The Situation and Development Route of Greenhouse in Thailand and Republic of Korea: A review

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ABSTRACT

The greenhouse development currently plays an important role to the smart agriculture in many countries. Many documented evidences confirmed that smart technology, Information Communication Technology (ICT) enabled the efficient, productivity and prots farming.The greenhouses usage in Thailand mostly traditional greenhouse and needs to be developed further. It is necessary to find the development routes to assemble the smart technology to improve traditional greenhouse economically. Meanwhile thegreenhouse development has been developed and national widely adopted throughout the country more than 30 years ago in Republic of Korea. Especially the smart technology (ICT) currently has shown tremendous potential for vegetable and ornamental horticulture in greenhouse cultivation. This review paper tries to understand the current greenhouse situation of Thailand and Republic of Korea and analyzing the development routes from the advantage of technology point of view for the future of Thailand's smart greenhouse. Three sectors of human resources; publics, privates and farmers should be collaborated to push forward the action in agricultural ICT.

Keywords: Thailand, Republic of Korea, Greenhouse, Smart farm, ICT

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INTRODUCTION

World-wide, the agricultural in greenhouse is commonly practiced. The purpose is to protect the crop that might be damaged from weather.There are several types of traditional greenhouse which optimally apply to each country. The traditional greenhouses such as glasshouse, plastic greenhouse and plastic tunnel type are commonly practiced in several countries in Europe, Africa and Middle East, Asia and America. Nowadays the traditional greenhouses have been improved and modified to be smart greenhouses to produce high quality products. Smart farming has become the top priority issue in many countries. It has been rapidly developed in the developed countries and fast expanded to the developing countries. The smart precision technology is commonly applied to vegetable and ornamental horticulture protection in greenhouse. The good crop management can generate high production value. Information and communication technology (ICT) is deployed to the modern greenhouse. In developing country such as Thailand, the smart greenhouse is mostly in the first stage of development, i.e. modified from the traditional greenhouse. The lacking of big data makes it very difficult to develop AI for agriculture. Meanwhile Republic of Korean greenhouse has been developed through the white revolution and widely used throughout the country. Currently the smart technology is adopted to the greenhouse operation. To understand the current situation of greenhouse practice in Thailand and Republic of Korea and to analyze the optimal route that can push forward the technology for smart greenhouse development of Thailand and Republic of Korea, this paper contents focus on the current situation, analyze the weakness-advantage points and suggest the developmental pathway for the future smart greenhouse development in Thailand. From the related documents, the greenhouse development situation of Thailand and Korea were studied as; agricultural status, greenhouse situation and development construction, Korean smart farm development pathway and the challenger and pathway of Thailand smart greenhouse development for public organization.

Agricultural condition Background: Agricultural status of Thailand

Thailand is in the tropical country zone of South-East Asia, the average annual temperature is approximately 27.88 °C, the average rainfall is 1,356 mm. and the average annual rainy day is 160. The total arable land of country is 51.3 million ha. of which about 47% is used for agriculture. Approximately 47% of agricultural land is for paddy cultivation, 21% and 24% are used for upland and horticulture crops respectively. (Figure 1) The agricultural labor covers about 41% of total labor population.

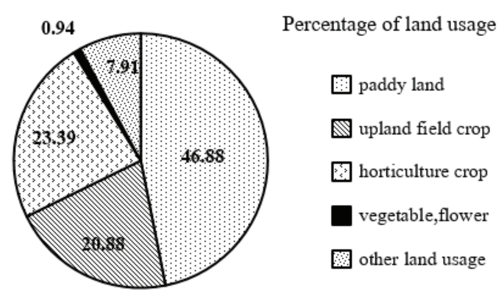

Figure 1 Land utilization proportion in Thailand *Source*: Office of Agricultural Economic (2016)

The main cultivated crops whose the planted area covers more than one million hectares are rice, para-rubber, sugarcane and cassava. They are the major exported agricultural products of Thailand. In 2018 the agricultural economic statistics showed that Thailand had 78.67, 35.84, 21.32 and 16.44% of world market share in cassava, para-rubber, rice and sugarcane respectively (Table 1) (Office of Agricultural Economic, 2016). Fruit such as durian, mangosteen, rambutan, and mango are also exported. Exporting of mangosteen and durian has exponentially increased in recent years, and currently about 70-90 % of products are exported. The value of exported agricultural products increases yearly and the main importers are China, Japan, Republic of Korea, USA, Malaysia, Indonesia and Vietnam. The total exported value of agricultural products in 2018 was about 46,284 million US$ (1.388 trillion THB)

Table 1 Top ten of Thailand agricultural planted area and production yield in 2018

		Area (1,000ha)	Yield (ton/ha)	World market share (%)
1	Rice	10,398	3.06	21.32
2	Rubber	3,196	1.48	35.84
3	Sugarcane	1,790	73.58	16.44
4	Cassava	1,332	22.04	78.67
5	Maize	1,083	4.60	0.05
6	Oil palm	814	18.24	0.72
7	Pepper	634	3.16	n.s.
8	Mango	316	9.89	n.s.
9	Longan	183	5.76	n.s.
10	Coconut	121	7.07	n.s.

