REVIEW

IMPLEMENTATION OF MCB'S INNOVATION ON IOT IN COCOA MANAGEMENT

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Malaysian Cocoa J. 16: 41-46 (2024)

ABSTRACT – *Information and communication technology employed in machinery, equipment, and sensors in network-based high-tech farm supervision cycles is the focus of the emerging field of "smart farming." It is expected that new technologies, including cloud computing and the Internet of Things (IoT), will spur development and introduce robotics and AI into farming. Such revolutionary changes pose several difficulties and disrupt established agricultural practices. This paper examines the instruments and apparatus invented by the Malaysian Cocoa Board (MCB) which have been utilized in wireless sensor applications in Internet of Things agriculture, as well as the expected difficulties encountered in integrating technology with traditional farming practices. Additionally, growers can benefit from this technological knowledge from planting to harvest; applications in soil nutrient status and smart fertigation systems are also being researched.*

Keywords: Crop management, sustainable agriculture, smart farming, internet-of-things (IoT), advanced agriculture practices

INTRODUCTION

Sustainable agriculture measures the endurance and sustenance of food grains produced in an eco-friendly manner. It promotes farming practices that sustain both farmers and resources. This approach is economically feasible, maintains soil quality, reduces soil degradation, conserves water, enhances land biodiversity, and ensures a natural and healthy environment. Moreover, sustainable agriculture plays a significant role in preserving natural resources, preventing biodiversity loss, and reducing greenhouse gas emissions.

Sustainable agriculture farming methods aim to preserve nature without compromising the basic needs of future generations while enhancing farming efficiency. Key accomplishments of smart farming in sustainable agriculture include crop rotation, nutrient deficiency management in crops, pest and disease control, recycling, and water harvesting, all contributing to a safer environment. Biodiversity is essential for living organisms, which are affected by waste emissions, fertilizers, pesticides, and degraded plant material. The emission of greenhouse gases impacts plants, animals, humans, and the environment, highlighting the need for a better living environment for all organisms.

According to the Ministry of Finance's Economic Outlook 2023 report, agriculture in Malaysia contributed 2.3% to GDP growth. From 2010 to 2024, the sector averaged a contribution of RM23,814.09 million annually. The agricultural sector reached an all-time high in the third quarter of 2019, with a contribution of RM28,082.00 million. Cocoa is one of the main contributors to GDP with data stating that from 2019 to 2023, the cocoa sector's contribution to Malaysia's GDP increased at an average annual rate of 7.2%. Cocoa exports were valued at RM8.2 billion, up from RM7.8 billion in 2022. The primary contributors to these exports were cocoa butter, cocoa powder, and chocolate.

Currently, Malaysia ranks among the top cocoa-grinding countries globally, holding the fifth position globally and the number one position in Asia. Local cocoa production capacity has drastically declined, rendering the grinding sector unsustainable and causing a significant imbalance between the upstream and downstream sectors (Ramle, 2012; Arshad & Ibragimov, 2015). The development of upstream cocoa activities has not kept pace with the downstream industry, which increasingly relies on imported cocoa beans to meet the processing industry's demands (Wood, 2017). This dependency highlights the urgent need to bolster domestic cocoa production to ensure a balanced and self-sufficient cocoa industry.

In rural areas, cocoa farming families are gradually losing the next generation of farmers due to several challenges. These include rising cultivation costs, low per capita productivity, inadequate soil maintenance, and a trend of migration towards non-farming or more lucrative occupations. Existing cocoa farms are increasingly fragmented by rapid urbanization, which consistently pressures the availability of arable land (Figure 1).

