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Optimizing Agricultural Yield and Supply Chain via Client-Server Architecture

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ABSTRACT
The agricultural sector in developing regions often faces dual challenges: the lack of systematic harvest data recording and inefficient supply chains dominated by intermediaries. These issues result in suboptimal land productivity management and reduced profit margins for farmers. This study addresses these problems by designing a system based on Client-Server Architecture to digitize harvest records and facilitate direct-to-partner transactions. Utilizing Flutter as the mobile client and Laravel as the server-side API provider backed by PostgreSQL, the system implements a specific Land Productivity Yield (LPY) algorithm ($\boldsymbol{P = H/A}$) to map high-performing cultivation methods. The architecture connects three strategic stakeholders: Farmers, Regional Coordinators, and Industrial Partners. Usability testing using the System Usability Scale (SUS) yielded a score of 79.25, indicating high acceptance among the user demographic. The results demonstrate that the proposed architecture successfully reduces information asymmetry and provides a robust framework for data-driven decision-making in regional agriculture.
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INTRODUCTION

Agriculture remains the bedrock of the Indonesian economy, absorbing a significant portion of the national workforce and contributing substantially to the Gross Domestic Product (GDP). In recent years, the global agricultural sector has witnessed a paradigm shift known as "Agriculture 4.0" or Smart Farming, characterized by the integration of Information and Communication Technology (ICT), Internet of Things (IoT), and Big Data into traditional farming practices (Ulva et al., 2023). This digital transformation promises to optimize crop yields, reduce waste, and enhance the economic viability of farming. However, despite the rapid technological advancement at the national level, the penetration of these technologies into rural areas, particularly in regencies like Kebumen, remains uneven and suboptimal (Dewi et al., 2022). The disparity between the availability of technology and its adoption at the grassroots level creates a "digital divide" that hinders the modernization of regional agriculture. While large-scale plantations have successfully adopted precision farming, smallholder farmers often remain isolated from these advancements, relying on traditional methods that are becoming increasingly unsustainable in the face of climate change and market volatility.

In the specific context of Kebumen Regency, the majority of farmers operate as smallholders utilizing methods passed down through generations. A critical impediment identified in this region is the lack of systematic data recording, often referred to as a "Data Void." Unlike industrial plantations that meticulously track every variable—from fertilizer usage to harvest weight per square meter—smallholder farmers in Kebumen rely heavily on intuition and memory (Arfianto et al., 2021). Without historical records, it is virtually impossible to perform a valid analysis of land productivity. Farmers cannot quantitatively determine which cultivation method or "recipe" yields the best output for their specific land characteristics. Consequently, agricultural failures are often repeated, and successful methods remain undocumented anecdotes rather than replicable formulas. This study posits that without digitizing this fundamental layer of data, any effort to improve regional food security will be ineffective, as decisions are made based on assumptions rather than empirical evidence.

Furthermore, beyond the production challenges, the agricultural ecosystem in Kebumen is plagued by severe inefficiencies in the supply chain. The distribution network is historically dominated by a long chain of intermediaries, locally known as *tengkulak*. These intermediaries capitalize on information asymmetry, possessing market price knowledge that farmers do not have access to. Farmers, lacking direct access to industrial partners or updated market prices, are forced to sell their produce at prices dictated by these middlemen, often significantly below the fair market value (Masnur et al., 2022). This structure not only erodes the farmers' profit margins but also discourages the younger generation from entering the agricultural sector due to its perceived low economic return. There is an urgent need for a mechanism that can "disintermediate" this chain, connecting producers directly to buyers through a Peer-to-Business (P2B) model, thereby creating a more transparent and equitable market environment.