Source: Office of Agricultural Economic (2018)

Thailand's greenhouse situation and development's structure

The traditional greenhouse in Thailand has been developed and commonly uses for vegetable and ornamental horticulture cultivation. It was simple structure made from bamboo or PVC pipe and covered with plastic or shaded net sheet. The structures are mostly a single layer or reverse U frame greenhouse type. Recently, modern type of the greenhouse structure has been developed and IOT is being used for long term experiment. The temperature, relative humidity and light intenisty are collected by sensors and it was controlled by fan, evaporation system and shade curtain throuqh IOT operation and monitor. Currently, the greenhouse has been adapted for hydroponic culture of vegetables and organic strawberry, melon and flowering plants-cultivation.

In the past decade, there were several related research papers of green-house development in Thailand. From the review of these related documents, the current development state of greenhouse in Thailand can be defined at 2 stages as before and after 2010. Before 2010, the development purpose was to solve the problem of greenhouse adaptation for ornamental horticulture and the researchers paid more attention to the types of greenhouse's structure, costs and the efficiency. From 2010 onward, the sensor, wireless and information of technology had been applied to greenhouse design and operation. The smart greenhouse in Thailand currently is in the first stage of development.

First period: is the period of modern greenhouse development for ornamental production. Researchers analyzed the optimal greenhouse types, environmental control for optimal growth and costs-return for economic crops such as orchid and Anthurium productions.The related documents are as follows; the efficiency comparative testing of two types of the greenhouse for orchid cultivation was carried out by Agricultural Engineering Research Institute in 2006. The study aimed to analyze the greenhouse effects in protecting orchid from Black Anther disease which high relative humidity is the environmental condition suitable for disease occurrence. The comparison experiment was done on four types of greenhouse; low–high roof height and cover material were Polyethylene sheet and without cover. The results showed that in rainy season, the disease was not found in low roof Polyethylene greenhouse. While in the cold season, the disease was not found in the greenhouse that had Polyethylene cover in both low and high roof types. From the results, the high roof Polyethylene type was recommended because the orchid yield was higher than that of low roof Polyethylene type. (Kupawanichapong *et al*., 2006). In the same year, the efficiency and durability test of three models of greenhouse for Anthurium production were evaluated. Three models were as follows; ① triangular greenhouse with nylon shaded sheet cover, ② triangular greenhouse type without nylon shaded sheet cover and ③ greenhouse flat roof type with nylon shaded sheet cover. The experiment was run for three years and the results showed that the triangular roof type with nylon-shaded sheet cover was the most suitable greenhouse for Anthurium (Kupawanichapong *et al*., 2006). The double roof –semi open type greenhouse for two types of Venus's slipper (Paphiopedilum) production was also developed. The first roof was plastic sheet and second roof was 60% shaded sheet. Four sides of greenhouse were covered by with 50% light shaded sheet which could be opened and closed manually. The temperature and light intensity in greenhouse were controlled by the light shaded sheets and the fogging system. The foggers were automatically operated at 10 am 12 pm and 14 pm within 5 min duration at each time to reduce the temperature and increase relative humidity. The experiment was to compare with the traditional greenhouse which operated by farmer using the opened greenhouse type. The temperature and relative humidity were recorded by Watch Dog data logger model 450. The light intensity was measured by light meter model DIGICON LX 70. The temperature and relative humidity were manually rechecked by Humidity-Temp meter model DIGICON HT 775-232. The results showed that both types of orchid grew better in the developed greenhouse than in the traditional greenhouse. The disease incidence was also lower in the developed type. The temperature and relative humidity in both types of greenhouse were not significantly different in April. While the light intensity in the developed greenhouse was lower than that of the traditional one. Considering the greenhouse costs and the returns, the prototype greenhouse costs were 15% higher than traditional type while the returns from the developed greenhouse were 18% higher than that of traditional type, and it has 20% lower disease incidence (Chansrakoo *et al*., 2006).