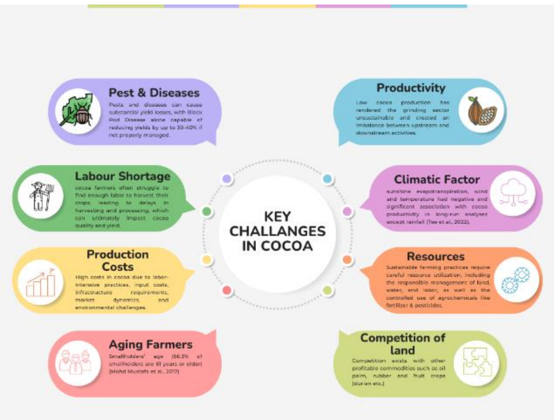

Figure 1: Key issues of technology in the cocoa industry

As a fact, the total cocoa land used for bean production has declined. To optimize cocoa bean production in the same field, it is essential to consider both spatial and temporal differences through good agricultural practices. Currently, as the world stands on the brink of a digital revolution, it is an opportune moment to integrate agricultural practices with wireless technology. By enhancing digital connectivity among farmers, we can introduce innovative solutions that address these challenges and support the sustainability of rural farming communities.

In many cases, variations in characteristics arise within a single crop, or the entire farm is dedicated to growing the same crop, necessitating site-specific analyses for optimal yield production. Innovative technology-driven approaches are essential to maximize output while minimizing land usage and addressing these diverse challenges. In traditional farming practices, farmers frequently visit their fields throughout the crop's lifecycle to monitor and understand crop conditions (Navulur *et al*., 2017). Current sensor and communication technologies provide precise field insights, enabling farmers to monitor ongoing activities and detect issues at early stages remotely. Wireless sensors offer higher accuracy in crop monitoring, facilitating the use of smart tools from initial growing to harvest (Ayaz *et al*., 2018).

SMART FARMING IN AGRICULTURE

In ancient times, agriculture was primarily focused on cultivating lands to produce food for human survival (Tekinerdogan, 2018). This era, known as the traditional agricultural era 1.0, relied heavily on human and animal labor. Simple tools like sickles and shovels were commonly used for farming activities. Work was predominantly conducted through manual labor, resulting in relatively low productivity levels (Figure 2).

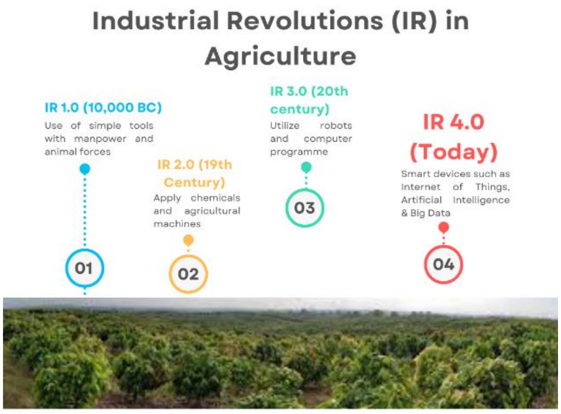

Figure 2: Agricultural revolutions

During the 19th century, the introduction of steam engines revolutionized the agricultural sector, marking the beginning of the agricultural era 2.0. This era saw widespread adoption of machinery and chemical inputs, leading to improved efficiency and productivity on farms. However, it also brought about significant challenges such as chemical pollution, environmental degradation, and overexploitation of natural resources (Ferrandez-Pastor *et al*., 2016). In response, the agricultural era 3.0 emerged in the 20th Century, driven by advancements in computation and electronics (Figure 2). Technologies like robotics, programmed machinery, and precision farming techniques addressed the shortcomings of the previous era, promoting sustainable practices such as precise irrigation and reduced chemical usage.

The current agricultural era, known as era 4.0, is characterized by the integration of cuttingedge technologies such as the Internet of Things (IoT), big data analysis, artificial intelligence (AI), cloud computing, and remote sensing (Figure 2). These technologies have led to the development of low-cost sensor networks aimed at optimizing production efficiency while minimizing environmental impact. Big data analytics provide farmers with real-time insights into agricultural conditions, enabling informed decision-making (Wolfert *et al*., 2017). AI-powered algorithms embedded in IoT devices facilitate real-time programming (Liakos *et al*., 2018), helping farmers make optimal choices for their operations.

Smart farming is an emerging modern technique that optimizes farm labor requirements and enhances the quantity and quality of products through the use of information and communication technologies (ICT) (O'Grady & O'Hare, 2017). Modern ICT technologies such as the Internet of Things (IoT), GPS, sensors, robotics, drones, precision equipment, actuators, and data analytics are employed to identify farmers' needs and provide suitable solutions (Quy *et al*., 2022). These innovations improve the accuracy and timeliness of decision-making, thereby increasing crop productivity. Several multilateral organizations and developing countries worldwide have advocated for smart farming technologies to boost agricultural output.

