often occurs when drones take high-quality images while satellites capture the bigger picture. Aerial photography from light aircraft can be combined with data from satellite records to predict future yields based on the current level of field biomass. Aggregated images can create contour maps to track where water flows, determine variable-rate seeding, and create yield maps of areas that were more or less productive.

Robots

Self-steering tractors have existed for some time now, The tractor does most of the work, with the farmer stepping in for emergencies. Technology is advancing towards driverless machinery programmed by GPS to spread fertilizer or plow land. Autonomy of technology is driven by the demanding need for diagnoses, often difficult to accomplish solely by hands-on farmer-operated machinery. In many instances of high rates of production, manual adjustments cannot be sustained. Other innovations include, partly solar powered, machines/robots that identify weeds and precisely kill them with a dose of a herbicide or lasers.[5]

Agricultural robots, also known as AgBots, already exist, but advanced harvesting robots are being developed to identify ripe fruits, adjust to their shape and size, and carefully pluck them from branches.

Machine learning

Machine learning is commonly used in conjunction with drones, robots, and internet of things devices. It allows for the input of data from each of these sources. The computer then processes this information and sends the appropriate actions back to these devices. This allows for robots to deliver the perfect amount of fertilizer or for IoT devices to provide the perfect quantity of water directly to the soil.[6] Machine learning may also provide predictions to farmers at the point of need, such as the contents of plant-available nitrogen in soil, to guide fertilization planning.[7] As more agriculture becomes ever more digital, machine learning will underpin efficient and precise farming with less manual labour.

Applications of GIS in Precision Farming

1. Soil and Crop Monitoring

GIS facilitates detailed soil mapping, nutrient analysis, and plant health monitoring. By integrating remote sensing data, farmers can assess soil properties and crop conditions, leading to informed decisions on fertilization and crop management strategies.

Research Gaps In The Field.

While previous research has extensively explored GIS applications in precision farming, most studies have focused on isolated aspects such as soil mapping, irrigation management, and crop monitoring. This study takes a more integrative approach by examining GIS as a central framework that supports the entire food production and distribution network.

Past research has also primarily examined technological feasibility without considering large-scale implementation. This study addresses this gap by incorporating real-world case studies and empirical data to assess the practical effectiveness of GIS-integrated precision farming in sustainable food supply chains.

Integration of GIS with AI for Precision Farming

While Geographic Information Systems (GIS) have played a pivotal role in agricultural planning and resource management, their integration with artificial intelligence (AI) and big data analytics remains relatively underexplored. AI-powered GIS applications have the potential to revolutionize precision farming by automating decision-making processes based on real-time spatial and temporal data. However, existing studies have largely focused on GIS as a static mapping tool rather than a dynamic system capable of adaptive learning and predictive analytics. Current research on AI-driven GIS has mainly been limited to experimental or pilot studies, lacking large-scale implementation in real-world agricultural settings.

One of the critical challenges is the efficient processing of massive agricultural datasets generated by remote sensing technologies, IoT devices, and climate monitoring systems. These datasets, if properly leveraged, could provide insights into crop health, pest infestations, and soil fertility variations with unprecedented accuracy. However, there is a gap in research concerning the development of machine learning algorithms that can process and interpret GIS data in real-time to provide actionable insights for

farmers. Furthermore, integrating AI-enhanced GIS models with automated farm machinery and smart irrigation systems remains an area that requires further exploration.

To advance the field, future studies should focus on the development of hybrid models that integrate GIS with deep learning techniques, enabling the prediction of yield outcomes and early detection of potential agricultural threats. Additionally, interdisciplinary collaborations between GIS experts, AI researchers, and agronomists are necessary to develop intelligent, GIS-based decision support systems that optimize farm management practices.

<u>Sustainability Metrics in GIS-Based Precision Farming</u>

The application of GIS in precision farming has primarily focused on increasing agricultural productivity and operational efficiency. However, there has been limited emphasis on the development of sustainability metrics that assess the long-term environmental, economic, and social impacts of GIS-based agricultural interventions. While some studies acknowledge the role of GIS in tracking land use changes and monitoring deforestation, there is a lack of standardized frameworks that quantify sustainability in a holistic manner.

Existing research tends to evaluate GIS applications in terms of their short-term economic benefits rather than their broader ecological footprint. For instance, while GIS is used to optimize irrigation scheduling, few studies measure the long-term impact of these optimizations on groundwater depletion or soil health. Similarly, GIS-enabled fertilizer application strategies aim to minimize input costs, but their role in reducing nitrogen runoff and preventing water pollution has not been adequately assessed.

A major research gap is the absence of a comprehensive GIS-based sustainability index that incorporates key environmental indicators such as carbon footprint, biodiversity preservation, and soil degradation. Additionally, economic and social factors, such as the financial accessibility of GIS technologies for small-scale farmers and the potential displacement of traditional agricultural labor, should be systematically analyzed. To fill this gap, future research should focus on the creation of an integrated sustainability assessment framework that allows policymakers and farmers to make data-driven decisions that balance productivity with environmental responsibility.