In 2007 the efficiency of hydroponic greenhouse for Thailand condition was tested. About 14 m^2 (2.04 m wide, 7.02 m long and 2.86 m high) hydroponic plastic roof greenhouse was used as prototype in this experiment. The air ventilation area was 17.5% of total greenhouse area. The 50% light shaded sheet was used for sun shading on the roof. The roof was of overlapped type that can easily ventilate air. (Figure 2) The temperature was 5.6°C lower than that of the traditional greenhouse. However, the paper did not mention the relative humidity inside the greenhouse. But the practical testing had been done to compare the organic vegetables production. The results showed the vegetables production from the developed greenhouse was 5.6 kg higher than the traditional one (Jiracheewee *et al*., 2008).

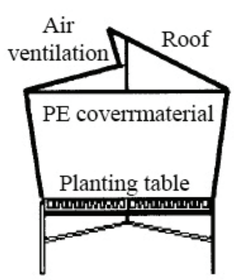

Figure 2 The developed hydroponic greenhouse with overlap roof
Source: Jiracheewee *et al.* (2008)

Three types of controlled environment greenhouse for Chrysanthemum were researched and developed, namely, type 1) 2.1 m high and 2.8 m wide tunnel greenhouse (HTG), type 2) 4 m. high and 6 m wide high-roof greenhouse (HRG) and type 3) 4.5 m high and 12 m wide high-roof and multi-span greenhouse (MSG) type. The experiments were conducted in both upland place (1,200 m. above mean sea level) and lowland place (500 m above mean sea level) in the northern part of Thailand. The results showed that the yield from HTG and HRG types were not significantly different in highland, HTG and MSG were not distinctively different. So considering the returns period, the results showed that HTG (Figure 3) could give 5 years earlier pay-back period than MSG and HRG (Kupawanichapong *et al*., 2011).

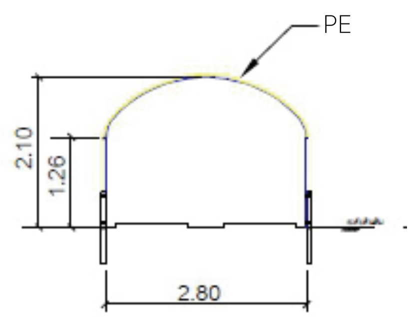

Figure 3 High tunnel greenhouse (HTG)
Source: Kupawanichapong *et al.* (2011)

Second period, the sensor had begun to play more roles in agricultural farming system. The controlled system for environmental controlled in greenhouse was tested. The wireless sensor network prototype for environmental monitoring in greenhouses was developed in 2010. The program was tested in 10 x 24 x 8 m. greenhouse, the sensors were set up at the front, middle and back position in the greenhouse. The temperature and relative humidity were recorded every minute through RS232 sink node port by using the different power supply type (12 VCD 5AH and 9VCD) (Itsariyawong, 2010). In the same year, the greenhouse for Curcuma off season production was developed. The double span and over-lap roof type greenhouse was designed. The dimension were 12 m wide, 24 m long and 4 m high. The structure was made of iron, the cover material was Polyethylene with UV protection 150 micron thick and the ventilation area was 14.4 m^2 incandescent and fluorescent types lighting were used at night, the light density was automatically controlled at 20-100 Lux. The automatic fogging system was used for temperature controlling. The data of environmental conditions and growth rate were recorded during the rainy season. The information would be imitated for off season Curcuma production. Results showed that the optimum light intensity by the incandescent was 100 Lux for Chiang Mai Pink variety and 20 Lux for Cherry Prince variety. The fogging system could reduce temperature by 30% and increase relative humidity by 40%. The automatic system could stabilize the optimized condition for 25-30 min interval. The suitable time for Curcuma off season production was in August, it showed the maximum number of flowers and good growth condition in both varieties (Chansako *et al.,* 2010).

In 2014, PLC-based automatically control system of temperature and relative humidity in soilless culture greenhouse with an evaporative cooling system and fogging system was developed. According to the nutrient film technique (NFT), hydroponic greenhouse requirement condition was to control the temperature at 25-35°C, the relative humidity at 60-80% and the temperature in solution was controlled at 18-30°C. The automation control system was designed by using LabVIEW. The results showed that average temperature and relative humidity inside greenhouse were 30.45°C and the average 80.54%. The average fogging system operation time was 10 min/day and the average evaporation cooling system operation time was 6.37 hr/day (Namchanhom and Seripattananon, 2014).

