Internet of things system for lime planting in Maha Sarakham community

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Article Info

Article history:

Received Feb 8, 2022
Revised Aug 8, 2023
Accepted Aug 30, 2023

Keywords:

Internet of things
Lime planting
Maha Sarakham
Smart farm
Thailand

ABSTRACT

The objectives of this research were: i) to study components of the internet of things (IoT) system to support community lime planting (CLP); in Maha Sarakham Province; ii) to develop IoT-CLP; and iii) to transfer IoT-CLP to the target community in Maha Sarakham Province. The research tools were: i) IoT-CLP system suitability assessment form; ii) IoT-CLP efficacy evaluation form; iii) a questionnaire to assess the effectiveness of the community lime planting; and iv) a survey of community satisfaction towards IoT-CLP. The research results showed that i) components of IoT-CLP consist of: (1.1) data receivers: soil moisture, temperature, soil pH, fertilizer/nutrient; (1.2) control units: water supply, water spraying, soil pH control, and processing, fertilizer/nutrients; (1.3) operating systems: water supply, water spraying, soil pH communication and distribution system of fertilizer/soil nutrients water; (1.4) mobile application; ii) the effectiveness of IoT-CLP was evaluated at the highest level; and iii) the results of lime cultivation using IoT-CLP showed a higher yield than the traditional practices in terms of the amount of lime, size, and weight. The community was satisfied with IoT-CLP at the highest level.

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1. INTRODUCTION

Today, it is undeniable that technologies play a role and permeate everywhere, every time, both in daily life, and in work. One of those is the internet of things (IoT) which is a technology connecting various electronic devices [1], [2] as it allows to link, transmit, and receive information and commands to control devices through the Internet network. One example of IoT applications in everyday life is to turn on and off various home devices through a smartphone or computer, such as light bulbs, air conditioners, televisions, or even to order pet food supplies while there is no one at home. Today, many types of businesses used IoT technology to support their operations, such as education, transportation, health care, industries [3]–[6] and so on. In the agricultural sector, IoT and modern technology are used to manage the cultivation and animal husbandry [7], [8] including the process of supervising and controlling the production to be effective in solving productive problems [9]–[11] caused by a lack of analysis and management of insights such as weather conditions, soil conditions, and environments that are essential to the growth of plants/animals, in order to get quality products, reduce costs and control risks [12]–[15]. This leads to smart farming and competitiveness in the agricultural sector for business [16]–[19].

In Thailand, lime is one of the most widely grown citrus fruits [20]. The important planting areas are Phetchaburi, Surat Thani, Nakhon Sawan, Kanchanaburi, Samut Sakhon, Nakhon Pathom, and Chiang Mai Provinces [21]. Lime is beneficial as it can be used to cook food and beverages. It also has medicinal properties because of its high vitamin C and can be used as herbal medicine, and is commonly used in cosmetics [20], [22], [23]. As a result, the industrial sector uses it as raw material and has a higher demand every year. When the economy expands, lime increasingly plays a vital role in trade and becomes an economically important crop with high market demand throughout the year. Especially during the dry season around march-april in Thailand, the price of lime will be 5-10 times higher than normal as it will be less productive to the market. Today, there are more people interested in growing lime off-season to make more profit. Maha Sarakham Province is considered to be one of largest provinces in Thailand that planting lime becomes essential in the community. In this province, planting lime in cement ponds is the main practice due to the limited area [20], [24], [25].

Based on the studies, there are two issues in caring for a lime tree in Maha Sarakham Province.

1) Watering

Lime in the early stages of planting should be watered at least once a day. About 15 days after planting, the lime tree will be able to establish itself, and it should be watered 2-3 times a month. Proper materials should cover the soil around the base of the lime tree to maintain humidity. The lime tree should not be watered from march until a flowering period to allow it to accumulate food to a level that can create flower buds. Lime usually blooms in april-may, and after its blossoming and fruiting, it is the period when lime needs much water for fruit growth.