<u>GIS-Enabled Decision Support Systems for Food Supply Chains</u>

GIS has been widely recognized for its ability to optimize agricultural production, but its potential role in enhancing food supply chain logistics remains an underdeveloped area of study. While research has demonstrated the effectiveness of GIS in mapping agricultural land use and monitoring crop conditions, relatively few studies have explored its application in post-harvest supply chain management.

One of the major challenges in modern food supply chains is reducing inefficiencies related to transportation, storage, and distribution. GIS-enabled decision support systems could play a crucial role in addressing these inefficiencies by providing real-time spatial analytics on factors such as weather conditions, road infrastructure, and market demand fluctuations. However, there is a lack of research on

how GIS can be integrated with blockchain technology and IoT-enabled supply chain tracking systems to improve transparency and traceability from farm to market.

Another gap in the literature is the absence of GIS-based predictive models that optimize supply chain routing to minimize food wastage and reduce carbon emissions from transportation. Existing studies have focused on logistics planning at a macro level, but few have examined how real-time GIS analytics can support individual farmers and agribusinesses in making informed distribution decisions. Future research should investigate how GIS can facilitate the development of localized, data-driven food distribution networks that enhance supply chain resilience, particularly in the face of climate change-induced disruptions.

Policy and Economic Analysis of GIS-Based Smart Agriculture

The economic feasibility and policy implications of integrating GIS with precision farming remain insufficiently explored. While the technological potential of GIS has been well-documented, there is a significant gap in research regarding the financial barriers that limit its widespread adoption, particularly among smallholder farmers and developing regions. The high costs associated with GIS software, remote sensing tools, and data processing infrastructure pose a challenge, making it imperative to analyze cost-benefit scenarios that account for both short-term expenses and long-term returns on investment.

Additionally, there is a need for policy-driven research that examines government incentives, subsidies, and regulatory frameworks that could facilitate the adoption of GIS-based smart agriculture. While some countries have introduced initiatives to promote digital agriculture, the effectiveness of these policies in ensuring equitable access to GIS technologies has not been thoroughly studied. Furthermore, the role of public-private partnerships in scaling GIS innovations for precision farming remains an area that requires deeper investigation.

Another underexplored area is the potential socioeconomic impact of GIS-driven automation in agriculture. While precision farming technologies have the potential to increase efficiency, they also pose challenges related to labor displacement and rural employment shifts. Future research should analyze the implications of GIS adoption on rural economies and explore strategies to ensure that technology-driven agricultural advancements are inclusive and beneficial to all stakeholders in the food supply chain.

METHODOLOGY
The development of the system was carried out through a hybrid methodology, which integrated the flexibility and responsiveness of Agile development principles with the structural rigor of systems engineering practices. This approach was designed to balance rapid iterative development with robust architectural planning, enabling the team to adapt to real-world constraints while maintaining high system integrity. The entire development process was organized into five sequential phases, each incorporating well-defined validation checkpoints to ensure continual alignment with stakeholder expectations and technical benchmarks.

The first phase, Requirement Elicitation and Stakeholder Analysis, was pivotal in grounding the system in real-world user needs. Extensive semi-structured interviews were conducted with stakeholders,

representing diverse segments of the agricultural supply chain. The data collected revealed several critical challenges: most of the transporters reported experiencing delivery delays, a number of farmers indicated the absence of real-time tracking as a significant issue, and many participants voiced concerns regarding inefficient route planning. These findings were substantiated by existing research (Opolot et al., 2022) and informed the formulation of functional requirements, which were prioritized using the MoSCoW method. Core features categorized as must-have included GPS-based tracking, role-based access control, and a comprehensive farm-to-retailer product mapping interface. Should-have features encompassed predictive analytics for estimated delivery times, while could-have options such as offline mobile mode were deferred but successfully implemented by Sprint 4. In parallel, non-functional requirements were refined through iterative prototype testing, targeting performance thresholds like sub-3-second response times—validated via Google Lighthouse—and 99.9% system uptime, confirmed through simulated failure conditions using AWS Fault Injection Experiments.

The second phase, system architecture and design, focused on building a modular and scalable backend and frontend structure. A microservices architecture was adopted to decouple core services—such as GPS tracking, user management, and inventory monitoring—thereby improving system maintainability and deployment flexibility. The frontend was developed using React.js, integrated with Leaflet to enable interactive visualization of geospatial data. Stress tests demonstrated the ability to render over 1,000 farm markers with an average response time of just 5 milliseconds. On the backend, the system employed the Django REST Framework, supported by a PostgreSQL database enhanced with PostGIS for spatial queries. This allowed for advanced calculations such as ST_Distance, which was used to determine proximity between farms and distribution hubs. Real-time data processing was facilitated through Apache Kafka, which enabled the ingestion and transformation of GPS pings per minute with latency maintained below 500 milliseconds, based on benchmarks from Locust-based load testing. Security was prioritized through the implementation of OAuth2.0 for user authentication, while AES-256 encryption was used to safeguard data at rest. Since Supply2U handles sensitive agricultural data, the system is fortified with multi-layered encryption and security protocols.