The economic greenhouses for Chrysanthemum were developed for Northeast region of country by Agricultural Engineering Research Institute in 2015. Traditional greenhouse size was quite small and the roof was too low level. Two types of greenhouse were developed; first type greenhouse structure was triangle type and made from wood with 3.2 x 20 x 2.5 m. The second type greenhouse's structure was made from steel pipe with 3.2 x 18 x 2.1 m. Plastic of 0.15 mm thickness was used for the roof of both greenhouses. The tests were conducted in farmer field during summer season. Results showed that the temperature inside of second type greenhouse was 0.7-2.2°C higher than the first. However the production yield and construction costs were not significantly different. Environmental conditions in both greenhouses types were optimum to Chrysanthemum production in Northeastern of Thailand. (Panthon *et al.*, 2015). In the same year, the double roof greenhouse type was developed for Curcuma off season production. The plastic greenhouse size was 12 x 24 x 4 m and the structure was made of iron, and 150 micron UV protection plastic was used as cover material. The roof space had 14.4 m^2 of air ventilation area and the artificial light for night time was applied by the fluorescent and incandescent lamps. The main affecting factors for Curcuma production were temperature and light. The light intensity was controlled at 20, 60 and 100 Lux. The irrigation was of dripping type. Four-ways fogger type was adopted with 28 L/hr flow rate at 4 bar pressure to reduce the inside temperature by automation controller. The results showed that artificial light from incandescent lamps was the most suitable light for Curcuma production. The fogging system had reduced the temperature in greenhouse from 41°C to be 27.5°C and increased relative humidity from 45% to be 95% (Chansakoo *et al*., 2015).

Researcher was conducted on automatic environmental controlled and monitored greenhouse for the leafy vegetables in 2015. The plastic greenhouse area was 9 m^2. Solar energy was the main power source of the automatic environmental controlled devices. Temperature, atmospheric humidity, soil moisture content and light intensity were controlled. The Lettuce 'Red Rapids' (*Lactuca Sativa*) was cultivated in the prototype greenhouse. Results showed that the automatic environmental controlled greenhouse was able to control the optimum moisture content and temperature for vegetables production. The average of substrate moisture content and temperature inside greenhouse were 19.12% and 33.14°C, respectively. The moisture content of plant media in greenhouse was 44% higher than those outside, the plant media's temperature was 9.5% lower than those outside. Yield from greenhouse was 36% higher than that of outside cultivation by weight, and the vegetables had good quality. (Arunjit *et al*., 2015).

The temperature sensor system was also developed for poultry farming in the east of Thailand in 2017. To concern the chicken healthy, the required temperature was 29°C in the open farm type. The microcontroller, 4 temperature sensors, wireless system and web browser were adopted and integrated to the relay system to control motor of water pump. When the temperature was higher than 29°C, the water pump was in ordered and operated to reduce the temperature. The system could work well in the laboratory operation. The system showed some problem as each sensor was different temperature when installed at the farm including to the problem of network efficiency. (Sittitiamjan *et al*., 2017).

Hydroponic greenhouse with dimensions of 2.4 m long, 5.3 m. wide and 2.0 m high was studied by IOT for planting False packchoi (*Brassica rapa L*) in 2017. The temperature-humidity and soil moisture content were controlled by sensor and Blynk application. The data was transferred to cloud in the Thing Speak. Results showed that the survival rate was 0 for plant without sunlight protection. After installing 50% UV filter SLAN black-sheet, the temperature was obviously decreased and optimized for plant, and the survival rate increase to 46%. The water level in plant tray was controlled by ultrasonic sensor which integrated with solenoid valve. The electric device was controlled by node MCU (Pitakphongmetha *et al*., 2019).

The automatic hydroponic greenhouse using IoT technology and deep learning was developed in 2018. The operation system comprised of four parts as; Part 1; the monitor for showing real time temperature, relative humidity, light intensity and equipment operating status, Part 2; the automation controller, the sensor signal was sent to this part and evaluated with the setting profiles. Part 3; the manual controller, this part was manual operation function for on/off system, fan, pump and motor. Part 4; the setting mode, the user could set the prole by input from keypad. There were three levels of automatic controlled profiles as small, medium and large class. The profiles were a function of temperature (^{o}C), Humidity (%), Light (Lux) and Fan (On/Off), Silent (On/Off), Water (On/Off), Cool (On/Off), Fogging (On/Off). The closed type hydroponic greenhouse was 2.4 m wide, 3.6 m long and 2.6 m high. Fan and evaporation were used for temperature controlling and fogging was used for humidity control. The system was continuously tested for 10 days, temperature and humidity were recorded. Results showed that day time and night time temperatures in greenhouse were 5.4^{o}C and 2.8^{o}C lower than those outside, and the day time and night time humidity in greenhouse were 25% and 21% higher than outside (Ranokpanuwat, 2018). The program for soil temperature and moisture content testing in intelligent organic vegetables farming was studied in 2019. Arduino is used for the controlling system through an analog input device as temperature and moisture sensors. The controlling system was designed to be both manual and automatic. Results showed that the system could be real time controlled, the crop watering time was accuracy as programmed and cooling system was certainly controlled at 30^{o}C (Wongbong-kotpaisan *et al*., 2019).