2) Fertilizing

After 3-4 months of age, lime should be applied by compost or manure at approximately 0.5 kg per tree. After shoveling the soil, chemical fertilizer should be applied to remove the weed and then water it to dissolve the fertilizer. When the lime is one year old, the fertilizer with formula 15-15-15 about 300 grams should be applied to each tree, and for two years old lime, agriculturists should increase the amount of fertilizer by applying it two times a year, about 1 kg each time [20]. In this province, lime growers have always faced problems from the process of preparing the planting site and selecting lime varieties to lime diseases [26] such as canker causing root rot, fruit loss due to acidic soil and insufficient water, and too much productivity of lime in the season resulting in selling limes at a low price. Farmers must have a proper method to select suitable planting areas and soil analysis in the planting fields. Typically, the soil was drilled to analyze its pH. If it is very acidic, there will be a problem of fruit loss. Therefore, the control of the environment in the lime garden is to control watering, total nutrients in the soil, soil moisture, and soil pH to meet the physical requirements and prevent diseases from improper humidity.

2. OBJECTIVES

The research team recognized the significance of agricultural product development, particularly in the cultivation of lime. To achieve optimal outcomes, including enhanced yield, ideal weight, and reduced loss, a system known as IoT-CLP (community lime planting) was devised. IoT-CLP functions by regulating water supply, total soil nutrients, soil moisture, and soil pH to ensure compliance with physical requirements, humidity, and temperature. By alleviating the burden of lime planting, IoT-CLP facilitates the production of abundant, high-quality products, enabling farmers to market their produce at fair prices. Therefore, the research is conducted with following objectives: i) to examine the components of IoT-CLP; ii) to develop IoT-CLP; and iii) to implement IoT-CLP within the target community, namely Ban Nong Yang Community in Hua Khwang Sub-district, Kosum Phisai District, Maha Sarakham Province.

3. LITERATURE REVIEW

Studied the development of an IoT system for increasing the productivity of lime planting in the cement pond underlayment to solve the problem of low yield and disease of 6 months to 2 years old lime. The system can control the humidity, total nutrients, and soil pH based on the moisture sensor, total nutrient sensor, and soil pH sensors connected to the MCU node. The data collected from the MCU node will be sent to raspberry pie for fuzzy logic and edge computing to create a signal to control water supply equipment and combined nutrients. In addition, operating status information of the system, such as moisture data, total nutrients, soil acidity, alkalinity, and the operation of the equipment supplying water and nutrients, is also sent to cloud storage. So, farmers can control and monitor the systems operating status through the cloud software service developed by the researchers. The results showed that the proposed system could automatically control the soils humidity, pH, and total nutrients in the bottom cement pond to be within the range suitable for lime growth under changing environmental conditions of moisture, total nutrients, and soil pH.

Sriamnuay *et al*. [27] studied the design of a smart farm system using IoT technology for a lime farm in Phetchaburi Province. This study aimed to design innovative smart agriculture with IoT to increase production efficiency for lime farms. There were four sensors to measure the data of the lime farm: i) temperature, ii) humidity, iii) moisture, and iv) pH. The research results revealed that from designing a diagram of connecting IoT devices (node MCU) with arduino board and sensor systems along with the development of an application for connecting with IoT devices, it could be used with various mobile phone applications on both IOS and android operating systems and the system can display the following standard data: i) temperature the appropriate temperature is about 26-32 degrees celcius; ii) humidity the moisture content of the soil is in the range of -10 to -60 kpa; iii) moisture: the water requirement of a liter of lime per plant per day according to age and season; and iv) pH-the optimum pH value is about 5.5-7.0.

Chaiprasart [28] said lime could be grown in almost any clay or sandy soil. To grow lime to thrive, be fruitful, and of good quality, it should be planted in an area that is sandy loam with good drainage and much organic matter. There should not be less than a percentage of organic matter, and an area near the water source should be selected. The groundwater level should not be higher than 1 meter, but if it is clay soil, the trench should have good drainage by preparing the embankment area with a width of about 6-8 meters. The height to observe the amount of previously flooded water was higher than the flood level by 50 centimeters to drain water in and out. Trench size is 1.5 meters wide, 1 meter deep, at the trench width 0.5-0.7 meters, pH value about 5.5-6.0, using a planting distance of about 4×4 meters or 6×6 meters. The soil in the planting pit (size 50×50×50 cm) is mixed with compost or manure with the soil at the rate of each kilogram along with 0.5 kg of phosphate rock fluff. Also, chemical fertilizers are always formulated, such as 15-15-15 at the rate of 0.1 kg. The farmers should cover the soil back into the hole. Since lime is in the same family as oranges, to prevent diseases that may be transmitted from oranges, the area should be at least 10 kilometers away from the original planting sites that may cause insect-borne.

