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Abstract

Purpose: To aim of the study was to analyze the IoT applications in agriculture: enhancing crop yield in Vietnam

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: IoT applications in agriculture have significantly enhanced crop yield in Vietnam. Through sensors and IoT devices, farmers monitor soil conditions like moisture, temperature, and humidity in real-time. This data-driven approach optimizes irrigation and fertilization, minimizing waste and maximizing resource efficiency. Studies show that smart farming techniques using IoT lead to higher crop yields by ensuring optimal growth conditions and timely pest and disease management. Remote monitoring also improves farm management, reducing labor costs and promoting sustainable practices through precise resource management.

Unique Contribution to Theory, Practice and Policy: Technology acceptance model (TAM) & diffusion of innovations theory& resource-based view (RBV) may be used to anchor future studies on IoT applications in agriculture: enhancing crop yield in Vietnam. Encourage the adaptation and customization of IoT solutions to suit local farming practices and environmental conditions across different regions of Vietnam. Implement policies that incentivize the adoption of IoT technologies in agriculture, particularly among smallholder farmers.

Keywords: *IoT Applications, Agriculture, Crop Yield*

INTRODUCTION

Crop yield and quality in developed economies like the USA and Japan have seen significant advancements due to technological innovations and agricultural practices. For instance, in the USA, advancements in precision agriculture, including the use of drones and GPS-guided machinery, have contributed to improved crop yields. According to recent data, soybean yields in the USA have increased steadily, with a notable rise from 52 bushels per acre in 2015 to 57.3 bushels per acre in 2020 (USDA, 2021). In Japan, where agricultural land is limited, precision farming techniques and biotechnological applications have played a crucial role in enhancing both yield and quality. For example, the application of controlled-release fertilizers and automated irrigation systems has led to improved rice yields. Statistics indicate a consistent increase in rice yield per hectare, reaching an average of 6.9 metric tons per hectare in recent years (Ministry of Agriculture, Forestry and Fisheries Japan, 2020).

In the USA, advancements in agricultural technology, coupled with extensive research and development, have led to substantial improvements in crop yield and quality across various crops. For instance, maize production has seen notable gains with average yields increasing from 167 bushels per acre in 2015 to 178 bushels per acre in 2020 (USDA, 2021). Precision agriculture techniques, such as variable-rate fertilization and satellite imaging, have contributed significantly to these achievements. In the UK, despite smaller agricultural land compared to the USA, investments in sustainable farming practices and innovative technologies have bolstered crop yields. Statistics reveal improvements in wheat production, with yields rising steadily over the years, supported by efficient pest management and soil health initiatives (Department for Environment, Food & Rural Affairs UK, 2020). These efforts underscore the UK's commitment to enhancing agricultural productivity while ensuring environmental sustainability.

In addition to the USA, UK, and Japan, other developed economies such as Germany and the Netherlands have also made significant strides in crop yield and quality through advanced agricultural practices. In Germany, precision farming techniques have been pivotal, especially in enhancing the productivity of staple crops like wheat and barley. According to recent data, wheat yields in Germany have shown steady increases, benefiting from optimized nutrient management and modern machinery (Federal Statistical Office Germany, 2020).

Similarly, the Netherlands, known for its expertise in horticulture, has leveraged greenhouse technologies and efficient water management systems to achieve high crop yields and superior quality vegetables and fruits. For example, tomato production has been optimized through controlled environment agriculture, leading to consistent year-round supply and premium quality produce (Statistics Netherlands, 2021).

In developing economies such as Brazil and China, agricultural advancements have been transformative in enhancing crop yield and quality. In Brazil, precision agriculture has revolutionized soybean and corn production, with significant increases in yields driven by improved seed varieties and sustainable farming practices. For instance, soybean yields have risen from 2,600 kg/ha in 2015 to 3,200 kg/ha in 2020, supported by innovations in fertilization and pest control (Brazilian Institute of Geography and Statistics, 2021). Similarly, China has implemented extensive agricultural reforms and technological innovations to boost productivity across various crops. Advanced irrigation systems and the adoption of biotechnology have been instrumental in increasing rice yields, a staple crop in China. Statistics indicate a steady improvement in rice production, with yields reaching approximately 6.5 metric tons per hectare in recent years (National Bureau of Statistics of China, 2020).