From the review of the above research documents, it is apparent that the previous researches on greenhouse are mostly concerned with type and effect of greenhouse to crop yield and disease occurrence. They pay much attention to economic and social implication, but lacking of data base and data base application. Thailand's smart greenhouse should be focused on the development route for future. The government has just launched the 20 years (2017-2036) national strategy to move the country towards Thailand 4.0. Agricultural development strategy is also included. This 20 years strategy framework will be used as guidance for developing the National Economic and Social Development 5 years-plan. The first five years (2017-2021) is Digital Agricultural strategy plan. Main purposes of the plan are to: secure farmers' better livelihood, sustainable used of agricultural resources, create the smart farmers and young smart farmers and to increase productivity and quality standards of agricultural products. The potential of competitiveness will be achieved through the developed technology and innovations. Public administration system will also be improved so as to be able to create the smart officers and researchers. This first step starts from preparing the digital agricultural ICT system. Then second step is to expand the use of smart agricultural technology (Pongsrihadulchai, 2019).

Agricultural condition Background: Agricultural status of Republic of Korea

Republic of Korean is located in East Asia where total area covered 1.60 million ha in 2018. Of that about 53 % was paddy field and other was upland field. The total number of farm households was 1.02 million with 2.57 million farmers, of which about 53% was fulltime farmer. The main agricultural production is paddy, vegetables and fruits which cover 37.88, 24.96% and 16.96% of total production land respectively.

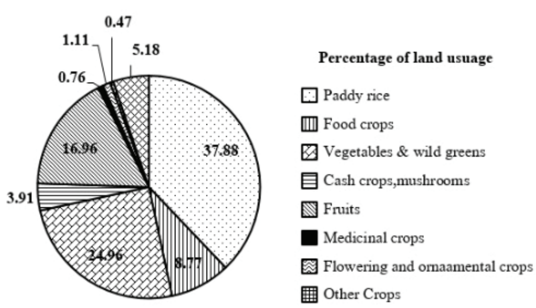

Figure 5 Agricultural land proportion in Republic of Korea
Source: Korea Statistic (2019)

About 737,673 ha was rice cultivation and total production was 5.20 million ton. The rice yield was about 7 ton/ha . The main vegetable produced is radish which has the planting area of about 6,095 ha, and 467,104 tons of production. The spice-culinary vegetables are such as pepper, onion, shallot, ginger and garlic with planting area of 83,601 ha. and 1.92 million tons of production. The fruit-bearing vegetables such as water melon, melon, strawberry, cucumber, pumpkin, tomato have total planting area of 41,943 ha and 1.89 million tons of production. The leafy vegetables such as Chinese cabbage, spinach, lettuce have total planting area 13,313 ha. and 1.4 million tons of production. Main fruits produced in Korea are apples, pears, peaches, grapes, tangerines, persimmons and, plums with 164,718 ha planting area and 2.16 million tons of production (Figure 5). According to the agricultural development of white revolution periods in 1980-1989, the vinyl and plastic film greenhouses had been widely expanded among fresh vegetables producers. The greenhouse area in 2017 covered 52,418 ha. of that about 60% was automated greenhouse (31,450 ha). Type of Korean adopted greenhouse classified by cover material was Polyethylene house (51,997 ha), glass house (346 ha.) and other (75 ha.). The hydroponic cultivation area was 6,196 ha (Korea Statistic, 2019).

Korea's greenhouse situation and smart farm development's structure

Korean greenhouse is commonly used for growing strawberry, tomato, paprika and cucumber. The traditional greenhouse was mostly a simple structure with plastic film or vinyl (PE) cover, and commonly adopted for small scale operation. Republic of Korean had been already passed the period of white evaluation since 1990. Currently, the sensor network and wireless sensor network are being deployed in Korean's greenhouse for environmental control.

The status and success factors of smart farm in Korea were analyzed in 2016. The analysis purpose was to pave the good way for farmers to easily understand the smart farm technology and operation and eventually adapt them to their farms which would result in increased production yield, quality enhancement, labor saving and the farm ICT combination. Information was analyzed from the interview of 67 smart farm leaders and success factors identified. The results showed that 74% of the smart farm were introduced to the voluntary smart farm leaders who aimed to do the convenient farm and improve the productivity. The satisfaction level of smart farm investment was in good level (score was four from five). Nevertheless, only 50% of farms had collected the growth data and the operation data by computerized management program. The smart farm leaders could concentrate on the quality control through smart farm ICT. In horticulture smart farm, the production and gross profit increased 44.6% and 40.5% respectively. The floriculture smart farm, the production increased 18% and gross profit increased 34.4%. There were 5 factors that led to the smart farm leaders'success: ***first***, the good environment for crops, labor reduction and management of the farm basing on data, ***second***, positive attitude and eagerness seeking professional consultation, ***third***, the ease to identify suitable conditions of each farm, *fourth*, the certainly of quality could meet with the market requirement and *fifth*, the ease of the advanced system introduction. The other main affecting factor was the introduction of ICT by the state or local government pilot projects (Kim *et al*., 2016).