Siwilai [29] said that IoT is how things around us are linked in the world of the internet. This allows us to control various devices, such as turning on-off lights, air conditioners, and televisions via the internet with smartphones, computers, or other portable devices. IoT is also applied to medical, agriculture, industrial machinery, and many others, especially in smart farming. It is the application of IoT technology in agriculture to help increase productivity and solve problems, including: i) to analyze farmland such as the use of various sensor devices to measure soil quality, humidity, or weather conditions and use the data to be processed to select crops suitable for the environment; ii) to maintain and increase yields, such as automatic irrigation systems for plants that require temperature or humidity control; and iii) to save labor and reduce the burden or risks to farmers, such as using drones to install equipment for spraying chemicals in high or hard-to-reach places. It also reduces the risk to farmers from direct exposure to harmful chemicals.

4. RESEARCH METHOD

4.1. Research tools

To thoroughly evaluate the effectiveness and impact of the IoT-CLP system, a comprehensive set of research tools was employed. The IoT-CLP system suitability assessment form provided insights into the systems adaptability to the specific agricultural conditions of the target community. The IoT-CLP system efficacy evaluation form assessed the systems ability to optimize lime planting practices and enhance crop productivity. Additionally, a questionnaire was administered to gauge the effectiveness of community-based lime planting operations, gathering valuable feedback from participants. To further assess the communitys perception of the IoT-CLP system, a survey was conducted to measure satisfaction levels and identify areas for improvement. Together, these research tools provided a holistic evaluation of the IoT-CLP system, enabling a comprehensive understanding of its impact on agricultural productivity and community engagement.

4.2. Target group

The target group for the IoT-CLP system implementation is the Ban Nong Yang community, located in Hua Khwang Sub-district, Kosum Phisai District, Maha Sarakham Province. This community comprises a group of lime farmers who are actively engaged in agricultural activities and are keen on adopting innovative technologies to enhance their productivity and livelihoods. The IoT-CLP system holds immense potential to address the challenges faced by these farmers, particularly in optimizing lime planting practices and improving crop quality and yield. By providing precise control over water supply, nutrient management, and soil conditions, the IoT-CLP system can significantly contribute to the economic well-being of the Ban Nong Yang community.

4.3. Research process

The research process is divided into 3 phases as follows:

- Phase 1. The study of components of the IoT-CLP system: i) study-related research documents; (ii) visit the site to study information in the community in terms of the environment of lime cultivation and other related information; (iii) interview the experts about the components of IoT-CLP system; (iv) summarize of the results from the field visit and interviews of experts and use the data to design the components of IoT-CLP system; (v) assess the suitability of the components of IoT-CLP by experts; and (vi) summarize the results of the assessment of the suitability of the components of IoT-CLP.
- Phase 2. IoT-CLP development: i) use the components of IoT-CLP obtained in phase 1 as a framework for the system design; ii) develop IoT-CLP; iii) test the efficiency of IoT-CLP; iv) assess the suitability of IoT-CLP by experts; and v) summarize the results of the assessment of the suitability of IoT-CLP by experts.
- Phase 3. IoT-CLP transfer to the community and a study of the results after using the developed IoT system: i) visit the target community to create an understanding of the developed system transfer; ii) install an IoT-CLP system for the target community; iii) collect data according to the duration of the research by visiting the target community and organizing a meeting to reflect research findings from using IoT-CLP; and iv) summarize the research results and write a research report.

4.4. Statistics

The statistics used in the research were: mean and standard deviation. The evaluation was made by comparing the mean value with the assessment criteria as follows: [4]

a) 4.50–5.00 means highest level.
b) 3.50–4.49 means high level.
c) 2.50–3.49 means moderate level.
d) 1.50–2.49 means low level.
e) 1.00–1.49 means lowest level.

5. RESEARCH RESULTS

5.1. Components of IoT-CLP

The researcher went to the site to study the contexts and problems and use this information as data for designing IoT-CLP components, as shown in Figure 1.