Sensors continuously monitor crops with high accuracy, detecting undesirable conditions early in the crop's lifecycle. Smart tools are utilized throughout the farming process, from sowing to harvest, storage, and transportation. The appropriate use of various sensors has made farming operations more efficient and profitable due to their precise monitoring capabilities. Additionally, sensors rapidly collect readily available online data for further analysis, enabling crop and site-specific agriculture tailored to each location.

Smart agriculture represents the evolution of precision agriculture by integrating modern, intelligent methods. These methods provide comprehensive information about farm activities, which can be remotely managed and supported by real-time farm maintenance solutions (Adamides, 2020). By leveraging IoT technologies, farmers can optimize various aspects of their operations, ensuring efficient and sustainable agricultural practices.

INTERNET of THINGS (IoT) IN COCOA

The Internet of Things (IoT) is a revolutionary technology that enables devices to connect remotely, facilitating smart farming practices (Patil & Kale, 2016). The IoT has begun to impact a wide range of industries, including health, trade, communications, energy, and agriculture, enhancing efficiency and performance across various markets (Sisinni *et al*., 2018; Shi *et al*., 2019; Elijah *et al*. 2018).

Current applications in cocoa demonstrate the IoT's potential effects, although some practices are still emerging. Considering the advancement of technologies, IoT is poised to play a crucial role in numerous farming activities. These activities include utilizing communication infrastructure, data acquisition, smart objects, sensors, mobile devices, cloud-based intelligent information, decision-making, and automating agricultural operations.

Global Positioning System (GPS)

GPS technology accurately records latitude, longitude, and elevation information by utilizing signals transmitted from Global Positioning System satellites. These signals enable GPS receivers to compute their real-time location, providing continuous positional data even while in motion. In cocoa, GPS allows precise location information for farmers to pinpoint specific field data, such as pest occurrences, soil types, nutrient status, and others. By recognizing various field locations, the system facilitates the targeted application of necessary inputs, including fertilizers, pesticides, and water, to specific areas within the cocoa field.

Geographic Information System (GIS)

GIS (Geographic Information System) comprises hardware and software designed for the compilation, storage, retrieval, attribute analysis, and location data to generate maps and analyze geographical and statistical characteristics. The GIS database provides comprehensive information on field soil types, nutrient status, topography, irrigation, surface and subsurface drainage, chemical application quantities, and crop production. It also establishes relationships between various elements that impact crops in a particular field (Ojo & Ilunga, 2018). Beyond data storage and display, GIS is used to evaluate current and alternative management practices by combining and modifying data layers to support decision-making.

Site-specific application in cocoa farm management aims to increase yields through an integrated pest management approach. The spatio-temporal variability of soil fertility and cocoa pod borer (CPB) infestation rates provides strategic information about soil nutrients and CPB population densities at different harvest intervals. This facilitates the transition of cocoa fields (cocoa-gliricidia and cocoa-coconut) from conventional to modern precision management.

Geostatistical methods were applied to interpolate data collected from a systematic grid based on clusters of six cocoa tree stands in both fields, producing maps representing the spatial variability of all soil variables and CPB attacks. Cocoa fresh bean weight and CPB infestation data were collected at two-week intervals from cocoa-gliricidia and cocoa-coconut fields. All field data points were geo-referenced using a differential global positioning system. Data were processed for outliers and analyzed using variography and interpolation techniques to quantify spatial variability.

Results showed that both plots exhibited definable spatial structures, described by exponential models. Precision cocoa management recorded yield increases of 52.8% and 37.5% in cocoa-gliricidia and cocoa-coconut fields, respectively. Site-specific nutrient management and integrated pest control in critical zones improved cocoa yields, particularly during the peak harvest season (Tee *et al*., 2022).

