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The Implementation of Agile Kanban in the Development of an IoT-Based Sugarcane Growth Monitoring System

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ABSTRACT

This research stems from the urgent demand for modernisation of sugarcane farming in Indonesia, which faces challenges such as declining productivity due to climate change, limited cultivation technology, and weather uncertainty. The main problem is the absence of a real-time environmental monitoring system that can support farmers in making timely and accurate cultivation decisions. The objective of this study is to develop an IoT-based Sugarcane Growth Monitoring System equipped with four sensors—temperature, humidity, air pressure, and light intensity—using the Agile Kanban project management method. The methodology consists of literature study, planning, implementation, and analysis, carried out iteratively with the aid of a Kanban Board to structure and monitor progress. The results demonstrate that the system successfully integrates hardware, software, and user interfaces to deliver real-time environmental data. At the same time, Agile Kanban proves effective in managing the complexity of the development process. This research contributes not only academically, by showing the applicability of Agile Kanban in agricultural IoT projects, but also practically, by providing sugarcane farmers with decision-making support tools that can enhance efficiency, reduce resource waste, and improve cultivation productivity.

INTRODUCTION

Sugarcane (*Saccharum officinarum L.*) is one of Indonesia's strategic plantation commodities and the primary raw material for the national sugar industry (Putra et al., 2024). As sugar is closely linked to food security, its production capacity directly affects Indonesia's resilience in meeting domestic needs (Ridla & Rahma, 2024). However, in the past few decades, sugarcane productivity has declined due to deteriorating soil quality, unpredictable climate, and the limited use of modern cultivation technologies (Maharani et al., 2024). These challenges highlight the urgent need for technological innovations that can optimise land management, monitor crop growth more accurately, and improve overall yield performance (Witra et al., 2025).

The Internet of Things (IoT) has been increasingly adopted in agriculture to support innovative farming practices, where sensors and connected devices collect and transmit real-time field data to assist farmers in decision-making (Wahyudi et al., 2025). In sugarcane farming, IoT has strong potential to monitor essential growth parameters such as temperature, humidity, light intensity, and soil conditions (Abduramadani & Harianto, 2025). While studies on IoT-based agriculture are growing globally (Rasid et al., 2025), research focusing on sugarcane in the Indonesian context remains limited, despite its importance as a national strategic commodity.

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At the same time, Agile methodologies have been widely implemented in IoT system development to improve adaptability and user-centered design. Previous research has shown successful applications of Agile Scrum in monitoring systems for climbers (Pamungkas et al., 2024) and automated fish feeding (Fadia et al., 2025). However, most studies still focus on general or non-agricultural IoT applications, with very few exploring agricultural commodities in Indonesia. More importantly, no previous studies have specifically applied Agile Kanban in the development of an IoT-based sugarcane growth monitoring system. This research gap underlines the novelty of this study.

Agile Kanban, which integrates Agile principles with Kanban's visual workflow and Work-In-Progress (WIP) limits, offers advantages in transparency, adaptability, and iterative improvement. This makes it highly suitable for agricultural IoT systems that require continuous updates and adjustments to field conditions.

Therefore, the objective of this research is to design and implement an IoT-based Sugarcane Growth Monitoring System using Agile Kanban. The expected contribution is twofold: (1) practically, providing a prototype that helps farmers monitor environmental parameters in real time and supports timely cultivation decisions, and (2) academically, filling the research gap by presenting the first empirical study that applies Agile Kanban in the context of sugarcane farming IoT systems in Indonesia. This combination of technological and methodological contributions seeks to enhance efficiency, productivity, and sustainability in Indonesia's sugarcane sector.

RESEARCH METHODS

This study uses an engineering experimental approach with the application of the Agile Kanban project management method to develop an IoT-based Sugarcane Growth Monitoring System. The research methodology is divided into four interconnected stages, namely literature study, planning, implementation, and analysis. Each stage is designed to ensure that the system development process is structured, adaptive, and aligned with the research objectives.