While several agricultural applications exist in the Indonesian market, such as TaniHub or SayurBox, most are focused primarily on the e-commerce aspect—selling the final product—rather than managing the production cycle itself. Additionally, existing solutions often require high-end devices or stable high-speed internet, which are not always available in rural Kebumen. There is a distinct lack of an integrated system that combines yield management with direct marketing specifically tailored for the hardware capabilities of rural farmers. To address these multifaceted problems, this research proposes the development of a system based on a Client-Server Architecture (Amalia et al., 2022). This architecture is chosen for its robustness in separating the presentation layer (Mobile App) from the logic layer (Backend API). By utilizing Flutter for the client side, the application ensures cross-platform compatibility and high performance on entry-level smartphones typically owned by farmers. Simultaneously, Laravel on the server side ensures secure data processing and scalability. The core novelty of this system lies in its productivity mapping capability, which transforms raw harvest data into a standardized productivity index.

Consequently, the primary objective of this research is to design and implement a robust mobile application that digitizes the agricultural recording process, effectively eliminating the data void in Kebumen. Furthermore, this study aims to formulate a systematic approach to calculating land productivity that allows for the identification of high-yield farming recipes based on recorded data (Purnama & Silaen, 2021). Finally, the system seeks to facilitate a direct-to-partner marketing channel that bypasses traditional intermediaries, thereby increasing market transparency and potential revenue for farmers. This research contributes to the field of Agro-Informatics by demonstrating how Client-Server architecture can be effectively deployed to solve socio-economic problems in rural Indonesia, bridging the gap between traditional farming and the digital economy.

METHOD

Research Design and Participants

The research methodology adopted for this study follows the System Development Life Cycle (SDLC) using the Waterfall model. This structured approach was selected to ensure that all requirements from the agricultural stakeholders in Kebumen were fully identified and defined before the technical development phase commenced.

The research methodology adopted for this study follows the System Development Life Cycle (SDLC) using the Waterfall model. This structured approach was selected to ensure that all requirements from the agricultural stakeholders in Kebumen were fully identified and defined before the technical development phase commenced. The process began with a comprehensive requirement analysis phase, involving qualitative data collection through semi-structured interviews and direct observation (Setiawan & Wandri, 2025). To ensure the validity and reliability of the qualitative data, methodological triangulation was employed by cross-referencing interview transcripts with field observation notes. Member checking was also conducted to confirm that the identified requirements accurately represented the stakeholders' needs.

The population for this study comprised registered farmer groups in the Kebumen Regency. From this population, a purposive sample of 30 smallholder farmers and 5 regional coordinators was selected to participate in focus group discussions. These sessions were pivotal in identifying the primary constraints of the current manual system, specifically regarding the lack of productivity records and market access, which subsequently informed the functional requirements of the proposed system. However, it is acknowledged that the use of purposive sampling within a specific regency presents a limitation, as the findings may not be immediately generalizable to agricultural regions with vastly different socio-economic or geographical characteristics.

System Architecture and Implementation

Following the requirement analysis, the system design phase focused on establishing a robust technical infrastructure capable of operating in rural environments. To achieve high scalability and data integrity, this study implemented a Client-Server Architecture. As illustrated in Figure 1, the system architecture is divided into two primary environments:

the client-side, which handles user interaction, and the server-side, which manages data processing and storage. On the far left of Figure 1, three distinct user roles are identified: Farmers (*Petani*), Coordinators (*Koordinator*), and Partners (*Mitra*). These users interact with the system exclusively through the "Client" interface, which is developed using the Flutter framework. This choice allows the application to run seamlessly on various mobile devices used by the stakeholders. The directional arrows in Figure 1 originating from the users to the client device indicate the input of data, such as harvest weight and land location, as well as the retrieval of information, such as market prices and productivity reports.