Korea's ICT related agricultural projects and lessons learnt were presented in 2017. Due to the significant increasing percentage of farm labor aging, 7.4% in 5 years, the necessity to maintain crop competitiveness and the crisis of climate change, Korea need the good and sustainable solutions for these problems to improve the productivity and reduced the production costs through ICT application for agriculture. The high speed internet and smart phone supply were needed for the ICT agricultural application. The automated farm could provide the suitable and sustainable environments for agri-production without the restriction of external factors. ICT agriculture application can overcome the limitation of traditional farming by resources usages reduction and enhancing the productivity of the quality products. ICT applied to horticulture environmental control in Korean had resulted in 25% improved production, 8.6% reduction of the labor costs and 12% improved yield. It was applied to livestock environmental control as well as smart orchard and resulted in 0.5% improved productivity, 7% reduction of production costs and 2.7% reduction of labor. The online service could connect the farmers and recommend on time crop protection management. The farmer could easily get the agricultural information and financial support through one-stop service (Lee, 2015).

A connected farm based on Internet of Thing (IoT) system was studied in 2018. The purpose was to provide the smart farm based on IoT system for the end user. The connected farm was a new type of automated farming system developed using IoT infrastructure. Three main components of system connected IoT devices included monitoring sensor and controller (connected farm), IoT gateway (& Cube) and IoT service platform (Mobius). The end user was able to interact with the connected farm for monitoring its environmental condition. The overall operation procedure was deployed in the connected farm and had to be registered into the Mobius using &Cube. The environmental data from the monitored areas was collected by monitoring sensors and sent to the &Cube transmit to Mobius. Three types of sensors were deployed to the connected farm in order to monitor the environmental condition, including a compound sensor, a photosynthetic photon flux density (PPFD) sensor, and a soil moisture content sensor. Six types of controllers were deployed to the connected farm; intake and uptake fans, an air conditioner with heating and cooling systems, sprinklers, LED lights, a cover controller and an irrigation - nutrient management system. The application was developed for Android based smart phone for convenience to the end users by using REST APIs. The application provided two main menus; the monitoring and controlling menus. The service platform was a farm knowledge based on the experts which could guide the farmer to control their connected farm efficiency. The farmers could share their knowledge and experience that can make the farm knowledge base smarter (Ryu *et al.*, 2019).

In 2019, Korean government has paid much attention to smart farming and the key tasks of smart farming are widely disseminated. There are two tasks of smart farming.

1. the smart farming is an optimum solution to meet the market demand in terms of safety and consistent quality. The productivity can be increased through the precise environmental control and growth management data based that can stabilize supply and exportation of high quality and safe agricultural products. Those combined with the excellent cultivation technology with ICT have made agriculture the promising industry. Korea's products can compete well in international market.

2. even though the distribution area of smart farms is increasing but most of them are still of simple types. The technology gap between Korea and the advanced countries is approximately 4.5 years persists. The weak points of smart farm development in Korea lie in the industrial infrastructure such as shortage of professional manpower, big data availability and insufficient knowledge networking between academic-industry-institutional. There is a need to create an industrial ecosystem for creating the professional manpower from smart farm innovation valley.

The smart farm innovation models have been projected. The models emphasized on strengthening of the interim goal in 3 sectors; manpower, production and technology. By the year 2020, 500 young people will be trained as innovative talents, 70% of modern greenhouses will become a smart and their ecosystem will be controlled basing on big data. The expected results from the interim goal are; the professional manpower secured, the national and international markets created and the front and back industries expanded. For creating the smart farm innovative valley, the implementation plan has been completed since 2018 to modernize facility of horticulture farming. Two sites for valley were selected in 2018 and additional two sites added in 2019, and four implement smart farms will be completed in 2022. The agriculture and ICT combination had opened up the new markets and added values to agricultural products. (Food and Rural Affairs, 2019)

ICT technology adopted in the irrigation system for upland crop was studied by National Institute of Crop Science, RDA. The purpose of the study were to find the effect of subsurface dripping on soil-water distribution and soybean growth conditions, and to give the information for designing and managing the subsurface dripping system for sustainable field crop production. The experiment was done by installing the drip line size of 14.2 mm in diameter, maximum pressure of 3.5 bar at 40 cm. depth from the furrow. Four different dripping positions (70-140 cm. spacing) were studied including, amount of water per day, irrigation time and frequency per day. The results showed that the irrigation frequency and amount of water were influential factors to subsurface drip irrigation design. The irrigation practice at 70 cm. spacing and 40 cm. deep under ridge showed less water usages and the grain yield was 50% increased (Lee *et al.*, 2019).