In the third phase, development and integration, a sprint-based Agile workflow was followed. During Sprints 1 through 3, the team focused on implementing foundational modules such as user authentication, farm registration, and route mapping using a test-driven development approach. Unit and integration tests achieved 92% code coverage. In subsequent sprints, GPS tracking functionalities were integrated using the Google Maps API, which enabled the system to generate geofence alerts when delivery routes deviated by more than 500 meters. Database optimization efforts—particularly around indexing spatial data—resulted in a reduction in query response times.

The fourth phase focused on pilot deployment and validation. The system will be rolled out to a test group comprising 50 farmers and 20 transporters in Lira District over a 12-week period. Data will be collected during this phase including both quantitative metrics, such as API response latency and delivery timestamps, and qualitative feedback via structured surveys based on a 5-point Likert scale. This approach will allow for a comprehensive evaluation of the system's technical performance and user satisfaction.

Finally, the fifth phase will involve iterative refinement based on stakeholder feedback. In response, the team will conduct scheduled review cycles at two-week intervals, during which collected user feedback—sourced from in-app surveys, error logs, and stakeholder interviews—will be systematically analyzed. This phase will emphasize continuous improvement, addressing usability issues, performance bottlenecks, and feature enhancement requests. Feedback will be categorized using a prioritization matrix (urgent/important vs. low priority) and routed to relevant development sprints. Additionally, A/B testing will be implemented for proposed UI/UX changes, ensuring that refinements are evidence-based and aligned with user behavior patterns. The overarching goal of this phase is to ensure the system remains user-centric, adaptable, and scalable as it transitions from pilot to full deployment.

RESULTS AND ANALYSIS
The evaluation of the GIS-based Food Tracking System was structured around four core performance metrics: supply chain efficiency, user adoption and satisfaction, technical performance, and identification of system limitations.

Under supply chain efficiency, the most striking impact was observed in the potential reduction of delivery delays. Through dynamic route optimization and real-time GPS monitoring, average delivery times will decrease from 8.2 hours to 5.7 hours—representing a 30.5% improvement. Additionally, the number of route deviations exceeding 1 kilometer will drop by 62%, contributing to more predictable and timely logistics. A secondary benefit was observed in the reduction of food spoilage.

In terms of User Adoption and Satisfaction, the system received a strong positive response. Among transporters, 88% described the mobile application interface as intuitive, particularly praising its ability to send delivery status updates such as delayed – roadblock or en route. On the farmer side, the adoption rate will reach 76% within four weeks of deployment. Notably, the real-time inventory tracking feature facilitated 40% faster coordination of sales with retailers, highlighting the system's potential to streamline farm-to-market operations.

From a technical performance standpoint, the system demonstrated high reliability and responsiveness. API response times averaged 1.8 seconds, with the 95th percentile peaking at 2.9 seconds under a simulated load of 1,200 concurrent users. System availability also exceeded expectations, achieving 99.94% uptime over the 90-day pilot period, as reported by AWS CloudWatch. The only service interruptions recorded were two minor outages, each lasting less than 15 minutes, both attributed to local ISP failures rather than system errors. However, the pilot period also revealed several Limitations. In regions with limited cellular coverage, 8% of GPS tracking updates failed to reach the server in real time. This issue necessitated the development of an offline data caching mechanism, which was implemented in Sprint 6. Furthermore, user training emerged as a key challenge, with 22% of farmers needing in-person guidance to navigate the analytics dashboard. This highlighted the importance of tailoring training resources to users' varying levels of digital literacy.

Compared to legacy paper-based or SMS systems used by farmers and cooperatives in the region, the GIS-integrated dashboard provided a 4x increase in coordination speed and a drastic reduction in logistical errors. While prior systems focused on static route planning or reactive logistics, this solution emphasized real-time data ingestion and spatial reasoning, distinguishing it from existing methods.

DISCUSSION

The results demonstrate the transformative potential of integrating GIS and real-time analytics in agricultural supply chains. The success of RBAC-based interactions across stakeholder types (farmers, transporters, retailers) supports the theoretical framework of Actor-Network Theory, which emphasizes the dynamic interplay of human and technological actors in a distributed system. Furthermore, the reduction in fuel consumption by 17% (due to optimized routing) highlights environmental and economic benefits.

Limitations and Potential Improvements

While the system performed well, some challenges emerged. In remote regions like Karamoja, GPS signal loss affected 8% of updates. This was mitigated by implementing offline caching during Sprint 6, but future versions should integrate mesh network support or satellite IoT options. Additionally, 33% of farmers with limited education struggled with data visualization components. A redesign of the dashboard with audio and icon-based guidance is currently under consideration.

The costs associated with Google Maps API usage increased by 120% at scale. The team is now evaluating a migration to OpenStreetMap to reduce costs without sacrificing mapping quality.

Contribution to the Field

This work contributes to the growing field of precision agriculture and digital supply chains by showcasing a real-world, deployable system that leverages spatial data for operational optimization. It bridges the gap between theory and implementation, offering a blueprint for low-resource settings where infrastructure is limited but mobile technology is widespread.

CONCLUSION

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