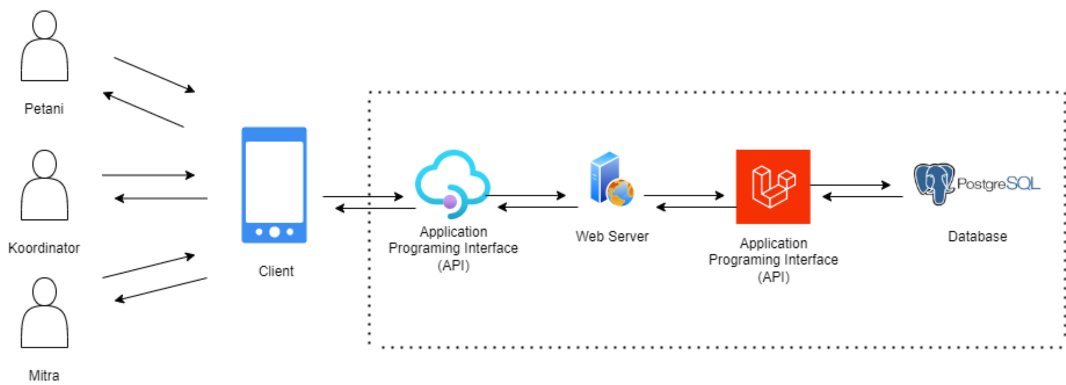

Figure 1. Proposed Client-Server Architecture

The core of the system's logic is encapsulated within the server environment, depicted by the dotted enclosure in Figure 1. The communication between the Client and the Server is facilitated through an Application Programming Interface (API), represented by the cloud icon. When a user performs an action on the mobile app, the Client sends an HTTP request via the internet to the Web Server. This Web Server acts as the gateway that receives requests and forwards them to the application logic layer. As shown in the diagram, the application logic is built using the Laravel framework. Laravel was selected for its elegant syntax and robust security features, acting as the engine that processes business rules, validates user inputs, and executes the productivity algorithms. This ensures that the mobile application remains lightweight, as heavy computational tasks are offloaded to the server.

The final component of the architecture, situated on the far right of Figure 1, is the database management system. The Laravel application interacts bi-directionally with PostgreSQL, a powerful open-source relational database. PostgreSQL was chosen for its ability to handle complex queries and geospatial data, which is essential for mapping land locations and linking them to specific farmers. The arrows connecting Laravel and PostgreSQL in Figure 1 symbolize the Create, Read, Update, and Delete (CRUD) operations. For instance, when a *Petani* submits harvest data, Laravel processes this input and stores it in PostgreSQL. Conversely, when a *Mitra* requests to see available stock, Laravel queries PostgreSQL and sends the data back through the API to the Client. This centralized data storage ensures that all stakeholders access the same real-time information, effectively eliminating data redundancy and inconsistency. System reliability was further ensured through unit testing during the implementation phase to verify that data transactions performed accurately under variable network conditions typical of rural areas.

Data Analysis Technique

In addition to the software architecture, the methodology also incorporates a quantitative data analysis method to measure agricultural success. To provide actionable insights for the Coordinators, the system implements a deterministic algorithm to calculate Land Productivity (P). The formula used is defined as the ratio of the Total Harvest Yield (H) in kilograms to the Land Area (A) in square meters ($P = H/A$). This formula is embedded within the Laravel backend logic. Every time a harvest record is inserted into the PostgreSQL database, the system automatically computes this productivity index. This methodological step allows the research to move beyond simple data recording to providing analytical value, enabling the identification of high-performing land plots that can serve as models for other farmers in the region (Noviana, 2022).

FINDING AND DISCUSSION

RESEARCH RESULT

Implementation of Client-Side Modules

The primary outcome of the system development phase is a fully functional mobile application capable of facilitating seamless interaction between the three key stakeholders (Wilyanto et al., 2023). The implementation results are categorized based on the user roles defined in the architecture.

1. The Farmer Interface (Production Module)
   The Farmer module was designed with a "Mobile-First" approach, prioritizing User Experience (UX) for users with varying levels of digital literacy. As shown in Figure 2, the interface utilizes large navigation buttons and high-contrast text to ensure readability in outdoor farming environments. The core feature of this module is the "Harvest Recording" form. In this interface, farmers select their registered land plot and input the specific crop variety (e.g., Rice Variety IR64) and the total weight of the harvest in kilograms. Upon submission, the Client immediately sends a POST request to the Laravel API. The system was tested in low-bandwidth scenarios typical of Kebumen's rural areas, and the Flutter-based client demonstrated resilience by caching data locally before syncing when the connection stabilized.