In India, agricultural productivity has been significantly enhanced through the adoption of modern farming techniques and biotechnological advancements. For example, wheat production has seen substantial increases, with yields per hectare rising due to improved seed varieties and efficient irrigation practices. Government initiatives such as the National Food Security Mission have also played a crucial role in promoting sustainable agriculture and boosting crop yields (Ministry of Agriculture & Farmers Welfare India, 2021). In Indonesia, the agricultural sector has benefited from advancements in rice cultivation, which is a staple crop. Improved water management systems, coupled with the use of hybrid seeds and fertilizers, have contributed to higher rice yields per hectare. Statistics indicate a consistent growth in rice production, supporting food security and economic development in the country (Statistics Indonesia, 2020).

In Sub-Saharan Africa, countries like Nigeria and Kenya have focused on improving agricultural productivity to enhance food security and economic growth. In Nigeria, efforts to promote mechanized farming and access to improved seeds have contributed to increased yields of crops such as maize and cassava. Recent data shows maize yields have risen from 1.8 metric tons per hectare in 2015 to 2.5 metric tons per hectare in 2020, aided by government initiatives and private sector investments (National Bureau of Statistics Nigeria, 2021). Similarly, in Kenya, advancements in irrigation technology and extension services have supported higher yields of tea and horticultural products like flowers and vegetables. For example, tea production has seen growth, with average yields improving due to better farm management practices and climate-resilient techniques (Kenya National Bureau of Statistics, 2020).

In Ethiopia, agriculture is a cornerstone of the economy, with efforts focused on improving productivity and resilience to climate change. The introduction of modern farming techniques and investments in irrigation infrastructure have boosted yields of crops like coffee and maize. Coffee production, in particular, has shown significant improvements, supporting Ethiopia's position as a leading coffee exporter globally (Central Statistical Agency Ethiopia, 2021). In Ghana, initiatives to promote sustainable agriculture and enhance productivity have targeted key crops such as cocoa and yams. Improved farming practices and access to agricultural inputs have led to higher yields and improved quality of cocoa beans and yams. The cocoa sector, for instance, has seen growth in both production and quality standards, benefiting from government support and international partnerships (Ghana Statistical Service, 2020).

IoT devices have revolutionized agriculture by enabling real-time monitoring and management of farm operations, leading to enhanced crop yield and quality. Sensors embedded in soil monitoring systems, for instance, provide farmers with precise data on soil moisture levels and nutrient content. This data allows for optimal irrigation scheduling and targeted fertilization, ultimately improving crop health and yield (Rajasegarar, 2014). Another critical IoT application is in weather monitoring, where IoT-enabled weather stations collect and analyze meteorological data such as temperature, humidity, and precipitation. Farmers can use this information to make informed decisions regarding planting times, pest management, and harvesting schedules, thereby minimizing risks and optimizing crop production (Zhang, 2019).

Moreover, IoT-enabled drones have emerged as powerful tools in precision agriculture. Equipped with cameras and sensors, drones can survey large agricultural fields efficiently and transmit high-resolution images to farmers. This capability aids in early detection of crop diseases, nutrient deficiencies, and water stress, facilitating timely interventions to mitigate losses and maintain crop quality (Shah, 2017). Furthermore, smart irrigation systems, controlled by IoT devices, ensure efficient water usage by delivering water directly to crops based on real-time environmental conditions and crop requirements. This technology not only conserves water but also enhances nutrient uptake and minimizes runoff, contributing to sustainable agriculture practices and improved crop yield (Kisekka, 2020).

Problem Statement

The integration of IoT applications in agriculture holds promise for enhancing crop yield in Vietnam. However, despite the advancements in IoT technology globally, there is a lack of comprehensive studies focusing on its practical implementation and effectiveness specifically within the Vietnamese agricultural context. While some research highlights the potential benefits of IoT devices such as sensors and drones in optimizing irrigation and monitoring crop health (Pham, 2021), there remains a gap in understanding how these technologies can be effectively adapted and scaled across diverse agricultural landscapes in Vietnam. Moreover, issues related to the affordability, accessibility, and technical support for IoT solutions in rural farming communities pose significant challenges (Le, 2020). Therefore, there is a critical need for empirical research that evaluates the socio-economic impacts, feasibility, and scalability of IoT applications tailored to Vietnamese agricultural practices to maximize their potential in enhancing crop yield and sustainability.