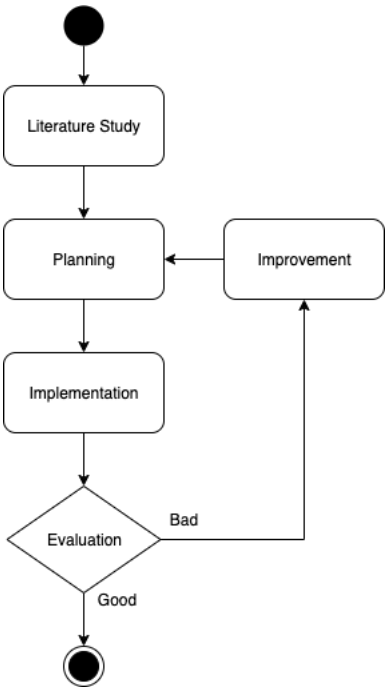

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Figure 1. Research Methodology

The first stage was a literature study, which aimed to collect and analyse scientific references related to the application of IoT in agriculture, particularly in sugarcane commodities, the use of environmental sensors, and the implementation of the Agile Kanban method in software and IoT system development. The literature used included scientific journals, proceedings, books,

and previous research reports (Rachmawati et al., 2024). From this study, a deep understanding was gained of the environmental parameters relevant to sugarcane growth—such as temperature, humidity, atmospheric pressure, and light intensity—as well as sensor integration techniques into IoT-based monitoring systems (Telaumbanua et al., 2023). The literature review established a methodological basis for optimal practices in Agile Kanban implementation to enhance the efficiency of the development process.

The second stage involves planning, which encompasses the formulation of development objectives, the identification of system requirements, and the design of the technical architecture (Wardani et al., 2023). At this juncture, a product backlog is assembled, encompassing a compilation of features and functionalities to be created, which includes the integration of temperature, humidity, air pressure, and light sensors with a microcontroller, alongside data communication to a monitoring platform. A Kanban Board serves to visualize workflow by categorizing activities into columns such as To Do, In Progress, Testing, and Done, while establishing Work In Progress boundaries to maintain team concentration (Ahmed et al., 2024). Planning encompasses role assignment within the team, time estimation, and the selection of hardware and software, including ESP32-based microcontrollers, DHT22, BMP280, and LDR sensors, as well as a web-based visualization platform.

The third stage is implementation, executed iteratively in accordance with Agile Kanban principles. Features are produced through iterative work cycles that facilitate the enhancement and improvement of the system depending on input and testing outcomes (Rachmawati et al., 2023). The implementation phase encompasses hardware assembly, sensor integration, software development for data gathering and transmission, and the building of web-based monitoring interfaces or applications. Testing occurs in two contexts: (1) laboratory simulation to confirm sensor connectivity and data transmission, and (2) field testing in sugarcane plantations in Mojokerto City, East Java Province, to assess system performance under actual agricultural settings. Each scheduled job is performed based on priority on the Kanban Board, assessed for functionality, and subsequently transferred to the Done column upon meeting the completion criteria (Schreier et al., 2025). Testing verifies that every component—hardware and software—operates as specified and can deliver real-time environmental data (Wong et al., 2022).

The concluding phase is analysis, which seeks to assess system performance and the efficacy of Agile Kanban deployment in the development process (Rachmawati & Darmawan, 2024). The system-generated data is validated by comparing sensor readings with conventional reference devices, including digital thermohygrometers, barometers, and lux meters. The efficacy of the Agile Kanban methodology is evaluated by measuring task completion velocity, accuracy in achieving sprint objectives, and the team's responsiveness to evolving needs (Guerrero-Ulloa et al., 2023). The analysis encompasses an assessment of user satisfaction with the system (Darmawan et al., 2025), derived from surveys and observations conducted during field testing in sugarcane plantations. The outcomes of this phase are utilized to offer recommendations for further advancement and to summarize the research's contribution to the modernization of sugarcane agriculture in Indonesia.