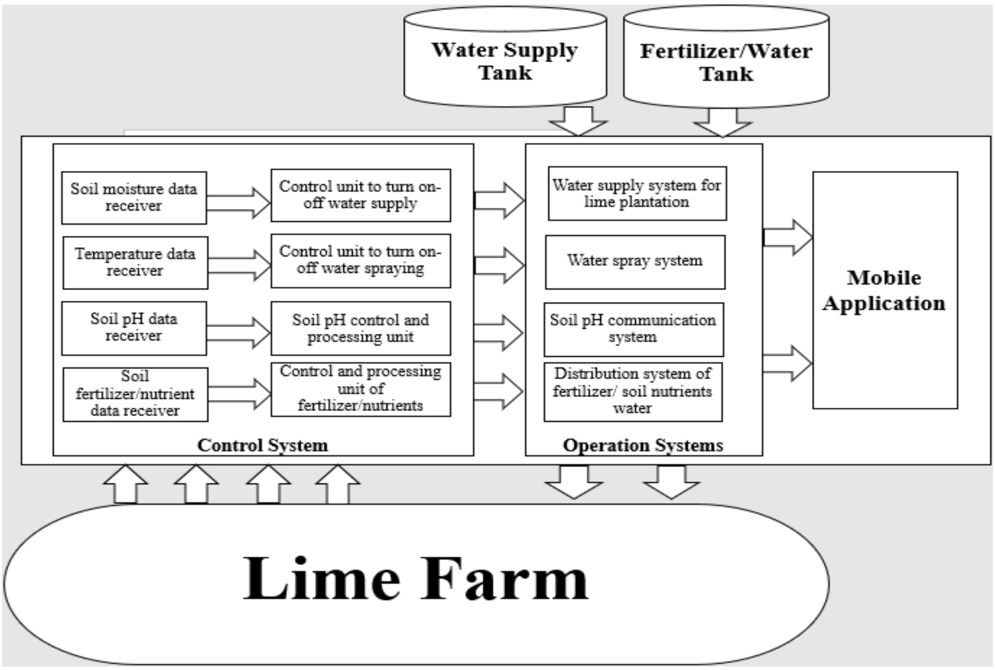

Figure 1. Components of the IoT-CLP

1) Data receiver means a device that receives data from a lime farm to be processed and executed as follows:
   - Soil moisture data receiver: it is responsible for receiving information from devices buried in the lime garden soil because lime likes moisture but does not like wet. If it is too wet, it can cause root rot. Most importantly, it will require more water than necessary. Therefore, this unit is responsible for receiving data and sending it to the control unit for further processing.
   - Temperature data receiver: it is responsible for receiving information from devices installed in the lime garden because lime grows and produces good yields in climatic conditions. The average optimum temperature is about 26-32 degrees celsius, so this unit is responsible for receiving data and sending it to the control unit for further processing.
   - Soil pH data receiver: it is responsible for receiving information from devices that are buried in the lime garden soil because lime grows and yields well in soil conditions that have a pH between 5.5-6.5, so this unit serves to receive data and send it to the control unit for further processing.
   - Soil fertilizer/nutrient data receiver: it is responsible for receiving information from devices buried in the lime garden soil because lime grows and produces good yields in loamy soil conditions or sandy loam with good drainage and high drainage fertility. The amount of organic matter is not less than 3 percent. In addition, periodic fertilization is required, for example, after the lime is 3-4 months old, when the lime is one year old, and the period is 1-2 months before flowering. Therefore, this unit receives information and sends it to the control unit for further processing.
2) Control unit and operating system means devices that receive information from the receiving unit and carry out the processing operations as follows:
   - The control unit to turn on-off the water supply is responsible for receiving information from the soil moisture data receiver and carrying out the required processing operations. If the soil in the lime plantation has insufficient moisture, it will order the system to supply water to the lime garden. When there is suitable humidity, the water supply will be stopped.
   - The control unit to turn on-off water spraying is responsible for receiving data from the temperature data receiver and carrying out the required processing operations. For example, if the temperature in the lime garden is higher than the specified rate, it will order the water spray system to spray water in the lime garden. When there is a suitable temperature, it will stop spraying water.
   - Soil pH control and processing unit: it is responsible for receiving information from the soil pH data receiver and carrying out the processing operations as specified. For example, if the soil acidity-alkalinity in the lime plantation is not within the specified range, it will immediately order the soil pH communication system to inform the farmers through the mobile application.
   - Control and processing unit of fertilizers/nutrients in the soil: it is responsible for receiving data from the soil fertilizer/nutrient data receiver unit and carrying out processing operations as required. For instance, if the value of fertilizer/nutrients in the soil is not in the specified range, it will order the distribution system to mix water with fertilizer/nutrients and give the water mixed with fertilizer/nutrients into the lime garden. This operating system can be set to work as required.
3) Mobile application: it is a device that the system will display the information on the mobile phone of the owner of the lime farm all the time.