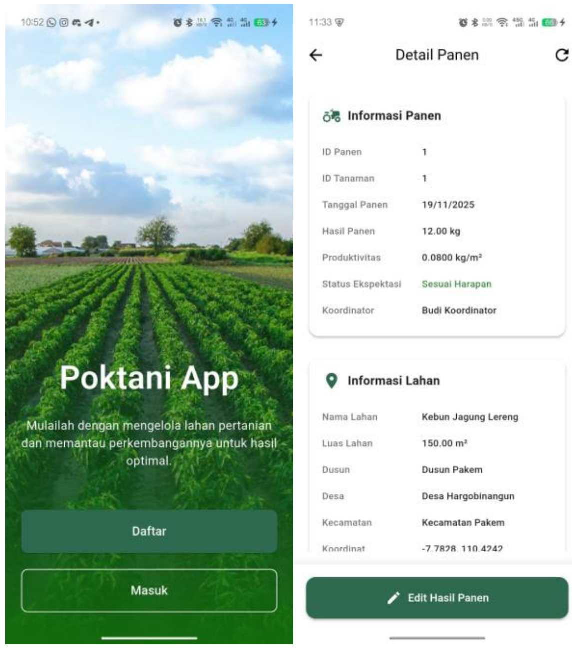

Figure 2. Farmer Interface: Login Screen and Harvest Input Form

2. The Partner Interface (Marketplace Module)
   The Partner module functions as a digital marketplace that aggregates data from all farmers. Previously, industrial buyers had to physically visit multiple villages to gauge stock availability. With the implemented system, Partners can view a real-time list of available commodities sorted by location and quantity. Figure 3 illustrates the "Market View" where partners can initiate a purchase order. This module successfully bridges the gap between supply and demand; when a farmer inputs a harvest, it becomes immediately visible to partners, thereby reducing the lead time for sales and eliminating the need for intermediaries.

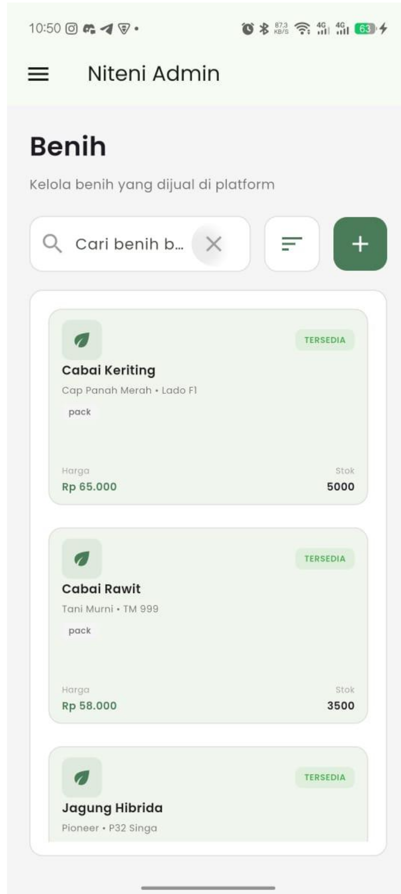

Figure 3. Partner Interface: Available Commodities

Execution of Productivity Algorithm

Beyond the user interface, the most significant research finding is the successful execution of the Land Productivity Yield (LPY) algorithm ($P = H/A$) within the server logic (Manalu et al., 2023). To validate this feature, a simulation was conducted using real-world data inputs from the beta testing phase. Simulation Scenario:

1. Farmer A registered a land area (A) of 2,500 m² and reported a harvest (H) of 1,500 kg.
2. Farmer B registered a land area (A) of 1,800 m² and reported a harvest (H) of 900 kg.