RESULTS AND DISCUSSION

Result

The creation of an IoT-based Sugarcane Growth Monitoring System utilizing the Agile Kanban methodology was accomplished through the implementation of a Kanban Board as the principal task management instrument. This Kanban Board comprises four primary columns: To-Do, In Progress, Review, and Done, which visually and systematically depict the project workflow. Each card on this board signifies a distinct unit of work, encompassing system design, hardware and software development, as well as functional field testing.

Each card is supplied with Cycle Time, defined as the duration necessary to perform a job from its transition from To-Do to Done. This data serves as a performance metric to assess work

completion speed and identify potential workflow impediments. The assignee on each card designates the individual accountable for the task, so assuring responsibility and ownership for each assignment. The description includes technical specifications regarding the objectives and extent of the job, while subtasks serve to decompose the work into smaller, quantifiable phases for enhanced implementation assessment.

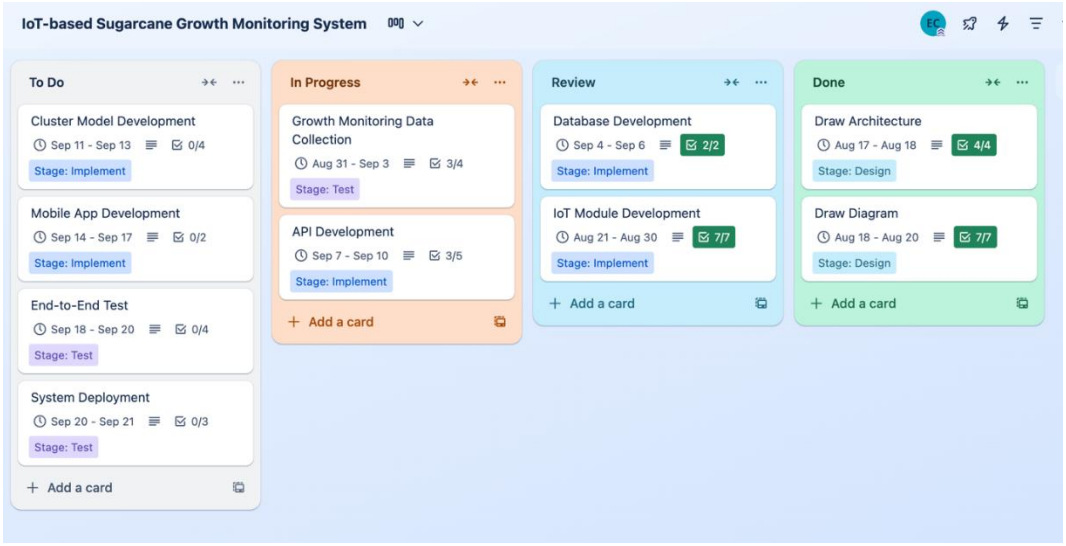

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Figure 2. Kanban Board

Furthermore, each card is assigned an effort label to denote the anticipated level of difficulty or resources needed, along with an effect label to illustrate the extent of the task's influence on the project's overall performance. These labels assist the team in prioritizing tasks of significant strategic importance while taking into account the workload. Each card is assigned a stage title that categorizes the activity into three primary phases: Design, Implement, and Test. These stages facilitate progress tracking while guaranteeing that each activity undergoes the requisite validation process prior to being deemed complete.

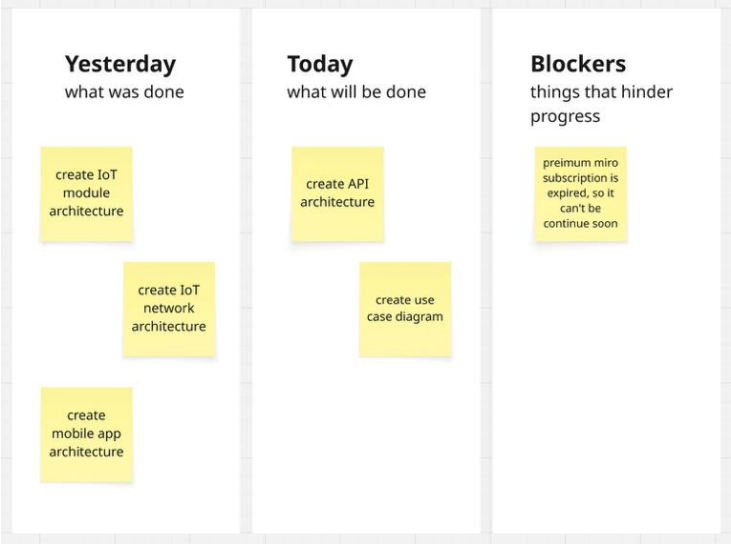

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Figure 3. Daily Standup Meeting