The researcher presented the components of the IoT-CLP system to 5 experts to check suitability using the IoT-CLP system suitability assessment form. The evaluation results are shown in Table 1. Based on the experts opinions on the suitability of IoT-CLP components, the components were rated at the highest level (mean=4.61 and standard deviation (SD)=0.50).

Table 1. The result of the suitability assessment of IoT-CLP components

Suitability	Evaluation level		
	$\bar{x}$	S.D.	Level
1. Suitability of data receivers	4.57	0.52	Highest
– Soil moisture data receiver	4.55	0.56	Highest
– Temperature data receiver	4.67	0.50	Highest
– Soil pH data receiver	4.34	0.57	High
– Soil fertilizer/nutrient data receiver	4.73	0.47	Highest
2. Suitability of control unit/operating system	4.67	0.51	Highest
– The control unit to turn on-off the water supply	4.84	0.38	Highest
– The control unit to turn on-off water spraying	4.75	0.50	Highest
– Soil pH control and processing unit	4.57	0.61	Highest
– Control and processing unit of fertilizers/nutrients in the soil	4.55	0.56	Highest
3. Suitability of mobile application	4.32	0.51	High
Total	4.61	0.50	Highest

5.2. IoT-CLP system development

The research team developed IoT-CLP and tested it in a laboratory, as shown in Figure 2. The researcher presented the IoT-CLP system to 5 experts to check its efficacy by using the IoT-CLP system efficacy evaluation form. The evaluation results are shown in Table 2. From Table 2, the opinion of experts on the efficacy of the IoT-CLP system was at the highest level (mean=4.53 and SD=0.51). The efficacy of all studied items was statistically rated at the highest level (mean=4.34-4.71 and SD=0.46-0.62).

Figure 2. IoT-CLP system development

Table 2. Opinion of experts on efficacy of the IoT-CLP system

Efficacy	Evaluation results		
	$\bar{X}$	S.D.	Level
1. Efficacy of data receivers	4.60	0.51	Highest
– The soil moisture data receiver can receive data from devices buried in the lime garden soil and send it to the control unit for continuous processing according to the specified conditions.	4.71	0.46	Highest
– The temperature data receiver: it is responsible for receiving information from devices installed in the lime garden and sending it to the control unit for continuous processing according to the specified conditions.	4.64	0.48	Highest
– Soil pH data receiver: it is responsible for receiving information from devices buried in the lime garden soil and sending it to the control unit for continuous processing according to the specified conditions.	4.52	0.50	Highest
– The soil fertilizer/nutrient data receiver: it is responsible for receiving information from devices buried in the lime garden soil and sending it to the control unit for continuous processing according to the specified conditions.	4.55	0.62	Highest
2. Efficacy of control systems	4.46	0.49	High
– The control unit to turn on the water supply: it is responsible for receiving data from the soil moisture data receiver and can command the related systems according to the specified conditions.	4.40	0.49	High
– The control unit to turn on-off water spraying: it is responsible for receiving data from the temperature data receiver and can command related systems according to the specified conditions.	4.34	0.48	High
– The soil pH control and processing unit: it is responsible for receiving information from the soil pH data receiver and can command related systems according to the specified conditions.	4.60	0.49	Highest
– The control and processing unit of fertilizer/nutrients in the soil: it is responsible for receiving information from the soils fertilizer/nutrient data receiver, and it can command related systems according to the specified conditions.	4.53	0.50	Highest
3. Efficacy of operating systems	4.56	0.53	Highest
– The water supply system for lime plantations can work under specified conditions.	4.51	0.62	Highest
– The water spray system in the lime garden can function according to the specified conditions.	4.66	0.48	Highest
– The soil pH communication system can function according to the specified conditions.	4.52	0.50	Highest
– The distribution system of fertilizer/ soil nutrients water in the soil can function according to the specified conditions.	4.48	0.62	High
4. Efficacy of mobile application: the mobile application can report the performance of the IoT system continuously all the time.	4.51	0.50	Highest
Total	4.53	0.51	Highest