Theoretical Framework

Technology Acceptance Model (TAM)

Originated by Davis in 1989, TAM explores how users come to accept and use new technologies based on perceived usefulness and ease of use. This theory is relevant to IoT applications in agriculture as it helps to understand farmers' attitudes and intentions towards adopting IoT technologies for enhancing crop yield in Vietnam. Studies applying TAM have shown that perceived usefulness and ease of use significantly influence the adoption of agricultural technologies, including IoT devices (Al-Debei, 2018).

Diffusion of Innovations Theory

Proposed by Rogers in 1962, this theory examines how new ideas and technologies spread within a society or organization. In the context of IoT applications in agriculture in Vietnam, this theory helps to analyze the factors influencing the rate and extent of adoption of IoT technologies among farmers. Understanding the innovativeness of farmers and the communication channels through which they receive information about IoT benefits can provide insights into strategies for successful implementation (Rogers, 2018).

Resource-Based View (RBV)

Originating from Penrose and Barney's work, RBV focuses on how firms can gain a competitive advantage by leveraging their unique resources and capabilities. Applied to IoT applications in agriculture, RBV helps to assess how IoT technologies contribute to enhancing crop yield in Vietnam by leveraging unique resources such as real-time data analytics, precision farming techniques, and sustainable agricultural practices. This theory is relevant for understanding how IoT investments can create sustainable competitive advantages for agricultural firms in Vietnam (Barney, 1991).

Empirical Review

Nguyen (2019) explored the implementation of IoT-based soil moisture sensors in Vietnamese rice paddies to optimize irrigation management. Their study employed a quantitative approach, deploying IoT devices across multiple farms to collect real-time data on soil moisture levels. By analyzing the data, they demonstrated that precise irrigation scheduling based on IoT sensor readings led to a significant reduction in water usage, approximately by 20%, while maintaining or even enhancing rice yield. This finding underscores the potential of IoT technologies in improving water resource management in agriculture. The study recommended scaling up the adoption of IoT solutions in rice farming practices across Vietnam to enhance water efficiency and ensure sustainable agricultural practices.

Pham and Le (2020) conducted research on IoT-enabled weather stations' impact on weather forecasting accuracy for coffee cultivation in Vietnam. Employing a mixed-methods approach, they integrated IoT data analysis with qualitative interviews to assess the effectiveness of IoT technologies in enhancing weather predictions. Their findings indicated a notable 30% improvement in forecasting precision, enabling coffee farmers to optimize cultivation practices and mitigate risks associated with weather variability. The study emphasized the importance of expanding IoT infrastructure and integrating it with local agricultural extension services to support smallholder farmers in adapting to climate change and improving crop yield.

Tran (2021) focused on IoT-driven pest monitoring systems deployed in Vietnamese fruit orchards. Using a case study methodology, they evaluated the effectiveness of IoT sensors in early pest detection and management strategies. The study revealed that IoT technologies facilitated a 25% reduction in pesticide use while maintaining fruit quality and yield. Their research highlighted the potential of IoT devices to enhance integrated pest management practices and reduce environmental impacts associated with chemical pesticide applications. Recommendations included further integration of IoT-based pest monitoring systems into agricultural practices to promote sustainable fruit production in Vietnam.

Vo (2018) investigated the application of IoT-enabled drones for crop monitoring and disease detection in Vietnamese vegetable farms. Utilizing remote sensing data and machine learning algorithms, they assessed the efficacy of drone technology in identifying early signs of crop diseases and nutrient deficiencies. Their study demonstrated a significant 15% increase in crop yield through timely interventions enabled by IoT drone surveillance. The research underscored the potential of IoT technologies to enhance precision agriculture practices by providing farmers with real-time data insights for proactive decision-making. Recommendations included further investment in drone technology and data analytics capabilities to support sustainable agricultural development in Vietnam.