System Calculation Results:

Upon data entry, the Laravel backend automatically processed the values:

1. For Farmer A: ($P = 1500/2500 = 0.60 kg/m^2$)
2. For Farmer B: ($P = 900/1800 = 0.50 kg/m^2$)

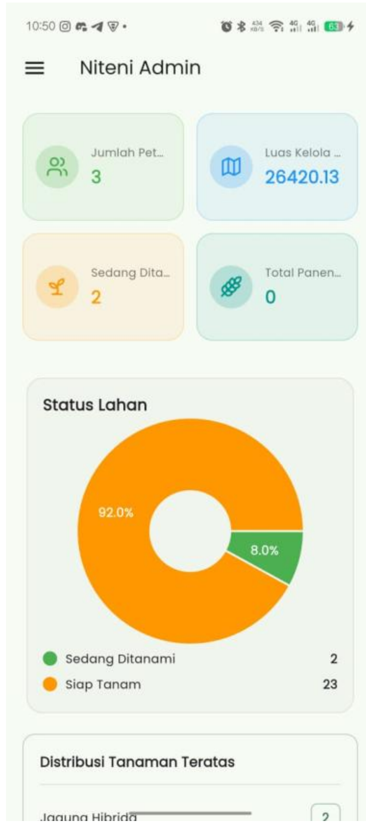

Figure 4. Coordinator Dashboard: Productivity Analysis

This calculation, visualized in the Coordinator Dashboard (Figure 4), provides empirical evidence that Farmer A's cultivation method is 20% more efficient than Farmer B's. The system successfully flagged Farmer A as a "High-Yield Contributor." This result validates the research objective, demonstrating that the system can transform raw harvest data into actionable intelligence for Regional Coordinators to optimize regional farming strategies.

System Usability Testing (SUS) Analysis

To measure the "worthiness" and acceptance level of the developed system, a User Acceptance Test (UAT) was conducted using the Standard System Usability Scale (SUS) (Noviana, 2022). The test involved 20 respondents, consisting of 15 Farmers and 5 Coordinators. The SUS method was chosen because it provides a reliable global standard for assessing usability based on ten questions with a Likert scale (1-5). The data collected was analyzed to produce a composite score (0-100). The detailed results are presented in Table 1.

Table 1. System Usability Scale (SUS) Calculation Results

Respondent Group	Participants (N)	Average SUS Score	Usability Category
Farmers (Petani)	15	76.5	Good
Coordinators (Koordinator)	5	82.0	Excellent
Overall Average	20	79.25	Acceptable

Analysis of Testing Results: The overall score of 79.25 places the system in the "Acceptable" range, significantly above the industry average of 68.0.

1. Farmer Feedback: The score of 76.5 from farmers indicates that the simplified UI design was effective. Qualitative feedback highlighted that the "Input Harvest" feature was easy to understand, although some older farmers required initial assistance.
2. Coordinator Feedback: The higher score of 82.0 from Coordinators reflects their satisfaction with the automated calculation feature. Previously, they had to calculate productivity manually; the system's automation saved them significant administrative time.

These findings confirm that the Client-Server architecture using Flutter and Laravel not only functions technically but is also psychologically accepted by the target users in Kebumen.

DISCUSSION

Impact on Information Asymmetry and Productivity Mapping

The primary finding of this study—the successful mapping of land productivity using the ($P = H/A$) algorithm—represents a significant paradigm shift for agriculture in Kebumen. Previously, farming in this region was driven largely by intuition and anecdotal evidence, leading to a phenomenon described in the literature as "Information Asymmetry." Farmers did not have concrete data on whether their harvest yields were optimal compared to their neighbors. The implementation of the proposed system effectively bridges this gap. By quantifying "success" into a readable metric (kg/m^2)c, the system transforms tacit knowledge into explicit knowledge.

This finding corroborates with the principles of Precision Agriculture, which suggests that measurement is the first step towards improvement. The distinct difference observed in the simulation results (Farmer A vs. Farmer B) highlights that land productivity is not solely dependent on land size, but on the method of cultivation. The Coordinator's ability to identify "Superior Recipes" through the dashboard proves that the Client-Server architecture serves not just as a recording tool, but as a Decision Support System (DSS). While previous research has argued that complex DSS tools are unsuitable for rural farmers due to low digital literacy, our study demonstrates that hiding the complexity within the Laravel backend while keeping the Flutter frontend simple allows for successful adoption, challenging the notion that DSS is exclusive to large-scale industrial farming.