Sensor Technologies in Nursery

Conventional agricultural systems are often inefficient and consume significant manpower and water resources. This project involves designing an automatic drip irrigation system based on an IoT platform. Implemented in the cocoa nursery at the Cocoa Research and Development Center (CRDC) Jengka, Pahang with the smart cocoa monitoring system for automatic drip irrigation using soil tension which aims to create optimal soil moisture conditions to facilitate healthy plant growth through proper irrigation frequencies (Figure 3).

Figure 3: Automation of cocoa nursery in the Cocoa Research and Development Center (CRDC) Jengka, Pahang using IoT-control system

The development of the IoT monitoring and automation system (Figure 4) leverages wireless sensor technologies in agriculture and the food industry. This modern application system enhances plantation efficiency and productivity by providing continuous monitoring of soil moisture in the cocoa nursery. Its functionalities help the industry minimize costs by reducing the need for manpower and improve plantation quality by supporting decision-making through the analysis of collected data. These methods offer a robust, efficient alternative to conventional manual monitoring, significantly improving overall performance.

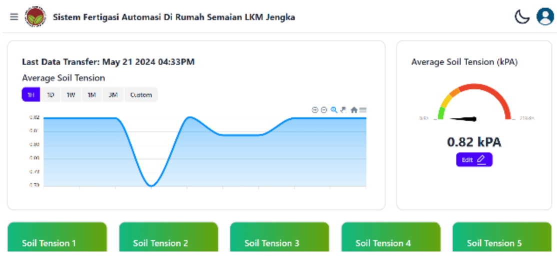

Figure 4: Development of a dashboard platform for monitoring and control of the fertigation system at nursery CRDC Jengka

Sensor Technologies in Cocoa Farms

In precision agriculture, water is crucial for healthy plant growth. Inadequate water supply can lead to plant defects and interrupted growth, ultimately increasing yield costs. Modern irrigation techniques often include the delivery of soluble fertilizers, which are absorbed by crop roots. Accurate soil moisture data is essential to determine the effectiveness of fertilizer absorption and to avoid water and fertilizer wastage, thereby reducing production costs. However, there is limited research on subsurface moisture data and prediction.

A study has been carried out at the Research and Development Center Bagan Datuk, Perak, to collect subsurface moisture data using IoT technology and analyze it with deep learning (Figure 5). This project presents an automated IoT-based real-time moisture level monitoring and irrigation system, combined with a recurrent neural network (RNN) based long short-term memory (LSTM) prediction model. Subsurface soil moisture probes with sensors at five different depths were deployed on a real plantation site using a Time Domain Reflectometer (TDR). These sensors were connected to the cloud via a Wireless Sensor Network (WSN) and deployed in a 1000-square-foot area with high water usage prediction.

Figure 5: Establishment of a pilot cocoa field plot at CRDC Bagan Datuk, Perak using an automated IoT system in controlling fertigation system.

Over six months, data was collected and analyzed. The data was trained using the RNN-LSTM algorithm to predict moisture levels at the plantation site, achieving a prediction accuracy of 95 ± 2%. This high accuracy allowed for the rescheduling of the irrigation system, reducing water usage by 30% and consequently lowering production costs.

In summary, this study proposed an IoT and RNN-LSTM-based solution for studying soil moisture content in agricultural farms. The prediction model effectively reduces water wastage and improves irrigation efficiency in the specified research area.

CONCLUSIONS

To tackle the challenges posed by shrinking arable land and the growing global population's food demands, smarter and more efficient crop production methods are imperative. Food security, within the framework of sustainable agriculture, is a concern that requires global attention. Encouraging the adoption of farming as a viable profession, especially among innovative young individuals, is essential for the industry's advancement. This paper underscores the pivotal role of various farming technologies in cocoa management, particularly the Internet of Things (IoT), in revolutionizing agriculture to meet future needs effectively. It addresses the current industry challenges while highlighting prospects to guide scholars and engineers. Thus, maximizing crop production requires leveraging every piece of farmland through sustainable IoT-based sensors and communication technologies.

ACKNOWLEDGEMENTS

This work was part of the program entitled ‘Project Mechanization and Automation in Cocoa Commodity’ and was funded by the 12th Malaysia Plan, Economic Planning Unit, Prime Minister’s Department. We gratefully thank the Ministry of Plantation and Commodities (MPC) for their long-term support. Special thanks to the Director General of Malaysian Cocoa Board and the Director of Cocoa Upstream Technology, Malaysian Cocoa Board for their kind approval in publishing the findings of this research.