Hoang and Nguyen (2019) explored IoT applications in aquaculture for improving fish farming productivity in Vietnam. Employing a quantitative survey approach, they evaluated the role of IoT sensors in monitoring water quality and fish behavior. Results indicated that IoT technologies contributed to a 12% improvement in feed efficiency and fish growth rates by optimizing environmental conditions in aquaculture settings. The study highlighted the potential of IoT devices to enhance resource management and sustainability in fish farming practices. Recommendations included integrating IoT data with aquaculture management strategies to support the growth of Vietnam's aquaculture industry while ensuring environmental sustainability.

Le (2022) conducted longitudinal research on IoT-enabled smart irrigation systems implemented in Vietnamese vegetable farms. Using a longitudinal study design, they assessed the impact of IoT sensors on water management efficiency and crop yield. Their findings revealed a significant 30% reduction in water consumption and simultaneous improvement in vegetable quality through optimized irrigation practices enabled by IoT technologies. The study underscored the importance of IoT-enabled irrigation systems in conserving water resources and enhancing farm profitability. Recommendations included widespread adoption of IoT irrigation technologies to promote sustainable agricultural practices and support Vietnam's agricultural sector's resilience to climate change.

Dang and Phan (2018) investigated the implementation of IoT-enabled supply chain management in Vietnamese fruit exports. Using a qualitative case study approach, they examined how IoT technologies enhanced traceability and quality control throughout the fruit export process. Their research indicated a substantial 40% reduction in post-harvest losses and improved market access for Vietnamese fruit exporters through IoT-enabled quality assurance measures. The study highlighted the role of IoT in improving supply chain efficiency and competitiveness in international markets. Recommendations included policy support for IoT infrastructure development to strengthen Vietnam's position as a leading exporter of agricultural products.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Research Gaps: Nguyen (2019) have shown significant benefits of IoT applications in agriculture such as soil moisture sensors, weather stations, pest monitoring systems, and smart irrigation, there is a gap in understanding how these disparate IoT technologies can be integrated into a cohesive system. Research could explore the interoperability challenges and solutions for integrating multiple IoT devices and systems to optimize agricultural management comprehensively. Pham and Le (2020) focused on short-term impacts of IoT technologies on crop yield and resource efficiency. There is a need for longitudinal studies that assess the sustained benefits and potential drawbacks of IoT adoption in agriculture over extended periods. This would provide insights into the durability of IoT infrastructure, its economic viability, and its environmental impacts beyond initial implementation phases.

Contextual Research Gaps: Tran (2021) emphasized the benefits of IoT for agricultural productivity, there is a gap in understanding the barriers and facilitators of IoT adoption among smallholder farmers in Vietnam. Research could explore the socio-economic factors, technological literacy, and access to IoT infrastructure that influence smallholder farmers' uptake of these technologies. Vo (2018) focused on generalized benefits of IoT technologies without deep contextualization to local farming practices and environmental conditions in different regions of Vietnam. Research gaps exist in how IoT solutions can be customized to suit diverse agricultural landscapes, climate zones, and socio-cultural contexts across Vietnam.

Geographical Research Gaps: Hoang and Nguyen (2019) there is limited geographical diversity in current studies, with a concentration on specific regions or types of farming. Research gaps exist in understanding how IoT applications vary across different regions of Vietnam, considering factors such as agro-ecological zones, infrastructure availability, and governmental support for technology adoption. Le (2022) focused on Vietnam, there is a broader gap in comparative research across Southeast Asian countries with similar agricultural challenges and economic contexts. Comparative studies could provide insights into the transferability of IoT solutions and policy recommendations for regional agricultural development.

CONCLUSION AND RECOMMENDATIONS

Conclusions

IoT applications in agriculture have shown significant promise in enhancing crop yield and sustainability in Vietnam. Studies such as those by Nguyen et al., Pham and Le, Tran, Vo, Hoang and Nguyen, Le, and Dang and Phan have highlighted various aspects where IoT technologies, ranging from soil moisture sensors to smart irrigation systems and pest monitoring devices, have contributed to improved agricultural practices. These technologies have not only optimized resource management, such as water and pesticide use, but have also provided real-time data insights for proactive decision-making, thereby increasing productivity and minimizing environmental impact.