The device for real time measuring air flow in greenhouse was developed by National Institute of Agricultural Science, RDA. The environmental sensors for temperature, humidity, wind speed and CO_2 concentration were installed in the greenhouse that can be visualized both in the horizontal and vertical sides (Noh *et al.*, 2019). The temperature and humidity distribution in single span plastic greenhouse was analyzed. The single span double layered plastic greenhouse was used for the experiment. Both cover layers were 0.1 mm. thick polyethylene films. The greenhouse's working area was 7.5 m wide, 3 m high and 30 m long use for growing strawberry. The experiment was conducted in March 2015, without heating system. The data logger was used for data recording at every 10 min intervals. The sensors' positions were 30 cm. above the ridge in three points. The data was compared to external environmental conditions measured at 100 cm above the ground. Results showed that the temperature and relative humidity distribution in vertical (east-west) and horizontal (north-south) were quite uniform. The temperature at middle point was quite lower than left and right side while the relative humidity was higher in the middle point. The temperature had effected on relative humidity (Kim *et al.*, 2019). The data reliability for IoT technology applied in smart greenhouse was evaluated. The wireless data transmission in smart greenhouse was tested with the internet communication device, there were seven tested devices at three points at 75 cm. height. The signal data of 168 points were collected and mapped by the monitoring at 900 MHz and 2.4 GHz receive sensitivity levels. The results showed that the average receive sensitivity level of 169 points were -62.6 dBm and -52.3 dBm. The receive sensitivity level was sufficient when compared to the receive sensitivity of -130 dBm and -110 dBm, which means there was no influence of the insulation and the reception level was higher when the distance of the receiving modules increased. It was expected to provide the sensor reliability and actuators of IoT application (Lee *et al*., 2019). The effectiveness of model management for reducing production costs of Zucchini in plastic house was analyzed by Jeonnam Agricultural Research & Extension Service. The intelligent smart farm and rail facility were adopted for analyzing the costs. Results showed 14.4% reduction of production costs per kilogram comparing to the traditional practice, labor working hours were 7.6% reduced, the water consumption was 7.8% reduced and the greenhouse's environmental management and harvesting times were 7.6% reduced. The reduced costs was translated into 56.9% increase of incomes (Shin *et al*., 2019).

The specification and ventilation of window in multi span greenhouse were studied. The basic data was collected from the field survey of three types of greenhouse as 07 multi with rollup roof, 10 multi with rollup roof and 10 multi with rack and pinion roof. Results showed that the average ventilation area ratio was 10% in the 10 multi with rollup roof type and 10 multi with rack and pinion type. It was 5% lower than the standard of ventilation area ratio (Park *et al*., 2019). The data base of Korean smart greenhouse service was implemented to cloud computing The data of inside-outside environment of tested base greenhouse including to the tomato growth information from 2017 to 2019 were analyzed and computed on the cloud service system. The visualization of collected data for analyzing information was done by virtual machine in cloud, nod (Jode) Jesse (Node.js), Python and congured on we services platform by JavaScript. The system accuracy was conrmed (Beak *et al*., 2019).

Korea's greenhouse types

Korea greenhouse has been widely adopted and nationally applied since the white revolution era in the early 1990. The crop production in greenhouse or it called protected horticulture, it can continue all around the year. The greenhouse farming culture has been very popular and its value accounted for about 12% of agricultural output in 2016 (Verdonk, 2018). Korea vegetables (fruit-bearing, leaf-stem, root and spicy-culinary) planting area covered 144,770 ha and the productivity was 39.27 ton/ha in 2018 (Table 2).The greenhouse culture covered 81,195 ha., or accounted for 56% of vegetables cultivation area. The greenhouse area has significantly increased.

Table 2 Korea vegetables planting area and production yield in 2018

	Area (ha)	Production (1,000 ton)
Fruit bearing vegetable	41,943	1,890
Leaf-stem vegetable	13,131	1,404
Root vegetable	6,095	467
Spicy-culinary vegetable	83,601	1,924

Source: Korea Statistic (2019).

From the greenhouse overview of Lan Seoul in 2016, reported that, greenhouse production had increased while the open-field production had decreased since 1950. The greenhouse in Korea was surveyed through the questionnaires taken from 148 farmers in 2014. Types of greenhouse practical in Korea were 51.4% single-span and 48.6% multi-span. Frame structure types were 39.2% concrete, 31.8% permanent pipe and 22.3% temporary pipe. The covering material was 95.3% plastic film. The water source for the irrigation system was 95.3% ground water (Choi *et al*., 2014).