In the execution of Agile Kanban for the creation of an IoT-based Sugarcane Growth Monitoring System, two primary activities were routinely conducted to facilitate workflow and enhance result quality: daily stand-up meetings and biweekly retrospective sessions. Daily stand-up meetings are succinct gatherings conducted each day for approximately 10–15 minutes, when

all team members remain standing to sustain the intensity and concentration of the dialogue. This meeting aims to deliver a concise update on each member's work progress, challenges faced, and plans for the day. This style enables the entire team to acquire a current picture of the project status, recognize potential barriers promptly, and swiftly realign priorities if needed.

Both activities have had a substantial influence on project management. Daily stand-up meetings enhance cooperation and transparency among team members, facilitating the prompt resolution of technical difficulties such as sensor integration challenges or interface flaws. Retrospective meetings facilitate the application of insights gained from prior iterations to enhance productivity and job quality in subsequent cycles (Bein, 2023). The integration of these two processes corresponds with Agile concepts, wherein robust communication and ongoing enhancement are essential for successful system development (Christensen et al., 2025).

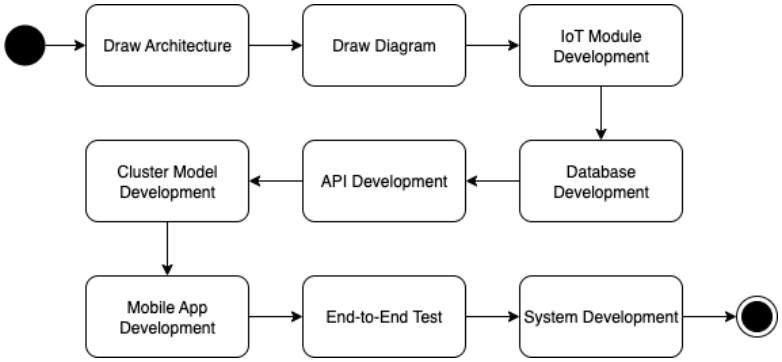

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Figure 4. System Development Flowchart

A burndown chart is a graphical representation utilized in the Agile approach to illustrate the remaining work in relation to the available time (Mišković et al., 2024). This chart assists project teams in tracking daily work completion progress and comparing it to the predetermined ideal target (Sravan et al., 2024). The vertical axis of a burndown chart represents the quantity of work (in tasks or subtasks), and the horizontal axis denotes the duration or days of labor (Natarajan & Pichai, 2024). By juxtaposing the ideal line with the actual line, the team may ascertain if the project is on plan, ahead of schedule, or encountering delays (Castillo et al., 2024). A burndown chart's primary advantage is its provision of a real-time perspective of project progress, facilitating decision-making, early identification of impediments, and necessary adjustments to the work plan (Pham & Neumann, 2024). Moreover, burndown charts foster transparency within the team, incentivize individuals to meet objectives, and function as an efficient communication medium between the development team and stakeholders (Pham & Neumann, 2025).