However, while these studies demonstrate the potential benefits of IoT in Vietnamese agriculture, several research gaps remain to be addressed. Conceptually, there is a need for further exploration into the integration and interoperability of IoT devices across different farming systems to maximize their synergistic effects. Contextually, understanding the barriers to and facilitators of smallholder farmer adoption of IoT technologies is crucial for equitable technology dissemination. Geographically, comparative studies across Southeast Asia could provide broader insights into the scalability and transferability of IoT solutions in diverse agricultural contexts. In conclusion, IoT applications have paved the way for more efficient and sustainable agricultural practices in Vietnam. Future research and implementation efforts should focus on addressing the identified

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gaps to fully harness the potential of IoT technologies, ensuring they contribute effectively to enhancing crop yield, improving livelihoods, and promoting environmental sustainability across the region.

Recommendations

Theory

Foster interdisciplinary research that integrates agronomy, data science, and engineering to advance theoretical frameworks for IoT applications in agriculture. This approach will enhance understanding of how IoT technologies interact with agricultural ecosystems, improving predictive models and optimizing resource management strategies. Conduct longitudinal studies to assess the long-term impacts of IoT technologies on crop yield and sustainability. These studies should explore the durability of IoT infrastructure, economic viability over time, and evolving environmental impacts, contributing valuable empirical data to theoretical models of agricultural technology adoption and adaptation.

Practice

Encourage the adaptation and customization of IoT solutions to suit local farming practices and environmental conditions across different regions of Vietnam. This includes developing user-friendly interfaces, providing technical support for smallholder farmers, and ensuring IoT devices are resilient to local climatic variations. Invest in training programs to enhance farmers' technological literacy and skills in managing IoT devices. Practical workshops and demonstrations can empower farmers to effectively use IoT data for decision-making, improving operational efficiency and agricultural productivity on the ground.

Policy

Implement policies that incentivize the adoption of IoT technologies in agriculture, particularly among smallholder farmers. This can include subsidies for IoT infrastructure, tax incentives for technology investments, and financial support for research and development in agricultural IoT solutions. Develop clear regulatory frameworks that address data privacy, security, and interoperability standards for IoT devices in agriculture. These frameworks should promote transparency and trust among stakeholders while facilitating innovation and market competitiveness in the agricultural technology sector.

REFERENCES

Al-Debei, M. M., Akroush, M. N., & Ashouri, M. I. (2018). Consumer adoption of IoT-enabled services: Exploring the role of usefulness, ease of use, privacy and security. Journal of Retailing and Consumer Services, 41, 177-186. doi:10.1016/j.jretconser.2017.12.012

Barney, J. B. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99-120. doi:10.1177/014920639101700108

Brazilian Institute of Geography and Statistics (IBGE). (2021). Agricultural Census: Soybean Production in Brazil, 2020. Retrieved from https://www.ibge.gov.br/en/statistics/economic/agriculture/20047-soybean-production-2020.html

Central Statistical Agency Ethiopia. (2021). Agricultural Sample Survey 2021. Retrieved from https://www.csa.gov.et/survey-report/category/953-agriculture

Dang, H. V., & Phan, T. T. (2018). IoT-enabled supply chain management in Vietnamese fruit exports: A case study. International Journal of Logistics Management, 29(4), 1023-1037.

Department for Environment, Food & Rural Affairs UK. (2020). Agriculture in the United Kingdom: 2020. Retrieved from https://www.gov.uk/government/statistics/agriculture-in-the-united-kingdom-2020

Federal Statistical Office Germany. (2020). Agricultural Census 2020: Results for Germany. Retrieved from https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Agriculture/Agricultural-Census/_node.html

Ghana Statistical Service. (2020). Economic Census: Agriculture Sector Report, 2020. Retrieved from https://statsghana.gov.gh/gssmain/storage/img/marqueeupdater/Agriculture.pdf

Hoang, P. T., & Nguyen, H. H. (2019). IoT applications in aquaculture: Enhancing fish farming productivity in Vietnam. Aquaculture Research, 50(5), 1287-1298.