5.3. IoT-CLP transfer to target community

After the IoT-CLP system had been developed, the research team contacted the target community to transfer the IoT-CLP system to support the communitys lime planting by installing the system in the communitys lime planting area, as shown in Figure 3. The researchers carried out the installation in August

2021, the seasonal flowering period for lime, considered the second season of the year. During December to January of the following year, it will be the time to harvest lime. The researchers studied three issues: diameter, number, and weight of lime. Based on the study, the result of the experiment was more effective than the past community practice. The details are shown in Table 3. The researcher studied the opinions of the community members regarding their satisfaction with the IoT-CLP system; the results are shown in Table 4. From Table 4, the community satisfaction toward the IoT-CLP system was at the highest level (mean=4.60 and SD=0.48). The satisfaction of all studied items was at the highest level (mean=4.45-4.73 and SD=0.45-0.50).

Figure 3. IoT-CLP system installation in Maha Sarakham Province

Table 3. Operation results

Issues	Operation results	
	Community practice	Control system
The diameter of lime	3-4 cm	4-5 cm
Number of lime fruits per a tree in a season	300-450	400-550
Weight of lemon	30-40 grams	40-55 grams
Income (increase)	–	20%

Table 4. Community satisfaction with IoT-CLP

Satisfaction	Results		
	$\bar{X}$	S.D.	Level
The system allows the community more time as it reduces time to care for the lime garden, such as watering.	4.60	0.49	Highest
The system allows for effective control of soil moisture.	4.67	0.47	Highest
The system allows temperature control close to the environment where lime grows well.	4.55	0.50	Highest
The system helps to control the pH of the soil well and can adjust the soil in time.	4.61	0.49	Highest
The system controls fertilizer/nutrients in the soil according to the right time.	4.51	0.50	Highest
The system enables continuous recognition of analysis results from the system through the mobile phone.	4.73	0.45	Highest
The system ensures excellent yields, good weight, bigger size, and more lime juice.	4.72	0.45	Highest
The system helps the community earn more.	4.45	0.50	High
The system allows the community to be a technological role model, causing other communities to come to study.	4.57	0.50	Highest
The system is a medium for community relations with Maha Sarakham Rajabhat University.	4.60	0.49	Highest
Total	4.60	0.48	Highest

6. DISCUSSION

The IoT-CLP system is more effective than the previous community practice because the developed IoT system controls humidity, temperature, nutrients, and pH in the soil. Therefore, it affects the size, weight, and juice of the lime and the yield that can be harvested in the studied season. The developed IoT system has several functions to control various factors to produce the highest quality lime. The water supply system has supplied water to the lime garden according to the environment-if the soil in the garden has insufficient moisture, it will order the system to supply water to the garden. When there is enough humidity, the system will stop. The water spray system maintains the proper temperature. It will order the system to spray water according to the environment at the set time. If the temperature in the garden is higher than the specified rate, it will spray water in the garden. The soil pH communication system will inform the garden owner continuously by passing the information to the application on the mobile phone according to the environment each time. For example, if the soil pH in the garden is not within the specified range, it will display the information on the application. The system of supplying water mixed with fertilizer/nutrients in the soil will proceed according to the environment at each time. If fertilizer/nutrients in the soil are not in the specified range. It will order the water distribution system to mix fertilizer/nutrients with water and give the mixed water into the garden. The results of this research are consistent with Sriamnuay, *et al.* [27] and Sinprasert *et al.* [30], who have researched IoT systems and provided effective results in other parts of the country.

7. CONCLUSION

As mentioned above this research aimed: i) to study components of the IoT-CLP; ii) to develop IoT-CLP; iii) to transfer IoT-CLP to the target community in Maha Sarakham Province. Its findings showed that: 1) components of IoT-CLP consist of: (1.1) data receivers: soil moisture, temperature, soil pH, fertilizer/nutrient; (1.2) control units: water supply, water spraying, soil pH control, and processing, fertilizer/nutrients; (1.3) operating systems: water supply, water spraying, soil pH communication and distribution system of fertilizer/soil nutrients water; (1.4) mobile application; 2) the effectiveness of IoT-CLP was evaluated at the highest level; and 3) the results of lime cultivation using IoT-CLP showed a higher yield than the traditional practices in terms of the amount of lime, size, and weight. The community was satisfied with IoT-CLP at the highest level. However, the research results have not yet been made into a ready-made package that other users can immediately install and apply. The research team must install them and transfer technology for efficient use.