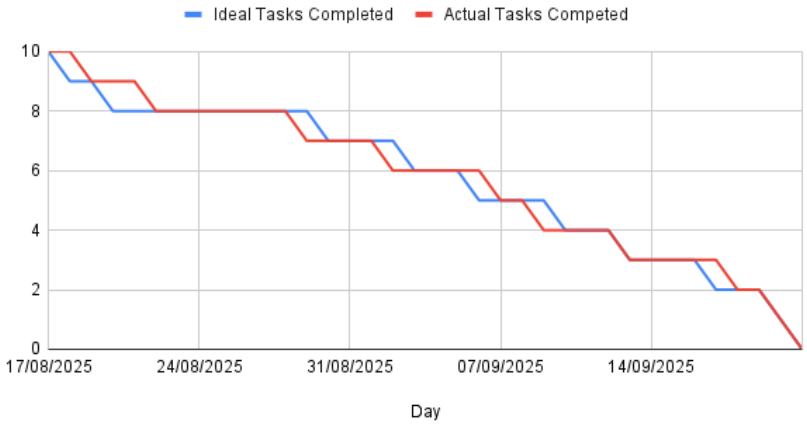

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Figure 5. Task Burndown Chart

Based on the two burndown charts shown, the first chart shows the progress of completing 10 tasks during the period from August 17, 2025, to September 21, 2025. The blue line represents the number of tasks that should have been completed according to plan (ideal), while the red line shows the number of tasks that were completed (actual). The data shows that at the beginning of the project, actual progress was faster than planned, such as on August 18, 2025, when the number of completed tasks remained at 10, exceeding the ideal target of 9. However, there was a period of stagnation between August 22 and 28, during which there was no decrease in the number of remaining tasks, indicating that no new tasks were completed during that time. After that, the completion rate returned to a consistent pace, with all tasks completed on time by September 21, 2025.

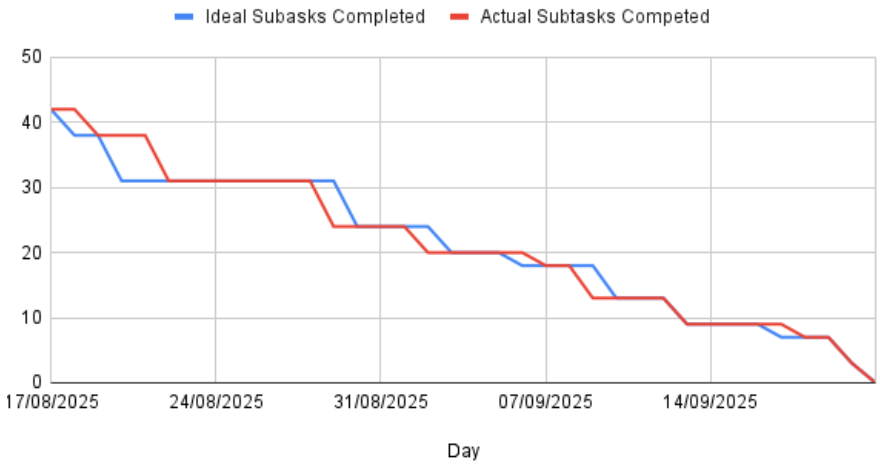

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Figure 6. Subtask Burndown Chart

The second graph illustrates the completion of 42 subtasks in greater detail than the task level. The pattern is similar to the task burndown chart, but there are more significant fluctuations. For example, on August 20, 2025, the number of subtasks completed was still 38, exceeding the ideal target of 31, indicating rapid initial progress. However, there was a relatively long period of stagnation from August 22 to 28, during which the number of completed subtasks remained at 31. A significant surge in completion occurred on August 29, with the number of remaining subtasks dropping from 31 to 24, indicating the simultaneous completion of several important tasks. Overall, the completion of subtasks was also on target by the end date, although actual progress occasionally fell slightly above or below the ideal line.

From the task and subtask data, it can be seen that the pattern of work completion tends to be not entirely linear, with periods of stagnation and spikes in progress. Periods of stagnation generally occur when the team focuses on complex subtasks or those that require inter-component dependencies, such as sensor integration or end-to-end testing. Progress spikes often occur after critical parts of the work are completed, allowing many subtasks to be completed simultaneously. This pattern is characteristic of IoT system development utilizing the Agile Kanban methodology, wherein technical complexity and field testing procedures affect the task completion rate.