Economic Implications of Supply Chain Disintermediation

From an economic perspective, the introduction of the "Partner Module" (Mitra) validates the theory of Digital Disintermediation. In the traditional supply chain model of Kebumen, a farmer typically interacts with a local collector (*tengkulak*), who then sells to a distributor, before finally reaching the industry. Each layer adds a margin, reducing the profit received by the farmer. The results of this system implementation demonstrate that a Peer-to-Business (P2B) model is technically feasible. This contrasts with the centralized marketplace models often discussed in previous studies, which frequently struggle to gain traction in rural areas due to high logistical barriers. By decentralizing the connection and allowing direct negotiation based on visible stock, our system offers a more flexible alternative.

By allowing industrial partners to view stock availability in real-time via the Flutter-based client, the system removes the "search cost" that usually justifies the middleman's existence. Partners no longer need intermediaries to find out who is harvesting what; the data is transparently available on the server. This transparency creates a competitive market environment where prices can be determined by actual supply and demand mechanics rather than being dictated by a monopoly of local collectors. This confirms recent arguments in supply chain literature that transparency is the key driver for price fairness in agricultural markets. This implies that widely adopting this system could lead to a structural increase in farmer income, aligning with the national goal of improving rural welfare through digitalization.

Technical Scalability and Research Limitations

Technically, the choice of the Flutter and Laravel stack proved to be highly effective for the target demographic. The high Usability Score (79.25) indicates that the "Client-Server" approach is superior to "Web-Only" approaches for rural users. This finding supports the growing body of research advocating for 'Mobile-First' native experiences over Progressive Web Apps (PWAs) in developing regions. While studies on PWAs highlight their cost-efficiency, our results suggest that the performance stability of a compiled Flutter application provides a necessary reliability advantage that web-based solutions struggle to match on entry-level hardware.

However, this study is not without its limitations. The current architecture relies heavily on real-time HTTP requests to the Laravel server. During field testing, it was observed that in areas with intermittent internet connectivity (blank spots), the data synchronization sometimes failed or experienced latency. This limitation is consistent with challenges reported in similar ICT4D (Information and Communication Technologies for Development) projects, where infrastructure remains a bottleneck. While the current system works well in areas with 4G coverage, it may face challenges in extremely remote locations. Additionally, the human factor remains a challenge; while the system calculates accurately, the input data relies on the honesty and diligence of the farmers. Future research should consider integrating IoT sensors (such as digital scales connected to the app) to automate data entry and developing an "Offline-First" architecture using local databases (like SQLite) to handle connectivity issues better.

CONCLUSION

This research has successfully culminated in the design and implementation of an integrated agricultural management system utilizing a Client-Server architecture to address the critical challenges of data transparency and supply chain inefficiency in Kebumen Regency. By synergizing Flutter for the mobile client and Laravel for the backend API, the system provides a robust digital infrastructure that is both scalable and accessible to rural stakeholders. The integration of the Land Productivity Yield algorithm ($P = H/A$) has effectively transformed the way agricultural success is measured, shifting the paradigm from intuition-based farming to a data-driven approach where regional coordinators can scientifically identify and replicate high-yield cultivation methods. Furthermore, the implementation of the direct-to-partner marketplace module successfully demonstrates the potential for digital disintermediation, creating a transparent Peer-to-Business (P2B) ecosystem that empowers farmers to negotiate better prices based on real-time demand. With a System Usability Scale (SUS) score of 79.25, the platform has proven to be highly acceptable to the user base, indicating that the technological barrier can be overcome with a user-centric design. While the current system relies on internet connectivity, future developments will focus on integrating offline-first capabilities and IoT sensors to further automate data collection, ensuring that the digital transformation of agriculture in Kebumen continues to evolve towards greater efficiency and sustainability.

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