Republic of Korean's smart greenhouse development pathways.

Greenhouse application in Republic of Korea has been adopted since 1980, it was called "white revolution period". The vinyl and plastic covered greenhouse were used to produce vegetable in the winter. It was evident that greenhouse had played very important role in moving agriculture to quality revolution period as well as in agricultural production. The area of greenhouse production has been increased significantly in recent years. Korean government instituted the smart farm policies with four steps direction.

First step started from 2004 to 2009, the policy focused on nding optimum growth conditions by sensor application which had been rapidly adopted. Consequently, the R&D of agriculture and ICT had been successfully expanded and disseminated, and resulted in the adoption of 25 models (Lee, 2019). The government has strongly strengthened R&D of smart farm. The continue allocation of smart farm R&D budget has resulted in 40% modern greenhouse application increase in 2014. The expansion of ICT farming foundation has been introduced to farmers.

Second step, the policy aimed to encourage the farmers to be volunteer smart farmers. The big data of suitable environmental condition for crop growth was focused and collected through the smart farmers who had adopted the smart farm technology. The data base of each model will be used for agricultural AI development.

Third step, the standard of smart farm technology and equipment related to the growth management condition had been strengthened.

Fourth step, the promotion of full smart farm technology application. Due to the smart farm policy, current Korean smart farms have been fast developed from step to step through the excellent communication facility. The smart farm needs a stable network for remote controlling.

The challenges and pathway of Thailand smart greenhouse development for public organization

Thailand is the tropical country. Most of greenhouse application purposes are to produce the organic or to lessen chemical applications for fresh vegetables, fruits and flowers. The lack of data base of the greenhouse practice area, uncertainly of greenhouse structure optimal design and shortage of environment data base in greenhouse for each crop as big data are the main problems of smart greenhouse development in Thailand. In addition the efficient policy and sustainable budget allocation to support the long- term research and development project to define the economic practice scale are required. Meanwhile, the project evaluation and analysis must be done after the first, middle and final phases. In order to upgrade traditional greenhouse with the low cost construction materials to the digital greenhouse system, the most important factors needed for moving forward Thailand 4.0 policies are the following.

1. The optimal type's standard of greenhouse structure for Thailand's environment and social condition are chosen.

2. The data base of environmental-condition suitable for growth such as temperature, humidity, CO_2 concentration, water requirement in each crop, optimal fertilizer requirement and light intensity should be collected from the farmers' farms who have already practiced with the standard sensor application. In addition the public servants shall be the ones who collect-analyze the data and establish the standard.

3. The national standard of smart greenhouse equipment should be made available and adopted.

4. The standard of farm knowledge management of the selected crop for smart greenhouse practice shall be published. It can provide the sustainable usageof agricultural resources and improve agricultural product's quality.

5. The public servants should be trained for the basic skill of digital farming to improve the potential of human resource. Meanwhile, the related public organization structure should be revamped and strengthen in the cooperation project. For example, computer engineer, mechatronic engineer and information technology engineer are required for Institute of Agricultural Engineering Research Institute. They should closely cooperate with the agricultural science researchers and collaborate with foreign countries under the effective projects.

6. The young farmers, farmer groups and the farmers who have high potential should be recruited for skill training to be the smart farmers.

7. The pilot projects joint venture between public smart researchers, communication enterprises and private smart farmers shall be supported, then the smart farming technology can expand to the interested farmers. These pilot projects shall join hands with the markets that can offer the reasonable price. The best digital

greenhouse production technology and economic production scale will be selected as production model.

CONCLUSION

From the reviewed documents, the greenhouse development stage of Thailand has been classified into two phases, the traditional greenhouse and information technology applied greenhouse. It is mostly used for the fresh vegetables, fruits and ornamentals production. Currently, IoT starts to be deployed in agriculture practice but it is still new technology for Thai's farmers and the investment is high. Nevertheless, the government promote it through the digital farm policy and is still in needs for improvement on multi-disciplinary works. Meanwhile, the greenhouse in Republic of Korea has been widely adopted by farmers, and the smart technology was deployed as sensor application. Smart greenhouse in Korean is developing faster than in Thailand. This review paper only presents the previous documents and recommends the route of digital agriculture for Thailand 4.0. Thai smart greenhouse development pathways should start from the standard of greenhouse structure model and the selected crop types, environmental model and the knowledge of management for those crop and the related device standard. At the same time the development of human resource should concern from three sectors such as public servants, private enterprises and farmers. The closely collaboration between researchers such as agricultural engineer, computer or ICT engineer and agricultural science researcher are required. The pilot project join venture of smart greenhouse development in selected crop possible hold out and join hands with the markets that can win-win together.

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