REFERENCES

Adamides, G., Kalatzis, N., Stylianou, A., Marianos, N., Chatzipapadopoulos, F., Giannakopoulou, M., Papadavid, G., Vassiliou, V. and Neocleous, D. (2020). Smart farming techniques for climate change adaptation in cyprus. *Atmosphere* **11**: 557.

Arshad, F. M. and A Ibragimov. (2015). Malaysia's cocoa beans decline: A prognosis. *International Journal of Agriculture and Forestry Plantation* **1**: 1-14.

Ayaz, M., Ammad-uddin, M., Baig, I., Aggoune, E. M. (2018). Wireless sensor‘s civil applications, prototypes, and future integration possibilities: A review. *IEEE Sensors Journal* **18**: 4–30.

Elijah, O., Rahman, T.A., Orikumhi, I., Leow, C.Y. and Hindia, M. N. (2018). An overview of internet of things (IoT) and data analytics in agriculture: benefits and challenges. *IEEE Internet Things Journal* **5**: 3758–3773.

Ferrandez-Pastor, F. J., Garcia-Chamizo, J. M., Nieto-Hidalgo, M., Mora-Pascual, J. and MoraMartinez, J. (2016). Developing ubiquitous sensor network platform using Internet of Things: Application in precision agriculture. *Sensors* **16**: 1141.

Liakos, K.G., Busato, P., Moshou, D., Pearson, S. and Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors*, **18**: 2674.

Navulur, S., Sastry, A. S. C. S. and Giri Prasad, M. N. (2017). Agricultural management through wireless sensors and internet of things. *International Journal of Electrical Computer Engineering* **7**: 3492–3499.

O'Grady, M.J. and O'Hare, G. M. P. (2017). Modelling the smart farm. *International Journal of Process Agriculture* **4**: 179–187.

Ojo, O.I. and Ilunga, M. F. (2018). Geospatial analysis for irrigated land assessment modeling and mapping. In Multi-Purposeful application of geospatial data; Rustamov, R.B., Ed., IntechOpen: London, UK, pp. 65–84.

Patil, K. A. and Kale, N. R. (2016). A model for smart agriculture using IoT. In Proceedings of the 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication, Jalgaon, India, 22–24 December 2016; IEEE: Jalgaon, India, pp. 543–545.

Quy, V. K., Hau, N. V., Anh, D. V., Quy, N. M., Ban, N. T., Lanza, S., Randazzo, G. and Muzirafuti, A. (2022). IoT-enabled smart agriculture: architecture, applications, and challenges. *Applied Sciences* **12**: 3396.

Ramle, K. P. (2012). Contribution of group dynamics factors to technology adoption among Malaysia cocoa clusters, Ph.D. Dissertation. Universiti Putra Malaysia, Selangor, Malaysia.

Shi, X., An, X., Zhao, Q., Liu, H., Xia, L., Sun, X. and Guo, Y. (2019). State-of-the-Art internet of things in protected agriculture. Sensors **19**: 1833.

Sisinni, E., Saifullah, A., Han, S., Jennehag, U. and Gidlund, M. (2018). Industrial internet of things: Challenges, opportunities, and directions. *IEEE Transaction on Industrial Information* **14**: 4724–4734.

Tee, Y. K., Tun, Y. L. and Karunanithi, K. (2022). An empirical analysis of the climate and price of cocoa production in Malaysia. *Malaysian Cocoa Journal* **14**: 77-91.

Tekinerdogan, B. (2018). Strategies for technological innovation in agriculture 4.0. Reports; Wageningen University: Wageningen, The Netherlands.

Wolfert, S., Ge, L., Verdouw, C. And Bogaardt, M. J. (2017). Big data in smart farming—A review. *Agricultural System* **153**: 69–80.

Wood, L. (2017). A study of Malaysia's cocoa industry: Malaysia cocoa industry report 2017.https://www.businesswire.com/news/home/20170503005811/en/Malaysia-Cocoa-Industry-Report-2017-Research, accessed July 2018.