REFERENCES

[1] J. E. Fischer *et al.*, "New horizons for the IoT in everyday life: Proactive, shared, sustainable," in *UbiComp 2016 Adjunct - Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, New York, NY, USA: ACM, Sep. 2016, pp. 657–660, doi: 10.1145/2968219.2968347.

[2] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of Things (IoT): A Literature Review," *Journal of Computer and Communications*, vol. 03, no. 05, pp. 164–173, 2015, doi: 10.4236/jcc.2015.35021.

[3] G. Tripathi and M. A. Ahad, "IoT in education: An integration of educator community to promote holistic teaching and learning," in *Advances in Intelligent Systems and Computing*, 2018, pp. 675–683, doi: 10.1007/978-981-13-0514-6_64.

[4] S. Muthuramalingam, A. Bharathi, S. Rakesh kumar, N. Gayathri, R. Sathiyaraj, and B. Balamurugan, "Iot based intelligent transportation system (iot-its) for global perspective: a case study," *Intelligent Systems Reference Library*, vol. 154, pp. 279–300, 2019, doi: 10.1007/978-3-030-04203-5_13.

[5] A. Chandy, "a Review on Iot Based Medical Imaging Technology for Healthcare Applications," *Journal of Innovative Image Processing*, vol. 1, no. 01, pp. 51–60, 2019, doi: 10.36548/jiip.2019.1.006.

[6] F. Aslam, W. Aimin, M. Li, and K. U. Rehman, "Innovation in the era of IoT and industry 5.0: Absolute innovation management (AIM) framework," *Information (Switzerland)*, vol. 11, no. 2, p. 124, Feb. 2020, doi: 10.3390/info11020124.

[7] M. S. Farooq, O. O. Sohail, A. Abid, and S. Rasheed, "A Survey on the Role of IoT in Agriculture for the Implementation of Smart Livestock Environment," *IEEE Access*, vol. 10, pp. 9483–9505, 2022, doi: 10.1109/ACCESS.2022.3142848.

[8] M. A. Haque, S. Haque, D. Sonal, K. Kumar, and E. Shakeb, "WITHDRAWN: Security Enhancement for IoT Enabled Agriculture," *Materials Today: Proceedings*, Feb. 2021, doi: 10.1016/j.matpr.2020.12.452.

[9] T. Arreerard, W. Arreerard, and N. Ruangsan, "IoT system for mushroom cultivation in greenhouse of Mahasarakham communities," *Journal of Green Engineering*, vol. 11, no. 2, pp. 1680–1695, 2021.

[10] and N. R. T. Arreerard, W. Arreerard, N. Sawatsri, "Smart Farm: Solar Chili Greenhouse by IoT Control System in Kalasin," *Psychology and Education Journal*, vol. 58, no. 2, pp. 3696–3703, 2021.

[11] M. S. Farooq and S. Akram, "IoT In Agriculture : Challenges and Opportunities," *Journal of Agriculture Research*, vol. 59, no. 1, pp. 63–87, 2021, [Online]. Available: https://apply.jar.punjab.gov.pk/upload/1616396203_143_09._JAR_1593.pdf

[12] P. Placidi, R. Morbidelli, D. Fortunati, N. Papini, F. Gobbi, and A. Scorzoni, "Monitoring soil and ambient parameters in the iot precision agriculture scenario: An original modeling approach dedicated to low-cost soil water content sensors," *Sensors*, vol. 21, no. 15, p. 5110, Jul. 2021, doi: 10.3390/s21155110.

[13] J. Shenoy and Y. Pingle, "IOT in agriculture," in *Proceedings of the 10th INDIACom; 2016 3rd International Conference on Computing for Sustainable Global Development, INDIACom 2016*, 2016, pp. 1456–1458.

[14] C. Brewster, I. Roussaki, N. Kalatzis, K. Doolin, and K. Ellis, "IoT in Agriculture: Designing a Europe-Wide Large-Scale Pilot," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 26–33, 2017, doi: 10.1109/MCOM.2017.1600528.

[15] V. Porkodi, D. Yuvaraj, A. S. Mohammed, M. Sivaram, and V. Manikandan, "IoT in agriculture," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 14, pp. 1986–1991, 2018, doi: 10.48175/ijarsct-1351.