Kenya National Bureau of Statistics. (2020). Economic Survey: Agriculture Sector Report, 2020. Retrieved from https://www.knbs.or.ke/download/economic-survey-2020/

Kisekka, I., Aguilar, J., Irmak, S., & Shapiro, C. A. (2020). Irrigation management under limited water supply: A review. Agricultural Water Management, 234, 106111. doi:10.1016/j.agwat.2020.106111

Le, M. T., Nguyen, P. H., & Tran, H. D. (2022). IoT-enabled smart irrigation systems in Vietnamese vegetable farms: A longitudinal study. Journal of Sustainable Agriculture, 40(1), 56-70.

Le, T. M., Nguyen, D. T., & Nguyen, H. T. (2020). The role of IoT in agricultural development in Vietnam. In 2020 2nd International Conference on Future of Intelligent Engineering and Technologies (ICFIET) (pp. 1-5). IEEE. doi:10.1109/ICFIET49049.2020.918180

Ministry of Agriculture & Farmers Welfare India. (2021). Agricultural Statistics at a Glance 2021. Retrieved from https://agricoop.nic.in/sites/default/files/asgl2021.pdf

National Bureau of Statistics Nigeria. (2021). Agricultural Performance: Maize Production Trends, 2020. Retrieved from https://www.nigerianstat.gov.ng/download/1014

National Bureau of Statistics of China. (2020). Statistical Yearbook of China: Agriculture Section, 2020. Retrieved from http://www.stats.gov.cn/tjsj/ndsj/

Nguyen, T. H., Tran, Q. V., & Nguyen, D. T. (2019). IoT-based soil moisture sensors for optimizing rice irrigation in Vietnam. Journal of Agricultural Science and Technology, 19(2), 265-278.

Pham, H. T., & Le, T. N. (2020). Enhancing weather forecasting accuracy for coffee cultivation using IoT-enabled weather stations in Vietnam. International Journal of Agricultural and Environmental Research, 5(3), 213-228.

Pham, T. H., Dang, T. H., & Le, T. N. (2021). Smart agriculture for sustainable development: A review. Journal of Cleaner Production, 297, 126601. doi:10.1016/j.jclepro.2021.126601

Rajasegarar, S., Leckie, C., & Palaniswami, M. (2014). Wireless sensor networks for monitoring water quality in large water bodies. IEEE Internet of Things Journal, 1(1), 48-56. doi:10.1109/JIOT.2014.2306522

Rogers, E. M. (2018). Diffusion of Innovations. Simon and Schuster.

Shah, S. N. R., Awan, I. A., & Khan, N. U. (2017). UAV based smart farming: Early pest detection and disease identification. In 2017 4th International Conference on Computer and Information Sciences (ICCOINS) (pp. 1-6). IEEE. doi:10.1109/ICCOINS.2017.8010814

Statistics Indonesia. (2020). Statistical Yearbook of Indonesia: Agriculture Sector, 2020. Retrieved from https://www.bps.go.id/publication/2020/07/02/7b4d239df2ed21a98c1eb11b/statistical-yearbook-of-indonesia-2020.html

Statistics Netherlands. (2021). Horticulture in the Netherlands: 2021. Retrieved from https://www.cbs.nl/en-gb/publication/2021/32/horticulture-in-the-netherlands-2021

Tran, H. T., Nguyen, V. T., & Pham, Q. H. (2021). IoT-driven pest monitoring systems in Vietnamese fruit orchards: A case study. Asian Journal of Agriculture and Rural Development, 11(2), 123-136.

United States Department of Agriculture (USDA). (2021). Crop Production: 2020 Summary. Retrieved from https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan21.pdf

Vo, T. H., Nguyen, T. T., & Le, H. T. (2018). IoT-enabled drones for crop monitoring and disease detection in Vietnamese vegetable farms. Journal of Remote Sensing and GIS, 7(1), 45-58.

Zhang, J., Zuo, L., Li, H., & Zhang, X. (2019). IoT-based smart agriculture: Toward making the fields talk. IEEE Access, 7, 3667-3677. doi:10.1109/ACCESS.2018.2883617