Table 1. Agile Kanban Metrics in the Development Process

Metric	Observation	Interpretation
Cycle Time (avg)	2.5 days per task	Indicates balanced task flow
Velocity (biweekly)	10 taks	Stable output across iterations
Stagnation periods	Aug 22–28, 2025	Due to complex sensor integration
Progress spikes	Aug 29, 2025	Completion of dependent subtasks

Table 1 encapsulates the essential metrics of Agile Kanban implementation in the creation of an IoT-based sugarcane monitoring system. The average cycle time of 2.5 days per job signifies

a balanced workflow, while the consistent velocity of 10 tasks biweekly affirms the reliability of the team's output. Nonetheless, a period of stasis occurred from August 22 to 28, 2025, attributable to the intricacies of sensor integration, which impeded task completion. After surmounting these technical challenges, a significant advancement occurred on August 29, 2025, when multiple interdependent subtasks were finalized concurrently, exemplifying a common trend in IoT projects characterized by inter-component dependencies.

Discussion

The analysis of the research findings indicates that the implementation of Agile Kanban in the creation of an IoT-based Sugarcane Growth Monitoring System offers both a systematic work framework and tangible benefits for end users, specifically sugarcane farmers. Real-time monitoring of environmental parameters, including temperature, humidity, air pressure, and light intensity, provides farmers with timely information to assist decisions regarding irrigation, fertilization, and crop protection. This diminishes dependence on intuition, minimizes resource wastage, and enhances efficiency and output at the plantation level. The advantages of Agile Kanban encompass not just project team coordination but also tangible results that directly promote agricultural sustainability.

The selection of Agile Kanban instead of other Agile methodologies like Scrum is noteworthy from a methodological standpoint. Predetermined sprints and established roles characterize Scrum, whereas Kanban offers greater flexibility through continuous workflow without rigid iteration limits. In IoT development for agriculture, where field testing and sensor calibration often face unpredictable delays, the adaptive nature of Kanban is more suitable. This is reflected in the project's ability to manage stagnation periods and recover quickly through progress spikes once critical subtasks (such as sensor integration) were completed. Thus, Kanban offers advantages in handling dynamic and interdependent tasks compared to Scrum, which may struggle with rigid sprint structures.

Scientifically, this study contributes novelty by being the first to empirically implement Agile Kanban in the development of an IoT system specifically for sugarcane cultivation in Indonesia. Previous studies have demonstrated IoT–Agile integration in other fields, such as fish feeding or climber monitoring, but none have examined its application in sugarcane farming, a commodity vital for national food security. This research therefore fills a gap in the literature by demonstrating that Agile Kanban can not only improve project management effectiveness but also enhance the performance and applicability of IoT systems in agriculture. Furthermore, the findings add to the academic discourse on agile project management in domain-specific IoT contexts, providing a foundation for future comparative studies across different agricultural commodities.

CONCLUSION

This study emphasizes the innovation of utilizing the Agile Kanban approach in the creation of an IoT-based Sugarcane Growth Monitoring System, positioning it as one of the first empirical applications of Agile Kanban in agricultural IoT initiatives within Indonesia. This research academically addresses the gap between current studies on Agile–IoT integration and the deficiency of domain-specific investigations in sugarcane agriculture, a commodity vital to national food security. The system effectively showcases its capability to aid farmers by delivering real-time environmental data that enhances decision-making in irrigation, fertilization, and crop protection, hence minimizing resource inefficiency and boosting output. This method provides a repeatable framework for various agricultural products, facilitating the wider modernization of smart farming in Indonesia.

FUTURE WORKS

For further development, this IoT-based sugarcane growth monitoring system can be enhanced by adding more advanced analytics technology, such as machine learning-based predictive analytics, to predict growth and crop yields more accurately. In addition, the system can be expanded by adding additional sensor types, such as soil moisture sensors and nutrient sensors,

to provide more comprehensive information about soil conditions. Mobile app development can also be directed toward supporting innovative notification features, integration with automated irrigation systems, and historical analysis dashboards to help farmers make strategic decisions. Larger-scale trials involving various regions and different climatic conditions will be a crucial step in testing the system's resilience, scalability, and effectiveness in supporting the modernisation of sugarcane cultivation in Indonesia.

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