[16] J. Muangprathub, N. Boonnam, S. Kajornkasirat, N. Lekbangpong, A. Wanichsombat, and P. Nillaor, "IoT and agriculture data analysis for smart farm," *Computers and Electronics in Agriculture*, vol. 156, pp. 467–474, Jan. 2019, doi: 10.1016/j.compag.2018.12.011.

[17] and Z. S. Y. Shifeng, F. Chungui, H. Yuanyuan, "Application of IoT in agriculture," *Journal of Agricultural Mechanization Research*, vol. 7, pp. 190–193, 2011.

[18] M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour, and E. H. M. Aggoune, "Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk," *IEEE Access*, vol. 7, pp. 129551–129583, 2019, doi: 10.1109/ACCESS.2019.2932609.

[19] A. Yazdinejad *et al.*, "A review on security of smart farming and precision agriculture: Security aspects, attacks, threats and countermeasures," *Applied Sciences (Switzerland)*, vol. 11, no. 16, p. 7518, Aug. 2021, doi: 10.3390/app11167518.

[20] W. Sriboon, U. Tuntiwaranuruk, and N. Sanoamuang, "Hourly soil temperature and moisture content variations within a concrete pipe container for planting lime trees in Eastern Thailand," *Case Studies in Thermal Engineering*, vol. 10, pp. 192–198, Sep. 2017, doi: 10.1016/j.csite.2017.06.005.

[21] M. Issarakraisilaa, "A review of Thailand commercial success in growing lime (Citrus aurantifolia) in containers to control flowering time and canopy size," *Acta Horticulturae*, vol. 1205, no. 1205, pp. 289–291, Jun. 2018, doi: 10.17660/ActaHortic.2018.1205.33.

[22] S. Jitbunjerdkul and K. Kijroongrojana, "Formulation of Thai herbal Namprik," *Songklanakarin Journal of Science and Technology*, vol. 29, no. 3, pp. 837–846, 2007.

[23] W. Ketpanyapong and A. Poh-etae, "The wisdom of the deep south of Thailand: Case study on utilization of herbal medicine to treat domestic animal diseases by traditional doctors in Pattani, Yala and Narathiwat," *Songklanakarin Journal of Science and Technology*, vol. 29, no. SUPPL. 1, pp. 167–185, 2007.

[24] P. Sanpakdee, "Comparision Analysis of Cost and Returns from Planting Lemons in Cement Blocks and on the Ground by Farmers in Wang Luek, Samchuk, Suphan Buri," *SSRN Electronic Journal*, vol. 8, no. 1, pp. 258–264, 2019, doi: 10.2139/ssrn.3462166.

[25] P. Chuenwarin *et al.*, "Genetic and morphological diversity analysis of lime and acidic Citrus spp. From two germplasm

collections in Thailand," *Agriculture and Natural Resources*, vol. 55, no. 4, pp. 589–600, 2021, doi: 10.34044/J.ANRES.2021.55.4.09.
[26] N. Suwannarach, S. Khuna, J. Kumla, R. Cheewangkoon, P. Suttiprapan, and S. Lumyong, "Morphology Characterization, Molecular Identification, and Pathogenicity of Fungal Pathogen Causing Kaffir Lime Leaf Blight in Northern Thailand," *Plants*, vol. 11, no. 3, p. 273, Jan. 2022, doi: 10.3390/plants11030273.
[27] B. Sriamnuay, S. Phlangsorn, W. Piticaroenporn, and P. Sihanam, "The Design of the Smart Farm System using the Internet of Things Technology for Lime Farms in Phetchaburi Province," *presented at the NMCCON 2019: The 6th National Conference Nakhonratchasima College, Nakhonratchasima Province, Thailand, 2019*, pp. 808–816, 2019.
[28] P. Chaiprasart, "Lime Planting," 2018.
[29] S. Siwilai, "Internet of Things: When all things are connected (Internet)," *Phitsanulok: Information Technology Center, Pibulsongkram Rajabhat University, 2016*, 2016.
[30] N. Sinprasert, S. Nattawuttisit, S. Mungsing, and T. Banditwattanawong, "Internet of Things System for Improving Productivity of Lime with Fuzzy Logic and Edge Computing," *The Science Journal of Phetchaburi Rajabhat University*, vol. 17, no. 1, pp. 55–70, 2020.

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